

Digital Transformation and Corporate ESG Performance: The Moderating Role of Financing Constraints

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Abstract

This investigation employs a panel of A-share listed Chinese enterprises (2011-2020) as the research sample to empirically analyze the impact of digital transformation on corporate ESG performance. The findings substantiate two critical propositions: Firstly, digital transformation demonstrates a significant positive effect on ESG performance enhancement. Furthermore, this marginal enhancement effect becomes more pronounced under conditions of reduced corporate financing constraints. The study makes dual theoretical contributions by extending the investigation of digital transformation's consequences to encompass non-economic outcomes through the ESG performance paradigm, while simultaneously enriching the scholarly understanding of determinants shaping corporate ESG practices.

Key words: Digital Transformation; ESG Performance; Financing Constraints

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1. Introduction

Amid intensifying global challenges including climate warming, energy security crises, and industrial transition imperatives, corporations as primary economic actors bear dual imperatives: serving as vanguards in environmental stewardship and social accountability, while functioning as catalytic agents for sustainable socioeconomic advancement. However, the persistent prioritization of economic returns has resulted in suboptimal corporate performance in ecological preservation and social commitment domains. The emergence of the ESG framework presents a strategic juncture for organizational realignment, where ESG performance - an integrated evaluation metric encompassing environmental responsibility (E), social engagement (S), and governance efficacy (G) - operationalizes sustainable development principles at the corporate level. Systematic elevation of ESG performance enables enterprises to generate sustainable value through tripartite value creation mechanisms: economic returns amplification, social welfare optimization, and ecological footprint mitigation, thereby catalyzing long-term sustainable socioeconomic development. Consequently, investigating determinants of corporate ESG performance constitutes both theoretical and practical imperatives for contemporary business scholarship.

The imperative question of enhancing corporate ESG performance necessitates systematic inquiry. Current scholarship has elucidated multifarious determinants through diverse analytical lenses: Huang and Xia (2022) demonstrate that capital market liberalization via the Stock Connect Program stimulates ESG optimization; Wang et al. (2022) establish the catalytic effect of green taxation reforms on sustainability capabilities within heavily polluting industries; Liu et al. (2022) identify positive correlations between Party organization governance structures and ESG outcomes; Li and Zhu (2022) reveal the enabling role of information infrastructure development in ESG advancement. Crucially, two persistent challenges constrain ESG performance enhancement: Capital Intensity Barriers: The capital-intensive nature of ESG initiatives imposes substantial financing constraints, particularly for small-to-medium enterprises; Technological Path Dependence: Organizational inertia rooted in legacy technological systems creates innovation bottlenecks, hindering sustainable transition. This dual-aspect constraint mechanism—financial resource scarcity coupled with technological modernization deficits—constitutes the primary impediment to ESG performance elevation. Consequently, strategic resolution of these interdependent financial and technological barriers emerges as a critical priority for achieving substantive ESG improvement.

The ubiquitous integration of big data analytics, cloud computing architectures, artificial intelligence systems, and internet-based technologies has catalyzed the emergence of the digital economy as a transformative economic paradigm, positioning digital transformation as the pivotal catalyst driving this technological revolution. Statistical evidence reveals that China's digital industrialization sector attained a scale of 8.35 trillion yuan in 2021 (constituting 18.3% of the total digital economy), while industrial digitalization achieved 37.18 trillion yuan (81.7%

share), demonstrating comprehensive technological permeation across operational ecosystems of physical enterprises. This digital infusion has fundamentally reconfigured production modalities, governance frameworks, and organizational architectures within contemporary business entities. Empirical scholarship has conclusively demonstrated that corporate digital transformation optimizes core operational domains encompassing production, governance, and distribution frameworks, thereby catalyzing enterprise growth trajectories and macroeconomic equilibrium (Downes & Nunes, 2017; Clohessy, 2016). The transformational impacts extend synergistically across multiple strategic vectors, such as innovation acceleration, productivity leap, market discipline, organizational metamorphosis, stakeholder alignment (Paunov & Rollo, 2016; Hess et al., 2016; Mubarak, 2021). This multifaceted impact mechanism substantiates digital transformation's capacity to mitigate dual constraints of capital inadequacy and technological obsolescence. This empirical reality provokes a pivotal inquiry: Does strategic digital transformation constitute an effective conduit for amplifying corporate ESG performance? Systematic investigation of this proposition bears significant implications for both sustainable business practices and economic development paradigms.

Building upon this theoretical foundation, this investigation employs a comprehensive panel dataset encompassing China's A-share listed enterprises from 2011–2020 to rigorously examine the nexus between digital transformation and corporate ESG performance, with particular emphasis on the moderating role of financing constraints. The study makes tripartite scholarly contributions: Firstly, By establishing digital transformation as a novel antecedent of ESG performance, we broaden the analytical paradigm for understanding ESG determinants beyond conventional institutional and regulatory perspectives; Secondly, Diverging from predominant economic outcome analyses of digital transformation, this research pioneers systematic investigation into its extra-economic organizational impacts through the ESG lens; Thirdly, The identification of financing constraints' moderating mechanism provides actionable insights for optimizing digital transformation implementation strategies to maximize ESG performance outcomes, particularly for capital-constrained enterprises.

2. Theoretical considerations and research hypotheses

Digital transformation fundamentally reconfigures enterprise productivity paradigms and production relations, engendering substantive impacts on corporate ESG performance through three distinct mechanisms. Firstly, Environmental Dimension Enhancement. The implementation of digital monitoring systems and predictive analytics enables comprehensive pollution surveillance across production cycles (Han et al., 2022). The transition from manual supervision to data-driven governance systems elevates environmental performance metrics, compelling enterprises to proactively fulfill ecological stewardship obligations. Secondly, Social Responsibility Actualization. Digital transformation catalyzes service-oriented organizational transitions (Zhao, 2022), fostering heightened consumer-centric consciousness. Enterprises

increasingly prioritize product quality optimization, brand equity preservation, and reputational risk mitigation. This paradigm shift manifests in enhanced post-sales service ecosystems, ethical supply chain management, and strategic philanthropic engagements. The evolutionary trajectory from shareholder primacy to stakeholder value maximization (Li & Gong, 2009) demonstrates digital transformation's capacity to institutionalize social responsibility frameworks. Thirdly, Corporate Governance Modernization. Advanced digital infrastructure (big data analytics, cloud computing, IoT networks) enables real-time production process monitoring and transparent operational oversight. The knowledge dissemination efficiency enabled by digital organizational restructuring reduces information asymmetry (Shen & Yuan, 2020), effectively mitigating agency problems and elevating governance benchmarks.

Hypothesis H1: Digital transformation demonstrates significant positive correlation with corporate ESG performance enhancement.

Divergent financing constraints engender heterogeneous strategic orientations in corporate decision-making. Enterprises experiencing mitigated financing constraints demonstrate heightened motivation and operational capacity to leverage digital technologies in fulfilling environmental stewardship, social accountability, and governance excellence, thereby achieving substantive ESG performance enhancement. Conversely, stringent capital constraints compel firms to prioritize short-term profit maximization at the expense of environmental preservation and governance integrity. This dichotomous reality substantiates that financing constraint alleviation amplifies the positive externality of digital transformation on ESG performance optimization.

Hypothesis H2: The marginal effect of digital transformation on ESG performance elevation exhibits positive correlation with the degree of financing constraint mitigation.

3. Methodology, variables, and data specification

To explore the impact of digital transformation on corporate ESG performance, this study constructs a two-way fixed effects model (Model 1) controlling for both firms and years.

$$ESG_{i,t} = \alpha_0 + \alpha_1 Dig_{i,t} + \alpha_i Control_{i,t} + E_i + T_t + \varepsilon_{i,t} \quad (1)$$

Where ESG represents corporate ESG performance; Dig denotes the degree of enterprise digital transformation, i indicates the selected A-share listed company samples, t represents time, E signifies firm fixed effects, T indicates time fixed effects, and ε stands for the random disturbance term. The control variables (Control) are as shown in Table 1.

3.1 Explanatory variables

Digital transformation serves as the explanatory variable in this study. Given the absence of universally established measurement protocols for corporate digital transformation, we adopt the methodology developed by Zhou and Wu (2022) to operationalize digital transformation intensity (Dig) through the proportion of digital assets to total intangible assets. Specifically, we extract digital-related assets from intangible asset disclosures in listed companies' financial

statement footnotes by identifying and aggregating entries containing the following digital lexemes: "software", "network infrastructure", "client-server architecture", "enterprise systems", "digital platforms", "information technologies", and "e-commerce infrastructure", and sum them up to obtain the enterprise's digital assets, then divide the digital assets by intangible assets and multiply by 100 to obtain an indicator measuring the degree of corporate digitalization.

3.2 Dependent variable

Corporate ESG performance constitutes the dependent variable in this investigation. While extant research predominantly employs self-constructed multidimensional evaluation frameworks or third-party rating agency assessments to measure ESG outcomes, endogenous methodological limitations inherent in researcher-developed indices may compromise analytical validity. To mitigate these constraints, this study adopts the Bloomberg Corporate Social Responsibility Disclosure Index – a well-validated metric widely utilized in domestic scholarly research. This composite index quantifies ESG performance through three discrete dimensions (environmental stewardship, social accountability, and governance efficacy), with elevated index values indicating superior ESG performance alignment.

3.3 Control variables

The control variables selected in this study are presented in Table 1.

Table 1 Definitions of control variables.

Acronym	Variable	Definitions
<i>Board</i>	Board Size	Natural Logarithm of (Board Size+1)
<i>Size</i>	Firm Size	Natural Logarithm of Total Assets
<i>Sep</i>	Separation of Ownership and Control	Difference Between Control Rights and Ownership Rights of the Actual Controller
<i>Shr</i>	Proportion of Shares Held by the Largest Shareholder	Number of Shares Held by the Largest Shareholder / Total Shares
<i>Idr</i>	Proportion of Independent Directors	Number of Independent Directors / Total Number of Directors
<i>Tur</i>	Asset Turnover Ratio	Operating Revenue / Total Assets
<i>Lev</i>	Debt to Asset Ratio	Total Liabilities / Total Assets
<i>Liq</i>	Current Ratio	Current Assets / Current Liabilities
<i>Age</i>	Age of Listing	Natural Logarithm of (Firm Age+1)

3.4 Data

This study constitutes its research sample from Chinese A-share listed enterprises spanning

2011–2020. The sample selection protocol adheres to three rigorous criteria: firstly, Exclusion of Special Treatment (ST) enterprises;secondly,Elimination of firms in financial, insurance, and real estate sectors;thirdly, Removal of observations with missing critical variables.Following this tripartite screening process, the final dataset comprises 7,302 firm-year observations across the ten-year observation window. To ensure empirical robustness, all continuous variables undergo winsorization at the 1st and 99th percentiles, effectively mitigating outlier distortion. Financial data originates from the China Stock Market & Accounting Research (CSMAR) database, while ESG metrics derive from the Bloomberg ESG Disclosure Index. Comprehensive variable definitions and descriptive statistics are systematically presented in Table 2.

Table 2 Descriptive statistics.

Variable	Mean	S.D.	Min	Max
<i>Esg</i>	20.51	6.685	9.091	44.21
<i>Dig</i>	0.212	0.477	0	3.340
<i>Size</i>	23.02	1.261	20.43	26.55
<i>Lev</i>	0.460	0.199	0.0638	0.876
<i>Age</i>	2.460	0.661	0	3.296
<i>Board</i>	2.288	0.184	1.792	2.773
<i>Idr</i>	0.375	0.0553	0.313	0.571
<i>Shr</i>	0.369	0.160	0.0880	0.757
<i>Liq</i>	2.025	1.986	0.233	13.50
<i>Tur</i>	0.654	0.445	0.0835	2.618
<i>Sep</i>	5.221	8.085	0	31.22

4. Empirical results

4.1 Baseline results

The regression results for Model (1) are presented in Table 3. Column (1) displays the results of the univariate regression, while Column (2) presents the estimates that include control variables. All regressions account for both year and firm fixed effects. In Column (1), the coefficient for *Dig* is 0.5092, which is statistically significant at the 1% level. This indicates that, in the absence of control variables, a deeper degree of digital transformation within firms correlates with improved ESG performance, thereby supporting Hypothesis 1. In Column (2), the coefficient for *Dig* increases to 0.5349 and remains significant, suggesting that through digital transformation, firms are better positioned to fulfill their environmental responsibilities, facilitate a transition towards service-oriented operations, enhance awareness of social

responsibility, mitigate agency issues arising from information asymmetry, and improve corporate governance. Consequently, this leads to superior ESG performance, thereby confirming Hypothesis H1.

Table 3 Baseline regression results of digital transformation and corporate ESG performance.

Variable	(1)	(2)
	ESG	ESG
<i>Dig</i>	0.5092*** (0.1826)	0.5349*** (0.1769)
<i>control</i>	<i>NO</i>	<i>YES</i>
<i>Firm</i>	<i>YES</i>	<i>YES</i>
<i>Year</i>	<i>YES</i>	<i>YES</i>
<i>Observations</i>	7276	7276
<i>Adjusted R-squared</i>	0.7670	0.7717

Note: The value in the summary is a solid standard error that is grouped to the city level,***,** and* are significant at the level of 1%, 5% and 10% respectively.

4.2Robustness checks

(1)Replace explanatory variables

The varying methods of measuring corporate digital transformation may influence the conclusions drawn. To verify that the core conclusions of this study are not affected by the measurement approach, this section employs a different set of indicators for corporate digital transformation than those used in the baseline regression. Existing research primarily categorizes the indicators for measuring corporate digital transformation into two types. The first type utilizes the frequency of digital-related terms found in corporate annual reports as a metric for the degree of digital transformation (Wu et al., 2021). The second type measures the extent of digital transformation by assessing the proportion of digital-related assets within the total assets of the firm (Zhou and Wu, 2022). In the baseline regression, this study adopts the second method to gauge corporate digital transformation, while this section employs the first method for measurement. The regression results using the alternative indicators for corporate digital transformation are presented in Column (1) of Table 4. The regression coefficient for Dig remains significant, and the results obtained using the alternative explanatory variable measurement method continue to be positively significant. This indicates that variations in the measurement approach for corporate digital transformation do not alter the core conclusions of this study, further affirming the robustness of the foundational conclusions.

(2) New sample

In the context of the computer and telecommunications industries, their unique advantages in digitalization and informatization may potentially influence the accuracy of the regression results. Consequently, firms from the computer, telecommunications, and other electronic equipment sectors were excluded from the sample, and the regression was conducted anew. The results of this analysis are presented in Column (2) of Table 4. The regression coefficient for Dig remains significant, indicating that the conclusions of this study continue to be robust and reliable. This adjustment effectively mitigates the impact that the inherent digitalization and informatization advantages of the sample may have introduced.

(3) One-period lag

Considering that the effects of digital transformation and control variables on corporate ESG performance may exhibit lagged effects, this study addresses potential endogeneity issues by substituting the data for digital transformation and control variables with their corresponding one-period lagged data for re-estimation. The results are presented in Column (3) of Table 4. The regression coefficient for Dig remains significant, indicating that the research conclusions of this study continue to hold even after accounting for the one-period lag.

(4) Instrumental variable method

The foundational conclusion demonstrates that digital transformation can enhance corporate ESG performance. However, from another perspective, firms with strong ESG performance are likely to be more motivated and inclined to pursue digital transformation in order to better fulfill their social responsibilities and improve corporate governance. This potential issue of reverse causality introduces an endogeneity concern that may affect the accuracy of the foundational conclusion. To mitigate this endogeneity problem, this study employs an instrumental variable approach for robustness testing. Specifically, the cubic difference between the firm's level of digital transformation and the industry and provincial averages of digital transformation serves as the instrumental variable, and the regression is conducted using the Two-Stage Least Squares (2SLS) method. This instrumental variable influences the digital transformation decisions of the sample firms, satisfying the relevance requirement; simultaneously, it does not directly affect the ESG performance of any specific firm, thus meeting the exogeneity requirement. Therefore, this indicator is deemed a suitable instrumental variable. The regression results are presented in Column (4) of Table 4, where the coefficient for Dig is 0.3766, which is significantly positive at the 10% level. Additionally, the LM statistic in the second stage is significant at the 1% level, and the Ward F statistic exceeds 16.38, indicating that the choice of instrumental variable is appropriate and that there are no issues of identification or weak instruments. This further substantiates the robustness of the conclusions drawn in this study.

Table 4 *Robustness checks*

	(1)	(2)	(3)	(4)
Variable	Replace explanatory variables	New sample	One-period lag	Instrumental variable method
	<i>ESG</i>	<i>ESG</i>	<i>ESG</i>	<i>ESG</i>
<i>Dig</i>	0.1307* (0.0706)	0.5349*** (0.1769)	0.4416** (0.2005)	0.3766* (0.2005)
<i>control</i>	YES	YES	YES	YES
<i>Firm</i>	YES	YES	YES	YES
<i>Year</i>	YES	YES	YES	YES
<i>Observations</i>	7276	7276	7276	7276
<i>Adjusted R-squared</i>	0.7715	0.7717	0.8018	-0.1301

Note: The value in the summary is a solid standard error that is grouped to the city level, ***, ** and * are significant at the level of 1%, 5% and 10% respectively.

5.The Moderating Effect of Financing Constraints

Theoretical analysis suggests that the impact of corporate digital transformation on ESG performance varies under different levels of financing constraints. This study adopts the approach of Kaplan et al. (1997) by utilizing the KZ index to measure the extent of financing constraints faced by firms, where a higher value indicates a greater degree of financing constraint. Using the mean of financing constraints as a threshold, firms experiencing financing constraints above the mean are classified into a high financing constraint group, while those below the mean are categorized into a low financing constraint group. Subsequently, group regressions are conducted to examine the influence of digital transformation on corporate ESG performance under varying levels of financing constraints. The results are presented in Columns (1) and (2) of Table 5. In the low financing constraint group, the regression coefficient for *Dig* is 0.7548, which is significantly positive at the 5% level; conversely, in the high financing constraint group, the regression coefficient for *Dig* is 0.3503 and is not statistically significant. This indicates that when financing constraints are low, corporate digital transformation is more effective in enhancing ESG performance. Hypothesis 2 is thus confirmed.

Table 5 The moderating effect of financing constraints.

Variable	(1)	(2)
	Low Level of Financing Constraints	High Level of Financing Constraints
	<i>ESG</i>	<i>ESG</i>
<i>Dig</i>	0.7548** (0.2965)	0.3503 (0.2713)
<i>control</i>	YES	YES
<i>Firm</i>	YES	YES
<i>Year</i>	YES	YES
<i>Observations</i>	3363	3679
<i>Adjusted R-squared</i>	0.7537	0.8081

Note: The value in the summary is a solid standard error that is grouped to the city level,***,** and* are significant at the level of 1%, 5% and 10% respectively.

6.Conclusion and policy implications

This study utilizes data from Chinese A-share listed companies spanning the years 2011 to 2020 to empirically examine the impact of digital transformation on corporate ESG performance. The findings indicate that digital transformation significantly enhances a firm's ESG performance. Subsequent re-estimations employing alternative explanatory variables, new samples, one-period lags, and instrumental variable methods confirm the robustness of the foundational conclusion. Furthermore, as financing constraints diminish, the positive effect of digital transformation on corporate ESG performance becomes increasingly pronounced.

The policy recommendations derived from this study are as follows: First, the government should implement policies that support corporate digital transformation, encouraging firms to integrate digital technologies into their production and operations to establish a new development paradigm. Second, there should be a proactive effort to enhance the level of internet development, thereby facilitating the digital transformation of enterprises. Third, it is essential to further strengthen economic support for corporate digital transformation by increasing credit availability and broadening financing channels. This will create a conducive financing environment for firms to leverage digital transformation in enhancing their ESG performance, ultimately achieving long-term sustainable development.

CRedit authorship contribution statement

Wang Peng: Writing - original draft, Software, Project administration, Formal analysis, Data curation, Conceptualization. Cheng Hang: Writing -review & editing, Investigation, Data curation, Conceptualization. Li Xuan: Visualization, Project administration, Data curation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The authors do not have permission to share data.

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