



Empirical Study on the Impact of Digital Transformation on ESG

Ruipeng Wang

Beijing Technology and Business University, Beijing, 100048, China

2917362599@qq.com

Abstract. This study explores how digital transformation influences the ESG performance of Chinese A-share listed companies from 2014 to 2022. It finds that digital transformation plays a crucial role in improving corporate ESG compliance, with positive effect even after addressing potential biases and conducting robustness checks. The analysis highlights that digital transformation boosts ESG performance primarily by fostering green innovation and increasing social responsibility within enterprises. Further analysis shows that the impact is especially significant in the manufacturing, high-polluting, and high-tech sectors. This research underscores the importance of digital transformation in enhancing ESG practices and supporting sustainable development in Chinese businesses.

Keywords: Digital Transformation; ESG Evaluation; Green Innovation; Social Responsibility; Corporate Governance

1 Introduction

Research primarily investigates the factors and optimization pathways that influence corporate ESG performance at macro-environment, regional policy, and micro-firm levels. For instance, some regions in China encourage businesses to undertake environmental protection investments and sustainable development projects through green financial policies, which helps enterprises enhance their ESG performance (Pan Xiaozhen, 2019). From the perspective of an enterprises' characteristics, a robust corporate governance structure can encourage companies to fulfill their social responsibilities and improve their ESG performance (Li Weian et al., 2021). The attitudes and perceptions of enterprise management increase the likelihood of actively promoting ESG-related activities (Ling Shixian, 2024). The nature of a firm's property rights impacts its ESG performance, as state-owned enterprises (SOEs) tend to engage more actively in ESG practices due to stronger policy orientation and heightened awareness of social responsibility (Fang Xianming et al., 2023).

Research indicates that digital transformation enhances environmental responsibility by enabling intelligent production, which reduces energy consumption and waste emissions (Song Deyong, 2022). At the same time, companies utilize digital technol-

ogy to enhance processes, reducing environmental impact while improving production efficiency and product quality (Xu Xianchun, 2019).

When it comes to social responsibility, it allows businesses to provide stakeholders with information in a more accurate and timely way. This improvement enhances communication and builds trust between companies and society, while also satisfying the public's right to know and to oversee companies' actions (Qi Huaijin, 2020). Enterprises can work together to minimize environmental pollution and reduce resource waste throughout the supply chain (Chen Deqiu, 2022). This collaboration also fosters the optimization and adjustment of the human capital structure (Chen Hong, 2022) and enhances the innovation capabilities of enterprises (Yuan Chun, 2021).

Digital transformation enhances corporate governance by optimizing resource integration, improving allocation efficiency of enterprises (Lvkov et al., 2023), and mitigating decision-making risks (Zhao Chenyu et al., 2021). Through digital technology, companies can automate and enhance the internal control process, thereby increasing its efficiency and effectiveness (Xiao Hongjun et al., 2021).

In conclusion, corporate digital transformation has a positive impact on ESG and assists companies in achieving their sustainability goals. However, there is insufficient research on how digital transformation enhances corporate ESG performance. Clarifying the effects and pathways of this transformation is significant both theoretically and practically. It can help enterprises achieve sustainable development goals, enhance financial performance, improve market competitiveness, and contribute to the sustainable development of society as a whole.

2 Theoretical Analysis and Research Hypotheses

In today's world, where digital advancements and sustainable development are closely intertwined, the digital transformation of businesses has emerged as a crucial factor in helping companies achieve their ESG goals. Numerous scholars have explored this topic from various angles, offering a solid theoretical foundation for understanding the connection between digital transformation and the fulfillment of ESG objectives.

Digital transformation offers remarkable opportunities for the green development of enterprises. By leveraging big data, artificial intelligence and other digital technologies can monitor energy consumption and pollutant emissions in the real-time and conduct precise analyses during the production process. This enables them to identify issues and implement optimization measures promptly, effectively reducing energy consumption and emissions while achieving sustainable production practices ^[1]. Research indicates that digital transformation can enhance information transfer and decision-making process in enterprises, leading to improved governance efficiency and transparency. At the same time, digital transformation can enhance a company's internal control system and response capabilities ^[2]. The ESG theoretical framework is a concept that emphasizes the sustainable development of businesses. It encompasses three main aspects: environment, society and corporate governance. The framework aims to promote the pursuit of economic benefits while also considering environmental protection, ful-

filling social responsibility, and ensuring good corporate governance, it seeks to achieve long-term sustainable development.

This paper proposes Hypothesis 1: Digital transformation significantly enhances the ESG compliance performance.

2.1 The Role of Green Innovation Levels as A Mediator

Digital transformation presents remarkable opportunities and technological support for green innovation. Artificial intelligence algorithms can optimize production processes, enhance energy efficiency, and minimize waste emissions. A study by Song Deyong (2022) demonstrated that digital transformation in enterprises significantly fosters green technology innovation, particularly in listed companies within heavily polluted industries. They concluded that applying digital technology aids enterprises in integrating internal and external resources, and accelerates the advancement and dissemination of green technologies ^[3]. This highlights the crucial role of green innovation in improving corporate environmental performance. Additionally, digital transformation serves as an important enabling tool for green innovation, which in turn enhances corporate ESG performance indirectly. Numerous scholars have conducted comprehensive studies from various perspectives, providing both theoretical foundations and empirical evidence supporting the hypothesis that digital transformation enhances the ESG performance of enterprises by increasing the level of green innovation.

This paper proposes Hypothesis 2: Digital transformation improves the ESG performance of enterprises by enhancing the level of green innovation.

2.2 The Role of Social Accountability as A Mediator

Corporate social responsibility involves actively addressing the reasonable expectations and needs of various stakeholders. When it comes to employee rights and interests, the use of digital tools, such as human resource management systems and online training platforms, enables companies to optimize their human resource management processes. This, in turn, enhances employee welfare and provides better opportunities for career development ^[4]. Companies can better understand consumer needs through digital means and provide products and services that more effectively meet their expectations ^[5]. Digital technology gives companies more channels for community engagement and public welfare efforts, along with better resource integration platforms ^[6]. In the digital era, information spreads quickly and widely, making it easier for the public to learn about and share the social responsibility practices of companies. Numerous studies conducted by scholars have provided robust theoretical foundations and empirical evidence supporting the idea that digital transformation enhances corporate ESG performance by improving social responsibility efforts.

This paper proposes Hypothesis 3: Digital transformation improves the ESG performance of enterprises by increasing their level of social responsibility.

2.3 The Role of Improving Internal Governance as A Mediator

Digital transformation offers robust technical support for improving corporate governance. It enables shareholders to access timely and accurate information about corporate operations, which strengthens the supervision and checks and balances on management. This effectively reduces agency costs and enhances the overall efficiency of corporate governance. The study reveals that digital technology enhances the internal transfer of information and decision-making process within the company. This leads to more scientific and transparent management decisions, effectively reduces agency costs, and improves the efficiency of corporate governance. In summary, numerous studies have provided strong evidence for the hypothesis that digital transformation improves ESG performance by enhancing internal governance [7].

This paper proposes Hypothesis 4: Digital transformation improves enterprises' ESG performance by enhancing internal governance.

3 Research Design

3.1 Selection of Samples and Sources of Data

The research sample for this paper comprises A-share listed companies in Shanghai and Shenzhen, China, from 2014 to 2022. The microdata used in this study comes from CSMAR database. The sample was screened based on established literature following the criteria: (1) listed companies in the finance and insurance sectors were excluded; (2) companies classified under the ST, ST*, and PT categories were excluded; and (3) companies with missing key financial data for the period from 2014 to 2022 were also excluded. The analysis focuses on samples with missing financial data from 2014 to 2022. To mitigate the impact of outliers, this paper employs two-sided 1% shrinkage on all continuous variables at the firm level. As a result, a final unbalanced panel dataset consisting of 4,535 firms has been created, totaling 28,028 observations.

3.2 Model Development and Variable Definition

3.2.1 Model Building.

To examine the impact of digital transformation on corporate ESG, this paper develops the following benchmark regression model:

$$ESG_{it} = \beta_0 + \beta_1 DIGI_{it} + \gamma Controls_{it} + \mu_i + \sum IND + \rho_t + \varepsilon_{it} \quad (1)$$

In this study, the explanatory variable ESG_{it} represents the ESG performance of firm i in year t , while the core variable $DIGI_{it}$ is the digital transformation index, reflecting the level of digital transformation for firm i in year t . The term $controls_{it}$ refers to firm-level control variables. To account for unobservable factors affecting ESG performance, the model includes firm, industry, and time fixed effects. The paper focuses on the coefficient β_1 of the core variable. A significantly positive β_1 suggests that digital transformation has a substantial positive impact on corporate ESG performance.

3.2.2 Variable Definition.

(1) The explanatory variable is a firms' ESG compliance performance. Currently, the most intuitive measure of a firm's ESG performance is its ESG rating. This paper uses CSI ESG ratings to depict corporate ESG performance. The CSI ESG Rating is grounded in the ESG theoretical framework and practical experience, while also considering China's national conditions and the realities of the capital market. It is a widely recognized and commonly used evaluation index in the academic community. The rating data is evaluated quarterly and updated dynamically. Nine grades are assigned, ranging from "AAA" to "C", with "AAA" being the highest and "C" the lowest. In this paper, CSI's ESG ratings are scored from 9 (AAA) to 1 (C). The mean (ESG1) and median (ESG2) of these assigned values are calculated for each of the four quarters of the year to estimate the company's overall annual ESG performance. A higher ESGit score indicates better quality and performance in the company's ESG compliance.

(2) The explanatory variable in this paper is the level of digital transformation within firms. This index is developed using a text recognition function implemented through Python web crawling, based on the annual reports of publicly listed companies. To assess the level of digital transformation, we employ a method known as "search-pair-sum", which involves identifying and counting the occurrence of 76 keywords related to digitization. By quantifying the frequency of these terms in the annual reports, we can effectively illustrate the digital transformation levels of enterprises. The feature word map is constructed by innovatively dividing the keywords into two categories: underlying technology and technology practice. This approach aligns more closely with the development logic of digital transformation. It not only systematically assesses the overall level of digital transformation within enterprises, but also offers insights into the economic benefits generated by key aspects of digital transformation from a more detailed perspective.

(3) In line with existing literature, this paper includes the following firm-level characteristics as control variables firm size (Size), leverage (Lev), return on assets (ROA), firm growth (Growth), total asset turnover (ATO), cash flow (Cashflow), the proportion of shares held by the largest shareholder (Top1), and the type of equity (SOE). The specific definition is shown in Table 1.

Table 1. Definition of Variables

Variables	Variable description
ESG1	The annual average score for the CSI ESG Rating Assignment
ESG2	The annual median scores of the CSI ESG Rating Assignment
DIG1	Thr results were determined through textual analysis. Please refer to the definition of "Explanatory Variables" for more information
Size	Natural logarithm of total assets at the end of the year
Lev	Ratio of total liabilities to total assets at the end of the year
ROA	The ratio of year-end net profit to year-end total assets
Growth	Growth rate of operating income
ATO	The ratio of net operating income to average total assets
Cashflow	Natural logarithm of net cash flow from operating activities
Top1	The ratio of shares held by the largest shareholder to the total number of shares
SOE	If enterprise ownership is a state-owned, its value is 1; otherwise, it is 0

3.2.3 Descriptive Statistics.

Table 2 presents the descriptive statistics for the main variables. The data reveal significant differences in the ESG compliance performance of enterprises in China. The annual mean and median scores are quite similar, ranging from a minimum of 1 point to a maximum value of 8 points. This indicates that the lowest-rated enterprises in the sample are categorized as C-ranked, while the highest-rated enterprises are classified as AA-ranked. Notably, there are no AAA-ranked enterprises in the sample. On average, the ESG evaluation grade of the enterprises is approximately B-ranked. The enterprise digital transformation index (DIGI) indicates that there are significant disparities in the degree of digital transformation among enterprises in China. The process of digital transformation still needs ongoing efforts, as there is considerable potential for improvement. The statistical data for other enterprise-level control variables aligns closely with findings from existing studies.

Table 2. Descriptive Statistics

Variables	Observations	Mean	Std.dev	Minimum	Maximum
ESG1	28028	4.155184	0.9579161	1	8
ESG2	28028	4.153222	0.992618	1	8
DIGI	28028	1.658015	1.433031	0	6.380123
Size	28028	22.27378	1.288204	19.63939	26.42972
Lev	28028	0.4097714	0.2004546	0.0505245	0.9246132
ROA	28028	0.0421301	0.0686281	-0.374996	0.25389
Growth	28028	0.1600774	0.3894166	-0.653478	3.808222
ATO	28028	0.632361	0.4178515	0.054562	2.891314
Cashflow	28028	0.0498567	0.0675324	-0.171999	0.2656142
Top1	28028	0.3364853	0.1465593	0.080566	0.757345
SOE	28028	0.3441558	0.4751007	0	1

4 Empirical Results and Analysis

4.1 Basic Regression Analysis

Table 3 illustrates the effect of digital transformation on firms' ESG performance. Columns (1) and (2) present the results of regressing the annual mean and median ESG assignment scores, respectively. The findings indicate that for each standard deviation increase in the firm-level digital transformation index, the annual average corporate ESG performance scores will rise by 1.517 percent. Additionally, all regression coefficients were significantly positive at the 1% statistical level. It is evident that digital transformation has a significantly positive impact on the overall ESG performance of enterprises. By empowering digital capabilities, companies can enhance the interoperability of both internal and external information and transform their management approaches. This allows for more effective integration and value management of data elements. As a result, resource allocation efficiency and the practice implementation of

ESG strategies improve, ultimately boosting ESG performance. Therefore, hypothesis 1 is supported.

Table 3. Benchmark Regression

VARIABLES	(1) ESG1	(2) ESG2
DIGI	0.044*** (0.005)	0.050*** (0.005)
Size	0.169*** (0.007)	0.176*** (0.007)
Lev	-0.852*** (0.041)	-0.866*** (0.044)
ROA	1.007*** (0.088)	1.139*** (0.096)
Growth	-0.084*** (0.012)	-0.087*** (0.013)
ATO	0.069*** (0.018)	0.068*** (0.019)
Cashflow	-0.318*** (0.076)	-0.340*** (0.083)
Top1	0.442*** (0.054)	0.394*** (0.055)
SOE	-0.053** (0.022)	-0.053** (0.022)
Constant	0.515*** (0.152)	0.354** (0.156)
Observations	28,028	28,028
Number of stkcd	4,535	4,535
Control	YES	YES
Year fix	YES	YES
ID fix	YES	YES

4.2 Endogenous Issues

4.2.1 Core Explanatory Variables with A One-Period Lag.

This paper identifies a potential endogeneity issue stemming from reverse causality. Firms that excel in ESG compliance tend to be better positioned to invest in digital initiatives, which can drive their digital transformation. Consequently, the improvement in a firms' compliance performance may actually be a driving factor behind its digital transformation, rather than merely a result of it. This paper re-estimates the core explanatory variable, the digital transformation index (DIGI), using a one-period lag to mitigate potential reverse causality in the regression analysis. Table 4 displays the

regression results for the core explanatory variable from the subsequent period. The coefficient estimates and the significance of the relevant control variables remain largely unchanged, which aligns with the conclusions reached in the benchmark regression.

Table 4. Results of The One-Period Lagged Regression

VARIABLES	(1)	(2)
	ESG1	ESG2
L.DIGI	0.031*** (0.008)	0.033*** (0.008)
Constant	4.094*** (0.013)	4.088*** (0.014)
Observations	22,419	22,419
R-squared	0.633	0.581
control	YES	YES
year fix	YES	YES
ID fix	YES	YES

4.2.2 Instrumental Variables.

This paper employs the average digital transformation level of other companies within the same industry for the same year as an instrumental variable for the digital transformation level of the enterprise being examined. Companies in the same industry typically face similar market conditions and industry risks during that year. Consequently, the average digital transformation level of these peer companies is closely related to the enterprise's performance, yet it does not have a direct impact on its ESG performance. This approach meets both the relevance and exogeneity assumptions. The test results for the instrumental variable are presented in Table 5.

Table 5. Instrumental Variables

VARIABLES	(1)	(2)	(3)
	DIGI	ESG1	ESG2
IV	0.703*** (0.007)		
DIGI		0.026*** (0.007)	0.027*** (0.007)
Observations	27,652	27,652	27,652
R-squared	0.411	0.001	0.001
Number of stkcd	4,159	4,159	4,159
control	YES	YES	YES
year fix	YES	YES	YES
ID fix	YES	YES	YES

Column (1) shows the results of the first-stage regression, revealing that the instrumental variable explains more variance than the endogenous variable, indicating a strong correlation between them. Column (2) and (3) present the second-stage regression results, where the coefficient for the key variable, DIGI, remains statistically significant at the 1% level, consistent with the baseline regression results.

The test results suggest that after correcting for endogeneity, the conclusions from the baseline regression remain valid, confirming that digital transformation positively impacts corporate ESG performance.

4.3 Robustness Check

4.3.1 Removing Sensitivity Samples.

The regression was re-estimated by excluding samples from before 2015, as the "Internet+" initiative, introduced in the government work report that year, significantly accelerated corporate digital transformation [8]. Focusing on data after 2015 allows for a clearer assessment of digital transformation’s impact on corporate ESG performance. Additionally, the regression was re-run after removing samples from directly controlled municipalities [9]. The updated results are shown in Table 6, with columns (1) and (2) representing the analysis excluding pre-2015 samples, and columns (3) and (4) reflecting the exclusion of samples from directly controlled municipalities.

Table 6. The Regression Results After Deleting the Sensitivity Samples

	(1)	(2)	(3)	(4)
	Exclude Samples Before 2015		Exclude the Samples from Directly Controlled Municipalities	
VARIABLES	ESG1	ESG2	ESG1	ESG2
DIGI	0.056*** (0.005)	0.061*** (0.005)	0.051*** (0.006)	0.057*** (0.006)
Constant	4.091*** (0.014)	4.078*** (0.014)	4.084*** (0.015)	4.068*** (0.016)
Observations	25,932	25,932	20,749	20,749
Number of stkcd	4,533	4,533	3,629	3,629
control	YES	YES	YES	YES
year fix	YES	YES	YES	YES
ID fix	YES	YES	YES	YES

The regression results indicate that even after excluding sensitive samples, the regression coefficients continue to align with the baseline results. This consistency confirms the positive impact of digital transformation on corporate ESG performance, thereby reinforcing the robustness of the conclusions drawn in this study.

4.3.2 Replace the Dependent Variable.

The indicator used to measure corporate ESG performance has been replaced with the ESG scores of companies from the CNRDS database. The regression results are

presented in Table 7. The coefficient for the dependent variable remains significantly positive, aligning with the conclusions drawn from the baseline regression.

Table 7. Replace the Dependent Variable

VARIABLES	(1)
	ESG is replaced with CNRDS database indicator
DIGI	0.208*** (0.080)
Observations	27,899
control	YES
year fix	YES
ID fix	YES
R2	0.239

The robustness tests conducted indicate that the baseline regression results remain consistent, whether sensitive samples are removed or replaced with indicators from the CNRDS database. The estimated coefficients continue to be significantly positive at the 1% level. Additionally, the estimated coefficients and significance levels of the control variables have not changed fundamentally, further confirming that digital transformation has a positive effect on corporate ESG performance.

5 Mechanism Analysis

5.1 Model Building

The theoretical framework of ESG consists of three main dimensions: environmental protection, social responsibility, and internal governance. This framework is designed to evaluate the non-financial performance and long-term sustainability of enterprises, providing a new pathway for businesses to achieve long-term value creation. To further investigate how digital transformation influences corporate ESG performance, this paper selects relevant indicators for these three dimensions, based on the ESG theoretical framework, to test the underlying mechanism. The following mediating variables are identified for each of the three dimensions.

In the context of environmental protection, the level of green innovation in a company is measured using a formula that calculates the natural logarithm of the sum of green invention and utility model patent applications, with one added to the total ^[10]. This forms the basis of measurement model (2).

$$Green\ Patent_{it} = \alpha_0 + \alpha_1 DIGI_{it} + \gamma Controls_{it} + \mu_i + \sum IND + \rho_t + \varepsilon_{it} \quad (2)$$

This assessment is based on the corporate social responsibility report, which outlines various social responsibility initiatives ^[11]. If a listed company discloses more items in its social responsibility report, it indicates a stronger fulfillment of its social responsibility obligations. An econometric model will be constructed to analyze this relationship (see Model 3).

$$CSR_{it} = \theta_0 + \theta_1 DIGI_{it} + \gamma Controls_{it} + \mu_i + \sum IND + \rho_t + \varepsilon_{it} \tag{3}$$

In terms of corporate governance, the combination of two roles is used to assess the decision-making power of the general manager. This assessment is represented as a composite indicator reflecting the level of internal corporate governance (Dual) [12]. An econometric model (4) is then constructed based on this indicator.

$$Dual_{it} = \delta_0 + \delta_1 DIGI_{it} + \gamma Controls_{it} + \mu_i + \sum IND + \rho_t + \varepsilon_{it} \tag{4}$$

In model (2), the explanatory variable Green Patent_{it} represents the level of green innovation within enterprises, while the main explanatory variable DIGI_{it} characterizes the digital transformation index of these enterprises. The parameter to be estimated, α_1 , measures the impact of the digital transformation index on corporate green innovation. Similarly, in models (3) and (4), the explanatory variables CSR_{it} and Dual_{it} correspond to the levels of corporate social responsibility and governance level, respectively. The parameters to be estimated θ_1 and δ_1 assess the effect of the digital transformation index on corporate social responsibility and governance level, respectively. Additionally, the control variables Controls_{it} and fixed effects in all three models remain consistent with previous models.

5.2 Analysis of Regression Results

The results indicate that digital transformation plays a significant role in the growth of firms' green patents (see Table 8). The findings demonstrate that green patents serve as a mediating variable, with their positive impact on firms' ESG scores being significant at the 1% level. This confirms that green innovation mediates the relationship between digital transformation and ESG performance, thereby supporting hypothesis 2.

Table 8. Mechanism Analysis

VARIABLES	(1)	(2)	(3)
	Green Patent	ESG1	ESG2
DIGI	0.480*** (0.059)	0.050*** (0.005)	0.055*** (0.005)
Green Patent		0.003*** (0.001)	0.004*** (0.001)
Constant	0.849*** (0.187)	4.099*** (0.013)	4.086*** (0.013)
Observations	28,018	28,018	28,018
Number of stkcd	4,525	4,525	4,525
control	YES	YES	YES
year fix	YES	YES	YES
ID fix	YES	YES	YES

The results indicate that digital transformation plays a significant role in improving this indicator (see Table 9). Additionally, the level of responsibility fulfillment posi-

tively influences the ESG score and is statistically significant at the 1% level. This finding validates the mediating role of social responsibility, confirming hypothesis 3.

Table 9. Mechanism Analysis

VARIABLES	(1) CSR	(2) ESG1	(3) ESG2
DIGI	0.300*** (0.013)	0.040*** (0.005)	0.044*** (0.005)
CSR		0.022*** (0.003)	0.028*** (0.003)
Constant	4.806*** (0.036)	4.087*** (0.018)	4.045*** (0.019)
Observations	23,931	23,931	23,931
Number of stkcd	3,989	3,989	3,989
control	YES	YES	YES
year fix	YES	YES	YES
ID fix	YES	YES	YES

The regression analysis conducted using Dual as a variable to assess the level of internal governance indicates that digital transformation has a significant positive effect on this measure. However, the impact of Dual on the ESG score is not significant (see Table 10). This suggests that while digital transformation can enhance the efficiency of information transfer and decision-making within the company, its direct role in improving ESG performance is relatively weak. Therefore, hypothesis 4 is rejected.

Table 10. Mechanism Analysis

VARIABLES	(1) Dual	(2) ESG1	(3) ESG2
DIGI	0.006*** (0.002)	0.052*** (0.005)	0.057*** (0.005)
Dual		0.017 (0.013)	0.017 (0.014)
Constant	0.337*** (0.007)	4.096*** (0.014)	4.083*** (0.014)
Observations	28,028	28,028	28,028
Number of stkcd	4,535	4,535	4,535
control	YES	YES	YES
year fix	YES	YES	YES
ID fix	YES	YES	YES

6 Heterogeneity Analysis

The benchmark regression findings indicate that digitization enhances firms' compliance with ESG standards. Additionally, this effect may vary across different types of firms. The next section of this paper will examine how digital transformation influences ESG compliance performance differently across various industries.

6.1 Heterogeneity Analysis Based on Heavily Polluting Enterprises

Enterprises in highly polluting industries generally face greater environmental burdens during their production processes. As a result, they may be more inclined to adopt digital technologies to implement green innovations, which can help reduce pollutant emissions, enhance resource efficiency, and support sustainable corporate development. In contrast, non-high-polluting firms typically experience less urgency to transform, leading to a smaller potential for improvement in their ESG performance. To investigate this difference, the data sample is divided into two categories: enterprises from highly polluting industries and those from non-high-polluting industries ^[13]. The regression analysis is conducted separately for each group, and the results are presented in Table 11.

Table 11. Heterogeneity Analysis: Whether They Are Heavy Polluters

	(1)	(2)	(3)	(4)
	Non-heavily Polluting Enterprises		Heavily Polluting Enterprises	
VARIABLES	ESG1	ESG2	ESG1	ESG2
DIGI	0.015	0.012	0.051***	0.056***
	(0.014)	(0.015)	(0.006)	(0.006)
Constant	4.225***	4.215***	4.184***	4.172***
	(0.026)	(0.026)	(0.016)	(0.016)
Observations	4,930	4,930	19,001	19,001
Number of stkcd	812	812	3,240	3,240
control	YES	YES	YES	YES
year fix	YES	YES	YES	YES
ID fix	YES	YES	YES	YES

Columns (3) and (4) show the results for enterprises in high-pollution industries, where the coefficient for DIGI is significantly positive. In contrast, columns (1) and (2) present the results for non-polluting industries, which show not significant findings. This indicates that digital transformation has a stronger impact on improving ESG performance in enterprises within heavily polluting sectors.

6.2 Heterogeneity Analysis Based on Property Rights Nature

Based on property rights classification, enterprises are categorized as state-owned and non-state-owned. The regression results in Table 12 show that the coefficient for digital transformation (DIGI) is 0.07 for both state-owned enterprises, and 0.037 and 0.043 for non-state-owned enterprises. All coefficients are statistically significant at the 1% level. This is because state-owned enterprises are more strongly influenced by government regulations and policies, which set stricter environmental protection, social responsibility, and governance standards. Consequently, these enterprises tend to focus more on integrating sustainable development and social responsibility into their digital transformation efforts. Moreover, state-owned enterprises generally have greater ac-

cess to resources and funding, allowing them to invest more in digital technologies. This increased investment enhances their capacity for environmental protection and social governance. As a result, state-owned enterprises not only improve operational efficiency through digital transformation but also show a stronger commitment to fulfilling their ESG obligations.

Table 12. Heterogeneity Analysis: Whether They Are Nationalized Business

	(1)	(2)	(3)	(4)
	Nationalized Business		Non-State Enterprise	
VARIABLES	ESG1	ESG2	ESG1	ESG2
DIGI	0.070*** (0.010)	0.070*** (0.011)	0.037*** (0.006)	0.043*** (0.006)
Constant	4.178*** (0.027)	4.177*** (0.027)	4.180*** (0.015)	4.165*** (0.015)
Observations	7,454	7,454	17,050	17,050
Number of stked	1,146	1,146	3,171	3,171
control	YES	YES	YES	YES
year fix	YES	YES	YES	YES
ID fix	YES	YES	YES	YES

6.3 Heterogeneity Analysis Based on Manufacturing Enterprises

In the manufacturing industry, digital transformation typically enhances resource efficiency and reduces environmental impact through smart production, Internet of Things applications, and big data analysis. This results in improved environmental and social performance for enterprises. Manufacturing companies often make significant investments in digital technologies, which enable more direct monitoring and optimization of the sustainability of their production processes. In contrast, non-manufacturing industries tend to focus more on optimizing business processes, innovating services, and enhancing customer experiences during their digital transformation. Although these efforts contribute to improved social responsibility and corporate governance, their direct impact on environmental performance is relatively smaller. To investigate this difference, the data sample was divided into manufacturing and non-manufacturing enterprises, and separate regression analyses was conducted. The results of the regression analyses can be found in Table 13.

Table 13. Heterogeneity Analysis: Whether They Are Manufacturing Enterprises

	(1)	(2)	(3)	(4)
	Manufacturing Enterprises		Non-Manufacturing Enterprises	
VARIABLES	ESG1	ESG2	ESG1	ESG2
DIGI	0.046*** (0.005)	0.050*** (0.006)	0.049** (0.020)	0.055** (0.022)
Constant	4.194*** (0.014)	4.181*** (0.014)	4.187*** (0.043)	4.178*** (0.044)
Observations	21,644	21,644	2,287	2,287

Number of stkcd	3,674	3,674	356	356
control	YES	YES	YES	YES
year fix	YES	YES	YES	YES
ID fix	YES	YES	YES	YES

Columns (1) and (2) present the regression results for manufacturing enterprises, showing that the coefficient for DIGI is positive and statistically significant at the 1% level. Conversely, columns (3) and (4) display the regression results for non-manufacturing enterprises, which indicate a positive effect at the 5% significance level. This suggests that digital transformation has a stronger impact on ESG performance in manufacturing enterprises compared to non-manufacturing ones.

7 Conclusions and Recommendations

7.1 Enhance policy guidance and promote digital transformation to support the development ESG initiatives

The government should develop more targeted policies to support the digital transformation of various industries, particularly manufacturing, high-pollution industries and state-owned enterprises. To encourage businesses to adopt digital tools and platforms, the government can offer tax incentives, technical support, and special fund subsidies. Additionally, for enterprises with low ESG performance, a mandatory disclosure system or supportive incentive policies can be established to guide them in integrating ESG compliance into their corporate development plans.

7.2 Create a sustainable innovation ecosystem to help businesses achieve low-carbon development

To enhance support for R&D in green technology and its transformation, it's essential to encourage enterprises to improve their green innovation capabilities through digitalization. The government and industry associations should establish a green innovation platform integrates industry, academia and research institutions. This platform will facilitate technological exchanges and collaboration, promoting the widespread adoption and application of green invention and utility model patents. Additionally, it's important to further encourage green innovation R&D in both high-tech industries and heavily polluting industries to achieve the goal of low-carbon development across all sectors.

7.3 Enhance the use of data analysis to improve the ESG assessment and management system

Enhance the capacity for quantitatively assessing corporate ESG performance. Encourage companies to leverage tools to monitor and optimize their ESG performance in real time. Develop a more localized and industry-specific ESG assessment index system to improve the scientificity accuracy and practicality of evaluations, thereby providing more valuable decision-making support for enterprises and investors.

References

1. ZHAO Chenyu, WANG Wenchun, LI Xuesong. How digital transformation affects enterprise total factor productivity[J]. *Finance and Trade Economics*,2021,42(07):114-129.
2. CHEN Deqiu, HU Qing. Corporate governance research in the era of digital economy: Paradigm innovation and practice frontiers[J]. *Management World*,2022(06).
3. Davenport, T. H., & Ronanki, R. Artificial intelligence for the real world[J]. *Harvard Business Review*, 2018(01).
4. XIAO Hongjun, YANG Zhen, LIU Meiyu. The social responsibility promotion effect of corporate digitalization: a test of internal and external dual paths[J]. *Economic Management*, 2021(11).
5. Song DY, Zhu WB, Ding H. Can corporate digitalization promote green technology innovation? -- An Examination Based on Listed Companies in Heavy Pollution Industries[J]. *Financial Research*,2022(04).
6. GUO Guoqing, ZHANG Zhongke, NIU Haipeng. Customer insight and marketing strategy transformation in the digital era[J]. *Management World*, 2022(05).
7. Bridgstock, R. The role of digital technologies in corporate social responsibility and sustainability[J]. *Journal of Cleaner Production*, 2019(233).
8. Shi Yutong, Wang Xiaodan, Guo Yue, et al. How ESG Ratings Achieve "Incremental Improvement" in Corporate Green Innovation [J]. *Science of Science and Management of S.& T*, 2024, 45(11): 162-179.
9. Liu Wei, Zhang Yingliang, Wang Yan. *Economic Management*, 2021, 43(07): 44-60.
10. Li Zhijun. Influencing Factors and Case Study on Financing Leasing of Listed Companies [D]. Beijing University of Chemical Technology,2020.
11. Aman Jin,Shixian Ling. A study on the impact of green finance reform policies on ESG risk premium--empirical evidence from China's A-share market [J]. *Economic Journal*,2024,11(04):183-216.
12. Sheng Ling,Wang Xinguang. Common institutional investors and corporate financial risk diffusion[J]. *Business Research*, 2024, (01):103-110.
13. Dong Cong, Dong Xucheng, Jiang Qingzhe, et al. Impact of ESG rating divergence on green innovation of listed companies and the mechanism of its role [J]. *China Population-Resources and Environment*, 2024, 34(08):103-113.

Open Access This chapter is licensed under the terms of the Creative Commons Attribution-NonCommercial 4.0 International License (<http://creativecommons.org/licenses/by-nc/4.0/>), which permits any noncommercial use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license and indicate if changes were made.

The images or other third party material in this chapter are included in the chapter's Creative Commons license, unless indicated otherwise in a credit line to the material. If material is not included in the chapter's Creative Commons license and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder.

