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Research on the Influence of Enterprise ESG Performance on Green Technology Innovation Performance Under Digital Transformation

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Abstract: With the acceleration of global digitalization process and the deepening integration of the concept of sustainable development, how the enterprise digital transformation affects the performance of enterprise ESG and green technology innovation has become an important issue of common concern to the academia and the industry. Taking China's A-share listed enterprises in 2013-2022 as the empirical research sample, the influence mechanism of enterprise ESG performance from the perspective of resource basis on the performance of green technology innovation is explored. The research shows that: (1) Enterprise ESG performance, and its three dimensions of environment, society and corporate governance have significantly promoted the improvement of enterprise green technology innovation performance, among which, environmental responsibility has a stronger role in promoting the green technology innovation performance.(2) Digital transformation positively regulates the promoting effect of enterprise ESG performance on the performance of green technology innovation. (3) Heterogeneity analysis shows that the ESG performance of enterprises with different property rights and industries has different effects on promoting green technology innovation performance, while the ESG performance of state-owned enterprises, manufacturing enterprises and non-heavy pollution enterprises has a stronger role in promoting green technology innovation performance. This study expands the related research on enterprise ESG performance, and provides more feasible solutions for enterprises to improve the performance of green technology innovation.

Keywords: Enterprise ESG Performance; Green Technology Innovation Performance; Digital Degree
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Introduction

In the context of global climate change and increasing pressure on resources and the environment, promoting green technology innovation has become a key path to achieve sustainable development. As the main body of economic activities, its environmental, social and governance (ESG) performance is closely related to the performance of green technology innovation. The ESG concept emphasizes that while pursuing economic benefits, enterprises both environmental protection, social responsibility and corporate governance, which is highly consistent with the goal of green technology innovation. In recent years, with the rise of the ESG investment concept and the improvement of the green financial system, the ESG performance of enterprises has been increasingly concerned by investors, regulators and all sectors of society. Good ESG performance not only helps enterprises to improve their brand image and reduce operational risks, but also brings more

financing opportunities and competitive advantages to enterprises, so as to promote the development of green technology innovation (Kamierczak M, 2022).

From a resource-based perspective, the better ESG performs, the more likely it are to actively search, acquire and integrate green technology innovation resources and carry out green technology innovation. However, the existing research on ESG performance and green technology innovation mechanism, mostly focus on strengthening environmental protection investment, ease financing constraints (li, 2024) and improve risk bearing ability (Peng BaiChuan, 2024), etc., few research from the perspective of resource acquisition, solve the practical problems in the process of green technology innovation. Existing studies focus on the impact of ESG performance on corporate financial performance, but less on its mechanism of action on green technology innovation. In addition, the differential impact of different dimensions of ESG performance (environment, society and governance) on green technology innovation.

Existing research shows that the digital transformation has a significant impact on the performance of ESG, but the conclusions are different: Liu Fangyuan and Wu Yunlong (2024) proved that digital transformation can improve the environment and social responsibility; Wang Yinghuan and Guo Yongzhen (2023) found an "inverted U-shaped" relationship; Wang Haijun et al (2023) showed through quantitative analysis that every 1% increase of digital transformation can improve the performance of ESG by 0.096%. It is worth noting that existing research focuses on the direct correlation between digital transformation and ESG performance (Guo Shujuan and Yan Caifeng, 2024; Wang Jin et al., 2024), but ignores the regulatory role of the key situational variable, the degree of digitalization, on the "ESG-green technology innovation" relationship. Based on the dynamic capability theory, this paper discusses how the degree of digitalization can regulate the effect of ESG performance on the performance of green technology innovation.

Based on the above background, this study aims to explore the following core issues: How does enterprise ESG performance affect the performance of green art innovation? Is there any difference in the impact of different dimensions of enterprise ESG performance (environment, society, and governance) on green technology innovation performance? How the degree of internal digitalization adjusts the relationship between enterprise ESG performance and green technology innovation performance.

1.Theoretical analysis and research hypotheses

1.1 Enterprise ESG performance and green technology innovation performance

Enterprise green technology innovation performance is an important indicator to measure the output of green technology innovation enterprise green technology innovation, green technology innovation activity involves research and development, production and other links, need long-term capital, human resources and other resources and government and stakeholders have key resources and capacity (RanRong, 2023,2021), to improve enterprise green technology innovation performance, not only need sustainable development as the strategic goal, but also have the resources of green technology innovation (Yang Zhen and Wang Yue, 2024). ESG concept can guide the enterprise green transformation, green development into the enterprise production, management and financial management, help enterprises to form the sustainable development of resource allocation structure, increase investment in green technology innovation (Lin Binghong and Li Bingxiang, 2024), improve enterprise green technology innovation performance.

First, a company's ESG performance not only reflects the impact of organizational decisions on the environment and society but also maximizes the demonstration of sustainable development concepts (Xiao Hongjun, 2024). This means that companies focus on long-termism in their development, emphasizing collaboration between the company and the environment, society, and stakeholders. It also indicates that companies place greater emphasis on sustainable development in strategic decision-making and resource allocation (Yang Zhen and Wang Yue, 2024). From the perspective of responsibility fulfillment, a company's good ESG performance can send positive signals to the public, increase market attention, and thereby establish a favorable corporate image.

Secondly, good ESG performance represents that enterprises have taken active actions in environmental responsibility and social responsibility, to a certain extent, established the value symbiotic relationship between enterprises and multiple stakeholders, won the trust and support of government regulatory departments and stakeholders, and formed a reputation

advantage (Meng Mengmeng et al., 2023; Qiu Muyuan and Yin Hong, 2019), enterprise social responsibility can drive enterprise green innovation strategy (Xiao Hongjun, 2023), strengthen enterprise environmental investment, optimize resource structure, form green resource advantage, and enhance green innovation willingness (Li Huiyun et al., 2022).

Further, based on the basic view of natural resources, environmental performance (E) requires enterprises to reduce pollution and reduce carbon emissions, which will directly force enterprises to meet the needs of regulators and stakeholders through green technology innovation (such as clean production technology and recycling technology). Stakeholder theory states that improving employee well-being (e. g., safety training) and community relationships (S) can enhance internal cohesion, attract highly qualified talent, and indirectly promote innovation; and consumer environmental preferences may drive companies to develop green products. Agency theory points out that better internal governance (G) can avoid short-sighted management decisions and promote long-term investment in green technology. Based on the above analysis, the following assumptions are proposed:

H1: Good ESG performance helps enterprises to improve their green technology innovation performance.

H1a: The better the performance of enterprise environmental performance (E), the higher the performance of green technology innovation.

H1b: The better the good social performance (S) performance, the higher the green technology innovation performance.

H1c: The better the good governance performance (G) performance, the higher the green technology innovation performance.

1.2 Regulatory effect of digitalization degree

In the context of the enterprise digital transformation, digital application helps to the management of enterprise resources combination, including external resource acquisition, internal resource accumulation and stripping no value resources process, help enterprises to achieve competitive resources combination, for the development of the enterprise to build innovation pool, integrate resources for the enterprise to promote green technology innovation overweight power. With the development of digital economy, more and more enterprises have accelerated the pace of digital transformation. The power of digital technology has improved the speed of enterprise information acquisition and improved the efficiency of enterprise resource allocation (Wu Fei, 2021; Chen Dongmei, 2020).

Access resources is only one of the prerequisites for improving enterprise performance, and dynamic management of resources is the key to transforming resources into capabilities to improve enterprise performance (Sirmon et al., 2007; Sirmon et al., 2011). First, through digital transformation, enterprises can strengthen the resource allocation capacity and resource utilization efficiency, promote effective communication between departments, and realize the integration of internal and external resources of the organization (Amit R, HanX, 2017; Feng H, Wang F, Song G, et al, 2022). From the resource-based theory, the green innovation activities of enterprises rely on the effective use of resources, while digitalization can improve the efficiency of the use of resources and provide support for the green innovation of enterprises (Li Dehui, 2023). Based on the theory of resource arrangement, digitalization further enhances the dynamic capacity of enterprises, helps enterprises to improve the production process and optimize the allocation structure of elements (Lin Xin et al., 2023), so as to improve the operational efficiency and improve the utilization rate of resources (Fan Hongzhong et al., 2022).

The degree of digital transformation reduces innovation transaction costs (Wang Xiaohong et al., 2023). Companies with high levels of digitalization can reduce contract costs through technologies such as smart contracts, making ESG investments more efficiently converted into innovative outputs. At the same time, digital technology enhances data collection and analysis efficiency, accelerates capital turnover and knowledge sharing, and optimizes the allocation of production factors (Fan Hongzhong et al., 2022), creating a scale effect for green innovation. High-digitalization companies achieve real-time monitoring of energy consumption through technologies like the Internet of Things, directly guiding ESG performance improvements towards green technology research and development (Bai Fuping et al., 2023). Companies with high levels of digitalization improve corporate governance by increasing information transparency (Guo Shujuan and Yan Caifeng, 2024) and restructuring management frameworks (Wang Yinghuan and Guo Yongzhen, 2023).

Based on the above analysis, the following assumptions are proposed:

H2: The degree of digital transformation of enterprises strengthens the relationship between enterprise ESG performance and

green technology innovation performance.

2.Study design

2.1 Sample selection and data source

Take China's A-share listed companies from 2013 to 2022 as the initial sample, and make the following treatment: (1) excluding ST and * ST listed companies; (2) remove companies with missing data related to major research variables. After screening and matching, 4,464 A-share listed enterprises had A total sample size of 33,673. Among them, the green patent data of enterprises comes from the number of green patent applications of China Research Data Service Platform (CNRDS), and the relevant data of control variables comes from the National Tai'an (CSMAR) database.

2.2 Model setting

In order to verify the above assumptions, the following regression models are constructed: (1) assumptions of enterprise ESG and green technology innovation; (2) assumptions of the regulatory effect of digitalization degree on enterprise ESG performance and green technology innovation performance; specifically as follows:

$$\mathrm{Green}_{i,t} = a_0 + a_1 \mathrm{ESG}_{i,t} + a_2 \sum \mathrm{Controls} + \sum \mathrm{Industry} + \sum \mathrm{Year} + \varepsilon_{i,t} \quad (1)$$

$$\mathrm{Green}_{i,t} = t_0 + t_1 \mathrm{ESG}_{i,t} + t_2 \mathrm{ESG}_{i,t} \cdot \mathrm{dig}_{i,t} + \mathrm{t}_4 \sum \mathrm{Controls} + \sum \mathrm{Industry} + \sum \mathrm{Year} + \varepsilon_{i,t} \quad (2)$$

In the above model, i represents the enterprise and t represents the time.

2.3 Variable selection and measurement

2.3.1 Interpreted variable: Green Innovation Performance (Green)

The performance data of green technology innovation is referred to the existing research, which is measured by the sum of the current number of green invention patent applications and the number of patent applications for green utility model (Xu Jianzhong and Wang Manman, 2019).

2.3.2 Interpretive Variables: Enterprise ESG Performance (ESG)

The measurement method of enterprise ESG performance, referring to the research of previous scholars, adopts the ESG score published by the third-party rating agency. In the process of robustness test, the ESG score published by Bloomberg Listed Company (PBESG) and CNRDS database (CNRDESG) plus 1 is used to measure the enterprise ESG performance.

2.3.3 Adjustment variables: degree of digital transformation (Dig)

In order to ensure the objectivity of the research method. Digital transformation data reference Tai'an (CSMAR) database of listed companies in Chinese digital transformation research database, including the strategy of listed companies, technology driven, organization can assign, enterprise digital achievements and application, the macro level of environmental support, etc., from the multidimensional enterprise digital transformation level. Therefore, the digital transformation index published in the National Tai'an (CSMAR) database was used to measure the degree of digital transformation.

2.3.4 Control variables

Control variables mainly include: 1) Firm Age (Age), which directly reflects the company's seniority and experience, influencing the resource endowment for green technology innovation; 2) Firm Size (Size), larger firms tend to be more rigid but have better resource advantages; 3) R&D Investment (RDinput), which directly affects the intensity of green technology innovation; 4) Debt-to-Asset Ratio (Lev); while also controlling for industry (Industry) and year (Year).

Specific variable definitions are shown in Table 1 below,

Table 1. Definitions of each variable

type of variable	Variable name	Specific definition	
explained variable	Green technology innovation performance	Green	Number of ln (1 + green patent applications)
explanatory variable	Enterprise ESG performance	ESG	The ln (1 + ESG score)

type of variable	Variable name	Specific definition	
regulated variable	Degree of digitization	Dig	CSMAR
controlled variable	scale	Size	Natural ln (1 + natural logarithm of total assets at the end of the year)
	asset-liability ratio	Lev	Total liabilities / total assets
	enterprise age	AGE	Enterprise listing years
	research input	RDinput	Source: Guotai An Database
	Enterprise nature	SOE	1 for state-owned enterprises and 0 for others

3.Empirical analysis

3.1 Descriptive statistical analysis

Table 2 presents the descriptive statistics of the main variables in this study. The mean value of corporate green technology innovation performance is 0.924, with a maximum of 7.782 and a minimum of 0. The maximum value for corporate ESG performance is 4.543, with a minimum of 3.628, and the sample mean is 4.303. It is evident that in recent years, many companies have begun to take effective measures to improve their ESG performance. The mean value of digitalization level is 3.599, with a standard deviation of 0.264, indicating significant differences in digitalization levels among companies. This further suggests that choosing differentiated levels of corporate digitalization as a contextual factor in the model for promoting corporate green technology innovation performance better aligns with the actual situation of each company.

In addition, the Pearson (Pearson) correlation analysis was conducted on the main variables, and the results showed that the correlation coefficient between all variables was less than 0.5, and there was no multicollinearity problem.

Table 2 Descriptive statistics of samples

variable		sample capacity	mean	standard error	least value	crest value
Enterprise ESG performance	ESG	32,815	4.303	0.0766	3.628	4.543
Environmental performance	E	32,815	4.115	0.126	3.416	4.566
social responsibility	S	32,815	4.317	0.147	0	4.615
corporate governance	G	32,815	4.373	0.105	3.025	4.605
Green technology innovation performance	Green	32,815	0.924	1.226	0	7.782
Digitization degree	Dig	32,815	3.599	0.264	3.107	4.395
scale	Size	32,809	3.149	0.0622	2.808	3.472
asset-liability ratio	Lev	32,747	0.429	0.214	0.00797	1.957
enterprise age	AGE	32,801	10.36	7.914	0	32
research input	RDinput	32,815	2.618	4.703	0	23.73

3.2 Analysis of the regression results

3.2.1 Enterprise ESG performance and green technology innovation performance

Table 3 reports the results of the regression analysis of enterprise ESG performance on green technology innovation performance. As shown in column (2), after controlling for the influence of other variables on green technology innovation performance, the regression coefficient of enterprise ESG performance on green technology innovation performance is 1.186 and significantly positive at the 1% level ($p < 0.01$), assuming H1 is supported. In addition, from the perspective of control variables, enterprise size, age and R & D investment have a significant positive impact on the green technology innovation of enterprises, which also shows that enterprises with good background can actively respond to the national two-carbon policy

and carry out green technology innovation.

Considering the ESG score, environmental performance (Environmental) mainly evaluates the positive measures taken by the enterprise in environmental protection; social responsibility performance (Social) reflects the responsibility of stakeholders and has more legitimacy and reputation advantages; corporate governance performance (Governance) mainly evaluates the overall strategic planning and internal management level of the enterprise, and good corporate governance ability will enhance the technological innovation level of the enterprise (Feng Genfu and Wen Jun, 2008). Based on the above analysis, ESG is divided into three dimensions to test the impact of different dimensions on the performance of green technology innovation of enterprises. Table 3 column (3) (4) (5) regression results show that environmental protection (E), social responsibility (S), corporate governance ability (G) to the regression coefficient of green technology innovation performance of 1.039,0.329,0.316 respectively, and all at 1% level is positive (p <0.01), in addition, the environmental responsibility of green technology innovation performance is stronger. Suppose H1, H 1, H1a, H1b, and H1c were verified.

Table 3 Enterprise ESG performance and green technology innovation performance

variable name	(1)	(2)	(3)	(4)	(5)
	Green	Green	Green	Green	Green
ESG	2.611***	1.186***			
	(32.136)	(15.618)			
E			1.039***		
			(22.471)		
S				0.329***	
				(8.168)	
G					0.316***
					(5.829)
Size		10.601***	10.550***	11.030***	11.100***
		(84.826)	(86.762)	(91.037)	(91.820)
Lev		0.175***	0.059*	0.071**	0.119***
		(5.414)	(1.887)	(2.255)	(3.578)
AGE		0.003***	0.002*	0.002*	0.001
		(3.112)	(1.926)	(1.908)	(1.072)
RDinput		-0.004**	-0.002	-0.004**	-0.004**
		(-2.373)	(-1.370)	(-2.232)	(-2.299)
Constant	-10.889***	-37.911***	-36.982***	-35.508***	-35.782***
	(-30.481)	(-90.125)	(-96.977)	(-93.097)	(-87.592)
Industry	YES	YES	YES	YES	YES
year	YES	YES	YES	YES	YES
Observations	32,815	32,734	32,734	32,734	32,734
R-squared	0.216	0.408	0.412	0.405	0.404

Note: t-statistics in parentheses, *** p<0.01, ** p<0.05, * p<0.1; unless otherwise specified, the following tables are the same.

3.2.3 Test of regulatory effect

The regulatory mechanism test is shown in Table 4, which tests the regulation effect of redundant resources and the

dual regulation mechanism of digital and redundant resources successively. Column (1), (2) test the degree of digital transformation, column (2), the enterprise digital transformation degree and ESG performance interaction of the enterprise green technology innovation performance regression coefficient of 2.330, verify the hypothesis H2, namely the enterprise digital transformation degree strengthen enterprise ESG performance and green technology innovation performance.

Table 4: Test of regulatory effects

	(1)	(2)
VARIABLES	**c_Green**	**c_Green**
c_lnESG	1.186***	1.167***
	(15.618)	(15.390)
c_lnESG*lndigg		2.330***
		(9.022)
lnsize1	10.601***	10.579***
	(84.826)	(84.738)
Lev	0.175***	0.172***
	(5.414)	(5.302)
AGE	0.003***	0.002**
	(3.112)	(2.237)
RD1	-0.004**	-0.004**
	(-2.373)	(-2.449)
Constant	-33.725***	-33.666***
	(-86.224)	(-86.167)
Observations	32,734	32,734
R-squared	0.408	0.409

t-statistics in parentheses； *** p<0.01, ** p<0.05, * p<0.1

3.3 Robustness Test

Considering the diversity of ESG rating indicators, this paper uses the ESG score published by Bloomberg listed companies and CNRD database plus 1 natural logarithm to remeasure the ESG performance of the enterprise, replace the original explanatory variable Huasheng ESG score, and regress the samples. In Table 5-8, columns (1) and (3), respectively, the estimated coefficients of Bloomberg ESG (PBESG) and CNRD database ESG (CNRDESG) were 1.707 and 0.426, respectively, which passed the 1% confidence level significance test. In addition, after the addition of control variables, the estimated coefficient of Bloomberg ESG (PBESG) and CNRD database ESG (CNRDESG) was 0.642 and 0.238, respectively, and was significantly positive at the 1% confidence level, indicating that the change of explanatory variables still has a significant positive impact of ESG performance on the enterprise green technology innovation, the regression results are basically consistent with the regression results of the above benchmark results, indicating that the main effect results are robust.

Table 5 Results of the robustness tests for replacing the ESG metric

	(1)	(2)	(3)	(4)
VARIABLES	**Green**	**Green**	**Green**	**Green**
CNRDESG			0.642***	0.238***
			(32.810)	(13.525)
PBESG	1.707***	0.426***		
	(30.608)	(7.768)		
lnsize1		13.329***		10.912***

	(1)	(2)	(3)	(4)
VARIABLES	Green	Green	Green	Green
		(50.405)		(90.427)
Lev		-0.096		0.041
		(-1.443)		(1.311)
AGE		-0.000		0.001
		(-0.182)		(0.768)
RDinput		-0.000		0.000***
		(-0.230)		(3.627)
Constant	-4.972***	-42.897***	-1.801***	-34.509***
	(-21.962)	(-55.313)	(-16.295)	(-92.675)
Observations	11,075	11,068	32,815	32,734
R-squared	0.360	0.498	0.217	0.407

t-statistics in parentheses； *** p<0.01, ** p<0.05, * p<0.1

3.4 Heterogeneity analysis

(1) Property property rights analysis

Based on the important impact of enterprise property rights on enterprise environmental performance, social performance and corporate governance performance (Li Yuee et al., 2018; Liu Xinji, Zhu Menglan, 2018), the sample enterprises are further divided into two sample groups according to the nature of state-owned enterprises and non-state-owned enterprises (Li Jinglin et al., 2024), and discuss the differences between ESG performance and green technology innovation performance under the nature of enterprise property rights.

Column (1) and (2) in Table 6 show that the regression coefficient of ESG performance of green technology innovation performance is 1.310, which is significantly higher than that of non-state-owned enterprises, and is significantly positive at 1% (p <0.01), indicating that ESG performance of state-owned enterprises has a stronger role in promoting green technology innovation performance. First of all, state-owned enterprises, as the market subject, are not only the pillar of the national economy, but also the support of the national strategy. Compared with non-state-owned enterprises, they pay social benefits more attention while pursuing economic benefits. Secondly, the state-owned nature of state-owned enterprises makes it easier for them to obtain the support of stakeholders, and coupled with their good ESG performance, it is more convenient to obtain government subsidies or financial support from investors, which further strengthens their role in promoting green technology innovation.

Table 6 Test of heterogeneity of property rights

	(1)	(2)
	state-owned enterprises	Non-state-owned enterprises
VARIABLES	Green	Green
ESG	1.310***	0.984***
	(8.859)	(11.263)
size	12.744***	8.853***
	(58.117)	(56.157)
Lev	-0.147**	0.396***
	(-2.435)	(10.371)

	(1)	(2)
	state-owned enterprises	Non-state-owned enterprises
VARIABLES	Green	Green
AGE	0.001	0.003***
	(0.534)	(3.092)
RDinput	0.325***	0.025***
	(16.497)	(7.297)
Constant	-45.440***	-31.402***
	(-61.213)	(-59.072)
Observations	10,441	21,993
R-squared	0.520	0.356

t-statistics in parentheses,*** p<0.01, ** p<0.05, * p<0.1

(2) Analysis of sub-industry nature

Previous studies have found that the industry in which an enterprise operates will have an important impact on the environmental performance (Wang Jianming, 2008), social performance and environmental governance (Xu Dongyan et al., 2020). Therefore, this study further put the enterprise industry by manufacturing and non-manufacturing and heavy pollution and non-heavy pollution industry, Table 5-11 column (1), (2) shows that the influence of manufacturing ESG performance on green technology innovation coefficient is 1.425, higher than the non-manufacturing enterprise group coefficient of 1.284, and in the 1% confidence level is positive (p <0.01). Analysis of the reasons: First of all, the manufacturing industry itself has a high technical content and a good foundation for technological innovation. Under the policy drive and strict environmental regulation, enterprises actively respond to national policies and increase investment in green technology research and development. Secondly, the technology content of non-manufacturing enterprises is relatively low, the technology foundation is weak, and lack the foundation and conditions for green technology innovation. With the deepening of green development, non-manufacturing enterprises also need to strengthen green technology innovation to realize the green transformation of the whole industry.

Further, this paper categorizes listed company samples into heavily polluting industries and non-heavily polluting industries based on industry characteristics. Columns (3) and (4) in Table 5-11 show that the coefficient of ESG performance for heavily polluting companies on green technology innovation is 0.612, significantly lower than the coefficient of 1.402 for non-heavily polluting companies, and it is significantly positive at the 1% confidence level (p<0.01). The reasons may lie in: heavily polluting industries typically rely on traditional production technologies and energy structures, with highly specialized equipment and technology, lacking relevant technical reserves and R&D capabilities, making technological transformation difficult and facing talent shortages. In contrast, non-heavily polluting industries (such as high-tech manufacturing) have less pollution during production processes, lower technical barriers and cost pressures for green technology innovation, and are more likely to receive policy support and market recognition, thus having greater motivation to increase investment in green technology innovation.

Table 7 tests of heterogeneity by sector

	(1)	(2)	(3)	(4)
	manufacturing industry	non-manufacturing industry	Heavy pollution	Non-heavy pollution
VARIABLES	Green	Green	Green	Green
ESG	1.480***	0.790***	0.513**	1.059***
	(14.617)	(5.432)	(2.289)	(11.527)

	(1)	(2)	(3)	(4)
	manufacturing industry	non-manufacturing industry	Heavy pollution	Non-heavy pollution
VARIABLES	Green	Green	Green	Green
size	10.523***	6.669***	11.706***	7.369***
	(61.289)	(33.852)	(35.848)	(53.146)
Lev	0.647***	-0.346***	0.041	0.151***
	(15.354)	(-5.732)	(0.452)	(3.949)
AGE	-0.006***	-0.016***	-0.010***	-0.006***
	(-5.168)	(-11.751)	(-4.430)	(-6.438)
RDinput	0.013***	0.031***	-0.011**	0.030***
	(5.178)	(8.379)	(-2.129)	(13.637)
Constant	-38.722***	-23.640***	-38.434***	-27.027***
	(-67.343)	(-33.941)	(-35.498)	(-56.727)
Observations	21,613	11,121	3,431	29,303
R-squared	0.272	0.165	0.385	0.168

t-statistics in parentheses； *** p<0.01, ** p<0.05, * p<0.1

4.Conclusions and revelation

4.1 Study Conclusions

This study takes the a-share listed companies from 2013 to 2022 and empirically test the relationship between ESG performance and green technology innovation performance. The research results of this paper show that: first, good ESG performance is conducive to the improvement of green technology innovation performance. From the perspective of enterprise ESG performance, enterprise environmental responsibility has a stronger effect on the improvement of green technology innovation performance; second, digital transformation positively regulates the promotion of enterprise ESG performance on green technology innovation performance. Third, the heterogeneity analysis shows that the ESG performance of state-owned enterprises, manufacturing enterprises and non-heavy pollution industries plays a stronger role in promoting the performance of green technology innovation.

4.2 Management implications

Based on the empirical analysis of China's A-share listed companies, this study provides important inspiration for the formulation of enterprise sustainable development strategy and digital transformation practice:

(1) Strengthen ESG management and focus on environmental responsibility to drive green innovation. The study has found that ESG performance (especially environmental responsibility fulfillment) has significantly promoted green technology innovation. Enterprises should systematically optimize the ESG management system and bring environmental governance into the core of their strategy, such as upgrading cleaner production technology, carbon footprint tracking and other means to transform ESG investment into green innovation competitiveness. For manufacturing and state-owned enterprises (with a more significant effect), a differentiated ESG technology roadmap can be developed in light of industry characteristics.

(2) Deepen the digital transformation and enable ESG resource transformation efficiency. Digital transformation is a key lever to amplify the innovation effect of ESG. Enterprises need to accelerate the application of the Internet of Things, big data and other technologies, build an intelligent environment management system to reduce the cost of green research and development (such as real-time monitoring of energy consumption), and integrate supply chain resources through digital platform to promote ESG data sharing and collaborative innovation. Non-heavy pollution industries can focus on the layout

of digital green product design, while heavy pollution industries need to strengthen the intelligent transformation of pollution control technology.

(3) Classified measures were taken to optimize the collaborative path between ESG and digitalization. Heheterogeneity analysis shows that the ESG innovation effect of state-owned enterprises and manufacturing industry is more prominent. State-owned enterprises can take the advantages of resource integration to build industry-level ESG digital ecology; manufacturing enterprises should focus on production process digitalization and green process innovation; non-heavy polluting enterprises can explore ESG-oriented digital service mode (such as carbon asset management platform). Management needs to regularly evaluate the synergies between digitization and ESG and dynamically adjust resource allocation.

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Conflict of Interests

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