

Corporate Digital Transformation and ESG Performance - Evidence from Chinese Listed Companies

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Abstract. Corporate digital transformation provides conditions to stimulate the endogenous motivation of corporate ESG performance by helping enterprises optimize the allocation of innovation resources and reduce financing costs. This paper empirically examines the impact and mechanism of corporate digital transformation on corporate ESG performance using A-share listed companies in Shanghai and Shenzhen from 2011 to 2022 as the research sample. It is found that digital transformation significantly improves the ESG performance of enterprises and still holds after a series of robustness tests and endogeneity treatment. The results of this paper enrich the research on the economic consequences of digital transformation for real enterprises and the influencing factors of enterprises' ESG performance, which are of great revelation and reference value for promoting the digital transformation of real enterprises and constructing a new pattern of digital economy.

Keywords: corporate digitalization; ESG; firm size; corporate property rights.

1. Introduction

With climate and environmental issues becoming more and more prominent, externalities have become a part of the value creation process that cannot be ignored by enterprises, and investors have begun to solidly explore an indicator that can measure the performance of enterprises in terms of environmental protection behavior, social responsibility contribution behavior, etc. ESG, or Environmental, Social and Governance, is a kind of investment concept and corporate evaluation standard that focuses on the environmental, social and governance performance of enterprises rather than financial performance. An investment concept and corporate evaluation standard that focuses on corporate environmental, social and governance performance rather than financial performance's report reflects the company's performance in addition to financial statements, and is one of the important forms of non-financial disclosure of listed companies, as well as a good way for companies to disclose and communicate with all stakeholders on a regular basis. 2021 The Party Central Committee will be the " In 2021, the Party Central Committee incorporated the goal of "carbon peak and carbon neutrality" into the overall layout of ecological civilization construction, and in the context of China's green development and the in-depth advancement of the "dual-carbon" goal, the society's concern for sustainable development is growing, and the ESG performance has become an important factor for investors and financing institutions to consider, and enterprises urgently need to improve their ESG performance to build new competitive advantages. performance to build new competitive advantages. Therefore, how to improve ESG performance has become an important issue for enterprises nowadays.

Today, against the backdrop of information technology and big data becoming key production factors and the increasing maturity and popularization of cutting-edge technologies such as cloud computing, big data and artificial intelligence, the digital economy has become a new engine for driving economic growth, with the mode of production gradually shifting towards artificial intelligence. Enterprises, as the driving force of national economic development and social welfare enhancement, are an important force in promoting innovation, employment and improving people's livelihood. Digital transformation has become a new driving force for innovation and development of enterprises. Digital transformation of enterprises refers to the reconstruction and upgrading of traditional business,



processes and models by enterprises using digital technology to enhance efficiency, create value, and promote change and development. Driven by the new round of industrial revolution, enterprise digital transformation has become an important focus point for China to enhance enterprise competitiveness and cultivate new quality productivity. Digitalization has reshaped enterprise business models, changed traditional business models and promoted business model innovation and customer value creation. Through digitalization, enterprises can deeply analyze consumer data and provide accurate products and services to enhance customer satisfaction and loyalty. Digital transformation can not only optimize the internal processes of enterprises, enable enterprises to rationally and efficiently allocate resources, improve the utilization efficiency of capital, labor, technology and other factors of production, but also help enterprises to achieve greater flexibility and responsiveness in product development, marketing and other aspects.

Digital transformation can increase the willingness of enterprises to fulfill their social and environmental responsibilities, thus improving their ESG performance. The digital development of the real economy and the materialization of digital technology have led to great changes in the way enterprises produce and operate. Empowered and supported by digital technology, digital transformation further improves the service capability of enterprises, making them pay more attention to product quality, brand image and external reputation, and improving their ESG performance. At the same time, digital transformation also enhances the contribution of enterprises to the environment and sustainable development by promoting green and low-carbon production, thus contributing to the improvement of ESG performance. Therefore, with the deep integration of digital technology into the real economy, and with the help of advanced information systems, automation tools and big data analysis, enterprise digital transformation can, to a certain extent, improve the operational efficiency of enterprises, enhance their green innovation capability, and improve the transparency of their internal information, which is expected to improve their own ESG performance.

The marginal contributions of this paper mainly lie in the following: firstly, there are more studies on enterprise digital transformation and enterprise ESG performance in the past literature, but few of them directly link the two, and this paper enriches the literature on the factors influencing the degree of enterprise ESG performance by studying from the perspective of enterprise digital transformation. Second, this paper combs the mechanism of the impact of enterprise digital transformation on ESG from the theoretical aspect, and uses OLS model and fixed effect model to quantitatively and empirically test the impact of enterprise digital transformation on ESG, which provides a new way of thinking for the quantitative analysis of the research related to the development of enterprises. Third, this study can be a powerful tool for realizing the goal of "double carbon". The digital transformation of enterprises not only helps to improve ESG ratings, but also paves the way for enterprises to promote green and low-carbon transformation, prompting them to reduce carbon emissions and resource consumption, and ultimately realize the "dual-carbon" goal.

2. Literature review

2.1. Academic Research on Corporate ESG Performance

The study finds that corporate ESG performance has far-reaching economic implications. First, in terms of financial performance, good ESG performance is positively correlated with a firm's financial performance. Enterprises can control risks through ESG management, enhance operational soundness, and improve corporate financial performance (Wang et al., 2022). Good ESG performance also has a positive impact on corporate profitability, which is more significant for large firms (Bissoondoyal-Bheenick et al., 2023). Further research has found that, on the one hand, ESG performance indirectly enhances financial performance by improving firms' innovative capabilities, and on the other hand, ESG performance promotes financial performance by improving firms' information transparency (Li et al., 2021). Therefore, to develop effective strategies to enhance their ESG performance and financial performance, firms need to focus on the relative importance of different ESG factors.

Second, in terms of firm innovation, there is a significant positive correlation between ESG performance and the quantity and quality of firm innovation. Li et al. (2023) finds that good ESG performance can significantly increase the quantity of firm innovation, such as the number of granted invention patents, and the quality of innovation, such as the number of patent citations. In addition, since ESG criteria usually include environmental protection requirements, firms will adopt more environmentally friendly technologies and methods in their R&D and production processes, thus strengthening their own green technology innovation capabilities. Meanwhile, the path of ESG performance to promote corporate innovation is characterized by diversification, which can enhance the efficiency of corporate innovation by alleviating internal and external financing constraints, improving corporate transparency, and increasing analysts' attention (Xiao et al., 2024), which suggests that a firm's ESG performance not only directly affects its innovation capability, but also indirectly promotes innovation by improving the firm's financing environment and market evaluation.

Third, corporate ESG performance also helps to increase the firm's own value (Wong et al., 2021). Taking China's A-share listed companies from 2015-2019 as a research sample, Wang and Yang (2022) conclude that corporate ESG performance significantly enhances both book value and market value of enterprises. Good ESG responsibility fulfillment can reduce the financing cost and the financial burden of enterprises, thus promoting the book value of enterprises. At the same time, a good evaluation of ESG responsibility fulfillment can significantly increase the degree of market attention, release more positive signals, and thus increase the market value of enterprises. However, it is worth noting that the impact of ESG performance on corporate value varies depending on the nature of the enterprise. Compared with state-owned enterprises, the ESG performance of non-state-owned enterprises has a greater effect on enterprise value enhancement; compared with enterprises in low-pollution industries, the ESG performance of enterprises in high-pollution industries has a greater effect on enterprise value enhancement (Chen and Xia, 2022).

Corporate ESG performance can also be affected by a variety of factors. First, in terms of factors external to firms, social institutions (political, labor and cultural institutions, etc.) and policies have a significant impact on firms' ESG performance. For example, unemployment rates and labor protection measures have a positive impact on firms' ESG performance, while high levels of state corruption, social cohesion, and equality of opportunity may lead to negative ESG performance. Alentejan and Al-Shaer (2023), on the other hand, find that firms are more inclined to engage in ESG activities, including the establishment of emission reduction targets, during periods of high economic policy uncertainty. It is evident that in an environment of policy uncertainty, firms want to enhance their social responsibility image by strengthening their ESG performance to gain more protection and advantage from potential policy changes. Meanwhile, in countries and regions that are politically unstable or culturally less tolerant of risk, companies are more socially and environmentally engaged, thereby reducing information asymmetry and increasing transparency in response to potential political or social risks.

Second, internal firm factors also affect ESG performance. There is an overall positive impact on ESG performance when the proportion of female corporate executives is high. A study in the European banking sector shows that board size, proportion of women and proportion of independent directors are positively associated with ESG disclosure scores (Gurol and Lagasio, 2023). Studies in Germany and Austria have also shown that female members of management boards have a positive impact on ESG performance (Cambrea et al., 2023). In a study of Chinese listed firms, the higher the proportion of female directors, the higher the firm's ESG practice scores, and the relationship was more significant in favorable institutional environments and in non-state-owned firms (Peng and Chandarasupsang, 2023).

2.2. Academic Research on Enterprise Digital Transformation

Digital transformation refers to the process of improving enterprise value creation by triggering significant changes in enterprise attributes through a combination of information, computing, communication and connectivity technologies (Wu et al., 2021). Currently, most scholars are

committed to studying the impact of enterprise digital transformation on the enterprise itself. First, enterprise digital transformation can promote enterprise innovation through multiple ways. Ji et al. (2023) found that digital transformation can promote enterprise innovation by improving R&D investment and R&D efficiency. Enterprises should use digital tools and platforms to optimize R&D processes and improve the efficiency and effectiveness of R&D activities. Digital transformation can reduce management's salary reduction and career risk due to innovation failure, and increase the firm's tolerance for management's innovation failure. This fault-tolerance mechanism can motivate management to be more active in innovation attempts (Wang and Yao, 2023). Zhou and Huang (2023), on the other hand, point out that good external institutional conditions and government policy support are important guarantees for the digital transformation of enterprises to exert their innovation promotion effects. This suggests that enterprises should actively cooperate with the government and other institutions to utilize policy resources to support innovation activities and improve innovation capabilities.

Second, digital transformation has a multifaceted impact on corporate sustainability. In the area of environmental sustainability, corporate digital transformation has brought about significant changes. Through the application of technologies such as artificial intelligence, big data analytics, cloud computing, and the Internet of Things, companies can control pollution, manage waste, achieve sustainable production, and enhance urban sustainability more effectively (George and Schillebeeckx, 2022). In terms of financial sustainability, digital transformation can enhance firms' financial resilience by improving internal corporate governance, increasing analyst coverage, easing financial constraints, and reducing operational risks (Cui and Wang, 2023). However, firms also face a portion of risks during digital transformation. Cybersecurity risks increase significantly as organizations increasingly rely on information technology solutions. While emerging technologies such as artificial intelligence, big data, blockchain, and cloud computing drive digital transformation, they also increase the cybersecurity threats faced by organizations, including data breaches and cyberattacks (Rauniyar et al., 2023; Zhao et al., 2023).

2.3. Academic Research on Corporate Digital Transformation and ESG Performance

With the help of Industry 4.0 technologies, such as IoT, AI and blockchain, enterprises can collect and process ESG-related data in real time, and the completeness, reliability and processing efficiency of the data are improved (Yu et al., 2023). Taking the corporate ESG information management and disclosure system developed by Beijing Green Exchange as an example, it solves the problems encountered by enterprises in the process of ESG governance and information disclosure, such as the lack of professionals and the difficulty of information collection and management, by means of informatization and automation. This ESG-related information, with the addition of Internet technology, is more easily accessible and monitored by the public. Enterprises can publish ESG reports through their official websites or specialized platforms and interact with the public through social media and other online channels, thus enhancing public attention to and participation in CSR. The application of Internet technology has also facilitated the process of certifying and predicting ESG data, however, this process needs to be augmented by AI and big data technologies.

As two pillars of modern technology, AI and big data technologies are the backbone of driving digital transformation for enterprises. Traditional ESG ratings rely on company self-reporting and manual analysis, which can lead to subjective and inconsistent ratings. However, AI and big data technologies can help companies perform data analytics and forecasting, which can improve the accuracy and reliability of ESG reports and help investors and other stakeholders better understand companies' sustainability performance (Saxena et al., 2023). By collecting data from social media and news sites using Python web crawlers and analyzing the sentiment tendencies of this data using Natural Language Processing (NLP) algorithms, a more objective assessment of a company's ESG performance can be made. In addition, machine learning models such as Random Forests, Extreme Learning Machines, Support Vector Machines, and XGBoost have been used to predict ESG scores, showing good performance (Lin and Hsu, 2023). These models can handle many financial and

corporate governance metrics, thus providing more accurate ESG scores. In conclusion, AI and big data technologies can provide a more systematic and objective approach to ESG evaluation, thus improving the accuracy and reliability of corporate ESG ratings (Hu et al., 2023).

2.4. More Detailed Literature Review

Currently, existing studies around corporate ESG performance generally agree that good ESG performance has a positive impact on a company's financial performance, innovation capability, and self-worth, and that ESG performance is affected by a variety of factors both internal and external to the company, such as company size, executive gender ratio, and policy environment. In terms of digital transformation of enterprises, most of the existing literature examines the economic consequences of digital transformation, including improving the innovation capacity of enterprises and promoting sustainable development. However, some scholars have also pointed out that challenges such as cybersecurity risks and financial risks also exist in the process of digital transformation, which require enterprises to strengthen risk identification and control. In response to the cross-sectional study of corporate ESG performance and digital transformation, the literature suggests that Internet technology plays an important role in improving the standardization and transparency of corporate ESG disclosure, and enhances the accuracy and reliability of the information through the creation of standardized data frameworks and the real-time collection and processing of ESG-related data. In addition, the application of AI and big data technologies has boosted the process of certifying, predicting and evaluating ESG data, improving the accuracy and reliability of ESG ratings. Existing literature is rich in research results, but there is less literature directly linking corporate digital transformation and corporate ESG performance, this paper combines the two directly to explore the impact of corporate digital transformation on corporate ESG performance, which is innovative compared with previous literature.

3. Indicator Construction, Data Sources and Identification Strategies

3.1. Indicator Construction

3.1.1. Dependent Variable Selection.

The explanatory variable is the ESG score of the enterprise, which specifically refers to the performance and evaluation score of the enterprise in the environmental, social and governance dimensions. Currently, the representative ESG rating agencies at home and abroad include Bloomberg, FTSE Russell, CSI, Vantage, and ShangDao RongLu, etc. Among them, the reliability of the Bloomberg data scoring system is very high. Among them, the Bloomberg data rating system is more reliable, as its ratings are more correlated with the ratings of other organizations; the Bloomberg ESG data evaluation system is scientifically comprehensive and comes from a wide range of sources, which include corporate responsibility reports, annual reports, ESG reports, as well as Bloomberg's own surveys, etc.; the Bloomberg organization's ESG rating system covers a large sample size of domestic listed companies with a long vintage period. Therefore, this paper refers to the study of Nie et al. (2022) and chooses the Bloomberg ESG Score Index to measure the ESG performance of enterprises; the ESG disclosure index provided by Bloomberg Consulting varies within the numerical interval of [0, 100], and the higher the score of this variable, the higher the degree of ESG disclosure of listed companies is reflected, i.e., the better the ESG performance of the enterprise.

3.1.2. Independent Variable Selection.

As a core strategy of enterprise development, digital transformation (DIGT) is more likely to be reflected in the textual information disclosed in the annual reports of enterprises. Some scholars have conducted effective research on this issue, such as measuring digital transformation by treating the dummy variable of "whether to carry out digital transformation", but this method can only measure whether to carry out digital transformation or not, but ignores the degree of digital transformation of

enterprises. Based on this, this paper draws on the research of Wu et al. (2021), and applies text analysis to measure the level of digital transformation by using text mining technology to determine the percentage of the number or frequency of keywords related to "digitalization" in the annual reports of listed companies in China. Compared with the method of directly selecting an observable indicator to refer to the independent variable, the text mining method is more comprehensive and relatively reasonable.

Specifically, this paper firstly screens the specific vocabulary related to digital transformation, which is divided into two categories of "ABCD" underlying digital technology (artificial intelligence, blockchain, cloud computing, big data) and digital technology application (such as mobile payment, Internet finance, unmanned retail, digital finance, etc.). Secondly, at the technical level, the text adopts python crawler technology and Java PDFbox library to extract and summarize all text information of annual reports of all A-share listed companies on Shanghai Stock Exchange and Shenzhen Stock Exchange, and compare and match the summarized results with keywords of digital transformation of enterprises and frequency measurement, to construct the index system of digital transformation of enterprises. Finally, due to the prominent right-skewed performance of the obtained data, to mitigate the impact of sample outliers on the estimation results, this paper logarizes the measured data.

3.2. Modeling

$$ESG_{it} = \alpha_0 + \alpha_1 digt_{it} + \alpha_2 Z_{it} + \mu_i + \delta_t + \varepsilon_{it} \quad (1)$$

Where ESG_{it} is the ESG performance score of firms i in period t , and $DIGT_{it}$ is the degree of digital transformation of firm i in period t . In order to solve the endogeneity problem interference caused by omitted variables, this paper introduces the following control variables (Z_{it}) with reference to the existing literature (Wang Haijun et al., 2022; Hu Jie et al., 2022). Specifically, firm size (*size*), measured as the logarithm of the firm's total assets; firm age (*age*), measured as the logarithm of the firm's years of establishment; return on assets (*roa*), measured as the ratio of net profit to total assets; board size (*board*), measured as the logarithm of the number of board members of the firm; and shareholding concentration (*top1*), measured as the proportion of shares held by the first largest shareholder. The ratio of two positions in an enterprise (*dual*) is measured by the concurrent appointment of the chairman and the general manager of an enterprise; meanwhile, the model includes μ_i for the individual fixed effect that city i does not change over time, and δ_t for the time fixed effect in order to avoid individual heterogeneity in the within-group regression. Further, the random error term $\varepsilon_{i,t}$ in this paper clusters to the firm level to solve the systematic heteroskedasticity problem of the model.

3.3. Data Sources and Descriptive Statistics

In this paper, the A-share listed companies in Shanghai and Shenzhen from 2011 to 2022 are selected as the research object and screened according to the following steps: (1) exclude the financial listed companies; (2) exclude the samples with missing financial data or insolvency; and (3) exclude the samples that are labeled as ST or *ST in the current year. Firm-level cluster regression is performed on the samples to eliminate the interference of differences between data groups and to reasonably control the effect of heteroskedasticity. The financial data used in the study are derived from the CSMAR database.

Table 1. Descriptive Statistics

<i>Variable</i>	<i>Obs</i>	<i>Mean</i>	<i>Std. Dev.</i>	<i>Min</i>	<i>Max.</i>
<i>DIGT</i>	15724	1.432	1.376	0.000	5.037
<i>ESG</i>	15724	3.207	0.417	0.609	4.356
<i>size</i>	15724	22.372	1.400	17.813	28.615
<i>age</i>	15724	18.366	5.914	1.000	63.000
<i>growth</i>	15724	0.425	15.693	-0.953	1878.372
<i>board</i>	15724	2.131	0.201	1.099	2.890
<i>top1</i>	15724	35.500	15.382	3.000	89.410
<i>dual</i>	15724	0.288	0.453	0.000	1.000

4. Empirical Analysis

4.1. Return to Baseline

Table 2 shows the results of the benchmark regression of this paper. Only the core explanatory variable enterprise digital transformation is added in column (1) of Table 2, and the results show that enterprise digital transformation positively contributes to enterprise ESG performance at the 1% significance level. Columns (2) to (5) in Table 1 show the regression results after gradually adding the control variables such as enterprise size and enterprise age capability, and the results show that enterprise digital transformation still positively promotes enterprise ESG performance at the 1% significance level. Among them, the regression results in column (7) indicate that every 1% increase in the degree of enterprise digital transformation will positively promote enterprise ESG performance by 0.011%. The above results indicate that enterprise digital transformation can effectively help to promote enterprise ESG practices, which in turn improves the performance of enterprises in the three aspects of environment, society and governance, thus verifying that Hypothesis 1 is valid.

Table 2. Benchmark Regression

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	ESG	ESG	ESG	ESG	ESG	ESG	ESG
DIGT	0.013***	0.011***	0.011***	0.011***	0.011***	0.011***	0.011***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
size		0.034***	0.034***	0.035***	0.036***	0.037***	0.037***
		(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)
age			-0.018	-0.018	-0.018	-0.019	-0.019
			(0.025)	(0.025)	(0.025)	(0.025)	(0.025)
roa				-0.072	-0.072	-0.075	-0.075
				(0.061)	(0.060)	(0.061)	(0.061)
board					-0.049*	-0.047*	-0.046*
					(0.027)	(0.027)	(0.027)
top1						0.001*	0.001*
						(0.001)	(0.001)
dual							0.002
							(0.010)
cons	3.190***	2.436***	2.762***	2.738***	2.826***	2.782***	2.781***
	(0.006)	(0.186)	(0.497)	(0.497)	(0.499)	(0.498)	(0.498)
<i>Firm FE</i>	Y	Y	Y	Y	Y	Y	Y
<i>Industry FE</i>	Y	Y	Y	Y	Y	Y	Y
<i>Year FE</i>	Y	Y	Y	Y	Y	Y	Y
<i>N</i>	15418	15418	15418	15418	15418	15418	15418
adj. <i>R</i> ²	0.625	0.626	0.626	0.626	0.626	0.626	0.626

4.2. Robustness Analysis

4.2.1. Substitution of Aariables.

In the benchmark regression part, this paper uses the total indicators of enterprise digital transformation for regression. In the robustness test, drawing on existing research (Jin Xingye et al., 2024), sentences in the annual reports of listed companies from 2011 to 2022 are manually tagged, and then the tagging results are used to train and fine-tune multiple machine learning models, including the big language model, and the ERNIE model, which has the best classification effect, is selected as the sentence classification model to predict all the tags of sentences in the text, and finally constructed the enterprise digital transformation metrics. Column (1) of Table 3 reports this result, and finds that different methods of measuring digital transformation do not affect the core findings of this paper, and the conclusion that corporate digital transformation promotes firms' ESG performance remains robust and credible.

4.2.2. Interaction Fixed Effect.

Industries with a very high level of technology or cities with a high level of economic development may have relatively well-developed digital infrastructures, and firms have more advantages in the development of digital transformation. Based on this, this paper adds industry-by-year and city-by-year interaction fixed effects to control for the effects of industry- and city-level factors that change with year, and thus mitigate the changes in the macro environment caused by the development of the digital economy (Bai, 2013). The regression results in columns (2) and (3) of Table 3 show that the estimated coefficients of digital transformation of enterprises are significantly positive, which is consistent with the benchmark regression results.

4.2.3. Double Clustering Robust Criterion Error.

Considering the intrinsic correlation between different firms, we adjust for the double clustering of standard errors on individual and temporal basis, which can overcome the impact of problems such as autocorrelation and heteroskedasticity on statistical inference (Tao and Li, 2023). The results are shown in column (4) of Table 3. The coefficients on the core explanatory variables remain significantly positive, consistent with the benchmark results.

4.2.4. Considering the Impact of Major Public Health Shocks.

Since the sample period of this paper is 2011-2021, and the 2020 New Crown Pneumonia epidemic profoundly affected the digital transformation process of enterprises (Liu et al., 2022). For this reason, this paper divides the sample into two time periods, 2011-2019 and 2020-2022, to examine the effect of model estimation within the sample subintervals. The test results in columns (5) and (6) of Table 3 illustrate that in 2011-2019, the estimated coefficients of the core explanatory variables of enterprise digital transformation remain consistent with the baseline regression results, which once again supports this paper's research hypothesis.¹ In 2020-2022, on the other hand, the coefficients of the core explanatory variables are negative, which is probably due to the fact that in the face of the new Crown Pneumonia, which is the century's most sweeping global Epidemic, many enterprises face the crisis of business impact or even closure, only a few enterprises are able to quickly adjust their operation strategies and stand firm in the storm, and more enterprises tend to focus on their own financial performance and to some extent neglect the development of ESG.

Table 3. Robustness Analysis

	(1)	(2)	(3)	(4)	(5)	(6)
	Substitution of variables	Panel interaction fixed effects		Double Clustering Robust Criterion Error	2011-2019	2020-2022
DIGT	0.025*** (0.007)	0.014*** (0.004)	0.013*** (0.005)	0.011** (0.005)	0.010** (0.005)	-0.002 (0.011)
size	0.039*** (0.009)	0.043*** (0.009)	0.039*** (0.010)	0.037*** (0.011)	0.035*** (0.010)	0.041 (0.043)
age	-0.018 (0.026)	-0.002 (0.028)	-0.027 (0.021)	-0.019 (0.015)	0.000 (0.000)	-0.028 (0.018)
roa	-0.081 (0.064)	-0.083 (0.067)	-0.070 (0.068)	-0.075 (0.053)	-0.076 (0.081)	0.082 (0.105)
board	-0.041 (0.027)	-0.050* (0.027)	-0.033 (0.031)	-0.046 (0.033)	-0.070** (0.033)	-0.062 (0.075)
top1	0.001 (0.001)	0.001 (0.001)	0.001** (0.001)	0.001 (0.001)	0.000 (0.001)	0.002 (0.002)
dual	-0.002 (0.010)	0.001 (0.010)	0.006 (0.011)	0.002 (0.010)	0.003 (0.012)	-0.068*** (0.026)
cons	2.708*** (0.514)	2.338*** (0.556)	2.827*** (0.436)	2.781*** (0.358)	2.508*** (0.238)	3.079*** (0.986)
<i>Firm FE</i>	Y	Y	Y	Y	Y	Y
<i>Industry FE</i>	Y	Y	Y	Y	Y	Y
<i>Year FE</i>	Y	Y	Y	Y	Y	Y
<i>Industry*Year FE</i>		Y				
<i>City*Year FE</i>			Y			
<i>N</i>	15003	15320	14271	15418	10867	4181
<i>adj. R²</i>	0.629	0.637	0.627	0.626	0.623	0.635

4.3. Heterogeneity analysis

4.3.1. Enterprise Size.

The impact of digital transformation on ESG of enterprises of different sizes may have more significant differences. Therefore, this paper constructs a dummy variable for firm size, i.e., firms with total assets greater than the industry median are defined as large firms, otherwise they are small and medium-sized firms. The test results are shown in columns (1) and (2) of Table 4. It is found that the estimated coefficients of DIGT for large firms are positive and the coefficients and significance are slightly due to SMEs. This suggests that digital transformation contributes more significantly to the ESG of large firms than SMEs. Large firms usually have richer resources and stronger technological capabilities, can carry out digital transformation more easily, and are better able to apply digital technologies to improve ESG performance (Du and Li 2024).

4.3.2. Corporate Property.

Compared with non-state-owned enterprises, state-owned enterprises assume certain government functions, have a weaker profit motive, and are subject to a stronger role of government regulation. Therefore, this paper classifies enterprises into state-owned and non-state-owned for group regression according to enterprise property rights attributes. The regression results are shown in columns (3) and (4) of Table 4, the coefficient of the influence of the degree of digital transformation of state-owned enterprises is positive at the 1% significance level, while it is positive in non-state-owned enterprises but fails to be significant. Compared to non-SOEs, SOEs have strong affiliation with the government, are more advantaged in terms of corporate size and strength, and tend to enjoy higher social reputation (Guo and Shi, 2022). Moreover, among China's heavy polluters, SOEs are more aware of their environmental responsibility (Su and Lian, 2018), and thus are better able to improve their corporate ESG performance through digital transformation.

Table 4. Heterogeneity Test

	(1)	(2)	(3)	(4)
	major industry	small and medium enterprise	nationalized business	non-state enterprise
DIGT	0.051**	0.046*	0.041**	0.026
	(0.021)	(0.025)	(0.019)	(0.031)
size	0.534***	0.569***	0.457***	0.609***
	(0.041)	(0.023)	(0.020)	(0.023)
age	-0.021***	-0.021***	-0.016***	-0.023***
	(0.004)	(0.005)	(0.004)	(0.006)
roa	2.522***	5.333***	2.896***	3.900***
	(0.397)	(0.510)	(0.429)	(0.613)
board	-0.247**	-0.173	-0.108	-0.148
	(0.121)	(0.123)	(0.112)	(0.146)
top1	0.004**	-0.000	0.005***	0.001
	(0.002)	(0.002)	(0.001)	(0.002)
dual	0.094**	0.104*	0.064	0.038
	(0.046)	(0.062)	(0.041)	(0.092)
_cons	-0.653	-1.795***	0.755*	-2.874***
	(0.892)	(0.555)	(0.452)	(0.584)
<i>Firm FE</i>	Y	Y	Y	Y
<i>Industry FE</i>	Y	Y	Y	Y
<i>Year FE</i>	Y	Y	Y	Y
<i>N</i>	7861	7859	9891	5828
adj. <i>R</i> ²	0.186	0.156	0.168	0.242

5. Conclusions and Insights

Under the wave of the new round of technological revolution, it is increasingly becoming an important strategic means for enterprises to accelerate digital development, promote digital transformation of economic activities, and accelerate digital technology to empower traditional industries. This paper selects A-share listed companies in Shanghai and Shenzhen from 2011 to 2022 as the research sample, and empirically examines the effect and mechanism of enterprise digital transformation on enterprise ESG performance of listed companies in the context of the booming development of digital economy. The results of the empirical study show that corporate digital transformation can significantly enhance corporate ESG performance, and this conclusion still holds after a series of robustness tests and endogeneity treatment. At the same time, enterprise digital transformation has heterogeneous effects on ESG performance. From the perspective of enterprise size, compared with small and medium-sized enterprises, enterprise digital transformation is more conducive to improving the ESG performance of large enterprises; from the perspective of enterprise ownership, enterprise digital transformation positively affects the ESG performance of state-owned enterprises, while the effect on the ESG performance of non-state-owned enterprises is not significant.

Based on the above findings, this paper offers the following insights:

First, based on the corporate governance level, enterprises should fully recognize the importance of digital transformation and vigorously promote the digital transformation process as an opportunity to improve ESG performance. Enterprises should significantly increase their capital investment and human resource allocation in digital technology, and utilize cutting-edge technologies such as cloud computing, big data, and artificial intelligence to reconstruct and upgrade their traditional businesses, processes, and models. Through digital transformation, enterprises can automate and intelligentize internal processes, optimize resource allocation, improve operational efficiency, and more accurately grasp market demand and consumer behavior, thereby reducing operational and financing costs, thus providing stronger support for corporate ESG performance.

Second, based on corporate strategy, large enterprises should play a leading role. Since large enterprises are uniquely positioned for digital transformation, they should take the lead in embracing the wave of digital transformation and setting a benchmark for the industry. At the same time, large enterprises have the responsibility and ability to provide guidance and support to small and medium-sized enterprises by sharing their successful experiences and technological achievements in digital transformation. Large enterprises can share their own technical paths and management experience in the process of digital transformation with SMEs by establishing industry alliances and carrying out technical exchanges, to promote the digital transformation process of the whole industry and form benign interaction and synergistic development.

Thirdly, based on the government policy level, according to the characteristics of different enterprises, the government should introduce differentiated policies to guide and support the digital transformation process of enterprises. For state-owned enterprises (SOEs), which occupy an important position in the national economy, the government can further strengthen the supervision and assessment standards for their digital transformation. Through the establishment of a sound regulatory mechanism, it can ensure that state-owned enterprises can actively fulfill their social responsibilities in the process of digital transformation and give full play to their leading role in resource allocation and technological innovation. As for non-state-owned enterprises, especially those small and medium-sized enterprises facing bottlenecks in terms of capital and technology, the government should provide more policy inclination and financial support, such as setting up a special support fund, providing tax exemptions and optimizing the financing environment, etc., so as to reduce the costs and risks of non-state-owned enterprises in the process of digital transformation and accelerate the pace of digital transformation of non-state-owned enterprises.

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