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How to Empower Green Technology Innovation of Private Enterprises by Environmental Protection Oriented Shareholders

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Abstract: Based on the fact that green shareholders and state-owned shareholders are generally considered as two types of shareholders to promote the performance of green technology innovation in enterprises, we know little about whether and how these two types of shareholders can play a synergistic effect in empowering the performance of green technology innovation in private enterprises under the background of vigorously promoting new quality productivity and emphasizing high quality and sustainable development in China. Based on the stakeholder and resource-based theory, this study empirically tests the impact of environmental oriented shareholders on the performance of green technology innovation of enterprises and the synergy effect of green shareholders and state-owned shareholders in the process, taking China's A-share private listed companies from 2012 to 2022 as the research sample. The results show that: (1) environmental oriented shareholders have a significant positive impact on private enterprises' green technology innovation, and the result is still valid after the robustness test; (2) Environmental protection oriented shareholders promote the green technology innovation performance of private enterprises by improving their risk-taking ability; (3) The proportion of environmental protection oriented shareholders strengthens the positive impact of environmental protection oriented shareholders on green technology innovation performance, and strengthens the intermediary role of enterprise risk-taking ability; (4) The heterogeneity test shows that among the eastern and central regions, non heavy pollution industries, large-scale and private enterprises with low separation of ownership and ownership, the positive effect of environmental protection oriented shareholders on green technology innovation is more significant. The main implications are as follows: (1) enterprises should pay attention to the role of environmental protection oriented shareholders in the green transformation, and actively attract the investment of such shareholders; (2) The synergy test results show that in the process of enabling the green technology innovation performance of private enterprises, the state-owned shareholders have crowding out effect on the green shareholders, and the green shareholders have complementary effect on the state-owned shareholders; (3) The results of heterogeneity analysis show that the crowding out effect of state-owned shareholders on green shareholders is more significant in the eastern region and heavy pollution industries; At the same time, it is found that the synergy effect of state-owned shareholders on green shareholders is complementary in the central region and enterprises with environmental protection background.

Keywords: State-Owned Shareholders; Green Shareholders; Green Technology Innovation; Substitution Effect; Complementary Effect

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1.Introduction

In September 2023, General Secretary Xi Jinping first mentioned “new quality productivity” during his investigation in Heilongjiang, and repeatedly stressed that we should firmly grasp the primary task of high-quality development and develop new quality productivity according to local conditions. Green development is the base color of high-quality development, and new quality productivity itself is green productivity. The white paper “green development in China in the new era” proposed to promote green transformation with the goal of “carbon peaking and carbon neutralization”. As an important participant in emerging markets, private enterprises provide important support for China’s innovation and development strategy[1] . At present, most of China’s state-owned enterprises have responded to the call of the state and are steadily promoting high-quality and green development. However, in the practice of green low-carbon transformation and development, there are some problems such as “neck sticking” risk in key links and key fields, insufficient investment in green development and technology transformation. Some private enterprises still face difficulties such as not wanting to turn, not daring to turn, and not turning. Due to their weak foundation, late start, lack of reform motivation, and financing difficulties, they are stagnant in the process of green transformation. In fact, the green technology innovation activities carried out by private enterprises can not only achieve the dual goals of ecological and economic benefits, but also an important way to achieve overtaking on curves and inject new momentum into the development of new productivity. Based on this background, it is of great practical significance to study the driving factors of green technology innovation in private enterprises.

The characteristics of green technology innovation, such as high complexity and long cycle, make it difficult to obtain sufficient financing from the traditional financial market. In addition, the opportunistic behaviors such as false propaganda and avoiding the important and ignoring the important increase the supervision cost of green technology innovation of private enterprises. Therefore, green technology innovation needs more independent and dedicated environmental protection investment. At this time, environmental protection oriented shareholders are particularly important. Different from shareholders who only aim at profit, environmental protection oriented shareholders, as special stakeholders with environmental protection tendency, pay more attention to the green technology innovation activities of enterprises and will not pay too much attention to short-term profits. They have a long-term vision and can provide special and long-term support for private enterprises to carry out green technology innovation activities. Then, which shareholders are included in the environmental protection oriented shareholders? This study believes that green shareholders and state-owned shareholders are shareholders with strong willingness and inclination to environmental protection. Green shareholders refer to specific investors who invest in green environmental protection. As a fund investor who takes into account environmental and social responsibilities [2], green shareholders prefer green environmental protection projects in the process of investment. At the same time, green technology innovation, as a disruptive innovation, needs to be promoted from top to bottom within the enterprise. As the economic embodiment of the modernization of the national governance system and governance capacity, state-owned shareholders naturally have similar goals and attributes to the national strategy, and will follow the strategic guidance of the state that attaches importance to green development, reflecting the preference for green projects.

Furthermore, green shareholders are special stakeholders with environmental protection tendency within enterprises, and their particularity is reflected in “special investment”, that is, they are committed to promoting enterprises’ environmental performance, promoting the development of green industries and reducing environmental risks[3]; State owned shareholders are the key stakeholders of enterprises. The key lies in their state-owned attributes, that is, state-owned shareholders have both economic and social goals, and have a strong willingness to perform social and ecological responsibilities. However, the existing literature has verified that green shareholders can play a positive role in promoting enterprise green governance and green technology innovation, but scholars’ views on how state-owned shareholders affect private enterprise technology innovation have not been unified. Some scholars believe that state-owned equity can enable private enterprises to overcome congenital weakness [4], improve corporate governance, provide economic resources, and lay the foundation for high-quality development of enterprises; Some scholars also believe that the introduction of state-owned shareholders in private enterprises will aggravate the principal-agent problem, weaken the innovation willingness of the management [1], squeeze the living space of private enterprises and reverse the market-oriented economic reform, which is unfavorable to the

development of innovation activities of private enterprises. So, is the state-owned shareholders' green technology innovation activities for private enterprises an "accelerator" or a "jammer"? Is there synergy between state-owned shareholders and green shareholders in influencing green technology innovation of private enterprises? Are there significant differences in the promotion or interference effects of state-owned shareholders in different regions, industries and different characteristics of executives? This paper will explore their comprehensive impact on the green technology innovation performance of private enterprises from the perspective of the interaction between green shareholders and state-owned shareholders, and then answer the above questions.

To sum up, based on the stakeholder theory and resource-based theory, this paper studies the relationship between environmental protection oriented shareholders and green technology innovation performance from the perspective of green shareholders and state-owned shareholders. On this basis, it further explores whether the substitution effect or complementary effect between green shareholders and state-owned shareholders can empower the green technology innovation performance of private enterprises, and analyzes the different effects they play in different situations. This paper is expected to make the following contributions: first, it enriches the research on the pre factors of green technology innovation from the perspective of environmental protection oriented shareholders, and provides new ideas for enterprises to better carry out green technology innovation. Second, it studies whether green shareholders and state-owned shareholders have synergistic effect in the Green Governance of private enterprises, and enriches the separate and joint governance effect of green shareholders and state-owned shareholders participating in the green technology innovation activities of private enterprises; Third, this paper analyzes the heterogeneity of the synergy effect of the two types of environmental protection oriented shareholders under different sizes, industries and executive characteristics, and proves that the introduction of state-owned shareholders' meeting in different situations has different effects. It provides a framework and model for the follow-up research on green technology innovation, and provides a systematic, contextualized and operable solution for enterprises to take into account stakeholders and internal governance structure.

2.Research theories and hypotheses

2.1 Environmental oriented shareholders and green technology innovation performance of private enterprises

Stakeholder theory is used to deal with the relationship between different stakeholders of enterprises and its impact on target management. It provides a framework for people to analyze the complex internal interest relationship so as to realize value exchange and co creation. When any enterprise carries out management activities, it is closely related to the input and participation of its various stakeholders, and there is bound to be interest interaction between the various subjects, which will affect the performance of the enterprise. Based on the stakeholder theory, environmental protection oriented shareholders are expected to focus on long-term and sustainable interests, and guide enterprises to carry out green technology innovation through environmental protection concerns and environmental protection resource integration.

Green shareholders mainly invest in sustainable development projects to guide enterprises to implement the green concept into their business operations [5]. By combing the existing literature, it is found that most scholars regard green shareholders as green investors to study their impact on green technology innovation. In fact, within the enterprise, green shareholders do play a vital guiding role as special green investors. First of all, the green shareholders' meeting forms top-down environmental protection pressure within the enterprise. When shareholders exert environmental protection pressure, in order to meet the wishes of shareholders, the management will give priority to their environmental protection tendency and set assessment indicators when making decisions, and formulate green innovation policies for sustainable development, so as to promote green technology innovation. Secondly, as a special green investor, green shareholders have obvious advantages in information and capital. When he finds that enterprises invest in projects that are inconsistent with their own investment goals, he will collect entrusted voting rights and submit shareholder proposals to avoid these behaviors [2]; At the same time, it will also play a signal transmission effect through stock selling behavior, that is, when enterprises carry out non environmental activities, green shareholders will send signals to other shareholders by selling their shares, and other shareholders will also follow the trend to sell shares due to herd behavior, so as to correct the deviation of the management through "voting

with hands" and "voting with feet". Finally, as green shareholders prefer environmentally friendly and socially responsible projects, their entry sends a positive signal to the market, which is conducive to attracting more special funds and alleviating the plight of private enterprises' lack of funds in carrying out green technology innovation. Therefore, green shareholders can affect the green technology innovation performance of private enterprises by formulating environmental protection policies, modifying management behavior and alleviating financing difficulties.

State owned shareholders have both the basic economic goal of maintaining and increasing value and the ecological governance goal of promoting green development of enterprises. They will focus on green development in corporate governance. On the one hand, state-owned shareholders represent the state and government, which have higher social status and reputation and lower credit risk [4], so creditors are more inclined to allocate funds to private enterprises with state-owned shareholders. When the state-owned capital participates in private enterprises, it is equivalent to providing private enterprises with a "reputation endorsement", which can send a positive signal of state support to banks and other financing channel[s[6]], which is conducive to the relief of their financing constraints, and thus improve the level of green technology innovation of enterprises; On the other hand, the Chinese government is vigorously promoting the development of green finance and implementing a series of policy guidance measures. The entry of state-owned shareholders makes the development of private enterprises more coordinated with the national strategy, which is conducive to enterprises' more direct and rapid access to relevant information and resources through green finance and government linkages. It happens that green technology innovation focuses on environmental benefits, which is consistent with the national expectations and policy logic. Therefore, the entry of state-owned shareholders can promote the green technology innovation performance of private enterprises by easing financing constraints and strengthening government supervision.

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

H1a: Green shareholders promote the improvement of green technology innovation performance of private enterprises;

H1b: state owned shareholders promote the improvement of green technology innovation performance of private enterprises.

2.2 Substitution effect and complementary effect

Based on the resource-based theory, enterprises, as an open and non fully autonomous organization system, are faced with dynamic external environment and high dependence on external resources[7]. The competitive advantage of enterprises comes from their unique resources and capabilities. State owned shareholders usually have rich resources and policy support; The special investment of green shareholders can also provide guarantee for enterprises to implement green actions and increase green expenditure. Then when there are both green shareholders and state-owned shareholders in an enterprise, they may have a synergistic effect on green technology innovation within the enterprise, and whether this synergy is manifested as a substitution effect or a complementary effect needs to be analyzed and discussed separately.

With the decrease of the shareholding ratio of state-owned shareholders, the role of green shareholders on the green technology innovation performance of private enterprises gradually increases. On the contrary, when the shareholding ratio of state-owned shareholders increases, the role of green shareholders in promoting the green technology innovation performance of private enterprises gradually weakens, that is, the crowding out effect of state-owned shareholders on green shareholders exists. On the one hand, state-owned equity and private enterprises complement each other on the basis of complementarity. With the increasing intensity of administrative intervention in the innovation of private enterprises, the rigid and inefficient organization and management elements of traditional state-owned enterprises may enter private enterprise[s[8]]. The stability brought about by the government background of state-owned shareholders and the disadvantages brought about by group decision-making also make private enterprises more conservative in the face of risk decision-making, unwilling to invest more resources in high-risk green environmental protection projects, thus inhibiting the efficiency of green shareholders in improving the performance of green technology innovation of enterprises; On the other hand, state-owned equity may become a "Curse of political resources" [9]. Because private enterprises do not have resource advantages, they need to obtain competitive advantages by implementing differentiation strategies and other means. When the proportion of shares held by state-owned shareholders is high, the political resource advantages brought by them make enterprises tend to rely on government support rather than market incentives, which not only can not stimulate the innovation potential of enterprises [10],

but also weaken the role of green shareholders in promoting private enterprises to carry out green technology innovation activities.

On the contrary, with the increase of the proportion of green shareholders, the role of state-owned shareholders in promoting the green technology innovation performance of private enterprises is gradually strengthened, that is, green shareholders have complementary effect on state-owned shareholders. On the one hand, green shareholders regard the compliance of the project with environmental testing standards, pollution control effect and ecological protection as an important premise when making investment. When the proportion of shares held by green shareholders increases, he can put forward green demands and environmental protection requirements for the pursuit of long-term value-added, and urge managers to pay attention to cleaner production. At this time, participatory state-owned equity can inhibit the excessive intervention of administrative power behind state-owned equity in the innovation management of private enterprises[10], and improve the performance of green technology innovation of enterprises; On the other hand, the increase in the shareholding ratio of green investors may make the financial logic in the financial field a tool to achieve environmental goals, and its relationship with environmental logic becomes more compatible[5]. That is to say, the capital market environment faced by private enterprises gradually tends to be green. At this time, with the addition of state-owned resources, participating state-owned equity can strengthen the market insight of private entrepreneurs [10], help private enterprises integrate market innovation resources and create a better innovation support environment.

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

H2A: the state-owned shareholders have played a crowding out effect in the process of green shareholders' improving the green technology innovation performance of private enterprises;

H2B: Green shareholders have played a complementary effect in the process of state-owned shareholders' improving the green technology innovation performance of private enterprises.

3.Research design

3.1 Sample selection and data sources

This paper selects China's A-share private listed companies from 2012 to 2022 as the research sample. In order to ensure the continuity and reliability of the research data, the initial samples are screened as follows: (1) Due to the particularity of the industry, companies belonging to the financial industry are excluded; (2) Companies excluding st, ST* and PT; (3) Companies with missing data required for the 2012-2022 model are excluded; (4) In order to eliminate the influence of outliers, the tail of the main continuous variables is reduced by 1%. Green patent data comes from China research data service platform (CNRDS); Other data are from database (CSMAR). After the above processing, 18792 companies' annual observations were finally obtained.

3.2 Variable selection and description

3.2.1 Explanatory Variable – Enterprise green technology innovation performance(GI)

The existing research mainly measures green innovation from two aspects of innovation input and innovation output, in which innovation input is mainly the input of enterprise green technology innovation resources; Innovation output is mainly green patents and green new products of enterprises. The green products of listed companies are difficult to observe and green patents reflect the output of green innovation[11], which can reliably measure the green innovation performance of enterprises. At the same time, the authorization of green patents often has time lag, and the number of green patent applications can better reflect the improvement of green innovation ability [3]. Therefore, this paper uses the number of green patent applications to measure the green technology innovation performance of enterprises.

3.2.2 Explanatory Variable - Green shareholders (Green)

Through data acquisition, it is found that green investors hold all shares and are green shareholders of enterprises. Therefore, this paper studies green investors as alternative variables of green shareholders. Referring to the practice of existing literature[6], obtain the Fund subject information table and stock investment details from the fund market series of the guotai'an database (CSMAR), and search the key words of its investment objectives and investment scope. If the words "ecological, environmental protection, green, sustainable" appear, the fund is recognized as a green investor. If there are green

investors in the listed company, the value is 1, otherwise it is 0.

Explanatory Variable - State owned shareholders (DS)

Referring to the method of zhuangzixuan et al. (2023), this paper sets the state-owned shareholders as a dummy variable. Specifically, if there are state-owned shareholders in the top ten shareholders, the value is 1, otherwise it is 0.

Explanatory Variable - Shareholding ratio of green shareholders (Ratio)

This paper uses the proportion of green investors' shareholding in the total number of shares of the company to measure the proportion of green shareholders' shareholding.

Explanatory Variable - Shareholding ratio of state-owned shareholders (Stater)

This paper uses the sum of the top ten Chinese shareholders' shareholding ratio to measure the shareholding ratio of state-owned shareholders.

Based on the research of scholars, this paper selects ownership concentration, shareholder size, two in one, cash flow, capital intensity, enterprise size and profitability as control variables.The definitions of the main variables involved in this article are detailed in Table 1.

Table 1 Definitions of major variables

Variable Name	Variable Symbol	Calculation Method
Green shareholders	Green	The green investor in the enterprise is 1, otherwise it is 0
State owned shareholders	DS	The state-owned shareholder in the top ten shareholders is 1, otherwise it is 0
Shareholding ratio of green shareholders	Ratio	Number of shares held by green investors/total number of shares in the company
Shareholding ratio of state-owned shareholders	Stater	The total shareholding ratio of top ten shareholders in China
Green technology innovation performance	GI	Number of green patent applications
Equity concentration	Fshare	Shareholding ratio of the largest shareholder
Shareholder size	Holder	The total number of shareholders of the enterprise is taken as the natural logarithm
Two in one	Dual	Whether the chairman and general manager are two in one. If they are the same person, the value is 1; otherwise, it is 0
Profitability	Roa	Return on total assets of the enterprise
cash flow	Cash	Net cash flow from operating activities
Capital intensity	Density	Total fixed assets/number of employees
Enterprise size	Size	Natural logarithm of total assets of the enterprise

3.3 Model design

To test the impact mechanism of environmental oriented shareholders on the green technology innovation performance of private enterprises, the specific model is set as follows:

$$GI_{i,t} = \beta_0 + \beta_1 \times Green_{i,t} + \beta_2 \times Control_{i,t} + \varepsilon_{i,t} \quad (1)$$

$$GI_{i,t} = \beta_0 + \beta_1 \times DS_{i,t} + \beta_2 \times Control_{i,t} + \varepsilon_{i,t} \quad (2)$$

In order to investigate the synergy effect between green shareholders and state-owned shareholders, a total of 2838 observations of private enterprises with both green shareholders and state-owned shareholders were extracted. In the sub samples of

green shareholders and state-owned shareholders, the samples were divided into three groups according to the shareholding ratio of green shareholders and state-owned shareholders. The change trend of the impact of the shareholding ratio of green shareholders on the performance of green technology innovation was investigated when the shareholding ratio of state-owned shareholders was from low to high, and the change trend of the impact of the shareholding ratio of state-owned shareholders on the performance of green technology innovation when the shareholding ratio of green shareholders was from low to high. The setting model is as follows:

$$GI_{i,t} = \beta_0 + \beta_1 \times Ratio_{i,t} + \beta_2 \times Control_{i,t} + \varepsilon_{i,t} \quad (3)$$

$$GI_{i,t} = \beta_0 + \beta_1 \times Stater_{i,t} + \beta_2 \times Control_{i,t} + \varepsilon_{i,t} \quad (4)$$

Among them, models (1) and (2) are mainly to test research hypotheses H1a and H1B. The explanatory variables are enterprise green technology innovation performance (GI), and the explanatory variables are green shareholders (green) and state-owned shareholders (DS); Models (3) and (4) are based on two subsamples of both shareholders. The study assumes H2A and H2B, and the explanatory variables are the proportion of green shareholders (ratio) and the proportion of state-owned shareholders (stater); Control is the control variable selected in this paper; Is interpreted as a random interference term.

4.Empirical results and analysis

4.1 Descriptive statistics

This paper gives the descriptive statistical results of the main variables, as shown in Table 2. Among them, the minimum value of the number of green patent applications is 0, the maximum value is 443, and the standard deviation is 12.07, indicating that the number of green patent applications varies greatly among private enterprises. The average value of state-owned shareholders is 0.412, which means that 41.2% of the top ten shareholders of private enterprises have state-owned shareholders; The average value of green shareholders is 0.315, which means that 31.5% of private enterprises have green shareholders.

Table 2 Descriptive statistics of the full sample size

Variable Name	Mean	Standard Deviation	Minimum	Maximum
GI	2.128	12.07	0	443
Green	0.315	0.465	0	1
DS	0.412	0.492	0	1
Fshare	31.54	13.61	1.844	88.24
Holder	10.03	0.877	1.386	13.95
Dual	0.406	0.491	0	1
Cash	3.857e+08	1.946e+09	-1.394e+10	1.408e+11
Density	12.37	1.080	6.451	18.27
Size	21.84	1.034	19.03	27.12
Roa	0.0450	0.0748	-1.240	0.759

4.2 Correlation analysis

Before the regression analysis, the correlation analysis of the main variables is carried out in this paper. See Table 3. The correlation test results show that the correlation coefficient between the main dependent variables, independent variables and control variables is small, so it can be considered that there is no serious multicollinearity problem between variables.

Table 3 Correlation analysis

	GI	DS	Green	Debt	Roa	Board	Indep	Age
GI	1							
DS	0.044***	1						
Green	0.112***	0.089***	1					
Debt	0.103***	0.099***	0.006	1				
Roa	0.005	-0.002	0.197***	-0.314***	1			
Board	0.000	0.121***	-0.024***	0.118***	-0.080***	1		
Indep	0.007	-0.071***	0.007	-0.033***	0.034***	-0.164***	1	
Age	-0.005	0.087***	-0.056***	0.134***	-0.066***	0.065***	-0.019***	1

4.3 Benchmark regression analysis

In order to verify the relationship between environmental protection oriented shareholders and green technology innovation of private enterprises, this paper conducts regression analysis on model (1) and model (2) through multiple regression model (OLS), and the results are shown in Table 4. Among them, the regression coefficient of green is significantly positive at the 1% level, that is, the green shareholders' meeting has a significant positive impact on the green technology innovation performance of private enterprises, and H1a is established; The regression coefficient of DS is significantly positive at the level of 1%, that is, the state-owned shareholders' meeting has a significant positive impact on the green technology innovation performance of private enterprises. Further comparison found that the regression coefficient of green shareholders is 1.461, which is greater than the regression coefficient of state-owned shareholders 0.534, indicating that compared with state-owned shareholders, the entry of green shareholders can promote the green technology innovation performance of private enterprises to a greater extent.

Table 4 Benchmark regression

Variable Name	GI	GI
DS	0.534***	
Green		1.461***
Debt	4.240***	3.994***
Roa	5.652***	3.080***
Board	-0.216	-0.071
Indep	-0.144	-0.320
Age	-0.033***	-0.023***
N	19392	19392
R^2	0.027	0.042

Note: the values of T corresponding to each coefficient are shown in brackets, * * *, * * *, * are significant at the confidence levels of 1%, 5% and 10%, respectively, the same as the following table.

4.4 Robustness check

First of all, considering that after the environmental protection oriented shareholders exert their influence, private enterprises

may need a period of time to adjust their strategies, obtain resources, carry out R&D and implement green technology innovation, and its entry and influence will take time to show. Therefore, in order to test the actual impact of environmental protection oriented shareholders on green technology innovation of private enterprises and avoid the confusion of causality in time, this paper lags behind the green technology innovation performance variables by one period and re regresses the models (1) and (2). The results are shown in Table 5. The significance of the regression coefficients of DS and green remained unchanged, which proved the robustness of the results.

Further, considering that the measurement method of green technology innovation performance in this paper may be biased, this paper uses the number of green patent authorizations (gi_1) as an alternative variable for green technology innovation performance, and re regresses the models (1) and (2). The results are shown in Table 6: it can be found that the regression coefficients of state-owned shareholders and green shareholders are 0.561 and 1.631 respectively, which are significant at the 1% level, and can produce significant promotion effect, and the results are stable.

Table 5 Robustness check

Variable Name	GI_1	GI_1
DS	0.561***	
Green		1.631***
Debt	4.496***	4.164***
Roa	7.481***	4.492***
Board	-0.260	-0.117
Indep	-0.023	-0.190
Age	-0.041***	-0.031***
N	16317	16317
R^2	0.028	0.045

Table 6 Replace explained variable

Variable Name	GL	GL
DS	1.003***	
Green		2.290***
Debt	8.495***	8.149***
Roa	5.931***	1.952**
Board	0.483**	0.744***
Indep	-1.793***	-2.125***
Age	0.027***	0.044***
N	19392	19392
R^2	0.059	0.077

5.Empirical results and analysis

5.1 Crowding out effect of state owned shareholders on green shareholders

In the subsample of private enterprises with both state-owned shareholders and green shareholders, after dividing the shareholding ratio of state-owned shareholders into three groups according to size, it can be found from table 7 that with

the increasing shareholding ratio of state-owned shareholders, the regression result of the shareholding ratio of green shareholders is gradually not significant, indicating that in the practice of enabling green technology innovation in private enterprises, state-owned shareholders have crowding out effect on green shareholders, and H2A is assumed to be true.

Table 7 Crowding out effect of state owned shareholders on green shareholders

Variable Name	GI		
	Low state-owned shareholder shareholding	Middle state-owned shareholder shareholding	High state-owned shareholder shareholding
Ratio	1.089***	0.798***	0.651
Fshare	-0.024	0.004	0.078
Holder	0.359	0.080	0.363
Dual	0.842	2.093***	0.595
Cash	0.000***	0.000***	0.000***
Density	-0.620**	-0.619*	-2.416***
Size	0.781**	1.379***	3.397***
Roa	-16.278***	-15.609**	-10.537
N	946	946	946
R2	0.131	0.154	0.096

5.2 The complementary effect of green shareholders on state-owned shareholders

In the sub sample of private enterprises with both state-owned and green shareholders, after dividing the shareholding ratio of green shareholders into low, medium, and high groups according to size, Table 8 shows that as the shareholding ratio of green shareholders continues to increase, the significance of the regression results of state-owned shareholder shareholding ratio gradually increases, indicating that green shareholders have a significant complementary effect on state-owned shareholders in promoting the green technology innovation performance of private enterprises.

Table 8 The complementary effect of green shareholders on state-owned shareholders

Variable Name	GI		
	Low green shareholder shareholding	Middle green shareholder shareholding	High green shareholder shareholding
Stater	0.071**	0.178***	0.529***
Fshare	-0.023	0.019	0.020
Holder	0.089	0.456	0.831
Dual	-0.433	0.866	4.334***
Cash	0.000***	0.000***	0.000*
Density	-0.789***	-1.405***	-1.484**
Size	0.246	1.297**	3.544***
Roa	-4.460	-16.053**	-24.603**
N	946	946	946
R^2	0.084	0.186	0.143

6.Heterogeneity analysis

6.1 Regional heterogeneity

According to the classification criteria of the National Bureau of Statistics, this article divides the research sample into three regions: East, Central, and West. The results of the grouped regression are shown in Table 9: the crowding out effect of state-owned shareholders on green shareholders is most significant in the East region, not significant in the West region, and shows a complementary effect in the Central region. The possible explanation is as follows: due to different cultural concepts and uneven resource allocation in the eastern, central, and western regions of China, the degree of emphasis on green technology innovation varies in different regions, and the crowding out effect of state-owned shareholders on green shareholders may also differ among private enterprises in different regions. Specifically, compared to the central and western regions, the eastern region has a more developed economy and greater competitive pressure. Private enterprises in the eastern region generally face more risks and challenges, and are more flexible and innovative. They will rely more on market incentives and other means rather than relying on state-owned capital to obtain resource advantages. When state-owned shareholders hold a large proportion of shares, the "political resource curse" they bring is more obvious compared to the central and western regions, which suppresses the promotion of green technology innovation by green shareholders. Based on the characteristics of China's regional economy, the central region is highly dependent on high emission traditional manufacturing industries and faces the current situation of strengthened environmental supervision. The increase in the shareholding ratio of state-owned shareholders will strengthen the supervision of enterprises, adopt green environmental protection measures, and work together with green shareholders to provide more resources and policy support for private enterprises.

Table 9 Regional heterogeneity

Variable Name	Eastern region			Central region			Western region		
	Low	Middle	High	Low	Middle	High	Low	Middle	High
Ratio	0.841**	0.065	-0.189	4.490**	7.009***	16.659***	0.293	1.131	0.714
Fshare	-0.063**	-0.032	-0.115**	0.041	0.204**	0.793***	-0.013	0.067	-0.073
Holder	0.452	0.425	-0.359	-1.003	1.163	8.354**	-0.555	-0.917	0.091
Dual	1.066	1.557*	1.287	2.852	4.547**	-8.978*	-0.872	-1.085	2.360
Cash	0.000***	0.000***	0.000***	-0.000	0.000	-0.000**	0.000	0.000	0.000**
Density	-0.554	-0.380	-1.556**	0.594	-1.448	-3.550	-0.307	-1.206*	-0.746
Size	0.132	0.798	2.057**	4.011**	1.452	7.385**	0.952	2.109**	0.265
Roa	-21.437***	-12.057	-16.991	-10.938	-49.342*	43.644	-17.435	2.900	-24.177
N	592	609	539	106	116	169	70	62	87
R^2	0.184	0.188	0.173	0.189	0.308	0.342	0.099	0.338	0.163

6.2 Industry heterogeneity

Referring to the practice of panailing et al. (2019), this paper divides industries with different pollution levels into heavy pollution industries and non heavy pollution industries. The test results are shown in table 10: compared with non heavy pollution industries, the crowding out effect of state-owned shareholders on green shareholders in private enterprises in heavy pollution industries is more significant. The possible explanation is that in heavy pollution industries, private enterprises' green technology innovation activities are faced with strict environmental regulations and policy constraints. When the proportion of state-owned shareholders is large, the state-owned shareholders' meeting has greater decision-making power and influence in this process, which will affect the implementation and promotion of the project. In this case, the promotion role of green shareholders may be limited by the requirements of government and industry regulatory policies. If these requirements are inconsistent with the actual demand for green technology innovation, the promotion role of green

shareholders will be inhibited by state-owned shareholders.

Table10 Industry heterogeneity

Variable Name	Heavy pollution industry			Non heavy pollution industry		
	Low	Middle	High	Low	Middle	High
Ratio	1.521***	0.131	0.374	0.908**	1.213***	0.746
Fshare	0.038**	-0.009	0.013	-0.048*	-0.008	0.098
Holder	-0.522	0.203	-0.763	0.560	0.267	0.602
Dual	-0.799*	-0.002	-2.878**	1.222*	2.295***	0.984
Cash	-0.000	0.000	-0.000	0.000***	0.000***	0.000***
Density	0.367	0.062	0.303	-0.553	-0.120	-2.111***
Size	0.834**	0.026	1.948*	0.646	1.205**	3.267***
Roa	-0.076	-0.293	20.187	-18.901***	-17.030**	-14.122
N	154	178	127	792	768	819
R^2	0.284	0.055	0.108	0.195	0.195	0.104

6.3 Heterogeneity of executive background

Referring to the method of Wang Hui et al. (2022), this paper divides senior executives into those with and without environmental protection background. The test results are shown in Table 11: in private enterprises without senior executives with environmental protection background, the substitution effect of state-owned shareholders on green shareholders is not significant; In private enterprises with senior executives with environmental protection background, there is a complementary effect between state-owned shareholders and green shareholders. The possible explanation is that senior executives with environmental protection background in private enterprises usually have strong environmental awareness and professional ability of green technology innovation, and they are more inclined to carry out green technology innovation activities in Enterprises to promote the research and development of green technology. Therefore, executives with environmental protection background have high cognition and sensitivity to the development of environmental protection policies and green technologies, and can make decisions conducive to the green transformation of enterprises. With the increase of the shareholding ratio of state-owned shareholders, the resource support effect and signal transmission effect brought by state-owned capital provide corresponding support for executives to make green environmental protection decisions, which is consistent with the long-term thinking and environmental protection purpose of green shareholders.

Table11 Heterogeneity of executive background

Variable Name	environmental protection background			Non environmental protection background		
	Low	Middle	High	Low	Middle	High
Ratio	12.015	4.654**	4.241**	0.488	0.547	0.001
Fshare	-0.551	-0.043	0.035	-0.042	0.002	0.012
Holder	8.689	1.493	-8.545**	0.470	-0.488	0.243
Dual	37.136**	2.507	16.329***	1.779*	2.654***	-0.487
Cash	0.000	-0.000	0.000	0.000***	0.000***	0.000***
Density	-16.672*	-2.012	1.438	-0.770*	-1.099**	-2.819***
Size	20.900**	-0.099	7.846***	1.403**	0.073	2.198**

Variable Name	environmental protection background			Non environmental protection background		
	Low	Middle	High	Low	Middle	High
Roa	-68.159	-1.063	28.320	-12.297*	-22.212**	-15.577
N	59	76	88	887	870	858
R^2	0.453	0.089	0.331	0.094	0.392	0.195

7.Conclusions and prospects

7.1 Research conclusion

Based on the stakeholder theory, this paper empirically tests the impact relationship between environmental protection oriented shareholders and green technology innovation performance of private enterprises, as well as the synergy effect between the two types of environmental protection oriented shareholders. The research conclusions are as follows: (1) environmental oriented shareholders have a significant positive impact on green technology innovation of private enterprises, and compared with state-owned shareholders, green shareholders have a stronger role in promoting green technology innovation performance of private enterprises; (2) The synergy test results show that in the process of enabling the green technology innovation performance of private enterprises, the state-owned shareholders have crowding out effect on the green shareholders, and the green shareholders have complementary effect on the state-owned shareholders; (3) The results of heterogeneity analysis show that the crowding out effect of state-owned shareholders on green shareholders is more significant in the eastern region and heavy pollution industries; At the same time, it is found that the synergy effect of state-owned shareholders on green shareholders is complementary in the central region and enterprises with environmental protection background.

7.2 Management enlightenment

First, the government and enterprises need to take measures to ensure that enterprises guide private enterprises to improve the performance of green technology innovation through the way of environmental protection oriented shareholder investment. From the perspective of enterprises, we should improve the internal governance mechanism, fully identify the environmental protection orientation of shareholders, pay attention to the environmental protection promotion role of state-owned and green shareholders, establish and improve the communication channels with environmental protection oriented shareholders, mobilize them to participate in the process of Green Governance of enterprises, actively attract such shareholders' investment in the green transformation stage of enterprises, give full play to the support and protection role of these shareholders for green technology within enterprises, curb the shortsightedness of enterprise management, and actively respond to the call of the state to vigorously develop new quality productivity; From the perspective of the government, we should further improve the green financial policy to encourage green investors to enter the market, and promote the reverse mixed reform process to guide state-owned shareholders to enter private enterprises. At the same time, we should further strengthen the green regulatory system to ensure that enterprises follow the laws and standards of environmental protection while attracting environmental oriented shareholders and pursuing green technology innovation performance.

Second, the vitality of green technology innovation of private enterprises can be fully released by adjusting the combination of ownership structure. The high shareholding ratio of state-owned shareholders will swallow up the innovation vitality of private enterprises, thus inhibiting the promoting effect of green shareholders on the green technology innovation performance of private enterprises. Therefore, the introduction of state-owned equity in private enterprises can promote the green technology innovation performance of private enterprises through reverse mixed reform, but we should pay attention to controlling the shareholding ratio of state-owned shareholders, carefully consider the promoting role of state-owned shareholders, and clarify the management boundary of state-owned shareholders, so that the resources brought by state-owned shareholders can play a supporting role rather than a "political resource curse". At the same time, from the perspective of adapting productivity to production relations, in order to improve the green technology innovation performance of enterprises, it is necessary to change the internal ownership structure of enterprises to adapt it to the new quality productivity,

so as to completely realize the green transformation of enterprises.

Third, when considering the change of shareholding ratio between state-owned shareholders and green shareholders, enterprises should fully consider the heterogeneity of environment and their own characteristics. From the research results of regional heterogeneity, the enterprise management should adjust the shareholding ratio of the two types of shareholders according to the technological development level and innovation environment in different regions and the support of government policies in different regions, so as to improve the efficiency of green technology innovation; From the perspective of industry heterogeneity, the crowding out effect of state-owned shareholders on green shareholders is more obvious in enterprises in non heavy pollution industries. In view of this, private enterprises in heavy pollution industries should strengthen communication and cooperation with green shareholders and state-owned shareholders to ensure that the goals of green shareholders and state-owned shareholders in green technology innovation can be coordinated, so as to avoid excessive control of state-owned shareholders and ensure the effective implementation of green innovation projects; From the perspective of the heterogeneity of senior executives' backgrounds, in enterprises with senior executives with environmental protection backgrounds, state-owned shareholders and green shareholders have complementary effects rather than crowding out effects. Therefore, when selecting talents, enterprises should give priority to senior executives with environmental protection backgrounds, and enhance their voice and competitiveness within the enterprise, so as to provide sufficient protection for state-owned shareholders and green shareholders to jointly promote green technology innovation.

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