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The Impact of Female Directors on Corporate Green Innovation: Evidence from China

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Abstract

Green innovation has become an important driving force for enterprises to shape competitive advantages and for countries to restructure the industrial competitive landscape, but existing research has not reached a consistent conclusion on whether and how female directors affect corporate green innovation. Based on data from Chinese A-share listed companies from 2009 to 2023, this study empirically examines the impact of female directors on corporate green innovation. The results show that female directors can significantly improve the level of corporate green innovation, and this conclusion remains valid after a series of robustness tests. The mechanism analysis indicates that female directors promote green innovation by improving corporate environmental, social, and governance (ESG) performance. The heterogeneity analysis finds that this effect is more significant in non-state-owned enterprises, industries with low competition, and young enterprises. From the perspective of board gender composition, this study reveals the internal mechanism through which female directors affect corporate green innovation and provides empirical evidence for understanding the economic consequences of board gender diversity and for enterprises seeking to improve their green innovation level.

Keywords

female directors, corporate green innovation, upper echelons theory, ESG performance

1. Introduction

Green innovation has become an important path for countries to achieve sustainable development and a key force in reshaping the industrial competitive landscape. The European Union formally implemented the Carbon Border Adjustment Mechanism (CBAM) in 2026 to impose carbon tariffs on imported products; the United States adopted the Inflation Reduction Act (IRA), investing USD 369 billion to support clean energy and green technology innovation; and China established the world's largest carbon emissions trading market by coverage and has continued to promote the green transformation of industries through its carbon peaking and carbon neutrality goals. For enterprises, green innovation not only helps reduce environmental compliance costs but also creates differentiated competitive advantages, making it an important means for enterprises to adapt to the green transition and maintain market competitiveness. For the ecological environment, the development and application of green technologies can reduce pollutant emissions, improve resource utilization efficiency, and promote the transformation of the economy and society toward a low-carbon circular development model. For countries, green innovation is an important support for cultivating new drivers of green development,

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enhancing participation in global climate governance, and improving industrial competitiveness. Therefore, how to effectively improve the level of corporate green innovation has become an important issue of common concern to policymakers and academia. Existing studies on the factors affecting corporate green innovation have mainly examined the internal and external environments faced by enterprises. At the external level, factors such as environmental regulation, government subsidies, and market competition pressure affect enterprises' willingness and investment in green innovation. At the internal level, factors such as enterprise resource capabilities, executive incentives, and governance structures also influence green innovation decisions. In recent years, the governance effect of board gender diversity has received attention. Existing studies show that female directors help improve corporate environmental performance [1, 2]. Upper echelons theory states that the demographic characteristics of the top management team shape its cognitive basis and values, thereby affecting corporate strategic decisions [3]. This provides a theoretical perspective for understanding how gender characteristics affect green innovation decisions. In the Chinese context, corporate top management has long been male-dominated, and its decision-making style often shows stronger risk preference and an emphasis on short-term performance. Female directors, however, usually have stronger risk awareness, social responsibility, and long-term orientation and can bring differentiated decision-making perspectives [4], which may have a positive impact on corporate green innovation decisions. However, whether the governance advantages of female directors can extend to the field of green innovation and through what mechanism they operate have not been fully explored in existing research.

Using data from Chinese A-share listed companies from 2009 to 2023, this study empirically examines the impact of female directors on corporate green innovation and its mechanism. The results show that female directors can significantly improve the level of corporate green innovation, and this conclusion remains valid after a series of robustness tests. The mechanism analysis indicates that female directors can promote green innovation by improving corporate ESG performance. The heterogeneity analysis finds that the green innovation effect of female directors is more significant in non-state-owned enterprises, industries with low competition, and young enterprises. The marginal contributions of this study are mainly reflected in three aspects. First, it examines the internal governance factors of corporate green innovation from the perspective of board gender diversity, further enriching research on the factors affecting corporate green innovation. Second, it introduces upper echelons theory into research on corporate green innovation, reveals how the cognitive characteristics and value orientations of female directors are transformed into corporate green innovation behavior, and extends the application of upper echelons theory in the field of corporate environmental strategy. Third, the conclusions of this study provide empirical evidence for enterprises to optimize board composition and make use of the governance role of female directors, as well as for regulators to further improve board diversity governance mechanisms.

2. Theoretical Analysis and Research Hypotheses

Upper echelons theory holds that demographic characteristics of the top management team, such as age, gender, and educational background, shape its cognitive basis and values, thereby affecting corporate strategic decisions [3]. As the board is the core institution for corporate strategic decision-making, the characteristics of its members also determine the strategic direction of the enterprise. Existing studies show that female directors differ systematically from male directors in risk preferences, ethical cognition, and decision-making styles. They tend to be more sensitive to operational and compliance risks and are inclined to conduct stricter risk reviews in decision-making. At the same time, female directors generally have a stronger sense of social responsibility and empathy, pay greater attention to the demands of stakeholders such as employees, consumers, and communities, and are more active in matters of ethical responsibility and social welfare [4]. These characteristics mean that female directors may guide enterprises to pay greater attention to long-term interests and sustainable development, thereby affecting their environmental strategy choices.

Specifically, after entering the board, female directors may have a positive effect on corporate green innovation through the following three paths. First, female directors have stronger risk awareness and environmental sensitivity, which may enable them to identify increasingly stringent environmental regulations and climate-related risks earlier and promote forward-looking response measures by enterprises [5]. Second, female directors pay greater attention to long-term sustainable development and may be more inclined to support green research and development projects that have long cycles and high risks but offer long-term returns, thereby alleviating managerial short-termism [6]. Third, female directors can enrich the board's

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decision-making perspectives, promote adequate information exchange and in-depth discussion, and may improve the quality of decisions related to green innovation. Cross-country evidence likewise shows that board gender diversity significantly improves corporate environmental innovation [7]. In summary, the risk awareness, long-term orientation, and diverse perspectives of female directors make them pay greater attention to climate change and environmental risks, value long-term green investment projects, and promote full discussion of related decisions, thereby helping enterprises carry out green innovation. Based on this, this study proposes:

H1: Female directors can improve the level of corporate green innovation.

Female directors may also indirectly promote green innovation by improving corporate ESG performance. ESG performance reflects the level at which an enterprise fulfills its responsibilities in the three dimensions of environment, society, and governance and is an important vehicle for enterprises to obtain external resources and stakeholder recognition. Female directors attach greater importance to social responsibility and stakeholder relations. After entering the board, they may promote the improvement of ESG management systems, proactive disclosure of ESG information, and active responses to stakeholders' environmental demands, thereby improving corporate ESG performance (Sandretto et al., 2025)[8]. Improved ESG performance, in turn, helps enterprises gain investor trust and policy resource support. On the one hand, good ESG performance can send a signal of sustainable operations to the capital market, effectively alleviate financing constraints, and provide stable financial support for green innovation that requires large investment and long cycles. On the other hand, actively fulfilling environmental and social responsibilities helps enterprises accumulate social capital and strengthen their ties with governments and communities, making it easier for them to obtain green subsidies and policy support and enhancing their ability to identify green technology opportunities and manage innovation risks (Liu et al., 2024)[9]. Issa and Bensalem (2023) also find that corporate social responsibility strategy plays a mediating role between board gender diversity and eco-innovation[10]. Based on this, this study proposes:

H2: Female directors can improve corporate ESG performance, thereby improving the level of corporate green innovation.

3. Research Design

3.1 Data Sources and Sample Selection

This study uses Chinese A-share listed companies from 2009 to 2023 as the research sample and processes the data as follows: (1) listed financial companies are excluded; (2) companies designated as special treatment (ST) and *ST are excluded; (3) samples with missing core variables are excluded; and (4) to eliminate the influence of extreme values, all continuous variables are Winsorized at the 1st and 99th percentiles. The data used in this study mainly come from the Chinese Research Data Services Platform (CNRDS) and the China Stock Market & Accounting Research (CSMAR) database.

3.2 Variable Selection

(1) Dependent variable: corporate green innovation (GI). This study measures corporate green innovation as the total number of green patents applied for by an enterprise in a given year—that is, the sum of green invention patents, green utility model patents, and green design patents—and uses the natural logarithm of this total after adding 1. The logarithm of the number of green invention patent applications is also used for the robustness test.

(2) Core explanatory variable: proportion of female directors (Female). Strategic decisions on whether an enterprise conducts green innovation are mainly made by the board, so this study focuses on female directors rather than executives. This study uses the number of female directors as a proportion of the total number of board members. This measure can exclude the influence of differences in board size and better measure the strength of female representation at the decision-making level. The number of female directors and its logarithm are also used for the robustness tests.

(3) Control variables. Following the studies of Wang et al. (2022), Hao et al. (2025), and Luo and Liao (2026), this study selects the following control variables: enterprise size (Size), enterprise age (Age), leverage

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(Lev), return on assets (ROA), research and development intensity (RD), shareholding ratio of the largest shareholder (Top), and chief executive officer duality (Dual)[11, 12, 13]. The specific measurements are shown in Table 1.

Table 1: Variable Definitions

Variable Category	Variable Name	Symbol	Measurement
Dependent variable	Corporate green innovation	GI	ln(number of green patent applications + 1)
Core explanatory variable	Proportion of female directors	Female	Number of female directors / total number of board members
Control variable	Enterprise size	Size	ln(total assets + 1)
	Enterprise age	Age	ln(year of establishment + 1)
	Leverage	Lev	Total liabilities / total assets
	Return on assets	ROA	Net profit / total assets
	R&D intensity	RD	R&D expenditure / operating revenue
	Ownership concentration	Top	Shareholding ratio of the largest shareholder
	CEO duality	Dual	1 if the chairperson also serves as chief executive officer (CEO), and 0 otherwise

3.3 Model Specification

To test the impact of the proportion of female directors on corporate green innovation, this study constructs a two-way fixed-effects panel regression model for enterprise and year:

$$GI_{i,t}=\alpha_0+\alpha_1 Female_{i,t}+\alpha_2 Controls_{i,t}+\mu_i+\lambda_t+\varepsilon_{i,t} \quad (1)$$

Here, i denotes the enterprise, t denotes the year, GI denotes the level of corporate green innovation, Female denotes the proportion of female directors, and Controls denotes a series of control variables; μ_i denotes enterprise fixed effects, λ_t denotes year fixed effects, and ε_{it} denotes the random disturbance term. This study mainly focuses on the coefficient α_1. If α_1 is significantly positive, this indicates that the proportion of female directors has a positive effect on corporate green innovation.

4. Empirical Results and Analysis

4.1 Descriptive Statistics

The descriptive statistical results of this study are shown in Table 2. The mean of corporate green innovation (GI), the dependent variable, is 0.449, the standard deviation is 0.833, the minimum is 0, the maximum is 3.401, and the median is 0. This indicates that more than half of the sample enterprises have no green patent output, green innovation is unevenly distributed among enterprises, and only a small number of enterprises have relatively high green patent output. The core explanatory variable, the proportion of female directors (Female), is measured as the number of female directors divided by the total number of board members. Its mean is 0.156, its standard deviation is 0.132, its minimum is 0, and its maximum is 0.556. This indicates that female directors account for approximately 15.6% of board members on average in the sample enterprises, but there are large differences among enterprises. Some enterprises have no female directors on their boards, whereas the proportion of female directors in some enterprises reaches as high as 55.6%.

Table 2: Descriptive Statistical Analysis

VarName	Obs	Mean	SD	Min	Median	Max
GI	30808	0.449	0.833	0	0	3.401
Female	30808	0.156	0.132	0	0.125	0.556
Size	30808	22.067	1.279	18.956	21.866	26.164
Age	30808	9.555	7.599	0	7	29
Lev	30808	0.394	0.201	0.054	0.380	0.948
ROA	30808	0.041	0.069	-0.288	0.042	0.280
RD	30808	5.158	5.297	0.040	3.840	33.550
Top	30808	33.889	14.691	8.560	31.630	75.050
Dual	30808	0.332	0.471	0	0	1

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4.2 Baseline Regression Analysis

The baseline regression results of this study are shown in Table 3. Column (1) reports the results of a two-way fixed-effects model for enterprise and year that includes only the core explanatory variable, female directors. The coefficient of the proportion of female directors (Female) is 0.080 and is significantly positive at the 5% level, indicating that female directors have a positive impact on corporate green innovation. Column (2) reports the results after adding the control variables. The coefficient of the proportion of female directors (Female) is 0.090 and is significant at the 5% level, indicating that a higher proportion of female directors is associated with a higher level of corporate green innovation. This verifies Hypothesis 1 of this study.

Table 3: Baseline Regression Analysis

	(1) GI	(2) GI
Female	0.080**	0.090**
	(2.173)	(2.437)
Size		0.104***
		(12.337)
Age		-0.021
		(-0.826)
Lev		-0.116***
		(-3.540)
ROA		-0.006
		(-0.105)
RD		0.006***
		(4.701)
Top		-0.002***
		(-3.515)
Dual		-0.018*
		(-1.793)
_cons	0.436***	-1.568***
	(67.924)	(-5.273)
Firm_FE	YES	YES
Year_FE	YES	YES
N	30808	30808
r2	0.695	0.697

*Note: The t-values are reported in parentheses; *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively. The same applies below.*

4.3 Robustness Tests

To test the robustness of the baseline regression results, this study uses four methods: replacing the core explanatory variable, replacing the dependent variable, adjusting the sample period, and using high-dimensional fixed effects. The results are shown in Table 4.

(1) Replacing the core explanatory variable. To test whether the measurement of the core explanatory variable affects the conclusions of this study, the number of female directors (Female2) and the logarithm of the number of female directors (Female3) are used separately to replace the proportion of female directors (Female). The regression results are shown in columns (1) and (2) of Table 4. The regression coefficients are 0.009 and 0.024, respectively, and both are significantly positive at the 5% level. These results are consistent with the baseline regression conclusion, indicating that the conclusion of this study does not depend on a specific measurement of the core explanatory variable and is robust.

(2) Replacing the dependent variable. To test whether the measurement of the dependent variable affects the conclusion of this study, the logarithm of the number of green invention patent applications (GI2) is used to replace the logarithm of the number of green patent applications (GI), and the regression is re-estimated. The results in column (3) of Table 4 show that the coefficient of the proportion of female directors (Female) is 0.083 and is significantly positive at the 1% level. This is consistent with the baseline regression conclusion, indicating that the conclusion remains valid after changing the measurement of the dependent variable and that the result is robust.

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(3) Adjusting the sample period. To test whether the selection of the sample period affects the conclusion of this study, the regressions are re-estimated using two subsamples, 2009-2020 and 2012-2023. The regression results are shown in columns (4) and (5) of Table 4. The coefficients of the proportion of female directors (Female) are 0.101 and 0.092, respectively, and both are significantly positive at the 5% level. These results are consistent with the baseline regression conclusion, indicating that the conclusion of this study is not affected by the selection of the sample period and is robust.

(4) High-dimensional fixed effects. To further control for unobservable factors such as unique shocks faced by a specific industry in a specific year, industry-by-year interaction fixed effects are added to the two-way fixed effects for enterprise and year, and the regression is re-estimated. The results in column (6) of Table 4 show that the coefficient of the proportion of female directors (Female) is 0.084 and is significantly positive at the 5% level. This is consistent with the baseline regression conclusion, indicating that the positive effect remains valid after controlling for high-dimensional fixed effects and that the result is robust.

Table 4: Robustness Tests

	(1)	(2)	(3)	(4)	(5)	(6)
	GI	GI	GI2	GI	GI	GI
Female			0.083***	0.101**	0.092**	0.084**
			(2.770)	(2.246)	(2.438)	(2.263)
Female2	0.009**					
	(2.047)					
Female3		0.024**				
		(2.456)				
Size	0.103***	0.103***	0.077***	0.091***	0.099***	0.108***
	(12.305)	(12.304)	(11.438)	(9.048)	(11.144)	(12.291)
Age	-0.021	-0.021	-0.012	0.144	-0.019	-0.020
	(-0.844)	(-0.836)	(-0.536)	(1.594)	(-0.783)	(-0.773)
Lev	-0.116***	-0.116***	-0.059**	-0.105***	-0.119***	-0.110***
	(-3.539)	(-3.538)	(-2.271)	(-2.747)	(-3.492)	(-3.339)
ROA	-0.006	-0.007	0.025	0.092	-0.013	-0.008
	(-0.115)	(-0.120)	(0.558)	(1.417)	(-0.222)	(-0.143)
RD	0.006***	0.006***	0.005***	0.007***	0.005***	0.006***
	(4.696)	(4.692)	(5.115)	(4.630)	(3.804)	(4.679)
Top	-0.002***	-0.002***	-0.001**	-0.003***	-0.002***	-0.002***
	(-3.512)	(-3.509)	(-2.096)	(-4.416)	(-3.406)	(-2.993)
Dual	-0.018*	-0.018*	-0.010	-0.012	-0.011	-0.018*
	(-1.766)	(-1.766)	(-1.248)	(-1.009)	(-1.072)	(-1.778)
_cons	-1.554***	-1.561***	-1.264***	-2.803***	-1.456***	-1.667***
	(-5.224)	(-5.243)	(-5.008)	(-3.217)	(-4.711)	(-5.353)
Firm_FE	YES	YES	YES	YES	YES	YES
Year_FE	YES	YES	YES	YES	YES	YES
N	30808	30808	30808	22324	29377	30782
r2	0.697	0.697	0.675	0.708	0.709	0.701

4.4 Heterogeneity Analysis

The baseline regression results show that female directors can improve the level of corporate green innovation, but this impact may differ among enterprises with different characteristics. To further examine the applicable boundaries of the green innovation effect of female directors, this study conducts a heterogeneity analysis from three dimensions: ownership nature, industry competition, and enterprise age.

(1) Heterogeneity in ownership nature. State-owned and non-state-owned enterprises differ in corporate governance structures and policy burdens, which may affect the role of female directors in green innovation decisions. This study divides the sample into non-state-owned enterprises and state-owned enterprises for group regressions. As shown in columns (1) and (2) of Table 5, the coefficient of the proportion of female directors (Female) is 0.153 and significantly positive at the 1% level in the non-state-owned enterprise group, whereas the coefficient is not significant in the state-owned enterprise group. This indicates that the green innovation effect of female directors mainly exists in non-state-owned enterprises. A possible reason is that non-state-owned enterprises are more market-oriented, female directors have greater influence in decision-

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making, and their long-term orientation can better promote green innovation. State-owned enterprises, however, are more strongly affected by policy guidance, and the individual characteristics of female directors have a relatively limited impact on innovation decisions.

(2) Heterogeneity in industry competition. The degree of industry competition may affect enterprises' innovation motivation and resource allocation efficiency. Using the median Herfindahl-Hirschman Index (HHI) as the cutoff, this study divides the sample into groups with high and low industry competition for group regressions. As shown in columns (3) and (4) of Table 5, the Female coefficient is 0.064 and not significant in the high-industry-competition group, whereas it is 0.126 and significantly positive at the 5% level in the low-industry-competition group. This indicates that the positive effect of female directors on green innovation is more significant in markets with a lower degree of industry competition.

(3) Heterogeneity in enterprise age. Enterprise age may affect organizational innovation inertia and resource allocation patterns. This study divides the sample into young enterprises and older enterprises according to the median enterprise age for group regressions. As shown in columns (5) and (6) of Table 5, the Female coefficient is 0.115 and significantly positive at the 10% level in the young enterprise group, whereas it is 0.052 and not significant in the older enterprise group. This indicates that the green innovation effect of female directors is more evident in young enterprises.

Table 5: Heterogeneity Analysis

	(1)	(2)	(3)	(4)	(5)	(6)
	GI	GI	GI	GI	GI	GI
Female	0.153***	-0.077	0.064	0.126**	0.115*	0.052
	(3.600)	(-0.975)	(1.191)	(2.278)	(1.939)	(1.016)
Size	0.123***	0.062***	0.111***	0.097***	0.148***	0.052***
	(12.542)	(3.406)	(8.467)	(7.571)	(8.747)	(4.280)
Age	-0.050	0.010	-0.052	0.034	0	-0.017
	(-1.274)	(0.303)	(-1.363)	(0.847)	(.)	(-0.648)
Lev	-0.077**	-0.179**	-0.110**	-0.163***	-0.200***	-0.050
	(-2.095)	(-2.300)	(-2.213)	(-3.456)	(-3.495)	(-1.093)
ROA	-0.049	-0.103	0.095	-0.064	-0.187*	0.021
	(-0.802)	(-0.758)	(1.064)	(-0.875)	(-1.747)	(0.314)
RD	0.005***	0.008*	0.006***	0.005**	0.002	0.005***
	(4.057)	(1.883)	(3.268)	(2.355)	(1.058)	(2.663)
Top	-0.001**	-0.005***	-0.003***	-0.001	-0.001	-0.004***
	(-2.096)	(-4.631)	(-3.338)	(-1.263)	(-0.932)	(-4.326)
Dual	-0.027**	0.012	-0.012	-0.030**	-0.012	0.008
	(-2.312)	(0.467)	(-0.793)	(-2.042)	(-0.774)	(0.536)
_cons	-1.889***	-0.732	-1.396***	-1.978***	-2.670***	-0.318
	(-5.449)	(-1.120)	(-3.120)	(-4.043)	(-7.135)	(-0.652)
Firm_FE	YES	YES	YES	YES	YES	YES
Year_FE	YES	YES	YES	YES	YES	YES
N	21791	8695	14887	14941	15734	14841
r2	0.672	0.746	0.707	0.733	0.714	0.747

4.5 Mechanism Analysis

To further explore the internal mechanism through which female directors affect corporate green innovation, this study conducts a mechanism test from the dimension of ESG performance. Female directors usually pay greater attention to social responsibility and sustainable development and may promote green innovation by improving corporate ESG performance. This study uses the Huazheng ESG score (ESG_Score_mean) to measure corporate ESG performance and tests the impact of female directors on ESG performance. The results in column (1) of Table 6 show that the coefficient of the proportion of female directors (Female) is 0.180 and significantly positive at the 1% level, indicating that female directors can significantly improve corporate ESG performance. This shows that female directors promote corporate social responsibility and improve ESG performance, thereby facilitating corporate green innovation and verifying the existence of the ESG performance channel.

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Table 6: Mechanism Analysis

	ESG	GI
Female	0.180***	0.097**
	(3.407)	(2.562)
ESG_Score_mean		0.025***
		(5.207)
Size	0.234***	0.073***
	(17.750)	(8.283)
Age	-0.090*	-0.023
	(-1.655)	(-0.916)
Lev	-1.018***	0.007
	(-19.055)	(0.212)
ROA	0.221**	0.071
	(2.112)	(1.225)
RD	0.006***	0.007***
	(3.051)	(5.083)
Top	0.004***	-0.001
	(4.056)	(-1.318)
Dual	0.003	-0.021**
	(0.182)	(-2.031)
_cons	0.089	-1.052***
	(0.146)	(-3.370)
Firm_FE	YES	YES
Year_FE	YES	YES
N	29053	29053
r2	0.578	0.709

5. Conclusion

Using Chinese A-share listed companies from 2009 to 2023 as the research sample, this study empirically examines the impact of female directors on corporate green innovation and its mechanism. The results show that female directors can significantly improve the level of corporate green innovation, and the conclusion remains valid after a series of robustness tests. The mechanism analysis indicates that female directors promote green innovation by improving corporate ESG performance. The heterogeneity analysis finds that this effect is more significant in non-state-owned enterprises, industries with low competition, and young enterprises. Based on these findings, this study proposes the following three recommendations:

(1) Enterprises should optimize the gender composition of their boards, appropriately increase the proportion of female directors in director selection, and pay attention to their professional backgrounds and governance capabilities. At the same time, enterprises should avoid the token appointment of female directors and ensure their substantive participation in green innovation, environmental governance, and long-term strategic decisions by improving rules of procedure and increasing their participation in major decisions, thereby giving full play to their governance role.

(2) Enterprises should strengthen the coordination between ESG management and green innovation strategies and embed ESG concepts throughout environmental governance, social responsibility, and internal governance. They can make full use of the advantages of female directors in stakeholder communication and social responsibility, improve ESG information disclosure and management mechanisms, enhance external recognition and resource acquisition capabilities, and provide stable financial and governance support for green innovation.

(3) Regulators should implement differentiated guidance according to ownership nature, the degree of industry competition, and the stage of enterprise development. For non-state-owned enterprises and young enterprises, board diversity governance mechanisms can be further improved. For enterprises in industries with a low degree of competition, internal governance constraints and green innovation incentives should be strengthened. At the same time, relevant information disclosure systems should be improved to guide enterprises in increasing the substantive governance participation of female directors.

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