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Can Mixed-Ownership Reform Drive the Green Transformation of SOEs?

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Abstract: In the construction of ecological civilization, green innovation has become an important driving force for the sustainable development of state-owned enterprises (SOEs). This paper uses panel data of state-owned listed enterprises from 2008 to 2019 to explore mixed-ownership reform's influence on the green transformation of SOEs and its specific mechanisms. The results show that the diversity of mixed shareholders, the depth of mixed equity, and the restriction of mixed equity significantly promote the SOEs' green innovation. Moreover, there are distinctions in the impact of the shareholding ratio of heterogeneous shareholders on green innovation. Only the increase in the shareholding ratio of foreign shareholders has a positive correlation with green innovation. The mechanism tests indicate that the mixed-ownership reform plays a governance role in the green transformation of SOEs by optimizing the reasonable allocation of environmental protection subsidies and propelling environmental social responsibility's active performance. Our study further subdivides the significant promotion effect of mixed-ownership reform on green innovation, finding that it only exists in the SOEs in heavily polluting industries and regions with a high degree of marketization. Finally, we find that the ownership structure adjustment caused by the mixed-ownership reform has improved SOEs' environmental management system and facilitated its sustainable development capabilities.

Keywords: mixed-ownership reform; green innovation; environmental protection subsidy; environmental responsibility; sustainable development

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1. Introduction

With the economic development entering the new normal, the current extent of resource consumption and environmental damage is approaching the ecological environment's upper limit. Under the increasingly severe constraints of resources and environment, the extensive development mode of rapid economic growth relying on an overdraft of resources, environment, and ecological dividends can no longer survive. It is urgent to seek a new avenue of green transformation, break and solve the deadlock between environmental protection and economic growth, and expedite the sustainable development of the economy and society [1]. The Fifth Plenary Session of the 18th Communist Party of China Central Committee put forward the five development concepts of innovation-driven development, balanced development, green development, open development, and development for all, highlighting the importance of green and innovation. The report of the 19th Session of the National Congress of the Communist Party of China proposed to "speed up the reform of the ecological civilization system and build a beautiful China". Once again, the need to build a market-oriented green technology innovation system was emphasized. Taking green innovation as the critical strategy to drive green transformation, preventing and treating environmental pollution, and achieving a "win-win" between

economic efficiency and environmental protection are eventful directions for China to practice green development in the long term. As microcarriers of social and economic wealth creation, enterprises are also the initiators of resource consumption and pollutant emission. Determining how to drive enterprises to carry out green innovation activities vigorously, improve the production process and technology, reduce the cost of environmental governance, and precipitate the transformation of green development concept to policy dividend is of great significance for the country to realize the socialist economy with Chinese characteristics and the construction of ecological civilization.

The existing literature generally elaborates the driving factors of green transformation from green innovation, focusing on the microenterprise level, mainly revolving around the external institutional environment and internal corporate governance. In terms of the institutional environment, based on institutional theory and stakeholder theory, we explore the influence of environmental regulation [2,3], government supervision [4], upstream and downstream relationship [5,6], government subsidies [7], and other factors. For corporate governance, based on resource dependence theory and information asymmetry theory, the effects of organizational capabilities [8], political connections [9], redundant resources [10], board governance [11], knowledge coupling [12], and comparability of accounting information [13] on green innovation have been probed. Wang and Wang [14] found that government subsidies positively affect green innovation, and appropriate executive incentive strategies can compensate for innovation to achieve the optimal drive of fiscal and tax subsidies for green innovation activities. Extant studies have contributed to clarifying the interfering factors and mechanisms of green innovation but have neglected the market forces' function in green transformation.

With the advent of the critical year for pollution prevention and control, SOEs began to gather strength to accelerate the transformation path and made certain achievements in improving the quality of the ecological environment through green innovation. Nevertheless, due to the lower level of marketization of SOE management [15], the phenomenon of environmental inefficiency caused by excessive reliance on government support often occurs in large-scale SOEs. The process of pushing the green transformation requires not only relying on government forces but also using market forces to effectively give play to the internal incentive mechanism of the market [16] to stimulate the enthusiasm for green innovation activities. Since the "Decision of the Central Committee of the Communist Party of China on Some Major Issues Concerning Comprehensively Deepening the Reform" adopted at the Third Plenary Session of the 18th Central Committee in 2013 clearly stated that China should actively develop the mixed-ownership economy, the mixed-ownership reform has become a major direction for the development of SOEs. The state expects to fulfill the effective integration of heterogeneous capital, establish a market-oriented governance system and operation mechanism, give full play to the role of the market in resource allocation, and release the reform dividend. Therefore, mixed-ownership reform is a major driving force for the SOEs' green transformation.

At present, some SOEs have matters of environmental protection funds controlled by the government and weak awareness of environmental protection. The impact of mixed-ownership reform on green innovation may be implemented through the following two channels: From the environmental protection subsidies, the widespread existence of problems such as the "lack of actual controllers" and the "executive compensation control" in SOEs lead to the mismatch of environmental subsidies. The entry of non-state-owned capital reduces government intervention [17] and has a certain voice in the arrangement of environmental protection subsidy funds. Establishing effective supervision and restriction mechanisms can alleviate the two types of agency conflicts, prevent the controlling shareholders and managers from encroaching on environmental protection subsidies, achieve the reasonable allocation of environmental protection subsidies, and provide a resource basis for green innovation. From the environmental responsibility, enterprises are required to participate in more green innovation activities [18]. As policy burdens should be undertaken by SOEs [19], managers who are subject to government

intervention only regard environmental responsibility as a task that SOEs must fulfill and fail to pay attention to it. However, environmental information disclosure is a major channel for stakeholders to obtain environmental rights [20]. Non-state shareholders who take the marketization as the guidance have a strong motivation to establish good relationships with stakeholders via actively performing environmental responsibilities for their interests, attract external investors' support, and improve SOEs' willingness and ability to launch green innovation. Then, whether and how the mixed-ownership reform impacts green innovation will be the main emphasis of the research.

Based on this, we take panel data of state-owned listed enterprises from 2008 to 2019 to explore the influence of mixed-ownership reform on the green transformation of SOEs and its specific mechanisms. The main results are as follows: (1) The diversity of mixed shareholders, the depth of mixed equity, and the restriction of mixed equity are significantly positively correlated with the number of green patent applications, and the mixed-ownership reform contributes to promoting the SOEs' green transformation. (2) The shareholding ratios of heterogeneous equity have different effects on green innovation. Only the increase in the shareholding ratio of foreign shareholders has facilitated green innovation. (3) This paper proposes and confirms the two possible mechanisms of "environmental protection subsidies" and "environmental responsibility". (4) Additional analysis indicates that mixed-ownership reform has a positive impact on green innovation only when SOEs are in heavily polluting industries or regions with a high degree of marketization. (5) We also detect that the mixed-ownership reform stimulates the development of green innovation activities of SOEs and then enhances the enterprise's sustainable development ability.

This paper's contributions are reflected in the following four aspects: Firstly, it expands the domain of the impact of mixed-ownership reform on SOEs' investment decisions. Previous studies have found that the reform has optimized the investment decisions in terms of merger efficiency [21], investment efficiency [22], diversification [23], and technological innovation [24]. However, they all neglect the effect on environmental governance. This paper discusses how to allocate the government environmental subsidies to promote the green development of SOEs from the green innovation for the first time. Secondly, it enriches the research on the interfering factors of green innovation. Existing literature studies the driving factors from external institutional environment and internal corporate governance. Still, there is little attention paid to the driving role of dynamic adjustment of the ownership structure. Based on the practice of heterogeneous capital cross-shareholding and mutual restriction to optimize SOEs' governance mechanism, we explore whether the mixed-ownership reform can propel enterprise green innovation. Thirdly, it reveals the internal logic of the mixed-ownership reform driving the green transformation of SOEs. Under the concern of stakeholders, the fulfillment of environmental responsibility helps to transform scientific practice to the green innovation that protects public health and ecological environment [20]. Therefore, we analyze and verify the mechanisms from environmental protection subsidy and environmental responsibility. It provides a useful supplement to the related research on the governance path of SOE mixed-ownership reform. Finally, it provides empirical evidence to clarify the dispute on the effectiveness of SOE reform. On one side, SOE reform improves corporate efficiency by strengthening internal and external supervision mechanisms, such as by reducing financing costs [25] and increasing risk-taking levels [26,27] and corporate value [28,29]. On the other side, Reinsberg et al. [30] found that the privatization of SOEs in developing countries created opportunities for rent-seeking and had an adverse effect on the implementation of anticorruption policies. The results of this paper show that mixed-ownership reform has actively promoted the SOEs' green transformation, which means that reform has improved the governance mechanisms and operation decisions of companies and resolved the controversy over the effectiveness of SOE reform in China.

2. Theoretical Analysis and Research Hypothesis

Green innovation is the essential method to drive green transformation. This paper uses it to represent the process of green transformation of enterprises. Green innovation mainly refers to improving products or processes related to energy conservation and emission reduction, pollution prevention, waste recycling, green product design, and environmental management by enterprises [31]. Through green innovation, enterprises can offset the cost of environmental investment, improve resource utilization, increase the added value of enterprise products, meet market participants' expectations, and effectively achieve the dual objectives of environmental protection and green competitiveness. Green innovation has evolved into an important strategic tool for enterprises to achieve sustainable development [32]. It is crucial for the SOEs that are widely intervened in by the government to search for market forces to promote the enterprises' green transformation.

Hao and Gong [15] found that the mixed-ownership structure helps to make up for SOEs' lack of marketization. The shift from public to private ownership stimulates more efficient management of available resources [33]. With the mixed-ownership reform, the entry of external strategic investors can improve the operating efficiency and marketization level and release the motion of SOEs' green transformation. The amount of resource input directly determines the intensity of enterprise innovation activities [34]. The government's environmental protection subsidies provide a source of funding for green innovation; thus, non-state capital has the motivation to promote the rational allocation of environmental protection subsidies to achieve sustainable development of enterprises. In addition, green innovation is an important form for enterprises to actively undertake their environmental responsibilities. The emergence of market forces possessed by non-state-owned shareholders will inevitably impact the performance of SOEs' environmental responsibilities and prompt the environmental strategy from passive governance to active prevention and control. On this basis, from the dual path of capital allocation and responsibility fulfillment, this paper explores how the mixed-ownership reform drives the green transformation of SOEs, which has certain theoretical and practical value.

2.1. Mixed-Ownership Reform and Green Transformation of SOEs

The dedication of green innovation to environmental externalities is difficult to be converted into economic benefits in a short time [35], and the long-term competitive advantage brought by green innovation cannot meet the urgent needs of the political promotion of SOEs' executives. Therefore, catering to the superior government's target and completing the political performance in a brief period are the mainstay for executives to make strategic decisions. The obtained environmental protection funds are more likely to expand SOEs' scale and produce a "crowding effect" on the resources of green innovation activities. This is similar to the case in which local communities of Roşia Montană carefully weigh the costs and benefits of gold-mining projects to make decisions for avoiding village decline [36]. Existing research manifests that environmental regulations have a positive impact on green innovation, but the high political connection of state-owned controlling shareholders provides the possibility for SOEs to circumvent environmental regulatory constraints, which will reduce the incentive function of environmental regulations. As the controlling shareholder, the government does not understand the specific situation of green innovation, and its excessive intervention in decision-making is likely to cause deviations from the original technological track and managers' aversion and resistance, which inhibits the expansion of green innovation activities.

According to the resource-based theory, the formation of corporate competitive advantage begins with heterogeneous resources. There are huge distinctions in the resource endowments owned by different property rights enterprises. Non-state-owned shareholders can bring capital, technology, and advanced management concepts to SOEs. With the improvement of heterogeneous shareholders' diversity, they use their social resources to satisfy the knowledge and technology requirements of green innovation and reduce the non-professional intervention of state-owned controlling shareholders. It ultimately ensures the

rationality and scientificity of green innovation decision-making of SOEs. The shareholding ratio of non-state-owned shareholders represents the capital provided for SOEs and the autonomy in operating decisions; non-state-owned capital offers equity financing to ease the financing constraints and strictly supervises managers [37]. When the equity restriction of non-state-owned capital reaches a certain degree, the bargaining power of non-state-owned shareholders increases in competing for control with the controlling shareholders, which restrains the opportunistic behavior of controlling shareholders and modifies their decision-making tendency. Although a certain cost is required for green transformation, in the long run, the benefits of green transformation are much higher than the cost [38]. This effectively drives SOEs' long-term economic performance and environmental performance. Under the condition that the non-state-owned shareholders play the role of restriction, the strategic resources occupied by the controlling shareholders are released, which promotes the occurrence of green innovation activities with large capital demand.

Regarding the considerations mentioned above, this paper presents the following hypothesis:

Hypothesis (H1). *Mixed-ownership reform can drive the green transformation of SOEs.*

2.2. The Mechanism of Environmental Protection Subsidies

Green innovation can reduce economic cost and environmental externality by improving the green process and producing a double value effect on the economy and environment [39]. However, green innovation often involves the amelioration of production technology and process, which requires a large amount of resource input. Resource constraints and insufficient incentives are the main factors restricting enterprises from green innovation [40]. The support of government environmental protection subsidies ameliorates the dilemma of green innovation funds shortage in enterprises [41]. The 2019 "State of the ecological environment in China's bulletin" disclosed that the central government had arranged RMB 53.2 billion of special funds for environmental protection. The wide existence of government intervention and agency problems in SOEs makes government environmental protection subsidies invalid. Green innovation has the characteristics of a long investment cycle, high uncertainty, and superior discretionary power. The "absence of actual controller" of SOEs and the "inherent compensation" of executives highlight the opportunistic motivation of management, which easily leads to the inflow of resources into the fields that bring private benefits to management, rather than into the fields that create enterprise value and social benefits [42]. Wang and Zhang [43] pointed out that compared with NSOEs, SOEs are less likely to lose government support and make few efforts to solve the corporate pollution problem. The lack of information of state-owned controlling shareholders leads to the misuse of environmental protection subsidy domination and inability to exert the function of environmental protection funds in SOEs' green technology breakthroughs.

The introduction of non-state-owned strategic investors adds the proper channels for SOEs to obtain information, boosts the service efficiency of environmental protection subsidies, and brings down government intervention. SOEs no longer only cater to the government's willingness to invest. Instead, they apply environmental subsidies for green innovation activities, reduce enterprises' environmental pollution, and accelerate the exploitation of green products. Choi et al. [44] indicate that non-state-owned shareholders are more concerned about how enterprises gain long-term competitive advantages than state-owned shareholders. Green innovation brings reputation advantages, competitive advantages, and competitiveness to enterprises [45]. Therefore, non-state shareholders begin with the construction of sound environmental culture, improve the environmental awareness of management, complete the environmental management system, and allocate environmental protection subsidies in green innovation projects rationally. Yang, Ren, and Yang [23] detect that the profit-seeking nature of non-state-owned shareholders gives them a strong motivation to supervise the controlling shareholders and management, which is conducive to building a governance mechanism with restriction and incentive compatibility, relieves the problems of "insider control" and "lack of supervision", and cuts

down the occupation of environmental protection subsidies. Furthermore, the professional management system implemented by the mixed-ownership reform employs managers through market-oriented mode and establishes the mechanism of manager compensation incentive [15]. It alters managers' attitude towards risk-taking, prompts the implementation of environmental protection subsidies, and pushes the smooth progress of green innovation.

In reliance on the above analysis, this paper suggests the following hypothesis:

Hypothesis (H2). *Mixed-ownership reform can drive the green transformation of SOEs by promoting the rational allocation of environmental protection subsidies.*

2.3. The Mechanism of Environmental Responsibility

As a part of corporate social responsibility, environmental responsibility requires enterprises to participate in more green innovation activities [18]. Now the development of information technology and the improvement of user requirement complexity put forward new demands for the quality of enterprise products and services [46]. Corporate environmental responsibility demands enterprises to produce more environmental protection products through green innovation to establish win–win cooperation with suppliers and customers. It can be seen that the fulfillment of environmental responsibilities is extremely important to drive the occurrence of green innovation behaviors. In 2019, the Party Central Committee approved the central leading group for ecological and environmental protection supervision, which inspected two central enterprises, China Minmetals Corporation Ltd. and China National Chemical Corporation Ltd. They found that some of its subsidiaries had weak awareness of environmental law and fraud in environmental protection issues (http://www.xinhuanet.com/energy/2020-05/14/c_1125982597.htm, accessed on 5 April 2021). The gold-mining project implemented by the state-owned joint venture RMGC of Romania also has major health hazards and environmental degradation risks. Some SOEs still lack environmental awareness and neglect the fulfillment of environmental responsibility. SOEs have long been responsible for various policy goals [47]. Therefore, external investors regard environmental responsibilities as SOEs' obligations, which cannot be a means to enhance the corporate image and obtain investors' funds, resulting in a shortage of managers' willingness to fulfill. On account of the government and banks' financial support, SOEs have no difficulties in resources and manpower and do not incorporate environmental compliance into their strategic planning.

With the decrease in state-owned equity, the policy tasks that SOEs need to undertake are reduced. At the same time, they also face the decline in implicit contract guarantee of state-owned property rights, which leads to the rise of bankruptcy risk and default risk [23]. The absence of unconditional support from the government compels SOEs to attach importance to environmental compliance, actively assume environmental responsibilities, reduce the occurrence of corporate environmental violations, and increase the possibility of obtaining external financing. The enhancement of the discourse power and the strengthening of the restriction effect of non-state-owned shareholders can supervise the behavior of managers, improve their awareness of environmental protection, and urge them to actively fulfill environmental responsibilities, as well as drawing investors to provide capital support related to environment-friendly and mutually beneficial coexistence with enterprises. The continuous adjustment of the internal ownership structure of SOEs will appeal to the concern of all stakeholders. When social attention is high, enterprises need to consider how to satisfy market participants' expectations, lessen waste, and protect the environment [18]. Environmental information disclosure is the key for stakeholders to understand the environmental consequences of enterprises' business activities [20]. At this time, non-state shareholders are committed to assuming the responsibility of environmental information disclosure, gaining the recognition of stakeholders, establishing a good social image and reputation for the company, retaining employees with R&D capabilities, and increasing the SOEs' green innovation output. Eventually, the scientific practice of society will gradually move towards the direction of green innovation to promote the emergence and consolidation of a "green country".

In reliance on the above analysis, this paper proposes the following hypothesis:

Hypothesis (H3). *Mixed-ownership reform can drive the green transformation of SOEs by promoting the active fulfillment of environmental responsibilities.*

3. Research Design

3.1. Sample Selection and Data Sources

Based on the data of non-state shareholders' ownership structure and green patents of China's state-owned listed enterprises from 2008 to 2019, this study adopts a regression model with fixed effects of controlling industries and years to test the impact of mixed-ownership reform on the green transformation of SOEs. For the collection of green patent data, we use the "Green List of International Patent Classification" launched by the World Intellectual Property Organization (WIPO) in 2010 for reference, draw on the classification of green patents in the "United Nations Framework Convention on Climate Change", and combine the international patent classification numbers to identify and screen out the types and quantities of green patents of listed companies. Moreover, the basic data of mixed-ownership reform are mainly obtained through manual compilation by querying the annual reports and related information websites of listed state-owned companies. The data of other variables are derived from the CSMAR database. Industry classification is derived from the WIND database.

According to the past practices and the needs of the research questions, the samples were processed as follows: (1) excluding ST, * ST, and financial industry samples; (2) eliminating data anomaly samples (asset–liability ratio greater than 1 or operating income less than 0); (3) removing the samples with missing main variables, leading ultimately to 9526 firm-year observations. Data processing and empirical testing were completed through the software of STATA.14.0. All continuous variables were winsorized at 1% and 99% quantiles to eliminate the influence of outliers.

3.2. Model Construction and Variable Definition

Based on the practice of Ren et al. [48], this study constructs the model (1) to test the impact of mixed-ownership reform of SOEs on green transformation:

$$AGP_{i,t+1} = \alpha_0 + \alpha_1 MIX_{i,t} + \alpha_2 CONTROLS_{i,t} + \eta_{ind} + \eta_{year} + \varepsilon_{i,t} \quad (1)$$

where i and t represent the firm and year. Explained variable $AGP_{i,t+1}$ delegates the number of green patent applications of firm i in year $t+1$. The explanatory variable is the degree of mixed-ownership reform in SOEs. $CONTROLS$ is a batch of control variables. η_{ind} and η_{year} represent the industry and time fixed effects, respectively. Besides, to ensure the conclusion's robustness, this study further follows the research of Zhu et al. [49] and clusters the standard errors at the firm level.

The explained variable is the number of green patent applications (AGP), and the index selection refers to the patent index construction method in the examinations of Qi, Lin, and Cui [3] and Xu and Cui [50]. The indicators for the number of green patent applications are divided into three categories: total green patents (AGP), green invention patents ($AGIP$), and green utility model patents ($AGUP$). The classification of green patents granted is the same as above. This study adopts the total amount of green patent applications to measure the green innovation of SOEs. The primary cause is that green patent number, as the output of green technology innovation activities, can directly reflect the effect of green transformation of SOEs. Moreover, the total amount of green patents has the characteristics of quantification and spillover within and outside the industry, which embodies SOEs' overall green innovation capabilities and more accurately and comprehensively evaluates the actual effect of mixed-ownership reform on green innovation activities of SOEs. Specifically, the natural logarithm is taken after the total number of green patent applications is added to 1, which is used as the proxy index of green innovation.

The explanatory variable is the degree of mixed-ownership reform of SOEs (MIX), which is mainly measured from the adjustment of the internal ownership structure, including the three indicators of the diversity of mixed shareholders ($MIXS$), the depth of mixed equity ($MIXO$), and the restriction of mixed equity ($MIXB$). For the properties of heterogeneous shareholders of SOEs, this study relies on the research of Porta et al. [51] and Hao and Gong [15] to divide the properties of shareholders into state-owned, private, foreign, natural persons, institutional investors, and others. Because the number of other shareholders and their shareholding ratio are very small, they are not the research object of this paper.

The diversity of mixed shareholders ($MIXS$), based on the research of Wang and Song [52], is measured by the Herfindahl index of shareholder categories ($HHI = 1 - \sum P_i^2$, P_i represents the proportion of the class i shareholders in the top 10 shareholders), with a value ranging from 0 to 1. Broadly, a larger value of $MIXS$ corresponds to a higher level of diversification of shareholders and a greater degree of mixed-ownership reform of SOEs. The depth of mixed equity ($MIXO$) is defined as the sum of the four non-state-owned shareholding ratios of private, foreign, natural person, and institutional investors among the top 10 shareholders according to the practice of Ma et al. [53]. The shareholding ratio of non-state-owned shareholders is positively associated with the degree of SOEs' mixed-ownership reform. The restriction of mixed equity ($MIXB$), referring to the research of Yang, Ren, and Yang [23], is defined as the difference between the proportion of non-state-owned shareholders and the proportion of state-owned shareholders. A greater difference is indicative of a stronger role of non-state-owned shareholders in supervision and restriction. Besides, concerning the research of Lu and Jiang [54], this study also calculates the total shareholding ratio of each type of non-state-owned shareholders in the top 10 shareholders and analyzes the discrepancy of the influence of each type of shareholders' shareholding ratio on the green innovation of SOEs.

Following Yu, Zhang, and Bi [16], Xu et al. [55], and other previous literature, this study chooses two beddings of control variables. In the aspect of basic characteristics of corporate, seven variables are selected, which are company size ($SIZE$), return on assets (ROA), growth ($GROWTH$), current ratio (LIQ), tangible assets ratio (TA), capital intensity (AI), and turnover of total capital ($TOTA$). In the aspect of corporate governance characteristics, the four variables selected are the proportion of the largest shareholder ($TOP1$), duality ($DUAL$), the scale of the board ($BOARD$), and the proportion of independent directors ($INDEP$). The definitions and descriptions of the variables are shown in Table 1.

Table 1. The definitions and descriptions of the variables.

Variable Type	Variable Name	Symbol	Measurement of Variable
Explained variable	Green innovation	AGP	The natural logarithm of total annual patent applications plus 1
Explanatory variable	Diversity of mixed shareholders	MIXS	Herfindahl index of shareholder categories HHI $= 1 - \sum P_i^2$, P_i represents the proportion of the class i shareholders in the top 10 shareholders
	Depth of mixed equity	MIXO	The sum of the four non-state-owned shareholding ratios of private, foreign, natural person, and institutional investors in the top 10 shareholders
	Restriction of mixed equity	MIXB	The difference between the proportion of non-state-owned shareholders and the proportion of state-owned shareholders in the top 10 shareholders
	The shareholding ratio of private shareholders	MIXO_P	The sum of the shareholding ratios of private shareholders in the top 10 shareholders
	The shareholding ratio of foreign shareholders	MIXO_F	The sum of the shareholding ratios of foreign shareholders in the top 10 shareholders
	The shareholding ratio of natural persons	MIXO_N	The sum of the shareholding ratios of natural persons in the top 10 shareholders
	The shareholding ratio of institutional investors	MIXO_I	The sum of the shareholding ratios of institutional investors in the top 10 shareholders

Table 1. *Cont.*

Variable Type	Variable Name	Symbol	Measurement of Variable
Control variable	Company size	SIZE	Natural logarithm of the total market value of listed companies
	Return on assets	ROA	The company's total profits/total assets at the fiscal year-end
	Growth	GROWTH	Percentage change in operating revenue over the fiscal year
	Current ratio	LIQ	Current assets/current liabilities
	Tangible assets ratio	TA	(Tangible fixed assets + inventory)/total assets at the fiscal year-end
	Capital intensity	AI	Fixed assets/total assets at the fiscal year-end
	Turnover of total capital	TATO	Net operating income/average total assets
	The proportion of the largest shareholder	TOP1	The sum of the shareholding ratio of the largest shareholder
	Duality	DUAL	A dummy variable with a value of 1 if the firm's chairman and CEO are held by the same person, and 0 otherwise
	The scale of the board	BOARD	Natural logarithm of the number of directors on the board
	The proportion of independent directors	INDEP	The number of independent directors/the number of directors on the board

4. Results and Discussion

4.1. Summary Statistics

Table 2 reports the descriptive statistical results of the main variables. According to the relevant indicators for green patent applications, the mean value of the total number of green patent applications (*AGP*) is 0.289. Further subdividing patent types, the average numbers of green invention patent applications (*AGIP*) and green utility model patent applications (*AGUP*) are 0.213 and 0.161, respectively, which are lower than those of Xu and Cui [50], taking all listed companies as samples by similarity measure. This shows that compared with private enterprises, the green patent applications of SOEs are at a low level, lacking the motivation and resources for green transformation, and the standard deviation is larger than the mean value, which indicates that there is a great discrepancy in the strength of green innovation among SOEs. The mean value of diversity of mixed shareholders (*MIXS*) is 0.274, illustrating that the degree of diversification of heterogeneous shareholders in SOEs remains improved. The mean value of depth of mixed equity (*MIXO*) is 0.108, which means that the shareholding ratio of non-state-owned shareholders is 10.8% and the problem of "one share dominance" of SOEs does not have an effective solution. The mean value of restriction of mixed equity (*MIXB*) is –0.232, which indicates that the non-state-owned shareholders have a certain restriction effect but cannot reach the situation of mutual constraints with the state-owned shareholders. The above statistical results reveal that although the mixed-ownership reform of SOEs is beginning to take effect at this stage, the intensity of mixed-ownership reform among enterprises is uneven, and there is still much upside potential in the overall reform degree.

4.2. Basic Regression Results of Mixed-Ownership Reform and Green Transformation of SOEs

Table 3 reports the regression results of mixed-ownership reform's impact on the green transformation of SOEs. Column 1 demonstrates that the regression coefficient of the diversity of mixed shareholders (*MIXS*) and green patent applications (*AGP*) is 0.307, which is significantly positively correlated at the 1% level, indicating that the green innovation output level of SOEs is enhanced with the increase in heterogeneous shareholder diversity. Column 2 shows that the regression coefficient of the depth of mixed equity (*MIXO*) and green patent applications (*AGP*) is 0.513, which is a significant positive correlation at the level of 1%, indicating that as the proportion of non-state-owned shareholders increases, their ability to promote the development of green innovation activities of SOEs increase. Column 3 displays that the regression coefficient of the restriction of mixed equity (*MIXB*) and green patent applications (*AGP*) is 0.208, which is significantly positively correlated at the level of 5%, illustrating as the strength of the restriction ability of non-state-owned capital increases, the likelihood of it propelling the SOEs' green transformation increases.

This is inconsistent with the view of Batory [56] that the privatization of state-owned assets in Central and Eastern European states may restrict the greening of enterprises due to the corruption of political elites. From the above consequences, it can be seen that China's adoption of the appropriate privatization method of direct sale of state-owned assets plays a positive function [57]. The diversity of mixed shareholders and the depth and restriction of mixed equity all embody the dynamic variations of equity power of state-owned and non-state-owned capital in the process of mixed-ownership reform. This emphasizes that non-state-owned capital brings rich resource elements to SOEs and obtains the discourse right matching its equity in the operational decision-making. The supervision and restriction of heterogeneous ownership structure exert the green innovation ability, internalize the negative impact on the environment, and promote SOEs' stable and sustainable development.

Table 2. Summary statistics.

Variable	N	Mean	Std	Min	P25	Median	P75	Max
AGP	9526	0.289	0.738	0.000	0.000	0.000	0.000	4.357
AGIP	9526	0.213	0.608	0.000	0.000	0.000	0.000	3.807
AGUP	9526	0.161	0.506	0.000	0.000	0.000	0.000	3.434
MIXS	9526	0.274	0.171	0.012	0.128	0.238	0.411	0.681
MIXO	9526	0.108	0.100	0.005	0.036	0.072	0.145	0.507
MIXB	9526	−0.232	0.284	−0.843	−0.459	−0.263	0.033	0.483
MIXO_P	9526	0.026	0.057	0.000	0.000	0.000	0.020	0.336
MIXO_F	9526	0.025	0.072	0.000	0.000	0.000	0.004	0.398
MIXO_N	9526	0.017	0.029	0.000	0.000	0.008	0.021	0.204
MIXO_I	9526	0.038	0.043	0.000	0.005	0.024	0.056	0.259
SIZE	9526	22.560	1.813	0.000	21.88	22.50	23.300	26.320
ROA	9526	0.037	0.052	−0.212	0.011	0.031	0.060	0.260
LEV	9526	0.507	0.197	0.057	0.360	0.517	0.661	0.922
GROWTH	9526	0.174	0.410	−0.464	0.009	0.085	0.206	5.003
LIQ	9526	1.695	1.528	0.193	0.901	1.295	1.918	15.190
TA	9526	0.392	0.202	0.020	0.238	0.369	0.536	0.894
AI	9526	0.271	0.198	0.000	0.108	0.232	0.408	0.807
TATO	9526	0.724	0.533	0.035	0.363	0.596	0.913	3.544
TOP1	9526	0.425	0.158	0.011	0.302	0.422	0.537	0.828
DUAL	9526	0.094	0.292	0.000	0.000	0.000	0.000	1.000
BOARD	9526	2.208	0.208	0.000	2.197	2.197	2.303	2.708
INDEP	9526	0.367	0.055	0.000	0.333	0.333	0.375	0.600

Table 4 further examines the impact of heterogeneous shareholdings on the green transformation of SOEs. Column 1 shows that the shareholding ratio of private shareholders (*MIXO_P*) is positively but not significantly correlated with green patent applications, indicating that private shareholders' existence has little effect on green innovation. Column 2 reveals that the shareholding ratio of foreign shareholders (*MIXO_F*) is significantly positively correlated with green patent applications, showing that the shareholding ratio of foreign shareholders is conducive to propelling the generation of green innovation activities of SOEs. Column 3 displays that the shareholding ratio of natural person shareholders (*MIXO_N*) is significantly negatively correlated with the green patent applications, indicating that the entry of natural person shareholders has a negative impact on green innovation output. Column 4 shows that the shareholding ratio of institutional investor shareholders (*MIXO_I*) is positively but not significantly correlated with the number of green patent applications, indicating that institutional investor shareholders' shareholding has no substantial effect on green innovation. The above situation may be due to the following facts: (1) The level of private shareholders' stock holding is relatively low, with an average holding of only 2.6%, which is far from their expectations. Therefore, it is hard for private shareholders to play the role of supervision and restriction with the existing equity and lack the willingness and ability to optimize green innovation decisions. (2) A foreign

shareholder with technology, management, culture, and system efficiency advantage [58] can effectively supervise management with higher environmental protection consciousness and innovation ability. Moreover, due to the lesser policy burden, foreign shareholders are not easily affected by the government concentrating on green innovation management. (3) Natural person shareholders, because of their low shareholding ratio, get minor income from green innovation. In the case of failing to safeguard their interests effectively, they prefer to invest funds in short-term projects to acquire actual income, which will hinder the occurrence of green innovation behavior of SOEs. (4) Institutional investor shareholders enter SOEs not for long-term investment to obtain dividends but for obtaining a high price difference and exit on time. The high-risk and high-cost peculiarities of green innovation make it unable to gain the favor of institutional investors.

Table 3. The impact of mixed-ownership reform on the green transformation of SOEs.

Y = AGP	1	2	3
MIXS	0.307 ***		
	(2.61)		
MIXO		0.513 ***	
		(2.64)	
MIXB			0.208 **
			(2.12)
SIZE	0.065 ***	0.065 ***	0.067 ***
	(3.99)	(3.96)	(4.01)
ROA	0.295	0.296	0.341
	(1.35)	(1.34)	(1.53)
LEV	0.819 ***	0.810 ***	0.806 ***
	(4.52)	(4.47)	(4.45)
GROWTH	−0.065 ***	−0.067 ***	−0.058 ***
	(−3.49)	(−3.60)	(−3.24)
LIQ	−0.010	−0.010	−0.009
	(−0.93)	(−0.96)	(−0.84)
TA	0.494 ***	0.492 ***	0.478 ***
	(2.89)	(2.88)	(2.80)
AI	−0.293 **	−0.299 **	−0.290 **
	(−2.47)	(−2.52)	(−2.43)
TATO	0.028	0.027	0.028
	(1.11)	(1.07)	(1.07)
TOP1	0.341 **	0.272 *	0.342 **
	(2.19)	(1.90)	(2.14)
DUAL	−0.009	−0.006	−0.006
	(−0.20)	(−0.13)	(−0.13)
BOARD	0.275 **	0.267 **	0.278 **
	(2.34)	(2.27)	(2.36)
INDEP	0.434	0.444	0.448
	(1.59)	(1.63)	(1.64)
CONSTANT	−2.713 ***	−2.617 ***	−2.625 ***
	(−5.31)	(−5.15)	(−5.08)
Industry F.E.	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes
N	9526	9526	9526
R^2	0.147	0.147	0.145
adj. R^2	0.143	0.143	0.141

Note: The t-statistics are reported in parentheses on robust standard errors clustered at the firm level. *, **, and *** designate statistical significance at the 10%, 5%, and 1% level, respectively.

Table 4. The impact of heterogeneous shareholding ratio on the green transformation of SOEs.

Y = AGP	1	2	3	4
MIXO_P	0.030			
	(0.13)			
MIXO_F		0.879 ***		
		(2.78)		
MIXO_N			−0.967 **	
			(−2.10)	
MIXO_I				0.145
				(0.44)
SIZE	0.068 ***	0.062 ***	0.066 ***	0.068 ***
	(4.01)	(3.87)	(3.86)	(3.90)
ROA	0.377 *	0.349	0.363	0.363
	(1.67)	(1.56)	(1.61)	(1.63)
LEV	0.804 ***	0.785 ***	0.792 ***	0.802 ***
	(4.41)	(4.33)	(4.39)	(4.44)
GROWTH	−0.058 ***	−0.052 ***	−0.054 ***	−0.058 ***
	(−3.18)	(−2.97)	(−3.05)	(−3.25)
LIQ	−0.008	−0.008	−0.005	−0.008
	(−0.78)	(−0.78)	(−0.47)	(−0.78)
TA1	0.471 ***	0.475 ***	0.459 ***	0.472 ***
	(2.75)	(2.80)	(2.68)	(2.76)
AI	−0.290 **	−0.298 **	−0.287 **	−0.290 **
	(−2.43)	(−2.52)	(−2.41)	(−2.43)
TATO	0.028	0.023	0.027	0.028
	(1.07)	(0.90)	(1.02)	(1.06)
TOP1	0.171	0.202	0.132	0.173
	(1.29)	(1.54)	(0.99)	(1.34)
DUAL	−0.003	−0.004	−0.001	−0.003
	(−0.07)	(−0.10)	(−0.03)	(−0.07)
BOARD	0.281 **	0.264 **	0.273 **	0.282 **
	(2.38)	(2.26)	(2.33)	(2.40)
INDEP	0.466 *	0.417	0.455 *	0.466 *
	(1.71)	(1.53)	(1.68)	(1.71)
CONSTANT	−2.643 ***	−2.454 ***	−2.523 ***	−2.635 ***
	(−5.05)	(−4.88)	(−4.74)	(−5.02)
Industry F.E.	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes
N	9526	9526	9526	9526
R^2	0.143	0.150	0.144	0.143
adj. R^2	0.139	0.146	0.140	0.139

Note: The t-statistics are reported in parentheses on robust standard errors clustered at the firm level. *, **, and *** designate statistical significance at the 10%, 5%, and 1% level, respectively.

4.3. Robustness Tests

4.3.1. Endogenous Tests

1. Instrumental variable method (IV)

There may be a few unobservable factors in Model (1) that affect both the degree of mixed-ownership reform and the green innovation output of SOEs, resulting in endogenous problems caused by omitted variables. Based on the research of Fan et al. [59] and Tang et al. [60], this study selects the number of coastal ports in each province (*SEA_PORT*) and the unemployment rate (*UNEMP*) of each province as the instrumental variables of the degree of SOEs' mixed-ownership reform and adopts two-stage least squares method (IV-2SLS) for regression. On the one hand, due to location advantages, coastal areas have more opportunities to interact with other countries. Therefore, the number of ports in the area where SOEs are located is closely related to their institutions' development. With the increase in the number of ports, the extent of opening to the outside world and marketization in the region are gradually improved, attracting non-state-owned capital to participate

in SOEs actively and promoting the enterprise green transformation. On the other hand, the regional unemployment rate level reflects the degree of economic development in the region. Regions with a low unemployment rate have a higher economic development level, a more mature market economy system, and better completion of policy tasks such as providing employment. This implies that the government has weaker incentives to intervene in SOEs, which is conducive to the advancement of SOEs' mixed-ownership reform. Meanwhile, green innovation activities belong to the SOEs' operation decision-making. The number of coastal ports and the unemployment rate of each province have a long path to impact them, which is in line with the exogenous standard of instrumental variables.

Table 5 lists the two-stage regression results. Columns 1–3 are the regression results of the first stage. The regression coefficient of the number of coastal ports in each province (*SEA_PORT*) is significantly positive, and the regression coefficient of the unemployment rate (*UNEMP*) of each province is significantly negative, which states that as the number of ports increases or the unemployment rate decreases, the degree of marketization and the level of economic development in the region increase, and the situation of non-state shareholders' equity participation improves. The second-stage regression results of columns 4–6 make it clear that SOEs' mixed-ownership reform can induce green innovation behavior under the control of endogenous problems. Besides, the Hansen test also manifests that there is no over-identification of instrumental variables.

Table 5. The two-stage 2SLS.

	1	2	3	4	5	6
		First Stage			Second Stage	
Variable	MIXS	MIXO	MIXB	AGP	AGP	AGP
SEA_PORT	0.0009 ***	0.0005 ***	0.0005 **			
	(3.77)	(3.44)	(2.22)			
UNEMP	−0.0191 ***	−0.0128 ***	−0.0129 ***			
	(−10.43)	(−10.82)	(−7.22)			
MIXS				2.189 ***		
				(4.56)		
MIXO					3.341 ***	
					(4.54)	
MIXB						3.300 ***
						(4.16)
CONSTANT	0.251 ***	−0.006	−0.196 ***	−3.280 ***	−2.705 ***	−2.081 ***
	(5.36)	(−0.19)	(−4.63)	(−13.88)	(−12.88)	(−7.20)
CONTROLS	Yes	Yes	Yes	Yes	Yes	Yes
Industry	Yes	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes	Yes
N	9526	9526	9526	9526	9526	9526
R^2	0.329	0.171	0.758	—	—	—
adj. R^2	0.325	0.166	0.757	—	—	—
Hansen test	—	—	—	0.795	0.909	0.908

Note: The t-statistics are reported in parentheses on robust standard errors clustered at the firm level. *, **, and *** designate statistical significance at the 10%, 5%, and 1% level, respectively.

2. Multiple-period lagged explained variable

The reverse causal problem may exist between the mixed-ownership reform of SOEs and green innovation. The green innovation output in the current period will not affect the non-state-owned capital participation in the previous period. Therefore, the explained variable has already been lagged for a period to effectively ease the endogenous problem caused by reverse causality in the model (1). In the robustness test, this study further follows Fang et al. [61] and Xu, Xu, Peng, and Zhang [55] by lagging the explained variable by multiple periods; i.e., the explained variable is lagged by two periods, three periods, and four periods. The corresponding empirical results are shown in Table 6. The regression coefficients of the *MIXS*, *MIXO,* and *MIXB* are significantly positive, which declares that

the previous research conclusions remain stable after alleviating the endogenous problem of reverse causality. This part of the results also proves that the mixed-ownership reform has a long-term effect in promoting the SOEs' green transformation.

Table 6. The multiple-period lagged explained variable.

	1	2	3	4	5	6	7	8	9
Variable	Foward2(AGP2)			Foward2(AGP2)			Foward4(AGP4)		
MIXS	0.402 ***			0.459 ***			0.428 ***		
	(2.88)			(3.13)			(2.81)		
MIXO		0.628 ***			0.693 ***			0.677 ***	
		(2.83)			(2.98)			(2.76)	
MIXB			0.230 **			0.263 **			0.423 **
			(2.07)			(2.26)			(2.38)
CONS	−3.055 ***	−2.927 ***	−2.944 ***	−3.204 ***	−3.059 ***	−3.075 ***	−3.318 ***	−3.184 ***	−3.186 ***
	(−4.63)	(−4.48)	(−4.42)	(−4.65)	(−4.48)	(−4.42)	(−4.76)	(−4.61)	(−4.57)
CONTROLS	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	8468	8468	8468	7446	7446	7446	6468	6468	6468
R^2	0.150	0.150	0.147	0.151	0.150	0.147	0.154	0.153	0.152
adj. R^2	0.145	0.145	0.142	0.146	0.145	0.141	0.148	0.148	0.146

Note: The t-statistics are reported in parentheses on robust standard errors clustered at the firm level. *, **, and *** designate statistical significance at the 10%, 5%, and 1% level, respectively.

4.3.2. Other Robustness Tests

In this study, we conduct the robustness analyses based on alternative measures of key variables, alternative model specifications, and alternative sample sizes.

1. Alternative measures of key variables

To eliminate the influence of index selection on the research conclusion, the index measurement methods of explained variables and explanatory variables are replaced. For green innovation, referring to Qi, Lin, and Cui's [3] research, green innovation (*GGP*) is measured by the natural logarithm of the total amount of green patents granted plus 1. Regarding the degree of mixed-ownership reform of SOEs, the depth of mixed equity (*MIXO*1) is measured by the entropy index ($EI = \sum Q_j \times \ln(1/Q_j)$, Q_j represents the proportion of shares held by class j shareholders in the total number of shares held by the top 10 shareholders) by following Zhu et al. [62]. Learning from the practice of Yang and Yin [63], the restriction of mixed equity (*MIXB1*) is measured by the ratio of non-state-owned and state-owned shares in the top 10 shareholders (the larger one is the denominator). The test results are shown in Table 7. The diversity of mixed shareholders (*MIXS*), the depth of mixed equity (*MIXO*), and the restriction of mixed equity (*MIXB*) are significantly positively correlated with the total number of green patents granted (*GGP*), indicating that the mixed-ownership reform of SOEs can enhance the amounts of green patents granted. After modifying the measurement method of SOEs' mixed-ownership reform degree index, the depth of mixed equity (*MIXO1*) and the restriction of mixed equity (*MIXB1*) are significantly positively correlated with the number of green patent applications (*AGP*), and the test results are consistent with the those of the previous test.

Table 7. Alternative measures of key variables.

	1	2	3	4	5
Variable	GGP	GGP	GGP	AGP	AGP
MIXS	0.237 ***				
	(2.59)				
MIXO		0.397 ***			
		(2.66)			
MIXB			0.162 **		
			(2.14)		
MIXO1				0.153 **	
				(2.07)	
MIXB1					0.211 ***
					(2.86)
CONSTANT	−2.110 ***	−2.037 ***	−2.042 ***	−2.725 ***	−2.648 ***
	(−5.35)	(−5.19)	(−5.13)	(−5.27)	(−5.15)
CONTROLS	Yes	Yes	Yes	Yes	Yes
Industry F.E.	Yes	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes	Yes
N	9526	9526	9526	9526	9526
R^2	0.140	0.141	0.139	0.145	0.146
adj. R^2	0.136	0.137	0.134	0.141	0.142

Note: The t-statistics are reported in parentheses on robust standard errors clustered at the firm level. *, **, and *** designate statistical significance at the 10%, 5%, and 1% level, respectively.

2. Alternative empirical specifications

Since the number of green patent applications is a non-negative and continuous value censored variable, there is the problem of zero deletion. Therefore, using the practice of Jiang [64] for reference, the Tobit model is adopted for estimation. Columns 1–3 of Table 8 report the test results. The diversity of mixed shareholders (*MIXS*), the depth of mixed equity (*MIXO*), and the restriction of mixed equity (*MIXB*) are significantly positively correlated with green innovation (*AGP*), and the results are consistent with the above.

Table 8. Alternative empirical specifications and sample sizes.

Y = AGP	1	2	3	4	5	6
MIXS	1.186 ***			0.440 ***		
	(4.78)			(2.95)		
MIXO		1.864 ***			0.818 ***	
		(4.94)			(3.19)	
MIXB			0.824 ***			0.304 ***
			(3.38)			(2.67)
CONSTANT	−19.92 ***	−19.52 ***	−19.58 ***	−2.700 ***	−2.635 ***	−2.526 ***
	(−19.71)	(−19.31)	(−19.39)	(−5.02)	(−5.02)	(−4.74)
CONTROLS	Yes	Yes	Yes	Yes	Yes	Yes
Industry F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes	Yes	Yes
N	9526	9526	9526	6498	6498	6498
R^2/Pseudo R^2	0.138	0.138	0.137	0.148	0.151	0.145
adj. R^2	—	—	—	0.142	0.144	0.139

Note: The t-statistics are reported in parentheses on robust standard errors clustered at the firm level. *, **, and *** designate statistical significance at the 10%, 5%, and 1% level, respectively.

3. Alternative sample sizes

In line with the research of Yang and Yin [63], the SOEs in which the total shareholding ratio of the top 10 shareholders is less than 50% are deleted to avoid the sample selection bias caused by the adoption of the properties of the top 10 shareholders of listed state-owned companies to construct the indicators of mixed-ownership reform degrees. Columns 4–6 of Table 8 report the regression results. The diversity of mixed shareholders (*MIXS*),

the depth of mixed equity (*MIXO*), and the restriction of mixed equity (*MIXB*) have a significant positive correlation with green innovation (*AGP*), and the results are stable.

5. Mechanism Tests and Additional Analysis

5.1. Mechanism Test of Green Transformation Driven by Mixed-Ownership Reform of SOEs

For testing whether the mixed-ownership reform of SOEs facilitates the green transformation by promoting the rational allocation of government environmental protection subsidies, this study constructs a model group (2) to test the mechanism of government environmental protection subsidies by consulting Li and Li [65] and Yang, Ren, and Yang [23]:

$$\begin{aligned} AGP_{i,t+1} &= \alpha_0 + \alpha_1 ENVS_{i,t} + \alpha_2 CONTROLS_{i,t} + \eta_{area} + \eta_{year} + \varepsilon_{i,t} \\ AGP_{i,t+1} &= \alpha_0 + \alpha_1 MIX_{i,t} + \alpha_2 ENVS_{i,t} + \alpha_3 MIX_{i,t} \times ENVS_{i,t} + \alpha_4 CONTROLS_{i,t} + \eta_{area} + \eta_{year} + \varepsilon_{i,t} \end{aligned} \quad (2)$$

The *ENVS* in model group (2) is environmental protection subsidy, concerning the research of Li and Xiao [66], which is measured by the ratio of the total government environmental protection subsidies to the total assets of the enterprise. The environmental protection subsidy data were manually collected and sorted by reading the annual environmental report prepared by listed companies following the "Guidelines for Environmental Information Disclosure of Listed Companies" and the financial statement notes. The control variables used in the model are consistent with the above.

For verifying whether the mixed-ownership reform of SOEs promotes the green transformation by motivating the performance of environmental responsibility, the model group (3) is built to test the mechanism of environmental social responsibility:

$$\begin{aligned} AGP_{i,t+1} &= \alpha_0 + \alpha_1 CSRE_{i,t} + \alpha_2 CONTROLS_{i,t} + \eta_{ind} + \eta_{year} + \varepsilon_{i,t} \\ AGP_{i,t+1} &= \alpha_0 + \alpha_1 MIX_{i,t} + \alpha_2 CSRE_{i,t} + \alpha_3 MIX_{i,t} \times CSRE_{i,t} + \alpha_4 CONTROLS_{i,t} + \eta_{ind} + \eta_{year} + \varepsilon_{i,t} \end{aligned} \quad (3)$$

The *CSRE* in the model group (3) delegates environmental responsibility, measured by the environmental social responsibility score of hexun.com based on Lu et al. [67]. The environmental social responsibility score data were mainly derived from the social responsibility report and the annual report issued by the exchange, including five indicators of corporate environmental awareness, certification of the environmental management system, amount of environmental protection investment, number of pollution types, and number of energy-saving species. The control variables used in the model are consistent with the above.

Table 9 presents the test results for the environmental protection subsidy mechanism. The regression coefficient of *ENVS* in column 1 is significantly positive at the level of 5%, which indicates that the increase in *ENVS* expedites green innovation behaviors to a certain extent. From columns 2–4, it can be seen that the interaction coefficients *(MIXS* × *ENVS*, *MIXO* × *ENVS*, and *MIXB* × *ENVS*) of the degree of mixed-ownership reform of SOEs and environmental protection subsidies are significantly positive, indicating that the diversity of mixed shareholders, the depth of mixed equity, and the restriction of mixed equity all contribute to the increase in green innovation output caused by environmental protection subsidies. The above results illustrate that the reform of SOEs has taken advantage of the reliance on incentive policy about government environmental protection subsidies. The mixed-ownership reform reduces the degree of government intervention, makes the distribution of environmental protection subsidies range from government-led to SOEs' independent allocation, increases the supervision of state-owned shareholders and management, lessens the selfish behavior generated by two types of agency problems, and urges SOEs to apply government environmental protection subsidies for green innovation activities to improve the enterprise green innovation ability.

Table 9. The environmental protection subsidy mechanism test.

Y = AGP	1	2	3	4
ENVS	107.0 **	89.63 ***	67.55 **	158.5 ***
	(2.57)	(4.43)	(2.34)	(5.55)
MIXS		0.332 ***		
		(6.42)		
MIXS × ENVS		23.13 ***		
		(2.86)		
MIXO			0.525 ***	
			(6.21)	
MIXO × ENVS			283.9 **	
			(2.08)	
MIXB				0.229 ***
				(4.34)
MIXB × ENVS				117.7 **
				(2.24)
CONSTANT	−2.273 ***	−2.391 ***	−2.298 ***	−2.284 ***
	(−4.83)	(−15.91)	(−15.40)	(−15.29)
CONTROLS	Yes	Yes	Yes	Yes
Province F.E.	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes
N	9526	9526	9526	9526
R^2	0.086	0.091	0.091	0.089
adj. R^2	0.081	0.086	0.086	0.084

Note: The t-statistics are reported in parentheses on robust standard errors clustered at the firm level. *, **, and *** designate statistical significance at the 10%, 5%, and 1% level, respectively.

Table 10 lists the test results for the environmental responsibility mechanism. The regression coefficient of environmental responsibility (*CSRE*) in column 1 is significantly positive at the level of 1%, indicating that as the performance of environmental social responsibility improves, the strength of the impetus of green innovation increases. The assumption of environmental responsibility is indeed an eventful factor in inducing the green transformation of SOEs. The interaction coefficients (*MIXS* × *CSRE*, *MIXO* × *CSRE*, and *MIXB* × *CSRE*) in columns 2–4 of the degree of mixed-ownership reform of SOEs and environmental responsibility are all significantly positive, indicating that the diversity of mixed shareholders, the depth of mixed equity, and the restriction of mixed equity have active effects on the relationship between environmental responsibility and green innovation. The above consequences show that heterogeneous strategic investors' participation has made SOEs receive extensive attention from external investors, which greatly increases the possibility of investors opposing projects that harm the ecological environment [36]. Under the interests driven, non-state-owned shareholders improve the awareness of environmental protection and attach importance to environmental compliance, strengthen the performance and disclosure of environmental social responsibility, and enable stakeholders to gain access to environmental information [20]. SOEs can retain talented employees while obtaining external funds, which provides a strong guarantee for the enterprise's green transformation.

Table 10. The environmental responsibility mechanism test.

Y = AGP	1	2	3	4
CSRE	0.0118 ***	0.00680 ***	0.00878 ***	0.0147 ***
	(4.18)	(2.85)	(4.62)	(6.79)
MIXS		0.177 ***		
		(2.88)		
MIXS × CSRE		0.0176 **		
		(2.46)		
MIXO			0.277 ***	
			(2.74)	
MIXO × CSRE			0.0231 **	
			(2.03)	
MIXB				0.135 **
				(2.30)
MIXB × CSRE				0.0109 *
				(1.79)
CONSTANT	−3.310 ***	−3.302 ***	−3.237 ***	−3.296 ***
	(−4.73)	(−16.84)	(−16.50)	(−16.83)
CONTROLS	Yes	Yes	Yes	Yes
Industry F.E.	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes
N	7917	7917	7917	7917
R^2	0.162	0.165	0.165	0.164
adj. R^2	0.158	0.160	0.160	0.159

Note: The t-statistics are reported in parentheses on robust standard errors clustered at the firm level. *, **, and *** designate statistical significance at the 10%, 5%, and 1% level, respectively.

5.2. Additional Analysis: Heterogeneity Test of Industry Attribute and Marketization Degree

Whether the internal governance mechanism of SOEs can give full play to the governance effect is closely related to the external governance environment. As significant components of the external governance environment, industry attributes and marketization process inevitably affect the allocation efficiency of power, capital, information, and technology resources of SOEs within the scope and then influence the enterprises' strategic decision-making.

The industry environment is a principal element in determining corporate strategic decisions [68]. Enterprises in heavily and non-heavily polluting industries face strikingly different environmental problems and are subject to disparate government interventions. As the primary origin of environmental pollution, enterprises' production and operation activities in heavily polluting industries receive more stringent environmental policy regulation [7], which is more obvious in the SOEs undertaking policy objectives. The environmental governance consequence of SOEs has a direct bearing on the formation of the corporate core competitiveness. Therefore, under rigorous government supervision, the non-state-owned capital introduced from the mixed-ownership reform of SOEs in heavily polluting industries pays more attention to the environmental problems, attaches importance to the cultivation of enterprise internal environmental protection culture and the strengthening of environmental protection awareness [69], stimulates the enthusiasm of managers for environmental governance, and reduces the unreasonable allocation of environmental protection subsidies. Besides, the SOEs of the heavily polluting industry will become more concerned with implementing the mixed-ownership reform. Under the monitoring of all stakeholders, non-state shareholders will actively fulfill their environmental responsibilities and autonomously amplify the intensity of green innovation. In conclusion, compared with non-heavily polluting industries, the environmental governance effectiveness of SOEs in heavily polluting industries is more closely related to their self-development, and non-state-owned shareholders are more proactive in playing the role of restriction and supervision. Therefore, the driving effect of mixed-ownership reform on the green transformation of SOEs is more obvious in such industries.

Market-oriented reform is an extremely significant institutional background in the study of enterprise behavior [70]. The exercise of shareholder power is bound up with the enterprise institutional environment. Regions with a high degree of marketization have better legal mechanisms than others and pay more attention to protecting corporate intellectual property rights. The green innovation achievements of SOEs are hard to gain or be imitated by competitors. The motivation for green innovation is stronger. The enterprise's environmental management system is complete, and the participation of non-state-owned shareholders in strategic decision-making has less room for elevating green innovation output. Hao and Gong [15] pointed out that the mixed-ownership structure is conducive to offsetting marketization deficiency and stretching heterogeneous capital advantages. The controlling shareholders and managers of the SOEs in the areas with a low degree of marketization, due to the low level of economic development, are more likely to seek wealth for themselves and give little thought to the sustainable development of enterprises. As a result, the environmental management system's construction is far behind the SOEs with a high degree of marketization. Non-state shareholders implement a stricter supervision mechanism and are committed to heightening the allocation efficiency of environmental protection subsidies and the quality of environmental information disclosure to relieve the passive impact of the weak institutional environment on the green innovation of SOEs. Given the above, in contrast to regions with a high degree of marketization, SOEs with a low degree of marketization lack the resource support and institutional guarantees for green innovation. Therefore, the mixed-ownership reform has a more evident driving effect on the green transformation of such SOEs.

For the division of industry attributes, this study uses Wu et al. [71] for reference. It selects 16 sub-sectors such as "B06 coal mining and washing industry" as heavily polluting industries, and the rest are defined as non-heavily polluting industries. According to SOEs' industry, the samples are divided into two groups: SOEs in heavily polluting industry and SOEs in non-heavily polluting industry, to test the impact of industry attributes on the relationship between mixed-ownership reform and enterprise green transformation. Table 11 reports the group inspection results. The diversity of mixed shareholders (*MIXS*), the depth of mixed equity (*MIXO*), and the restriction of mixed equity (*MIXB*) are significantly positively correlated with green innovation in the SOEs of heavily polluting industries, but this correlation is not seen in the other group, indicating that the promotion effect of mixed-ownership reform on green innovation activities only exists in the SOEs of heavily polluting industries.

Table 11. The relationship between mixed-ownership reform and green innovation of SOEs under different industry attributes.

	1	**2**	**3**	**4**	**5**	**6**
Y = AGP	Heavy	Non-heavy	Heavy	Non-heavy	Heavy	Non-heavy
MIXS	0.706 ***	0.175				
	(2.86)	(1.47)				
MIXO			1.252 ***	0.245		
			(2.89)	(1.28)		
MIXB					0.376 **	0.0870
					(2.01)	(0.82)
CONSTANT	−4.553 ***	−2.137 ***	−4.272 ***	−2.087 ***	−4.421 ***	−2.089 ***
	(−3.66)	(−4.29)	(−3.51)	(−4.16)	(−3.39)	(−4.13)
CONTROLS	Yes	Yes	Yes	Yes	Yes	Yes
Industry F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes	Yes	Yes
N	2085	7441	2085	7441	2085	7441
R^2	0.166	0.178	0.170	0.177	0.155	0.177
adj. R^2	0.156	0.172	0.160	0.172	0.145	0.171
Diff	−0.531 *** (0.000)		−1.007 *** (0.000)		−0.289 *** (0.000)	

Note: The t-statistics are reported in parentheses on robust standard errors clustered at the firm level. *, **, and *** designate statistical significance at the 10%, 5%, and 1% level, respectively.

For the judgment of marketization degree, in line with the research of Tang, Wu, Ma, and Song [60] and consulting with the "Marketization Index of China's Provinces: Neri Report 2018", the samples are divided into a group with higher marketization degree and a group with lower marketization degree, taking the median of the marketization index of the province where the SOEs are located as the standard. Table 12 lists the group inspection results. The diversity of mixed shareholders (MIXS), the depth of mixed equity (MIXO), and the restriction of mixed equity (MIXB) are significantly positively correlated with green innovation when SOEs are located in regions with low marketization degree. In the group with a higher degree of marketization, there is no relationship between them, illustrating that the effect of mixed-ownership reform on the green transformation depends on the enterprise's external governance environment.

Table 12. The relationship between mixed-ownership reform and green innovation of SOEs under different marketization processes.

	1	2	3	4	5	6
Y = AGP	High	Low	High	Low	High	Low
MIXS	0.135	0.323 **				
	(0.85)	(2.20)				
MIXO			0.212	0.551 **		
			(0.81)	(2.16)		
MIXB					0.0382	0.237 **
					(0.28)	(2.00)
CONSTANT	−2.913 ***	−2.459 ***	−2.868 ***	−2.376 ***	−2.884 ***	−2.351 ***
	(−4.03)	(−5.00)	(−3.94)	(−4.84)	(−3.93)	(−4.73)
CONTROLS	Yes	Yes	Yes	Yes	Yes	Yes
Industry F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes	Yes	Yes
N	4705	4821	4705	4821	4705	4821
R^2	0.202	0.129	0.202	0.130	0.202	0.127
adj. R^2	0.194	0.121	0.194	0.121	0.194	0.119
Diff	0.188 *** (0.000)		0.3407 *** (0.000)		0.198 *** (0.000)	

Note: The t-statistics are reported in parentheses on robust standard errors clustered at the firm level. *, **, and *** designate statistical significance at the 10%, 5%, and 1% level, respectively.

5.3. Additional Analysis: Does the Mixed-Ownership Reform Contribute to the Sustainable Development of SOEs?

Green innovation is a powerful tool to break through the constraints of resources and the environment and facilitate the sustainable development of enterprises [72]. Remus et al. [73] found that state-owned public property company (IKV) of Hungary provided unfair housing prices to poor Roma, which aggravated their poverty and was not conducive to the long-term development of the state economy. The government energetically deepens SOE reform to strengthen market-oriented construction, perfect the regulatory mechanism of environmental legality, encourage enterprises to assume environmental responsibility, spontaneously carry out green transformation, and release institutional bonuses for improving poverty alleviation, so as to propel the sustainable development of enterprise and country. Wu and Hu [74] also pointed out that the optimal allocation of external and internal resources of enterprises promotes the exploitation of new green technologies, effectively decreases the waste discharge in the process of production and operation, reduces environmental pollution and resource waste, saves production costs and environmental pollution control costs, and ultimately achieves environmental sustainability. The previous research conclusions furnish empirical evidence for the mixed-ownership reform to drive the green transformation of SOEs through the rational use of environmental protection subsidies and active performance of environmental responsibilities. Then, can the mixed-ownership reform create competitive advantages for SOEs and enhance their sustainable development ability by inducing green innovation activities? The basic test has found an increase in

green innovation activities. In this part, we build the model (4) to examine whether the mixed-ownership reform has an impact on the sustainable development of SOEs:

$$SGR_{i,t+1} = \alpha_0 + \alpha_1 MIX_{i,t} + \alpha_2 CONTROLS_{i,t} + \eta_{ind} + \eta_{year} + \varepsilon_{i,t} \quad (4)$$

The *SGR* in the model (4) represents the sustainable development capability of enterprises. Drawing lessons from the practice of Yang et al. [75], this study constructs the enterprise sustainable development index according to James C. Van Horne's sustainable growth model. The specific measurement formula is as follows: sustainable development capability = net profit margin on sales × earnings retention ratio × (1 + equity ratio)/(1/total assets turnover-net profit margin on sales × earnings retention ratio × (1 + equity ratio)). The control variables used in the model are consistent with the above.

Table 13 shows the regression test results. Columns 1–3 reveal that the diversity of mixed shareholders (*MIXS*), the depth of mixed equity (*MIXO*), and the restriction of mixed equity (*MIXB*) are significantly positively correlated with the sustainable development capability of SOEs at the level of 1%, which indicates that equity diversification and the integration and restriction between heterogeneous shareholders enable non-state shareholders to have an effective "voice" in the green strategic decisions, shape the enterprise core competitiveness, and push the sustainable development of SOEs.

Table 13. The impact of mixed-ownership reform on the sustainable development of SOEs.

Y = SGR	1	2	3
MIXS	0.035 ***		
	(4.71)		
MIXO		0.046 ***	
		(3.83)	
MIXB			0.015 **
			(2.27)
CONSTANT	−0.020	−0.009	−0.010
	(−0.92)	(−0.42)	(−0.49)
CONTROLS	Yes	Yes	Yes
Industry F.E.	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes
N	8549	8549	8549
R^2	0.257	0.255	0.252
adj. R^2	0.253	0.251	0.248

Note: The t-statistics are reported in parentheses on robust standard errors clustered at the firm level. *, **, and *** designate statistical significance at the 10%, 5%, and 1% level, respectively.

6. Conclusions

This paper emphasizes two perspectives of "environmental protection subsidy" and "environmental responsibility" to examine the impact of mixed-ownership reform on the green transformation of SOEs and its specific mechanisms. The main research conclusions are as follows: (1) After the non-state-owned capital shares in SOEs, the diversity of mixed shareholders, the depth of mixed equity, and the restriction of mixed equity enhance the green innovation output and consummate the environmental management mechanism of SOEs. (2) There are disparities in the impact of the shareholding ratio of heterogeneous equity on green innovation. Merely the increase in the proportion of foreign shareholders promotes green innovation. Private shareholders who fail to achieve the expected shareholding level and institutional investors who aim to earn the price difference have no effect. The self-protection psychology of natural person shareholders inhibits the occurrence of green innovation activities. (3) The positive impact of the mixed-ownership reform on the green transformation of SOEs is implemented through the dual path. On one side, by bringing down government intervention and agency conflicts, the mixed-ownership reform expedites the rational allocation and efficient use of government environmental protection subsidies and provides a resource base for green innovation activities. On the

other side, the mixed-ownership reform enhances the environmental awareness to induce the independent performance of environmental responsibilities and releases the motivation and ability of SOEs' green transformation after acquiring the support of the government and external investors. (4) If the SOEs belong to heavily polluting industries or regions with a high degree of marketization, the mixed-ownership reform has a significant role in promoting green transformation. In the case of different external environmental characteristics of SOEs, distinctions also exist in the impact of the adjustment of internal ownership structure on green innovation decisions. (5) The mixed-ownership reform has improved the enterprise environmental manifestation and realized the sustainable development of SOEs based on inducing green innovation.

On account of the above study findings, we suggest the following policy recommendations for accelerating the green transformation of SOEs and promoting sustainable development of the economy and society: (1) The governance mechanism of non-state-owned capital needs to be constantly consummated to give full play to its function of supervision and restriction of the green innovation decision-making of SOEs. The intensity of mixed-ownership reform should be gradually intensified to attract more heterogeneous non-state-owned shareholders, enhance their voice in operating activities, and improve the scientificity and correctness of SOEs' green innovation decisions. (2) A priority selection scheme for heterogeneous non-state-owned shareholders should be formulated to achieve the optimal level of governance effects of the SOE reform. The above research results show that except for foreign shareholders, other non-state-owned shareholders cannot reach a consensus on innovation decisions due to their different interest demands, self-expectations, and risk preferences. At present, SOEs should give priority to the introduction of foreign shareholders, simultaneously consider a reasonable arrangement of the equity composition, establish a protection mechanism for the rights and interests of different non-state shareholders, give full play to the advantages of various forms of social capital, and heighten the green innovation capabilities of SOEs. (3) The process of mixed-ownership reform of SOEs in low marketization areas should be accelerated, and stratification and classification reform should be facilitated. The action of mixed-ownership reform on green innovation activities of SOEs is more prominent in low marketization areas, which indicates that the reform makes up for the deficiency of the institutional environment to a certain extent. Government departments should mobilize SOEs' enthusiasm in low marketization regions to participate in mixed-ownership reform, establish a complete institutional system, better protect green innovation achievements, and stimulate enterprise innovative vitality. (4) There is a need to standardize the examination and approval mechanism of environmental protection subsidies, perfect the supervision mechanism, and ensure the rational distribution and use of SOEs' environmental protection subsidies. Through the implementation of more stringent approval procedures for SOEs, such as clarifying the use and service life of environmental protection subsidies and specifying the detailed range of application, the service efficiency and the social benefits of environmental protection funds can be improved and the sustainable development of SOEs can be realized.

This paper preliminarily examines the economic consequences of mixed-ownership reform. Due to the availability of data, there are still some limitations and areas to be further expanded. In the sample selection, we only included the state-owned listed companies that disclose data publicly for research. However, among the large number of state-owned non-listed enterprises in China, non-state-owned shareholders may also hold certain shares to exert a positive effect on green innovation, which requires long-term manual data collection for follow-up verification. Moreover, mixed-ownership reform is in the process of continuous advancement and expansion. With the disclosure of more detailed data, we can track and analyze the policy and conduct more dimensional studies in the future, such as on how mixed-ownership reform affects corporate financial behaviors, and provide abundant evidence to support the optimization of the governance practices of SOEs.

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