Is Digital Transformation Beneficial for ESG Performance? -- Evidence from Chinese Listed Companies

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Abstract. This article empirically examines the impact of digital transformation on ESG performance and explains digital transformation significantly enhances ESG performance, and this enhancement is further amplified through the channels of promoting green management and alleviating financing constraints. For state-owned enterprises, the positive impact of digital transformation on ESG performance is even more pronounced. This study expands upon existing research and offers pertinent recommendations and future outlook.

Keywords: digital transformation; ESG; green management; financing constraints.

1. Introduction

In 2004, the United Nations Global Compact organization first introduced the concept of ESG (Environmental, Social, Governance), emphasizing issues in investment research and corporate evaluation standards (Gillan et al., 2021) [1]. Digital transformation is an important support for high-quality development of enterprises Enterprise digital transformation relies on new digital means to improve data mobility (Wang Hui et al., 2021) [15].

While numerous scholars have researched digital transformation, there is currently limited literature directly exploring the mutual impact between digital transformation and ESG. Some scholars have mentioned that digital transformation can optimize both internal and external resource allocation for companies, enhancing their capacity for sustainable development and achieving green and inclusive growth (Ni Kejin, 2021) [9]. Liu Yanxia (2022) [8] and others focus on the outcomes of digital technology and corporate digital transformation, revealing that the significant enhancement of digital finance, particularly in terms of coverage breadth and depth, notably promotes corporate social responsibility.

This paper's potential margin contributions are mainly reflected in several aspects. First, an attempt is made to explore the social spillover effects of digital transformation from the perspective of ESG performance, thereby expanding the existing research in the field of corporate ESG. Second, this paper employs data from A-share listed companies from 2009 to 2022 to demonstrate the relationship between digital transformation and ESG, while also examining the impact direction of green management and financing constraints on ESG. Third, this paper is based on current events data, studying the roles played by green management and financing constraints in the interaction between digital transformation and ESG.

2. Theoretical Mechanisms and Research Hypotheses

2.1 Direct Effects

Digital transformation provides a database for technological innovation. In theory, corporate digital transformation is expected to have a positive impact on ESG development by empowering traditional industries.

First, the integration of digital technologies such as "Internet+" technology and artificial intelligence into corporate operations and management processes improves communication between companies, investors, and consumers, significantly enhancing information transparency (Qi Huaijin et al., 2022) [12]. Second, digital transformation can facilitate corporate growth, use digitized

operational information to enhance corporate governance and lower the costs of obtaining information (Jie Weimin et al., 2022) [6]. Third, digital transformation reshapes corporate supply and industrial chains, and providing a material basis for investment in ESG performance (Wang Haijun et al., 2022) [14]. With this in mind, we propose Hypothesis 1:

Hypothesis 1: Corporate digital transformation positively promotes ESG performance.

2.2 Indirect Effects

Green management integrates environmental protection concepts into corporate operations and management. Through green management, companies disclose environmentally related information and attract external investors. The enhancement of economic benefits provides the capital foundation for increased investment in ESG performance, thus playing a positive role in promoting ESG performance.

Corporate green management optimizes ESG performance. During the "14th Five-Year Plan" period, China's focus on carbon reduction positions high-quality development on efficient resource utilization and green management foundations (Zhou Xuefeng et al., 2022) [24]. Consistent green management assists in energy conservation, pollution reduction, and environmental improvement, bolstering a company's ESG performance during the digital transformation period (Shen Minghao and Tan Weijie, 2022) [13]. Based on this, we propose Hypothesis 2:

Hypothesis 2: Holding other conditions constant, the better a company's green management, the better its ESG performance.

Corporate digital transformation aligns with national development strategies, making companies more likely to receive favorable financial policies from financial institutions during fundraising, effectively easing the issue of financing difficulties (Hua Junguo et al., 2022) [4]. Capital serves as a vital foundation for companies' sustainable development, and fulfilling ESG responsibilities consumes substantial amounts of funds. If a company faces lower degrees of financing constraints, ample and low-cost funds will facilitate the company's implementation of ESG principles and proactive fulfillment of ESG responsibilities. Therefore, we propose Hypothesis 3:

Hypothesis 3: Corporate digital transformation positively promotes ESG performance through the alleviation of financing constraints.

3. Data Sources, Research Design, and Indicator Construction

3.1 Indicator Construction

3.1.1 Dependent Variable (ESG Performance)

Following the studies of Xie Hongjun and Lü Xue (2022) [22] and Wang Yu et al. (2022) [18], this study employs the Huaxia Securities ESG rating data as a proxy variable for corporate ESG performance. The Huaxia Securities ESG rating consists of 9 levels, and is evaluated 4 times annually, lending scientific and effective credibility to its results. Furthermore, this study assigns scores from 1 to 9 based on the rating levels, with higher scores indicating better ESG performance. To enhance the accuracy of rating results, the average rating of the 4 evaluations conducted annually is used as the company's ESG performance for that year.

3.1.2 Independent Variable (Corporate Digital Transformation)

Drawing from the research of Zhao Chenyu et al. (2021) [23], Wu Fei et al. (2021) [19], and Hu Jie et al. (2023) [3], this study extracts keywords related to digital transformation from annual reports using text analysis and uses the frequency of keyword occurrences to characterize the extent of corporate digital transformation. Specifically, higher frequencies of the term "digital transformation" indicate a greater degree of digital transformation within the company. To mitigate the effect of heteroscedasticity on empirical results, natural logarithm transformations are applied to the frequency count plus 1.

3.1.3 Mediating Variables

Green Management: Following the studies of Li Weian et al. (2019) [7] and Zhao (2015) [2], this study measures green management using five indicators. Considering data availability, the comprehensive score representing corporate green management innovation is obtained by summing up indicators derived from the disclosure of listed companies' environmental regulation and certification status in the CSMAR environmental database.

Financing Constraints: We adopts the absolute value of SA index as the indicator to measure the degree of financing constraints. A larger value indicates more severe financing constraints faced by the company. The calculation method is as follows:

$$SA = -0.737size + 0.043size^2 - 0.04age \quad (1)$$

Where size = ln(total assets / 1,000,000), with assets in yuan, and age referring to the company's years listed.

3.1.4 Control Variables

The measurement methods of control variables are presented in Table 1.

Table 1. Symbols and Definitions of Control Variables

Variable Name	Symbol	Definition
Company Size	Size	Natural logarithm of year-end total assets
Leverage	Lev	Year-end total liabilities divided by year-end total assets
Return on Assets	ROA	Net profit divided by average total assets
Cash Flow Ratio	Cashflow	Net cash flow from operating activities divided by total assets
Revenue Growth Rate	Growth	Current year's revenue / Previous year's revenue - 1
Number of Directors	Board	Natural logarithm of the number of directors on board
Proportion of Independent Directors	Indep	Number of independent directors divided by the total number of directors
Proportion of Shares Held by Top 10 Shareholders	Top10	Number of shares held by the top 10 shareholders divided by total shares outstanding

3.2 Model Design

$$ESG_{it} = \alpha_0 + \alpha_1 digt_{it} + \alpha_2 Z_{it} + \mu_i + \delta_t + \varepsilon_{it} \quad (2)$$

Where ESG_{it} represents the ESG performance score of firm i at time t, $digt_{it}$ denotes the level of digital transformation of firm i in period t. To address endogeneity concerns arising from omitted variables, this study introduces control variables (Zit) following existing literature. Additionally, to account for individual heterogeneity within group regressions, the model incorporates individual fixed effects denoted as representing firm i's characteristics that do not vary over time, and time fixed effects are also included. Furthermore, the random error term is clustered at the firm level to address the issue of systematic heteroskedasticity in the model.

4. Empirical Analysis

4.1 Baseline Regression

Table 4 presents the results of the baseline regression model in this study. Column (1) displays the regression results from 2009 to 2022 with only the core explanatory variable, digital transformation, included. It shows that the coefficient of digital transformation (Digital) on corporate ESG performance (ESG) is significant at the 1% level, with a value of 0.094. This implies that a higher degree of digital transformation leads to better ESG performance for companies. Column (2) presents

the regression results after incorporating control variables such as company size (Size) and leverage (Lev). It demonstrates that digital transformation (Digital) still significantly positively influences corporate ESG at the 5% significance level, with a coefficient of 0.052. In other words, through digital transformation, the overall connection between companies and stakeholders strengthens, prompting companies to fulfill their social responsibilities better, thereby enhancing their performance in environmental, social, and governance aspects. This showcases the non-economic value creation of digital transformation.

Note: ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively. Robust standard errors are shown in parentheses.

4.2 Robustness Analysis

4.2.1 Replacement of Explanatory Variables

In the baseline regression section, this study employed an aggregate measure of corporate digital transformation for regression. In the robustness analysis, following the approach of Hu Jie et al. (2022) [3], the core explanatory variable was replaced by five digital dictionaries: "Artificial Intelligence," "Blockchain," "Cloud Computing," "Big Data," and "Digital Applications." The frequency of mentions of blockchain technology was used as a proxy variable for the blockchain replacement. The summation of the aforementioned word frequencies yielded a new index characterizing the digital transformation of sampled companies. The results in Table 5 indicate that the positive influence of corporate digital transformation on the modified dependent variable remains statistically significant.

Table 2. Baseline Regression

	(1)	(2)
Digital	0.094***	0.052**
	(16.45)	(2.60)
Size		0.322***
		(7.55)
Lev		-0.002
		(-0.35)
ROA		0.001
		(0.04)
Cashflow		-0.020
		(-0.25)
Growth		-0.000***
		(-14.76)
Board		-0.035
		(-0.50)
Indep		1.163***
		(6.03)
Top10		-0.475
		(-1.57)
_cons	3.777***(138.15)	-3.345***
		(-3.50)
Firm FE	Yes	Yes
Time FE	Yes	Yes
N	42868	42328
adj. R^2	0.02	0.41

Table 3. Robustness Analysis

	(1)ESG
BCTech	0.0111**(2.89)
Size	0.331***(7.94)
Lev	-0.00154 (-0.31)
ROA	0.00162(0.07)
Cashflow	-0.0230 (-0.30)
Growth	0.000*** (-15.24)
Board	-0.0242 (-0.34)
Indep	1.166***(5.99)
Top10	-0.480 (-1.57)
_cons	-3.512*** (-3.75)
Firm FE	Yes
Time FE	Yes
N	42328
adj. R^2	0.13

4.2.2 Replacement of Dependent Variable

In the robustness analysis section, we conducted the test again using Bloomberg ESG rating data as the dependent variable. The Bloomberg data scoring system exhibits strong reliability due to its significant correlation with ratings from other institutions. Following the methodology of Nie Huihua (2022) [10], this study selected the Bloomberg ESG score index to measure corporate ESG performance. The Bloomberg ESG disclosure index varies within the range of [0, 100], with higher scores reflecting higher ESG disclosure levels for listed companies, indicating better ESG performance.

Table 4. Robustness Analysis

	ESGPB
Digital	0.281**
	(2.62)
Size	1.120**
	(2.96)
Lev	-2.193***
	(-3.62)
ROA	0.715
	(1.29)
Cashflow	1.659***
	(3.56)
Growth	-0.000220***
	(-3.99)
Board	1.030
	(1.57)
Indep	4.679**
	(2.28)
Top10	1.675
	(1.81)
_cons	-1.987
	(-0.20)
Firm FE	Yes
Time FE	Yes
N	12313

Table 5. Mechanism Testing

	ESG
Digital	0.0488**
	(2.95)
GM	0.371***
	(7.13)
M(digital*GM)	0.127***
	(3.41)
Size	0.276***
	(8.18)
Lev	-0.00219
	(-0.58)
ROA	-0.000423
	(-0.02)
Cashflow	-0.00659
	(-0.09)
Growth	-0.0000104***
	(-10.27)
Board	-0.0000748
	(-0.00)
Indep	1.123***
	(5.74)
Top10	-0.517
	(-1.60)
_cons	-2.456***
Firm FE	Yes
Time FE	Yes
N	37269

With the premise of maintaining a consistent set of included sample companies, replacing the dependent variable of ESG rating data with Bloomberg's ESG rating data still yields significant results at the 5% level. According to information disclosed on the Bloomberg official website, both companies conducted ESG ratings for a total of 1039 Chinese listed companies as of 2021, and the rating outcomes also have a broad influence.

5. Further Analysis

5.1 Mechanism Testing

5.1.1 Corporate Digital Transformation, Green Management, and ESG Performance

The overall level of green management in listed companies is relatively low. The impact of digital transformation on green management is relatively weak, presenting a situation where digital transformation is pushing for green management development. This scenario places a greater emphasis on actions rather than structural mechanism construction. Looking at the empirical regression results between green management and corporate ESG performance, although green management may not yield short-term profits, it contributes to enhancing the long-term value of companies. Companies with high levels of green management have achieved greater growth potential, lower risks, and higher long-term value.

5.1.2 Digital Transformation, Financing Constraints, and ESG Performance

Jiang Ting (2022) [5] pointed out that by theoretically proposing an intuitively comparable mediator variable's impact on the dependent variable, followed by testing the influences of the independent variable on both the dependent and mediator variables, it is possible to avoid formally distinguishing whether there are unexplained direct effects outside of the indirect effects. Therefore, we solely conducted regression analysis on digital transformation and the mediator variable to establish the impact of the mediator variable (financing constraints) on ESG performance.

Empirical results, as shown in Table 8, indicate that the degree of digital transformation (Digital) significantly influences financing constraints (SA) at the 1% significance level, highlighting its strong impact on financing constraints.

Table 6. Mechanism Test - Financing Constraints

	SA
Digital	0.0206***
	(15.02)
Size	0.0566***
	(21.94)
Lev	-0.199***
	(-21.92)
ROA	-0.193***
	(-8.52)
Cashflow	-0.147***
	(-7.38)
Growth	-0.00000194***
	(-3.63)
Board	0.0453***
	(4.68)
Indep	0.328***
	(8.98)
Top10	0.456***
	(43.01)
_cons	-5.164***
	(-79.89)
Firm FE	Yes
Time FE	Yes
N	36520

5.2 Heterogeneity Analysis

5.2.1 Temporal Heterogeneity Analysis

The impact of digital transformation on ESG was at the 1% level during the period from 2009 to 2022. The effect was notably accelerated by policy support during 2012 to 2014, and since 2017, it has demonstrated a consistent and positive trend.

Table 7. Heterogeneity Analysis - Temporal Dimension

	ESG09-12	ESG12-14	ESG15-17	ESG18-22
Digital	0.129***	0.136***	0.0704***	0.0647***
	(8.16)	(12.34)	(7.25)	(8.02)
Size	0.294***	0.260***	0.380***	0.257***
	(34.37)	(19.11)	(35.88)	(38.85)
Lev	-0.0230	-0.475***	-1.004***	0.00493
	(-1.29)	(-4.26)	(-13.57)	(0.19)
ROA	-0.0289	-0.0482	0.140	0.622*
	(-1.12)	(-0.91)	(0.57)	(1.84)
Cashflow	0.459***	0.163**	0.252	1.052***
	(4.07)	(1.98)	(1.50)	(4.73)
Growth	-0.0000109***	-0.0000112***	-0.00124**	-0.00173
	(-17.52)	(-33.06)	(-2.51)	(-1.50)
Board	-0.0648	-0.0427	-0.0188	0.130**
	(-1.01)	(-0.62)	(-0.25)	(2.24)
Indep	0.953***	1.309***	1.162***	1.647***
	(4.05)	(5.45)	(4.68)	(8.26)
Top10	-0.814***	-0.0984	-0.922***	0.0405
	(-11.13)	(-1.20)	(-10.96)	(0.57)
_cons	-2.363***	-1.798***	-4.059***	-2.713***
	(-11.37)	(-6.87)	(-15.57)	(14.58)
Firm FE	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes
N	8050	7183	8983	20890

5.2.2 Heterogeneity Analysis of Corporate Ownership Nature

Under the context of China's socialist market economy, corporate behavior is influenced by the nature of ownership, and this characteristic is also reflected in the ESG performance during corporate digital transformation. Therefore, in light of the ownership nature of enterprises, this paper divides them into state-owned and non-state-owned enterprises for grouped regression analysis. The regression results are shown in Table 10.

Table 8. Heterogeneity Analysis - Corporate Nature

(1)State-owned enterprises		(2)Non-state-owned enterprises
	ESG	ESG
Digital	0.0911***	0.0842***
	(9.00)	(13.02)
Size	0.277***	0.280***
	(29.04)	(45.57)
Lev	-0.650***	-0.0149
	(-6.64)	(-0.88)
ROA	0.419	0.220*
	(1.39)	(1.71)
Cashflow	0.169	0.733***
	(1.33)	(3.96)
Growth	-0.0000107***	-0.00000747
	(-29.06)	(-0.19)
Board	-0.104**	0.0530
	(-2.16)	(1.06)
Indep	1.426***	1.373***
	(8.44)	(7.87)
Top10	-0.515***	-0.114**
	(-7.61)	(-2.23)
_cons	-1.817***	-2.977***
	(-10.28)	(-16.32)
N	14655	28102

Grouping by ownership nature reveals that the estimated parameters of digital transformation and its sub-indicators for state-owned enterprises are significant at the 1% level, while non-state-owned enterprises are relatively weaker than state-owned enterprises but still significant. Therefore, they are more proactive in utilizing digital transformation to enhance ESG performance.

6. Conclusion and Implications

In the wave of the new technological revolution, accelerating digital development has become an increasingly crucial strategic approach for enterprises. The empirical results indicate the following findings: First, corporate digital transformation significantly enhances ESG performance. Second, digital transformation positively influences ESG performance through two channels: promoting green management and alleviating financing constraints. Third, heterogeneous analysis reveals that digital transformation has a stronger positive impact on ESG performance for state-owned enterprises. Based on these research conclusions, the following recommendations are proposed:

First, at the strategic level, enterprises should focus on high-quality development of the digital economy, this, in turn, can drive green management, promote sustainable development, and improve ESG performance.

Second, at the governance level, as digital technologies drive the transformation of economic activities, enterprises should seize the opportunity to proactively adapt to digital governance.

Third, at the governmental policy level, a strong emphasis should be placed on digital development, continuously optimizing policies that encourage enterprise digital transformation as part of industrial transformation and innovation. The ESG concept should also be given full attention, actively promoting ESG practices in enterprises.

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