

Research on the Impact of Digital and Intelligent Transformation on ESG Greenwashing Behaviors of Enterprises

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Abstract. Digital transformation is the core direction of the integration of the digital economy and green development, and the key path to solving the ESG greenwashing problem of enterprises and promoting sustainable development. This paper takes A-share listed companies from 2012 to 2024 as the research object and empirically examines the impact effect, mechanism of action and heterogeneity characteristics of digital and intelligent transformation on ESG greenwashing behavior of enterprises. The study found that: (1) Digital transformation has a significant inhibitory effect on ESG greenwashing behavior of enterprises, and this conclusion remains valid after endogeneity treatments such as instrumental variable method and Heckman two-stage method, as well as multiple robustness tests such as lag one period, sample screening, and addition of control variables; (2) Digital transformation mainly suppresses ESG greenwashing through three pathways: regulatory empowerment by improving the quality of internal control, reducing opportunistic motives by alleviating financing constraints, and compressing greenwashing space by reducing information asymmetry, forming a synergy of internal control effect, financing constraint effect and information asymmetry effect; (3) There are significant contextual differences in this inhibitory effect: at the micro level, non-state-owned enterprises and mature enterprises respond more positively to digital and intelligent transformation; Macroscopically, the digital empowerment effect is more prominent in high-tech and heavily polluting industries, which is related to the differences in industry technology foundation and environmental regulatory pressure. The research findings provide empirical evidence and decision-making references for regulatory authorities to address the chaos of ESG greenwashing and for enterprises to drive high-quality and sustainable development through digitalization.

Keywords: Digital transformation; ESG greenwashing; Internal controls; Financing constraints; Information asymmetry.

1. Introduction

The digital economy and green development are accelerating their integration at an unprecedented depth and breadth. Digital and intelligent transformation is not only a key means for enterprises to break through development bottlenecks and build core competitiveness, but also an important path to respond to the national dual carbon strategy and global sustainable development demands. However, in the process of enterprises' green development, ESG greenwashing has gradually evolved into a prominent problem that urgently needs to be solved. Some companies, in order to cater to the preferences of the capital market and circumvent regulatory constraints, falsely package their ESG performance by selectively disclosing positive ESG information, deliberately concealing negative environmental and social responsibility records, and manipulating exaggerated statements. This behavior not only seriously misleads investors' market decisions and disrupts the market's value judgment on the sustainable development capabilities of enterprises, but also distorts the resource allocation efficiency of the capital market and hinders the healthy development of green and low-carbon industries. Digital transformation, relying on the empowerment advantages of new-generation information technologies such as big data, cloud computing and artificial intelligence, provides new ideas and possibilities for solving the ESG greenwashing problem at its root by reshaping the enterprise information transmission mechanism, upgrading the internal governance model and optimizing the external supervision chain. In view of this, this study focuses on the correlation

between ESG greenwashing behavior and digital transformation in enterprises, aiming to clarify the specific direction of the impact of digital transformation on ESG greenwashing behavior and systematically analyze its internal influence mechanism. This study not only provides theoretical support for clarifying the relationship between digital transformation and sustainable behavior of enterprises, but also offers decision-making references for enterprises to regulate ESG practices through digital intelligence and for regulatory authorities to address the chaos of ESG greenwashing.

Existing research has extensively explored the factors influencing ESG greenwashing behavior in enterprises. Earlier studies mainly focused on traditional topics such as institutional legitimacy pressure (Bai et al., 2025), corporate internal governance structure (Zhou et al., 2025), external oversight intensity (Shi Nuo et al., 2025; Zeng Weiqin, 2024), and management characteristics (Shi Nuo et al., 2025; Shi Fu 'an et al., 2023). As research deepened, the academic focus gradually expanded to emerging variables in the context of the digital economy, and scholars began to systematically examine the specific roles of digital transformation in influencing the quality of corporate information disclosure (Ma Defang et al., 2023; Shi Dao Yuan et al., 2023), green technology innovation, and supply chain governance (Xie Jiaping et al., 2025). Despite the abundance of research results, there is still a lack of literature specifically exploring the intrinsic connection between digital and intelligent transformation and ESG greenwashing behavior of enterprises. Most of the existing related research is at the stage of indirect association or fragmented exploration. On the one hand, some scholars, based on macro and meso levels, have confirmed the positive impact of digital intelligence technology on regional green development and corporate sustainable behavior, and identified transmission mechanisms such as technological innovation and enhanced information transparency (Xie et al., 2025; Liu et al., 2024); On the other hand, some studies have revealed the inhibitory effect of digital transformation on information disclosure violations from the perspective of corporate governance (Ma et al., 2023), or have touched upon the impact of digitalization on ESG information disclosure (Shi et al., 2023; Su Yanli et al., 2023, although this provides indirect evidence for the connection between the two, neither focuses on the core feature of the disconnection between symbolic disclosure and substantive deficiency in ESG greenwashing, nor systematically constructs a theoretical framework for the impact of digital transformation on ESG greenwashing. The relevant research still needs to be deepened and expanded.

To sum up, although the theoretical basis and empirical evidence of existing studies provide a reference for this paper, there are still deficiencies. First, the academic research on the correlation between digital and intelligent transformation and corporate ESG greenwashing has not been fully explored, a systematic theoretical analysis framework has not yet been formed, and the in-depth exploration at the empirical level is limited. Second, although related research focuses on the drivers of ESG greenwashing, empirical evidence on micro-transmission paths such as alleviating information asymmetry, enhancing green innovation efficiency, and strengthening external supervision is relatively scarce. To address these issues, A-share listed companies were used as research subjects to systematically examine the impact effects and internal mechanisms of digital and intelligent transformation on ESG greenwashing behavior of enterprises. The marginal contribution of the article is mainly reflected in the following three aspects: (1) Exploring the influencing factors of ESG greenwashing from the perspective of digital and intelligent transformation can supplement the relevant theoretical research on corporate sustainable development behavior in the digital economy scenario and expand the research ideas and directions for academic exploration in related fields. (2) At the mechanism level, it identified and verified the triple transmission paths of the impact of digital transformation on corporate ESG greenwashing - the internal control effect, the financing constraint effect, and the information asymmetry effect - and deepened the understanding of the micro-processes by which digital technology restricts corporate non-standard ESG behavior. (3) At the practical level, from the perspective of how digital and intelligent transformation drives enterprises to standardize ESG behavior, it provides strong empirical evidence and decision-making references for regulatory authorities to prevent ESG greenwashing chaos and for enterprises to achieve high-quality and sustainable development through digital and intelligent transformation.

2. Theoretical analysis and Research Hypotheses

2.1. The direct impact of digital and intelligent transformation on ESG greenwashing behavior of enterprises

The information asymmetry theory suggests that the information gap between enterprises and external stakeholders is a significant cause of opportunistic behavior in enterprises. ESG greenwashing is essentially an impression management carried out by enterprises using information superiority, and digital transformation can break down information barriers through technological means: on the one hand, the accumulation of digital assets and the introduction of digital talents of enterprises can enhance the degree of automation of ESG information collection, processing and disclosure, and reduce the space for human manipulation of disclosure content (Liu et al., 2025); On the other hand, the frequent appearance of digital keywords in annual reports reflects the depth of digital operations of enterprises and implies that their information disclosure systems are more standardized, making it difficult to implement greenwashing through selective disclosure or representative manipulation.

The resource-based view holds that digital and intelligent transformation accumulates scarce resources such as data, technology, and talent for enterprises, helping them truly practice ESG concepts rather than just pretend. Digital transformation boosts the efficiency of green innovation in enterprises, enabling them to achieve ESG performance through substantial green technology breakthroughs and environmental investment without resorting to greenwashing to embellish performance (Zhang Cheng et al., 2025; Zhang Yansong et al., 2025); At the same time, the operational efficiency improvement and governance model optimization brought about by digitalization have also made enterprises pay more attention to long-term reputation and avoid the market trust crisis caused by ESG greenwashing.

In addition, the signal transmission theory suggests that digital transformation itself is a quality signal that enterprises send to the market. If enterprises implement ESG greenwashing at the same time, it will lead to signal conflicts and instead raise market doubts. Therefore, the higher the degree of digital transformation an enterprise is, the more inclined it is to reduce ESG greenwashing in order to maintain the consistency of its signals. Based on this, this paper proposes a research hypothesis: H1: An increase in the level of digital transformation of enterprises can significantly curb their ESG greenwashing behavior.

2.2. The indirect impact of digital transformation on corporate ESG greenwashing

The inhibitory effect of digital transformation on ESG greenwashing by enterprises is not limited to direct technological empowerment. It has far-reaching indirect effects through pathways such as reshaping the internal governance structure of enterprises, alleviating resource constraints, and improving the information environment. The core transmission mechanism is reflected in the internal control effect, financing constraint effect and information asymmetry effect.

2.2.1 The internal control effect of digital transformation

The digital and intelligent transformation reconstructs the internal control system of enterprises through technological empowerment, providing institutional guarantees for curbing ESG greenwashing behaviors. The deep application of digital technology drives the evolution of corporate organizational structures towards a flattened and networked structure. With the help of intelligent monitoring systems and automated auditing tools, full-process dynamic supervision of production and operation, environmental investment, social responsibility fulfillment and other links is achieved, effectively reducing control loopholes caused by human intervention (Li Meng et al., 2025). On the one hand, the digital-driven internal control system clarifies the responsible entities and operational norms for ESG information disclosure, and curbs greenwashing behaviors such as selective disclosure and exaggerated expression through standardized data collection and disclosure processes; On the other hand, big data analysis technology can accurately identify risk points in ESG management, warn

of opportunistic motives of management in advance, and prevent greenwashing (Chen et al., 2025). A sound internal control system imposes rigid constraints on the consistency of ESG practices and information disclosure, thereby compressing the survival space for greenwashing. Based on this, a research hypothesis is proposed:

H2: Internal control plays a mediating role in curbing ESG greenwashing by digital transformation, that is, digital transformation reduces ESG greenwashing tendencies by improving the quality of internal control.

2.2.2 The financing constraint effect of digital transformation

Digital transformation, by easing corporate financing constraints, fundamentally weakens the motivation for ESG greenwashing. The application of digital technology not only enhances the operational efficiency and profitability of enterprises, but also significantly increases the transparency and verifiability of enterprise credit information. With the help of big data, cloud computing and other technologies, enterprises can collect and intelligently analyze their own credit data in a near-zero cost manner, reduce credit ambiguity, and provide investors with more detailed and immediate non-financial information to help them comprehensively and objectively assess the potential and risks of enterprises, thereby alleviating the misallocation of credit resources and empowering the financing advantages of enterprises (Chen Qi et al., 2025). The optimization of information disclosure and the strengthening of credit endorsement effectively reduce the information friction between investors and enterprises, and significantly reduce financing costs and difficulties. When the financing channels of enterprises are unobstructed and the financial pressure is relieved, there is no need for opportunistic behavior such as ESG greenwashing to cater to the preferences of the capital market for financing support; Instead, the easing of financing constraints reserves more abundant resources for enterprises, enabling them to increase substantial ESG investments such as environmental technology research and development and social responsibility fulfillment, and win market recognition with long-term sustainable development performance (Li Meng et al., 2025). Studies have confirmed that when financing is insufficient, enterprises tend to send positive signals through ESG greenwashing to attract ESG-concerned investors, while the improved financing brought about by digital transformation makes enterprises more inclined to practice true greenwashing rather than greenwashing (Chen et al., 2025), reducing the necessity for enterprises to conduct ESG greenwashing to obtain funds from the demand side. Based on this, research hypotheses are proposed:

H3: Financing constraints play a mediating role in digital transformation in curbing ESG greenwashing by enterprises, that is, digital transformation reduces ESG greenwashing by enterprises to obtain financing by easing financing constraints.

2.2.3 Information asymmetry effects of digital transformation

Digital transformation compresses the survival space for ESG greenwashing by reducing the degree of information asymmetry within and outside the enterprise. From an internal perspective, digital technologies have broken down information barriers between departments, enabling real-time storage, analysis, and sharing of ESG-related operational data, business processes, and decision-making information, enhancing transparency, real-time performance, and traceability of information, and optimizing internal information flow efficiency. It also reduces the possibility of management manipulating ESG disclosures by taking advantage of information superiority (Li Meng et al., 2025); Meanwhile, digital transformation reconstructs the internal control system of enterprises, compensates for the information transmission deficiencies in traditional governance, makes the entire process of ESG practices monitorable and traceable, and further reduces the internal manipulation space (Chen et al., 2025). Externally, digital and intelligent transformation enables enterprises to provide more comprehensive and timely ESG information to investors, regulators and other stakeholders through diversified digital channels, while third-party supervisory agencies can conveniently obtain real operational data of enterprises through digital tools and expose ESG practices to market scrutiny through professional interpretation. Accurately identify the differences between ESG disclosures and actual performance (Chen et al., 2025). This improvement in the

internal and external information environment not only weakens the motivation of enterprises to exploit information asymmetry for greenwashing, but also significantly increases the probability of greenwashing being detected and the cost of compliance and reputational risks. Digital transformation has a more significant inhibitory effect on ESG greenwashing, especially in enterprises with a high degree of information asymmetry (Chen et al., 2025). Based on this, the research hypothesis is proposed:

H4: Information asymmetry plays a mediating role in digital transformation in curbing ESG greenwashing by enterprises, that is, digital transformation curbs ESG greenwashing by reducing information asymmetry.

3. Identify strategies and samples

3.1. Model Building

To test the impact of digital transformation on ESG greenwashing behavior, build a bidirectional fixed-effect model:

$$GWS_{i,t} = \alpha_0 + \alpha_1 DIG_{i,t} + \sum \alpha_i Control_{i,t} + \mu_f + \eta_t + \varepsilon_{i,t} \quad (1)$$

Here, $GWS_{i,t}$ represents the extent of ESG greenwashing of enterprise i in year t ; $DIG_{i,t}$ represents the level of digital transformation of enterprise i in year t ; $Control_{i,t}$ is a series of control variables; μ_f is the industry-fixed effect, η_t is the time-fixed effect, $\varepsilon_{i,t}$ is the random disturbance term.

3.2. Variable Selection

3.2.1 Explained Variable: ESG greenwashing behavior (GWS)

Referring to the practices of existing studies (Chen Qi et al., 2025), the absolute value of the residual between the ESG performance score and the ESG disclosure quality score is adopted to measure the ESG greenwashing behavior (GWS) of enterprises. The ESG performance score of the enterprise was used as the explained variable, and the enterprise characteristics such as company size, asset-liability ratio, and growth were used as explanatory variables for regression to obtain the fitted values; Next, calculate the absolute value of the residual between the actual value and the fitted value. The larger the value, the greater the deviation between the actual ESG performance of the enterprise and the quality of disclosure, and the more significant the greenwashing behavior.

3.2.2 Core explanatory Variable: Level of Digital Transformation (DIG)

Referring to existing research (Chen et al., 2025), using text analysis, Python was used to extract the frequency of digital intelligence keywords such as "big data", "AI", and "cloud computing" from the annual reports of listed companies. After standardization processing, they were used as proxy variables to objectively reflect the investment intensity and strategic importance of enterprises in digital intelligence.

3.2.3 Mediating variables

The first is the internal control (IC) test, which, following the practice of Li Meng et al. (2025), is measured by standardized data from the Dibo Internal Control Index, with a higher value indicating better internal control quality.

Second, the test of financing constraints (SA), following the practice of Zhang Yansong and Cao Linnan (2025), is measured by the SA index, with a higher index indicating a lesser degree of financing constraints for the enterprise.

Third, the test of information asymmetry (ASY), following the approach of Liu et al. (2025), is measured by the bid-ask spread rate of stock trading, with a higher spread rate indicating a more severe degree of information asymmetry.

3.2.4 Control variables

Select Size (natural logarithm of total assets at the end of the period), debt-to-asset ratio (Lev, ratio of total liabilities to total assets), Growth (Growth rate of operating income), Board size (natural logarithm of board members), Dual (chairman and general manager are the same person, value 1, Control variables include Top01, Age (natural logarithm of years of establishment), Inst (institutional investor shareholding ratio), etc.

3.3. Data sources and sample processing

This study takes A-share listed companies as the research subjects and selects panel data from 2012 to 2024 as the initial sample, screening according to the following criteria: (1) excluding ST, *ST and delisted companies; (2) Excluding financial listed companies; (3) Exclude samples with severe data loss and outliers; (4) Tail the continuous variable at the 1% level, resulting in 9,492 observations. In terms of data sources, the frequency of digital transformation keywords was obtained through annual report text crawling, ESG greenwashing data was calculated by referring to relevant research methods, the internal control index was from the Dibo database, and the rest of the financial and corporate governance data were from the Guotai 'an CSMAR database.

Table 1 presents the descriptive statistics of the main variables. The mean of corporate ESG greenwashing behavior (GWS) was -0.002, the standard deviation was 1.714, the minimum value was -8.91, and the maximum value was 6.717, indicating significant differences in ESG greenwashing among different listed companies. Some companies had a serious greenwashing tendency, while some companies' ESG disclosures were more consistent with their actual performance. The average value of the degree of digital transformation (DIG) was 0.21, the maximum value was 6.207, and the minimum value was 0, indicating a significant divergence in the digital transformation process of the sample companies. A few companies have achieved deep digital and intelligent layout, while some are still in the initial stage of transformation, which is in line with the current reality of digital and intelligent development of Chinese companies. The distribution characteristics of the control variables were largely consistent with existing studies of the same kind, further verifying the representativeness of the sample.

Table 1 Descriptive Statistics

variable	N	mean	sd	min	max
GWS	9492	-0.00200	1.714	-6.291	6.717
DIG	9492	0.751	1.148	0	6.207
Size	9492	23.40	1.324	20.25	26.72
Lev	9492	0.467	0.191	0.0640	0.870
Growth	9492	0.125	0.304	-0.531	1.758
Board	9492	2.166	0.202	1.609	2.708
Dual	9492	0.183	0.387	0	1
Top01	9492	0.362	0.156	0.0750	0.728
Age	9492	3.038	0.313	1.386	4.060
Inst	9492	0.532	0.220	0.00400	0.915

4. Empirical Analysis

4.1. Benchmark Regression

Table 2 reports the results of the benchmark regression. Column (1) without control variables and fixed effects, the coefficient of digital transformation (DIG) is -0.041 and significant at the 1% level, preliminarily suggesting that digital transformation has an inhibitory effect on ESG greenwashing. Column (2) With control variables added, the coefficient of DIG was -0.042, still maintaining 1% significance, indicating that the inhibitory effect of digital transformation remained robust after controlling for enterprise characteristic variables. Column (3) Further adding the industry fixed effect,

the absolute value of the DIG coefficient increases to 0.047, and the significance level remains unchanged. Column (4) While controlling for both industry and year fixed effects, the DIG coefficient was -0.040 and significant at the 1% level, verifying hypothesis H1.

Table 2 Benchmark regression Results

	(1)	(2)	(3)	(4)
	GWS	GWS	GWS	GWS
DIG	-0.041*** (0.014)	-0.042*** (0.014)	-0.047*** (0.015)	-0.040*** (0.015)
Size		-0.023 (0.019)	-0.030 (0.020)	0.002 (0.021)
Lev		0.382*** (0.112)	0.544*** (0.127)	0.444*** (0.127)
Growth		0.145** (0.066)	0.140** (0.064)	0.133** (0.066)
Board		-0.239*** (0.085)	-0.257*** (0.090)	-0.326*** (0.092)
Dual		0.089* (0.050)	0.129** (0.051)	0.123** (0.051)
Top01		-0.714*** (0.167)	-0.504*** (0.175)	-0.519*** (0.175)
Age		-0.257*** (0.063)	-0.252*** (0.066)	-0.063 (0.086)
Inst		0.728*** (0.147)	0.663*** (0.148)	0.604*** (0.150)
_cons	0.029 (0.022)	1.521*** (0.473)		
N	9492	9492	9492	9492
R ²	0.001	0.010	0.037	0.041
Controls	NO	YES	YES	YES
IndFE	NO	NO	YES	YES
YearFE	NO	NO	NO	YES
F	8.618	8.821	9.211	7.322

Note: *, **, *** represent the robust standard error in (), the same below.

4.2. Endogeneity handling

Considering that there may be a bidirectional causal relationship between digital and intelligent transformation and ESG greenwashing, two methods are adopted to address the endogeneity issue. Columns (1) - (2) of Table 3 use the instrumental variable method, with digital transformation lag one stage (L.digi) as the instrumental variable. The first-stage regression shows that the L.digi coefficient is 0.466 and significant at the 1% level, and the second-stage DIG coefficient is -0.051, still maintaining 1% significance, verifying the reliability of the inhibitory effect. In the instrumental variable test, the p-value of the Kleibergen-Paap rk LM statistic was 0.000, denying the identification of undernull hypotheses; The Cragg-Donald Wald F statistic is far above the 10% level threshold of 16.38, indicating the absence of a weak instrumental variable problem.

Columns (3) - (4) using the Heckman two-stage method, with the mean of digital transformation of other enterprises in the same industry as the instrumental variable, the inverse Mills ratio (IMR) coefficient is significantly positive, indicating that there is self-selection bias in the sample. However, after correction, the DIG coefficient is -0.056 and significant at the 1% level, further confirming the robustness of the baseline regression conclusion.

Table 3 Results of endogeneity tests

	(1) DIG	(2) GWS	(3) DIG	(4) GWS
L.DIG	0.466*** (0.015)			
DIG		-0.051*** (0.015)		-0.056*** (0.016)
Size	0.026 (0.017)	-0.005 (0.019)	0.286*** (0.070)	0.146*** (0.039)
Lev	-0.206*** (0.061)	0.398*** (0.111)	-0.981*** (0.297)	-0.047 (0.164)
Growth	0.020 (0.018)	0.147** (0.065)	0.039 (0.086)	0.152** (0.066)
Board	0.052 (0.048)	-0.203** (0.085)	0.086 (0.221)	-0.280*** (0.092)
Dual	0.028 (0.018)	0.078 (0.050)	0.112 (0.091)	0.182*** (0.053)
Top01	0.152 (0.100)	-0.722*** (0.166)	1.322*** (0.478)	0.152 (0.236)
Age	0.119 (0.109)	-0.208*** (0.066)	0.870** (0.366)	0.404*** (0.146)
Inst	-0.009 (0.066)	0.753*** (0.147)	0.386 (0.344)	0.810*** (0.158)
IV			0.630*** (0.128)	
IMR				0.605*** (0.147)
_cons		0.849* (0.483)	-12.707*** (1.817)	
Insig2u			2.428*** (0.098)	
N	8701	8701	9492	9492
R ²	0.878	0.011		0.042
Controls	YES	YES	YES	YES
IndFE	YES	YES	YES	YES
YearFE	YES	YES	YES	YES
F		9.249		8.110

4.3. Robustness test

Table 4 conducts the robustness test in five ways: (1) Lag the core explanatory variable by one period (L.ig), column (1) shows that the L.ig coefficient is -0.045 and is significant at the 1% level; (2) Excluding the municipality sample, the DIG coefficient in column (2) is -0.039, which is significant at the 5% level; (3) The sample interval was narrowed down to 2015 and beyond, and the DIG coefficient in column (3) was -0.042, maintaining 1% significance; (4) Add provincial fixed effects, column (4) DIG coefficient -0.033, significant at the 5% level; (5) cashflow and total asset turnover (ato) were added as control variables, with a DIG coefficient of -0.040 in column (5) still passing the 10% significance test. The results of all five tests suggest that the inhibitory effect of digital transformation on ESG greenwashing is robust.

Table 4 Robustness Test Results

	(1)	(2)	(3)	(4)	(5)
	GWS	GWS	GWS	GWS	GWS
L.DIG	-0.045*** (0.016)				
DIG		-0.039** (0.017)	-0.042*** (0.015)	-0.033** (0.016)	-0.040** (0.015)
Size	0.016 (0.021)	-0.009 (0.024)	0.031 (0.022)	-0.016 (0.021)	0.002 (0.021)
Lev	0.468*** (0.127)	0.336** (0.133)	0.412*** (0.128)	0.446*** (0.129)	0.429*** (0.128)
Growth	0.139** (0.065)	0.178** (0.081)	0.074 (0.066)	0.124* (0.065)	0.119* (0.067)
Board	-0.258*** (0.092)	-0.328*** (0.102)	-0.196** (0.093)	-0.296*** (0.094)	-0.320*** (0.092)
Dual	0.111** (0.051)	0.054 (0.058)	0.119** (0.051)	0.119** (0.051)	0.124** (0.051)
Top01	-0.527*** (0.175)	-0.440** (0.190)	-0.516*** (0.177)	-0.535*** (0.178)	-0.529*** (0.175)
Age	-0.017 (0.089)	-0.050 (0.094)	0.027 (0.094)	-0.077 (0.090)	-0.058 (0.086)
Inst	0.654*** (0.150)	0.362** (0.165)	0.695*** (0.151)	0.652*** (0.149)	0.580*** (0.150)
cashflow					0.104 (0.302)
ato					0.077 (0.047)
N	8701	7308	7910	9492	9492
R ²	0.044	0.011	0.048	0.057	0.041
Controls	YES	YES	YES	YES	YES
IndFE	YES	YES	YES	YES	YES
YearFE	YES	YES	YES	YES	YES
F	8.269	4.077	8.281	6.304	6.167

4.4. Mechanism Test

Table 5 reports the results of the mediating effect test. Column (1) shows that the coefficient of digital transformation (DIG) on internal control (IC) is 0.705 and significant at the 1% level, indicating that digital transformation can significantly improve the quality of internal control in enterprises. This conclusion is consistent with the findings of Yang et al. (2025), who, in exploring the empowerment of corporate governance by digital transformation, proposed that the deep application of digital technology can drive the evolution of corporate organizational structure towards flattening and networking, and achieve full-process dynamic supervision through intelligent monitoring systems, effectively reducing control loopholes caused by human intervention. Thereby enhancing the efficiency of internal control execution and the precision of supervision, and providing institutional guarantees for curbing non-compliant behavior.

The coefficient of DIG for financing constraints (SA) in column (2) is -0.002, which is significantly negative at the 1% level, indicating that digital transformation can effectively alleviate the financing constraints of enterprises. Wu et al. (2025) confirmed in their study of the transmission mechanism between ESG performance and enterprise value that the synergy of digital transformation and ESG practices can enhance corporate credit transparency, broaden green financing channels and reduce financing costs; At the same time, the operational efficiency improvement and profitability enhancement brought about by digital and intelligent transformation can also enhance the financing bargaining power of enterprises, further alleviate the financial pressure, and corroborate the financing constraint relief effect reflected by the SA index of digital and intelligent transformation in this paper.

Column (3) shows that the coefficient of DIG for information asymmetry (ASY) is -0.024. Through the 1% significance test, it is confirmed that digital transformation can reduce the degree of

information asymmetry within and outside the enterprise. Liu et al. (2025), in their study of the relationship between digital transformation and ESG rating divergence, clearly stated that digital technologies such as big data and artificial intelligence can transform unstructured and unstandardized data within enterprises into structured information, enhancing the availability and verifiability of information, while achieving real-time information disclosure through diversified digital channels. Reducing the information gap between rating agencies and enterprises confirms the key role of digital and intelligent transformation in improving the information environment and compressing the space of information asymmetry. Research hypotheses H2, H3, H4 have been validated.

Table 5 Results of the mechanism test

	(1) IC	(2) SA	(3) ASY
DIG	0.705*** (0.011)	-0.002*** (0.001)	-0.024*** (0.004)
Size	0.037*** (0.009)	-1.305*** (0.002)	-0.336*** (0.004)
Lev	-0.314*** (0.065)	0.073*** (0.007)	0.999*** (0.026)
Growth	0.101*** (0.026)	0.007** (0.003)	-0.152*** (0.016)
Board	0.097** (0.039)	0.027*** (0.006)	0.069*** (0.023)
Dual	-0.035* (0.020)	-0.006** (0.003)	-0.040*** (0.011)
Top01	0.281*** (0.068)	0.037*** (0.008)	0.749*** (0.034)
Age	-0.086*** (0.030)	0.033*** (0.004)	0.127*** (0.017)
Inst	0.233*** (0.047)	0.009 (0.006)	0.152*** (0.028)
<i>N</i>	9492	9492	9492
<i>R</i> ²	0.552	0.997	0.821
Controls	YES	YES	YES
IndFE	YES	YES	YES
YearFE	YES	YES	YES
<i>F</i>	627.139	9.2e+04	770.165

4.5. Heterogeneity Test

4.5.1 Heterogeneity test at the micro level

First, heterogeneity analysis based on the nature of property rights. Corporate property attributes are key variables that affect the effect of digital transformation in suppressing ESG greenwashing. Non-state-owned enterprises typically have more flexible governance mechanisms and are more efficient in implementing digital technologies; State-owned enterprises, constrained by multiple regulatory targets, have relatively scattered resource allocation and application scenarios for digital transformation. To verify this speculation, this paper divided the samples into non-state-owned and state-owned groups based on the attributes of the actual controllers of enterprises for regression tests, and the results are shown in columns (1) and (2) of Table 6. The study found that the DIG coefficient = -0.059, the 5% level is significant, that is, digital transformation has a significant negative inhibitory effect on ESG greenwashing in non-state-owned enterprises, but does not show a significant impact on state-owned enterprises. This suggests that the governance mechanism of non-state-owned enterprises is more adapted to the rapid implementation of digital intelligence technology, while the multi-level management structure of state-owned enterprises prolongs the implementation cycle of digital intelligence transformation, and the application of technology is difficult to quickly focus on ESG governance, thus the effect of suppressing greenwashing is not obvious. This also echoes the view pointed out by Zhang et al. (2025).

Secondly, heterogeneity analysis based on the enterprise life cycle. The growth stage of an enterprise will constrain the ESG empowerment effect of digital and intelligent transformation. Mature enterprises typically have a solid digital foundation and relatively standardized ESG management processes, making it easier for digital technologies to integrate with existing systems; In contrast, growth-stage enterprises tend to tilt their resources towards business expansion, and their foundations for digitalization and ESG governance are relatively weak. In this paper, the samples were divided into growth and mature groups for regression, and the results are shown in columns (3) and (4) of Table 6. The results show that the DIG coefficient is -0.072, and the 1% level is significant, indicating that digital transformation has a significant negative inhibitory effect on ESG greenbleaching in mature enterprises, while the coefficient is not significant for growth-stage enterprises. This finding is in perfect agreement with theoretical expectations.

Table 6 Results of heterogeneity tests at the micro level

	(1)	(2)	(3)	(4)
	non-state-owned	state-owned	growth group	mature group
	GWS	GWS	GWS	GWS
DIG	-0.059** (0.023)	-0.012 (0.021)	-0.016 (0.025)	-0.072*** (0.018)
Size	-0.046 (0.042)	0.015 (0.024)	-0.042 (0.032)	0.070** (0.027)
Lev	1.154*** (0.229)	0.159 (0.145)	0.651*** (0.198)	0.245 (0.160)
Growth	0.147 (0.097)	0.039 (0.088)	0.152* (0.092)	0.000 (0.089)
Board	-0.317* (0.167)	-0.229** (0.108)	-0.417*** (0.136)	-0.199 (0.125)
Dual	0.085 (0.067)	0.093 (0.075)	0.147* (0.076)	0.077 (0.066)
Top01	-0.638** (0.299)	-0.617*** (0.208)	-1.042*** (0.258)	0.002 (0.244)
Age	-0.082 (0.130)	0.028 (0.133)	-0.291** (0.127)	0.314 (0.223)
Inst	0.511** (0.205)	1.016*** (0.213)	1.012*** (0.205)	0.042 (0.222)
<i>N</i>	4392	5100	5109	4383
<i>R</i> ²	0.081	0.045	0.062	0.064
Controls	YES	YES	YES	YES
IndFE	YES	YES	YES	YES
YearFE	YES	YES	YES	YES
<i>F</i>	5.386	5.204	6.382	4.220

4.5.2 Heterogeneity tests at the macro level

Firstly, heterogeneity analysis based on industry attributes. Industry technology characteristics are an important external force in shaping the ESG empowerment effect of digital transformation. High-tech industries themselves have digital technology as their core competitiveness, with a higher degree of integration of digitalization and green development, and stronger adaptability to ESG governance for digital transformation; Non-high-tech industries, on the other hand, have a weak digital foundation and less synergy between digital intelligence and ESG governance. To test the moderating effect of industry attributes, this paper divided the samples into high-tech and non-high-tech groups based on industry echnology intensity for regression, and the results are shown in columns (1) and (2) of Table 7. Empirical results show that digital transformation has a significant negative inhibitory effect on ESG greenwashing in high-tech industries, but does not have a significant impact on non-high-tech industries. This may be because the technological genes of high-tech industries make it easier for them to apply digital tools to the precise accounting and transparent disclosure of ESG data, reducing greenwashing space from the source; In contrast, the digital transformation of non-high-tech

industries is more focused on production and operation and has a weaker business relevance to ESG governance, thus making it difficult to have an effective inhibitory effect. This also echoes the view proposed by Wang et al. (2024).

Next, heterogeneity analysis based on the degree of pollution. Industry pollution emissions levels can significantly affect the ESG compliance empowerment effect of digital transformation. Heavily polluting industries face greater environmental regulatory pressure, higher ESG governance priorities, and the application of digital technologies is more focused on the true disclosure of environmental data; In contrast, the environmental regulatory constraints in non-heavily polluting industries are relatively loose, and the ESG empowerment momentum for digital transformation is insufficient. In this paper, samples were divided into heavy pollution and non-heavy pollution groups based on the pollution emission levels of industries for testing, and the regression results are shown in columns (3) and (4) of Table 7. The results show that digital transformation has a significant negative inhibitory effect on ESG greenwashing in heavily polluting industries, while it fails the significance test for non-heavily polluting industries. A reasonable explanation for this result is that heavily polluting industries, under strict environmental supervision, need to achieve real-time monitoring and traceability of environmental data through digital intelligence technology to avoid compliance risks, and therefore the compliance empowerment effect of digital intelligence transformation is more prominent; In contrast, non-heavily polluting industries have less environmental regulatory pressure, lower opportunity costs for ESG greenwashing, and insufficient demand for digital transformation, so the inhibitory effect is not obvious. This is in line with the conclusion reached by Wu et al. (2025).

Table 7 Results of heterogeneity tests at the macro level

	(1)	(2)	(3)	(4)
	non-high-tech industry GWS	high-tech industry GWS	non-heavy polluting industry GWS	heavy polluting industry GWS
DIG	-0.010 (0.018)	-0.109*** (0.029)	-0.009 (0.017)	-0.165*** (0.039)
Size	-0.002 (0.024)	-0.003 (0.042)	-0.021 (0.025)	0.058 (0.039)
Lev	0.553*** (0.149)	0.293 (0.248)	0.430*** (0.152)	0.493** (0.235)
Growth	0.031 (0.074)	0.331** (0.134)	0.110 (0.076)	0.192 (0.130)
Board	-0.432*** (0.104)	-0.012 (0.186)	-0.244** (0.108)	-0.391** (0.174)
Dual	0.231*** (0.064)	-0.092 (0.084)	0.315*** (0.065)	-0.158* (0.082)
Top01	-0.204 (0.216)	-1.267*** (0.312)	-0.088 (0.214)	-1.377*** (0.311)
Age	0.162 (0.109)	-0.555*** (0.139)	-0.024 (0.099)	-0.156 (0.173)
Inst	0.557*** (0.199)	0.702*** (0.222)	0.558*** (0.198)	0.663*** (0.231)
<i>N</i>	6745	2747	6337	3155
<i>R</i> ²	0.051	0.036	0.050	0.041
Controls	YES	YES	YES	YES
IndFE	YES	YES	YES	YES
YearFE	YES	YES	YES	YES
<i>F</i>	6.789	6.084	5.448	6.096

5. Research Conclusions and Policy Implications

As a core direction of the integration of the digital economy and sustainable development, digital and intelligent transformation is becoming a key force in reshaping the logic of corporate ESG

practices. Based on panel data of A-share listed companies from 2012 to 2024, this paper systematically examines the impact effects, internal mechanisms and heterogeneous characteristics of digital and intelligent transformation on ESG greenwashing behavior of enterprises. The main findings are as follows: First, digital transformation has a significant inhibitory effect on ESG greenwashing behavior of enterprises, and this conclusion remains valid after endogeneity processing such as instrumental variable method and Heckman two-stage method, as well as multiple robustness tests such as lag one period, sample screening, and addition of control variables. Second, the analysis of the mechanism of action indicates that digital transformation mainly compresses the survival space of greenwashing through three paths: internal control effect, financing constraint effect, and information asymmetry effect. Third, heterogeneity analysis reveals that ESG greenwashing behaviors respond more positively to digital transformation in non-state-owned enterprises, mature enterprises, high-tech industries, and heavily polluting industries.

The above conclusion indicates that to maximize the governance potential of digital and intelligent transformation for ESG greenwashing, the key lies in enhancing the compatibility and depth of integration between technology application and ESG management. Companies should focus their strategic efforts on the organic integration of digital tools and ESG full-process management to enhance the authenticity and standardization of ESG practices. By fully leveraging the regulatory, efficiency and transparency effects of digital technologies, enterprises can effectively restrain non-compliant ESG behaviors, drive ESG performance from surface compliance to substantial improvement, ultimately achieve digital-intelligence-driven sustainable development, and contribute to the coordinated advancement of the "dual carbon" goals and high-quality development. Therefore, to fully activate the ESG governance effectiveness of digital transformation, measures need to be coordinated from multiple dimensions.

References

- [1] Liu Huake. AI Era: Urban Digital Transformation and Enterprise Innovation [J]. Science Research Management, 2023, 44(5): 89-98.
- [2] Bai Jingkun. Institutional legitimacy pressure and corporate ESG greenwashing [J]. China Industrial Economics, 2022, (7): 135-152.
- [3] Xin Lin. Research on Information Asymmetry Theory [M]. Beijing: China Social Sciences Press, 2021: 45-67.
- [4] Zhang Xinyue. Digital Transformation and Corporate ESG Performance: From the Perspective of Resource Acquisition and Allocation [J]. Financial Research, 2023, (3): 112-129.
- [5] Chen Hui. How Digital Transformation Affects Corporate Greenwashing Behavior [J]. Accounting Research, 2022, (10): 78-89.
- [6] Wang Jianxin. Can digital transformation curb greenwashing by enterprises [J]. Economic Management, 2023, 45(2): 65-82.
- [7] Li Tao. Can Digital Transformation curb Corporate greenwashing? - Empirical Evidence from ESG Reports of Chinese Listed Companies [J]. Nankai Business Review, 2024, 27(1): 99-108.
- [8] Li Sumei. Can digital transformation improve corporate greenwashing behavior [J]. Journal of Finance and Economics, 2022, 48(8): 103-116.
- [9] Chen Qi. The Impact of Digital Transformation on Corporate ESG Strategic Information Disclosure Behavior [J]. Accounting and Economic Research, 2023, 37(4): 56-72.
- [10] Ma Lingyuan, Zhang Shengli. The Impact of Digital Transformation on Corporate "Greenwashing" behavior: Based on the Mediating role of Environmental Costs and Media Supervision [J]. Research on Financial Development, 2024(7): 65-76.
- [11] Ma Defang, Li Liangwei, Wang Mengkai. Governance Effects of Digital Transformation: From the Perspective of Corporate Information Disclosure Violations [J]. Modern Finance and Economics (Journal of Tianjin University of Finance and Economics), 2024, 44(2): 89-105.

- [12] Su Yanli. A Review of Digital Transformation, ESG performance and Corporate Performance [J]. *Economic Trends*, 2023(8): 132-145.
- [13] Liu Zhifeng. Digital transformation, information asymmetry and ESG rating divergence [J]. *Financial Review*, 2024, 16(1): 78-93.
- [14] Xie Jiaping. Digital and intelligent transformation and New Quality Productivity Development of enterprises [J]. *China Industrial Economics*, 2023(11): 121-138.
- [15] Pang Lei. Digital and intelligent transformation, green innovation and corporate ESG performance [J]. *Science Research Management*, 2024, 45(3): 98-107.
- [16] Yang Zhen. Innovation and Governance of Corporate Social Responsibility in the Digital Age [J]. *China Soft Science*, 2023(5): 142-153.
- [17] Xie Xiaojun, Xu Pan. Information Effects of Government Environmental Audit in the Context of Digital Intelligence Empowerment: A Study Based on Corporate ESG Rating Divergence [J]. *Audit Research*, 2025(2): 29-42.
- [18] Li Meng, Li Bingxiang, Yang Huan, et al. Research on the Impact of Digital Transformation of Listed Companies on Greenwashing Behavior [J]. *Friends of Accounting*, 2025(12): 78-85.
- [19] Yu Shaolong, Shi Hong. The Impact of AI Policies on Corporate ESG Performance: Empirical Evidence from National AI Innovation and Application Pilot Zones [J]. *Western Forum*, 2025, 35(4): 52-67.
- [20] Han Yiming. ESG Performance of Enterprises and Resilience of Industrial chains and supply chains: From the Perspective of Signal Transmission [J]. *Business Research*, 2024(5): 63-75.
- [21] Zhang Cheng, Cao Linnan. Enterprise digital transformation, ESG performance and green innovation performance [J]. *Journal of Zhengzhou University (Philosophy and Social Sciences Edition)*, 2025(3): 58-66.
- [22] Zhang Yansong. Enterprise digital transformation, green innovation and ESG performance [J]. *Science & Technology Progress and Policy*, 2024, 41(8): 92-100.
- [23] Shi Daoyuan, Dai Jialin, Jiang Shuiquan. Enterprise Digital transformation, Quality of Accounting information disclosure and Enterprise innovation [J]. *Accounting Monthly*, 2023(20): 80-87.
- [24] Rong Dan, Wang Lei, Liu Lu. The impact of digital transformation on corporate greenwashing in different media environments [J]. *Research and Development Management*, 2025, 37(2): 111-121, 133.
- [25] Shi Nuo. Executive Environmental Attention and Corporate ESG Performance: From the Perspective of Corporate Greenwashing Behavior [J]. *Business Economics and Management*, 2025(3): 45-58.
- [26] Zhou Yan. Executive team stability, strategic foresight and corporate ESG greenbleaching [J]. *Economic and Management Research*, 2025, 46(1): 79-93.
- [27] Yin Juelin, Zhao Jiaxin, Hua Xinyi, et al. High-quality ESG information Disclosure: Decision-making and Governance of Corporate ESG Washing Behavior in the Digital Age [J]. *Journal of Xi 'an Jiaotong University (Social Sciences Edition)*, 2025(1): 67-78.
- [28] Chen Jianyu, Shen Jiao, CAI Yandong. Can disclosure of Key Audit Matters curb Corporate "greenwashing" behavior: Evidence Based on Heavily Polluting A-share Listed Companies [J]. *Audit & Economic Research*, 2025, 37(1): 59-72.
- [29] Zeng Weiqin. Review of Corporate Greenwashing: Behavior Identification, Motivation Analysis and Economic Effects [J]. *Accounting Monthly*, 2024, (10): 64-70.
- [30] Chen Qi, Li Menghan. Can corporate digital transformation curb ESG "greenwashing" behavior? [J]. *Finance & Trade Research*, 25,36(10):96-110.
- [31] Li Meng, Li Bingxiang, Yang Huan, et al. Research on the Impact of Digital Transformation of Listed Companies on Greenwashing Behavior [J]. *Accounting Friends*,2025,(24):99-107.
- [32] Zhang Yansong, Cao Linnan. Digital transformation, financing constraints and green innovation of enterprises [J]. *Journal of Dongbei University of Finance and Economics*, 2025, (2): 89-102.
- [33] Liu Zhifeng, Xiao Xiaoying, Zheng Yan. Digital transformation, information asymmetry and ESG rating divergence [J]. *Accounting Monthly*, 2025, (10): 49-55.
- [34] Wu Xiaoman, Wei Hongzhang, Zhou Zijie, et al. ESG performance, financing constraints and enterprise value [J]. *Friends of Accounting*, 2025, (24): 116-122.