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Digital Transformation and Corporate ESG Performance: A Mechanism Test Based on Information Disclosure and Investor Shareholding

Qiong Ge

School of Economics, Anhui University, Hefei, China
15056660860@163.com

Abstract: In the context of integrating digital economy and sustainable development, the role of digital transformation in enhancing corporate ESG performance remains a critical research focus. Using panel data from China's A-share listed companies (2013–2023), this study employs a two-way fixed-effects model to demonstrate that digital transformation significantly improves corporate ESG performance. Endogeneity checks (multi-period DID, instrumental variables) and robustness tests (alternative variables, adding control variables) confirm the validity of the findings. Mechanism analysis identifies ESG disclosure quality as a mediating factor, while the shareholding ratio of ESG investors exhibits a "double-edged sword" effect. Behaviors such as "greenwashing" and conflicting objectives can weaken the positive impact of digital transformation on corporate ESG performance. Heterogeneous analysis further reveals that the ESG-enhancing effect is more pronounced in state-owned enterprises (SOEs) and industries with high environmental sensitivity, with SOEs benefiting from policy incentives and resource advantages, and environmentally sensitive industries achieving emission reductions and process optimization through digital technology. This study provides theoretical and practical evidence for policymakers to promote technological innovation, refine the ESG institutional framework, and guide the sustainable allocation of capital.

Keywords: digital transformation, ESG performance, disclosure quality, investor ownership Introduction

1. Introduction

In the backdrop of the global sustainable development agenda's continuous advancement and the deepening of the "dual-carbon" strategy, the ESG (environmental, social, and governance) framework has emerged as a pivotal evaluation system for corporate sustainable development. Since the release of the "Guiding Opinions on Building a Green Financial System" in 2016, China has gradually established an ESG policy system centered on the "dual-carbon" goals. In 2018, the Securities and Futures Commission (SFC) revised the "Guidelines on the Governance of Listed Companies," advocating the adoption of international experience to construct a fundamental framework for ESG disclosure. The State-owned Assets Supervision and Administration Commission's (SASAC) "Work Program for Improving the Quality of Central Enterprises' Listed Companies" in May 2022 explicitly required full coverage of central enterprises' ESG special reports. Driven by policy, the ESG

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development of Chinese enterprises is exhibiting a trend of scale expansion, with the ESG report disclosure rate of A-share listed companies surpassing 40% in 2024. However, challenges persist in corporate ESG practices, including high internal financial pressure [1] , insufficient capacity [2] , talent shortages, and difficulties in external supervision. The contemporary world is undergoing a profound paradigm shift characterized by accelerated technological innovation and disruptive industrial transformations, with digital transformation becoming an irresistible developmental trend. As a technology-driven strategic change, it is poised to become a critical path for enhancing ESG performance through efficient data collection and analysis, promoting enterprise service transformation, and optimizing corporate governance systems.

Scholarly inquiry into corporate ESG dynamics has evolved along two trajectories: (1) consequential investigations mapping ESG's value-creation mechanisms through financing constraint alleviation, analyst coverage expansion, and governance quality enhancement, and (2) antecedent explorations identifying determinants ranging from disclosure transparency to techno-managerial innovation. Within the digital transformation paradigm, emerging research synthesizes stakeholder, resource-based, and signaling theories into a tripartite framework: digitalization mitigates negative externalities in multi-stakeholder coordination through blockchain-enabled accountability systems (stakeholder theory) [3], cultivates green innovation competencies via AI-driven resource recombination (resource-based view) [4], and enhances sustainability disclosure rigor through big data analytics (signaling theory) [5]. Crucially, meta-analyses reveal curvilinear dynamics—while moderate digital adoption improves ESG ratings, excessive implementation (>40% IT budget allocation) triggers performance decay through cognitive overload and capital misallocation, conforming to inverted-U thresholds [3]. Despite these advances, critical gaps persist in mapping the digital-ESG interface, particularly regarding (a) phase-dependent transformation pathways across industry maturity spectra, and (b) institutional contingency factors moderating technology absorption capacities in emerging markets.

In light of the aforementioned points, this paper selects data from China's A-share listed companies from 2013 to 2023 to systematically reveal the role of digital transformation on corporate ESG performance and addresses the deficiency of insufficient path resolution in existing literature. The marginal contributions of this paper may lie in the following aspects: first, unlike existing studies that focus on the unidirectional impact of information disclosure and enterprise value, this paper innovatively reveals its transmission role in the path of digitalization and ESG. Second, breaking through the generalized categorization of institutional investors in existing studies, this paper innovatively deconstructs the "double-edged sword" role of ESG investor ownership, exposing the positive regulatory effects of resource support and supervisory incentives, as well as the negative regulatory effects of greenwashing and goal conflict, thereby deepening the understanding of heterogeneous ESG investment behaviors. Third, it heterogeneously reveals that digital transformation has a more pronounced effect on the ESG performance of state-owned enterprises (SOEs) and firms in industries with high environmental sensitivity.

2. Theoretical analysis and research hypotheses

2.1. Enterprise digital transformation and corporate ESG performance

In today's context of global sustainable development and the rapid advancement of the digital economy, companies face challenges in ESG practices, such as excessive costs, financial pressures, insufficient data management capabilities, and poor stakeholder communication. These issues not only constrain the improvement of ESG performance but also affect long-term competitiveness and sustainability. Digital transformation offers significant opportunities for companies to overcome these obstacles.

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Firstly, digital transformation promotes optimal resource allocation and green innovation, thereby enhancing environmental performance. Technologies like IoT and AI enable real-time monitoring and dynamic optimization of production processes, reducing energy waste caused by resource mismatch [6]. Information platforms constructed through digital technology can improve internal resource efficiency, facilitate the integration of internal and external environmental information resources, and provide technical support for corporate environmental protection and green development [7]. Secondly, digital transformation aids enterprises in better fulfilling their social responsibilities and improving social performance. By introducing advanced technologies such as big data and artificial intelligence, enterprises can achieve precise monitoring and efficient disclosure of ESG information, making it easier for stakeholders to oversee corporate operations [5]. This compels enterprises to enhance their ESG performance to attract increased investment. Big data analysis helps accurately identify community needs and optimizes the efficiency of public welfare resource allocation, while social media interaction platforms enhance dialogue between enterprises and consumers [6], promoting a shift from passive response to active co-construction in fulfilling corporate social responsibility, thereby better meeting the needs of customers and society. Finally, digital transformation positively impacts internal corporate governance, contributing to improved governance performance. On the one hand, digital systems, through real-time data collection and algorithmic early warning models, can reduce agency costs and curb financial fraud [5], helping to promote the systematic reconstruction of corporate management systems [4] and encouraging the transition of traditional management models toward digitalization and collaboration. On the other hand, digital transformation promotes efficient information sharing within enterprises, alleviates principal-agent conflicts [7], and effectively improves corporate decision-making processes and governance levels. Based on this, the following hypothesis is proposed:

Hypothesis 1: Corporate digital transformation helps improve corporate ESG performance.

2.2. Mechanisms of corporate digital transformation on corporate ESG performance

2.2.1. Digital transformation, ESG disclosure quality and corporate ESG performance

Information asymmetry theory suggests that stakeholders primarily grasp basic information about corporate operations through comprehensive and effective information disclosure by the enterprise [8]. Digital empowerment provides a significant driving force for enterprises to enhance the quality of information disclosure, and digital transformation facilitates the efficiency and quality of ESG information disclosure. Specifically, digital transformation enables real-time collection and efficient analysis of ESG data through technological empowerment, significantly improving the quality of corporate disclosure and the efficiency of information processing [3]. Digital technology also facilitates information interaction between stakeholders and firms, enhancing the effectiveness of stakeholder supervision in corporate governance, thereby promoting the quality of corporate ESG disclosure [9]. Based on reputation mechanism theory and signaling theory, good ESG information disclosure effectively promotes information transfer and sharing between enterprises and stakeholders. A "righteous" corporate image and good reputation also attract more investors' attention, thereby improving enterprises' ability to obtain funds and resources [10], which in turn provides financial support for enterprises to improve ESG performance, forming a positive cycle of "digital investment → disclosure optimization → reduced financing costs → improved ESG performance." Based on this, the following hypothesis is proposed:

Hypothesis 2: Firms' digital transformation enhances firms' ESG performance by improving the quality of ESG disclosure.

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2.2.2. Digital transformation, ESG investor ownership and corporate ESG performance

The effect of ESG investor shareholding on digital transformation and firms' ESG performance exhibits heterogeneous moderating effects.

The positive moderating effect of ESG investors' shareholding ratio is mainly reflected in resource support and supervisory incentives. First, ESG investors typically adopt a long-term investment perspective [11] and prioritize corporate sustainability. They provide stable financial support to enterprises through shareholding, alleviating resource constraints for investing in high-cost digital technologies, thereby helping enterprises improve their ESG performance. Additionally, through technology synergy and governance participation, ESG investors supply enterprises with green technology resources and management experience, amplifying the environmental governance effectiveness of digital transformation. Second, ESG investors can effectively identify and constrain managerial self-interested behavior through monitoring and governance mechanisms, enhancing management's willingness to increase ESG investment [10]. This helps promote the deep integration of digital tools with the Sustainable Development Goals (SDGs) and better utilize digital technology in improving ESG performance. Therefore, a high ESG investor shareholding ratio may exert a positive moderating influence on the relationship between digital transformation and firms' ESG performance.

The negative moderating effect of ESG investor shareholding is primarily reflected in two aspects: "greenwashing" behavior and goal conflict. First, to attract potential ESG investors and maintain existing investor relations, companies generally prioritize the act of ESG disclosure over its content. They tend to focus on meeting short-term rating improvement needs by allocating digital technology resources to optimizing the disclosure process and other superficial tasks, while neglecting substantive ESG improvements [11], leading to "greenwashing" in disclosures. Although such behavior can enhance ratings in the short term, it increases the risk of environmental violations in the long run. Moreover, it may be challenging for different stakeholders to agree on the SDGs [12], as their diverse demands across the three dimensions of environmental performance optimization, social value creation, and governance effectiveness enhancement may force enterprises to disperse digital resources, resulting in fragmented technology applications. Consequently, a high ESG investor shareholding ratio may exert a negative moderating influence on the relationship between digital transformation and firms' ESG performance.

In summary, the moderating effect of ESG investors' shareholding on digital transformation and corporate ESG performance remains inconclusive. Based on this, the following hypotheses are proposed:

Hypothesis 3: A high proportion of ESG investors ownership will enhance the role of digital transformation in promoting corporate ESG performance.

Hypothesis 4: A high proportion of ESG investor ownership will weaken the role of digital transformation in promoting corporate ESG performance.

3. Research design

3.1. Model specifications

Based on the existing literature, the following two-way fixed effects model is constructed to investigate the impact of corporate digital transformation on corporate ESG performance:

$$ESG_{it} = \alpha_0 + \alpha_1 DT_{it} + \alpha_2 X_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (1)$$

In the formula, ESG_{it} represents the explanatory variable indicating the ESG performance of firm i in year t; Dt_{it} is the core explanatory variable denoting the level of digital transformation of firm i

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in year t; X_{it} is a series of control variables; μ_i and λ_t are industry fixed effects and year fixed effects, respectively; and ε_{it} is a random disturbance term.

3.2. Variable definition and data description

3.2.1. Explanatory variables

Digital Transformation (DT): From the annual report of the enterprise on the application of digital technology, Internet business models, intelligent manufacturing, modern information systems in four dimensions of 99 digitization-related word frequency capture and statistics, based on text analysis of the word frequency statistics plus one and take the logarithm [13].

3.2.2. Explained variable

Corporate ESG performance (ESG): This study selects the Sino-Securities Index ESG rating data as the explained variable [14]. The rating system divides corporate ESG performance into 9 tiers, rated quarterly. The 9 ratings are assigned scores of 1–9 in sequence, and the average of the 4 ratings of a firm in each year is used to measure its ESG performance for that year.

3.2.3. Mechanism variables

3.2.3.1. Quality of ESG disclosure (quality)

The evaluation criteria for ESG disclosure quality include comprehensiveness, timeliness, and transparency [15]. Issuing independent reports is typically regarded as a sign of high-quality disclosure. This study innovatively uses whether firms publish independent ESG reports (1 for yes, 0 for no) to measure the quality of ESG disclosure.

3.2.3.2. ESG Investor Ownership (IO)

Current scholarly conventions predominantly operationalize institutional influence through total ownership percentage within corporate equity structures. Departing from this conventional approach, our measurement framework introduces granular differentiation by specifically quantifying sustainability-aligned institutional positions. We calculate ESG-focused ownership concentration (%) through the shareholding of purely ESG-themed funds among institutional investors to indicate the shareholding of corporate ESG-focused investors to further analyze the mechanism of their role in the impact of digital transformation on corporate ESG. This methodological innovation enables systematic investigation into how specialized environmental, social, and governance investors moderate the digital transition-ESG performance continuum through capital market signaling mechanisms.

3.2.4. Control variables

To enhance the precision and accuracy of the study and avoid omitting relevant variables, this paper adds firm-level control variables to the model, including firm size (size), firm age (age), return on assets (roa), Tobin's Q value (tobin Q), proportion of independent directors (director), firm growth (growth), gearing ratio (lev), and nature of property rights (soe). The above variables are defined as shown in Table 1.

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3.2.5. Data sources and processing

This study constructs a longitudinal dataset of China's A-share listed firms (2013-2023) with four sample filters: (1) exclusion of financial firms, (2) removal of ST/*ST companies, (3) retention of entities with ⩾5-year continuous data, and (4) missing value imputation via linear interpolation.

Variable operationalization adopts Wind SNSI for ESG metrics and text-mining-based indices for digital transformation (DT). Mechanism variables (Disclosure Quality, Institutional Ownership) derive from Wind, with controls sourced from CSMAR. Continuous variables undergo 1% Winsorization to mitigate outlier effects.

Table 1: Variable definitions

Variable	Name	Indicator symbol	Description
Explanatory variable	Corporate ESG performance	ESG	Sino-Securities Index (SNSI) ESG rating Assignment 1-9 points
Explanatory variable	Enterprise Digital Transformation	DT	Logarization based on text analysis and word frequency statistics
Mechanism variables	Quality of ESG disclosure	quality	Whether to publish an independent ESG report (Yes=1, No=0)
	ESG investor shareholding	IO	Pure ESG-themed fund holdings among institutional investors
Control variable	Firm size	size	Natural logarithm of total business assets
	Firm age	age	Difference between the accounting year and the year of listing of the enterprise +1, treated as a logarithmic number
	Return on assets	roa	Ratio of net profit to closing balance of total assets
	Gearing ratio	lev	gearing ratio
	Propotion of independent directors	director	Number of independent directors/total number of directors
	Tobin’s Q value	tobinQ	(Market capitalization of outstanding shares + number of non-outstanding shares × net assets per share + Carrying value of liabilities) / Total assets
	Firm growth	growth	Annual growth rate of total business revenue
	Nature of property rights	soe	1 for state-controlled, 0 for non-state-controlled

4. Results and discussion

4.1. Benchmark regression

Table 2 displays the regression outcomes examining how corporate digital transformation (DT) influences ESG performance. Column (1) presents a univariate analysis with DT as the sole predictor, revealing a statistically significant positive coefficient at the 1% level. After introducing control variables in Column (2), the DT coefficient remains positive and significant, albeit slightly reduced in magnitude. Column (3) further incorporates industry and year fixed effects, yielding a DT coefficient of 0.0371 (1% significance level). These results confirm that DT enhances ESG performance through three primary mechanisms: (1) fostering green innovation and resource optimization, (2) improving information monitoring and disclosure accuracy to mitigate agency issues, and (3) curbing financial misconduct by strengthening governance frameworks. Collectively, these findings validate Hypothesis 1 regarding DT’s positive role in advancing corporate ESG outcomes.

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4.2. Robustness check

To ensure empirical robustness, we implemented four validation checks: (1) Predictor reconstruction using NLP techniques, developing a composite digitalization index (DT_A) through TF-IDF weighting of 76 technology-specific lexemes across five technological domains [16]; (2) Criterion substitution adopting Bloomberg's ESG metrics (ESG_A) [2]; (3) Lagging one period of the explanatory variable; (4) Addition of control variables. Adding control variables such as current assets ratio (LR), current ratio (CR), equity concentration (OCR), and gross operating profit margin (GPM) on the basis of existing control variables [14]. Across all specifications, digital transformation exhibited statistically significant positive coefficients (α=0.01), demonstrating empirical consistency with baseline estimates and confirming Hypothesis 1's validity (detailed results archived in supplementary materials).

Table 2: Benchmark regression

Variable	(1) ESG	(2) ESG	(3) ESG
DT	0.0558***	0.0420***	0.0371***
	(0.00549)	(0.00570)	(0.00676)
age		-0.229***	-0.271***
		(0.0102)	(0.0118)
growth		-0.0902***	-0.0766***
		(0.0115)	(0.0116)
size		0.260***	0.294***
		(0.00826)	(0.00852)
lev		-0.841***	-0.929***
		(0.0406)	(0.0408)
roa		0.532***	0.488***
		(0.0860)	(0.0856)
tobinQ		-0.0143***	0.00293
		(0.00444)	(0.00475)
director		0.784***	0.720***
		(0.104)	(0.103)
soe		0.0888***	0.128***
		(0.0200)	(0.0203)
_cons	3.976***	2.368***	1.540***
	(0.0218)	(0.0728)	(0.1810)
industry	No	No	Yes
year	No	No	Yes
N	28762	27604	27604
R^2	0.0223	0.1776	0.2514

Note: *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively, with t-values in parentheses (same for tables below).

4.3. Endogeneity test

4.3.1. DID test

To address potential endogeneity concerns stemming from regional variations in digital infrastructure and economic development levels, this study utilizes the policy implementation of China's National Comprehensive Big Data Pilot Zones as an exogenous shock. These pilot zones, approved in batches across ten provinces and municipalities since 2015, provide a quasi-experimental setting. Following established methodology [17], we designate 2015 as the policy commencement year for Guizhou

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Province and 2016 for other pilot regions, constructing a multi-period difference-in-differences (DID) model as follows:

$$ESG_{it} = \lambda_0 + \lambda_1 Treat_{it} \times Post_t + \lambda_2 X_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (2)$$

The difference-in-differences framework operationalizes the policy effect through the interaction term Treat×Post, where Treat indicates enterprise location in National Big Data Pilot Zones (1=yes, 0=no) and Post marks post-implementation periods (1=years after policy enactment). As shown in Table 3 Column (1), enterprises within pilot zones exhibit statistically stronger digital transformation effects on ESG performance at the 1% significance level compared to control firms, with coefficient directions and significance levels aligning consistently with baseline regression outcomes. This empirical validation through exogenous policy variation confirms the robustness of primary findings.

Table 3: Endogeneity test

Variable	(1) DID test	(2) nearest neighbor matching	(3) Phase I	(4) Phase II
	ESG	ESG	DT	ESG
Treat×Post	0.0439**	0.0485***		
	(0.0221)	(0.0105)		
IV			0.9642***	
			(174.21)	
DT				0.0886***
				(17.16)
Anderson canon. corr. LM statistic				2.0e+0.4***
Cragg-Donald Wald F statistic				869.880{16.38}
_cons	1.590***	1.386***	-0.7067***	2.0569***
	(0.204)	(0.221)	(-9.71)	(35.91)
Controls	Yes	Yes	Yes	Yes
Year, industry fixed	Yes	Yes	Yes	Yes
N	28041	14498	27604	27604
R^2	0.2500	0.2351	0.733	0.187

Note: Critical values for the Stock-Yogo weak instrumental variable identification F-test at the 10% significance level are in curly brackets.

4.3.2. PSM-DID test

To address potential self-selection bias in the sample data selection process, this study further conducted an endogeneity test using PSM-DID. Based on the digital transformation index grouping [2], firms with a digital transformation index above the median were set as the experimental group, and vice versa as the control group, generating a dummy variable where the experimental group was assigned 1 and the control group 0. A 1:1 nearest-neighbor matching was used to find the control group, and then DID estimation was performed based on Model (2) and regression analysis was conducted on the matched samples. The regression results are shown in Table 3. As seen in column (2), the results are not significantly different from the previous findings, indicating that after overcoming sample selection bias, digital transformation still significantly promotes firms to improve ESG performance, thereby verifying Hypothesis 1.

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4.3.3. Instrumental variables approach

To mitigate endogeneity concerns arising from the mutual causality between digital transformation and ESG performance, this study employs an instrumental variable (IV) approach utilizing regional-industry-year digitization level averages [18]. The selected IV satisfies relevance conditions through its correlation with firm-level digital adoption while maintaining exogeneity by theoretical independence from ESG outcomes. As presented in Table 3 Columns (3)-(4), the two-stage estimation confirms: (1) First-stage results show statistically significant positive correlation between the IV and endogenous regressor at the 1% level; (2) Established statistical tests validate the IV's appropriateness; (3) Second-stage estimates preserve the positive digitalization-ESG relationship with unchanged significance patterns, thereby reinforcing the baseline conclusions through rigorous endogeneity correction.

5. Further analysis

5.1. Mediation effect

Currently, the primary mediation effect tests commonly used in academia are stepwise regression [19] and the "two-step" method [20]. Given the limited research on ESG disclosure quality in existing literature, most of which focuses on the antecedent influencing factors of disclosure quality, this study further examines the impact of ESG disclosure quality on corporate ESG performance based on the consideration of the impact of digital transformation on ESG performance. This approach aims to deeply analyze the specific mechanism of its role in the transmission path. Accordingly, this study constructs the following mediation effect model, referencing the stepwise regression method, to thoroughly investigate the specific role mechanism of corporate digital transformation on corporate ESG performance:

$$quality_{i,t}=\beta_0+\beta_1 VG_{i,t}+\beta_2 X_{i,t}+\mu_i+\lambda_t+\varepsilon_{i,t} \quad (3)$$

$$ESG_{it}=\gamma_0+\gamma_1 DT_{it}+\gamma_2 quality_{it}+\gamma_3 X_{it}+\mu_i+\lambda_t+\varepsilon_{it} \quad (4)$$

Where, quality is the mediating variable, indicating the quality of ESG disclosure, and the other variables are the same as in Model 1.

The mediating pathway analysis, as illustrated in Table 4, follows a three-stage empirical framework. Initial findings in Model (1) establish the baseline relationship between digital transformation and ESG outcomes. Subsequent analysis in Model (2) reveals a significant positive association ($p<0.01$) between technological digitization and the enhancement of ESG reporting transparency. Model (3) further demonstrates that ESG disclosure quality exhibits a 1% significant positive correlation with corporate ESG advancement after controlling for explanatory variables.. Through this causal chain analysis, the study confirms that enterprises' digital adoption facilitates ESG progression through improved information transparency mechanisms, thereby providing empirical validation for Hypothesis 2.

To ensure the accuracy of the test results, this study employed the bootstrap sampling method to test the sample with 5,000 samples. The results indicate that the indirect effect of ESG disclosure quality is 0.017, with a 95% confidence interval of [0.0013, 0.014], which does not include 0, suggesting a significant mediating effect. The direct effect is 0.113, with a 95% confidence interval of [0.104, 0.121], which is also significant, indicating that the effect of digital transformation on firms' ESG performance is partially mediated through ESG disclosure quality.

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5.2. Moderating effect

This investigation examines the moderating effects of ESG-oriented institutional ownership through interaction term analysis between digital transformation (DT) and ESG investor shareholding ratios. Table 4 Column (4) demonstrates two critical findings: (1) The standalone ESG ownership ratio (IO) exhibits a 1% significant positive coefficient, confirming its direct enhancement effect on corporate ESG performance; (2) The DT×IO interaction term reveals a statistically significant negative coefficient at the 5% level, demonstrating an offsetting moderating mechanism where elevated ESG investor participation paradoxically attenuates digitalization's ESG benefits. These opposing coefficient directions systematically validate Hypothesis 4 regarding the dualistic moderating role of ESG ownership concentrations.

This indicates that a high proportion of ESG investor shareholding during corporate digital transformation may weaken the promoting effect of digital transformation on corporate ESG performance and exert a negative moderating effect through "greenwashing" behavior and goal conflict. The reasons may be as follows: First, the development of ESG in China is still insufficient, and most ESG investors may prioritize generating returns over ESG performance, tending to supervise enterprises to allocate digital technology primarily to operational efficiency optimization and other financial objectives while reducing its application in the ESG dimension. Second, in an institutional environment where the ESG rating system is not yet perfected, ESG investors with high shareholding ratios may be alienated into "digital greenwash conspirators." On one hand, they require companies to disclose standardized ESG data, but on the other hand, they lack the ability to assess the quality of such data, driving companies to focus digital technology resources on superficial tasks rather than substantive improvements.

Table 4: Mechanism tests

Variable	Mediation effect			Moderating effect
	(1) ESG	(2) quality	(3) ESG	(4) ESG
DT	0.0371***	0.0150***	0.0360***	0.0630***
	(0.00676)	(0.00251)	(0.00850)	(0.00568)
quality			0.448***	
			(0.0214)	
IO				0.0290***
				(0.00825)
DT*IO				-0.0140**
				(0.00567)
_cons	1.540***	-1.444***	2.103***	1.352***
	(0.1810)	(0.0491)	(0.174)	(0.107)
Controls	Yes	Yes	Yes	Yes
Year, industry fixed	Yes	Yes	Yes	Yes
N	27604	27604	27604	27604
R^2	0.2514	0.357	0.258	0.260

5.3. Heterogeneity analysis

5.3.1. Nature of property rights

Chinese listed companies can be categorized into state-controlled and non-state-controlled enterprises based on the nature of property rights, and differences in property rights can lead to significant variations in business management and digital transformation. Therefore, this study specifically

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examines whether the effect of digital transformation on firms' ESG performance is related to the nature of firms' property rights..

The empirical results indicate that digital transformation can significantly enhance the ESG performance of both state-owned and non-state-owned enterprises, but its impact on non-state-owned enterprises is relatively weaker. The possible reasons are: (1) State-owned enterprises (SOEs) are more constrained by government policy orientation and public objectives. Under national strategies such as the "dual carbon" targets and common prosperity, digital transformation becomes a key tool for them to respond to institutional pressures. (2) SOEs typically have more substantial capital reserves and more stable supply chain networks, allowing them to afford the high trial-and-error costs associated with digital transformation. Consequently, digital transformation contributes more significantly to the improvement of ESG performance in SOEs..

5.3.2. Environmental sensitivity of the industry to which the enterprise belongs

The analysis incorporates industry heterogeneity through ecological exposure stratification, recognizing distinct environmental compliance burdens across sectors. Environmentally intensive industries (e.g., chemical manufacturing, energy production) face heightened regulatory scrutiny and decarbonization mandates, whereas low-exposure sectors (e.g., ICT) experience minimal ecological compliance constraints. Building on this regulatory dichotomy, we implement a dichotomous classification framework [3] referencing China's Ministry of Ecology and Environment 2010 disclosure protocols for listed enterprises, where high ecological exposure industries are coded 0 and others 1. This statistical stratification enables empirical examination of whether digital transformation's ESG optimization effects demonstrate industry-specific heterogeneity contingent on operational sector environmental intensity.

The empirical results show that corporate digital transformation is more effective in promoting the ESG performance of firms in industries with high environmental sensitivity. The possible reasons are: (1) Industries with high environmental sensitivity typically consume more resources and emit more pollutants. Digital transformation can significantly enhance environmental performance through technological means such as optimizing production processes and improving energy efficiency, thereby elevating overall ESG performance. (2) Investors, regulators, and the public have higher expectations for environmental and social responsibility in highly sensitive industries, prompting these companies to more actively strengthen their ESG management through digital transformation to meet external expectations (tables omitted due to space limitations).

6. Conclusions and policy implications

This research employs longitudinal data analysis (2013-2023) on China's A-share listed corporations to investigate the mechanism through which organizational digitization influences sustainability metrics. The multilevel analysis yields four principal findings: (1) Corporate digitalization initiatives demonstrate a measurable improvement in ESG outcomes, (2) Information transparency acts as a critical mediator, where technological empowerment facilitates precise ESG data acquisition and dissemination, subsequently mitigating capital market information asymmetries while optimizing financial resource allocation. (3) ESG-oriented institutional ownership manifests paradoxical effects - sustainability facade practices and heterogeneous stakeholder objectives may counteract the digitalization-ESG nexus. (4) Heterogeneity analysis reveals that state-controlled enterprises exhibit amplified responsiveness to digital transformation through regulatory advantages, whereas eco-sensitive industries show heightened ESG metric optimization through operational digitization.

Based on these research findings, the following policy recommendations are proposed: First, strengthen policy guidance and incentive mechanisms for digital transformation and sustainable

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development. Governments should encourage businesses to increase investments in digitalization through tax incentives and special fund subsidies. Concurrently, enterprises with strong ESG performance should be publicly recognized to motivate further improvements in sustainable development. Second, refine the ESG information disclosure system. Regulators are advised to establish a unified ESG information disclosure framework, clarify disclosure content and scope, standardize disclosure formats and criteria, and promote the application of digital tools in data tracing to enhance information credibility. Third, guide ESG investors to optimize their investment behaviors. Cultivate long-term value-oriented ESG investment institutions and incentivize their participation in corporate governance through policy measures, reducing excessive focus on short-term rating fluctuations and preventing deviations from substantive ESG improvements to meet short-term demands. Fourth, implement differentiated support strategies. For state-owned enterprises, digital transformation can be incorporated into the "dual carbon" target assessment system. For highly environmentally sensitive industries, it is essential to strengthen research and development support for digital emission reduction technologies and establish green technology sharing platforms.

In summary, digital transformation is not merely a tool for enterprises to enhance quality and efficiency but also a strategic pathway to achieve sustainable development. Through the synergy of policy, market, and technology, enterprises should be guided to transform their digital capabilities into tangible ESG value, thereby contributing to high-quality economic development.

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