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Enterprise Digital Transformation and ESG Performance

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Abstract: At a critical juncture where the "dual carbon" goals are guiding enterprises toward green development, ESG performance has garnered widespread attention. This study selects A-share listed companies in China from 2012 to 2022 as a sample and employs textual analysis to measure the degree of enterprise digital transformation. The findings reveal that digital transformation significantly enhances ESG performance, a conclusion that remains robust after a series of robustness and endogeneity tests. Mechanism testing indicates that digital transformation improves ESG performance by enhancing green innovation capabilities, strengthening external supervision, and optimizing resource allocation. Heterogeneity tests show that the enabling effect of digital transformation on ESG performance is more pronounced in firms with high analyst coverage, high-carbon industries, and highly marketized environments. This study enriches the theoretical discourse on enterprise digital transformation and provides practical insights for enterprises to better implement ESG practices.

Keywords: Digital Transformation, ESG, Analyst Coverage, Carbon Emissions, Sustainable Development

1. Introduction

Communist Party of China emphasizes the need to "accelerate the development of the digital economy and enhance the integration of the digital economy with the real economy." Under this guidance, enterprise digital transformation has become an inevitable choice. Simultaneously, the report calls for accelerating the green transformation of development models and advancing the "carbon peak" and "carbon neutrality" initiatives in a steady and prudent manner. Since the introduction of the "dual carbon" goals in 2020, ESG (Environmental, Social, and Governance) has become a focal topic in both academic and practical fields. As regulatory agencies tighten requirements for corporate ESG information disclosure and as ESG indicators become critical benchmarks for evaluating corporate sustainability and social responsibility, enterprises urgently need to understand the impact of digital transformation on their ESG performance. This understanding will enable them to effectively manage environmental, social, and governance risks, enhance competitiveness, and drive innovation [1].

Existing literature has extensively explored the impact of enterprise digital transformation. At the operational level, digital transformation significantly improves production processes [2], optimizes organizational management, and facilitates rapid information flow within enterprises [3]. Externally, digital transformation reshapes business operations and stakeholder relationships [4], enhances supply chain management, and reduces supply risks [5]. While the economic value of digital

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transformation has been widely acknowledged, its impact on non-economic aspects, particularly ESG performance, remains relatively underexplored. Research on the determinants of ESG performance is currently insufficient. Internally, a well-structured ownership framework can promote checks and balances among shareholders, providing a solid institutional foundation for ESG strategies [6]. Financial indicators such as asset size, revenue levels, and cash flow status determine an enterprise's ability to sustain ESG initiatives in the long run [7]. Externally, governments enforce strict environmental regulations and social responsibility policies to exert strong constraints on enterprises, while investors and consumers drive companies to prioritize ESG performance through market mechanisms, thereby enhancing competitiveness and social recognition [8].

Given the lack of sufficient evidence clarifying the relationship between enterprise digital transformation and ESG performance, this study focuses on examining the impact of digital transformation on ESG performance to fill this research gap. Accordingly, this study selects A-share listed companies in China from 2012 to 2022, utilizing textual analysis to obtain digital transformation data and Bloomberg's ESG composite score index to assess ESG performance. Furthermore, the study constructs an enterprise digital governance heterogeneity analysis framework from three dimensions: micro-level analyst coverage, meso-level carbon emissions, and macro-level marketization degree.

This study may contribute in the following ways. First, from an academic perspective, prior research on enterprise digital transformation has primarily focused on economic value and operational efficiency, with insufficient attention to ESG performance. Through systematic analysis, this study enriches the literature, providing new perspectives for future research while also invigorating ESG-related theories, promoting their innovation in the digital era, and expanding their research boundaries. Second, regarding the heterogeneity analysis framework, existing literature mainly examines factors such as ownership structure [9], regional differences [10], and firm size [11]. This study innovatively constructs a heterogeneity analysis framework based on micro-level analyst coverage, meso-level carbon emissions, and macro-level marketization degree. By introducing analyst coverage as a dimension, the study reflects market attention to ESG practices, helping to identify how investor expectations and pressures influence corporate ESG performance. Incorporating carbon emissions into the framework underscores corporate environmental responsibility and aids in understanding how digital governance facilitates low-carbon transformation. Analyzing marketization degree reveals how different market environments shape the impact of digital governance on ESG performance, providing a new perspective on resource allocation and corporate behavior. Third, based on the study's findings, differentiated strategies can be implemented to promote corporate sustainability and industry advancement. For firms with high analyst coverage, sharing best practices in digital governance to enhance ESG performance is encouraged to serve as an industry benchmark. Firms with low analyst coverage should be incentivized to strengthen corporate governance and information disclosure. High-carbon industries should adopt a combination of mandatory emission reduction measures and incentivized transformation to fulfill their carbon reduction responsibilities, while low-carbon industries should be encouraged to deepen ESG governance and lead green upgrades. Highly marketized regions should leverage market forces to optimize resource allocation, encouraging enterprises to proactively enhance ESG performance based on market signals. In contrast, less marketized regions should focus on infrastructure development, improving digitalization and information flow to narrow regional disparities.

2. Theoretical Analysis and Research Hypothesis

Driven by a new wave of technological and industrial revolutions, enterprise digitalization may exhibit both positive and negative effects on corporate behavior [12]. Accordingly, digital transformation may have two entirely opposite impacts on corporate ESG performance.

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Enterprise digital transformation can enhance ESG performance. In terms of the environmental dimension, companies can leverage digital technologies such as big data analytics and the Internet of Things to collect and analyze environmental data on energy consumption and waste emissions. This enables firms to understand the internal mechanisms and specific links of their operational impact on the environment, thereby formulating and implementing resource optimization strategies to improve ESG performance in environmental aspects [13]. In the social dimension, digital platforms can facilitate efficient communication and interaction between enterprises, employees, communities, and various stakeholders. Companies can use such platforms to provide diverse and personalized learning resources, helping employees enhance their skills and meet their career development needs [14]. Moreover, businesses can leverage digital technologies to conduct various public welfare activities and expand their social impact, enhancing their reputation and securing a foothold in a highly competitive market [15]. Regarding corporate governance, digital technology can break down internal information flow barriers, enabling efficient communication and real-time sharing of information, thereby increasing operational transparency and providing data support and technological assurance for improving corporate governance structures [16]. Additionally, enterprises can utilize digital tools to optimize internal control processes, strengthen monitoring mechanisms, and support decision-making, ensuring the scientific and impartial nature of decisions, mitigating risks, maintaining stable operations, and achieving sustainable development. These factors attract more investors and partners and align with the high governance standards required by ESG frameworks [17].

However, digital transformation may also negatively impact ESG performance. On the one hand, digital transformation requires significant investment in technology research and development, equipment procurement, and personnel training [16]. Enterprises face high technological application costs, and some may even forgo transformation. Financial constraints can hinder firms from allocating sufficient resources to environmental protection, social responsibility fulfillment, and governance optimization. For instance, firms may struggle to adopt advanced environmental technologies, implement comprehensive employee welfare and community support programs, or establish sophisticated management information systems and governance teams, thereby affecting their ESG performance across all dimensions. On the other hand, from the perspective of technological application risks, innovations in business models driven by digital transformation introduce a degree of complexity, and the dynamic evolution of technologies can cause disruptions. Such complexities and disruptions manifest as operational and financial risks during digital transformation [18]. These risks may heighten technological uncertainty for firms and introduce challenges related to ESG compliance [19].

Despite these challenges, this study argues that the positive impact of digital transformation on corporate ESG performance outweighs the negatives. With continuous advancements and widespread adoption of digital technologies, the benefits of improved operational efficiency, enhanced innovation capabilities, and strengthened risk management become increasingly evident [20]. Through digital transformation, enterprises can integrate resources more effectively, actively promote environmental improvements, fulfill social responsibilities, and enhance governance efficiency. Hence, this study proposes the following hypothesis:

Hypothesis H1: Enterprise digital transformation enhances ESG performance.

3. Research Design

3.1. Sample Selection and Data Sources

This study selects A-share listed companies in China from 2012 to 2022 as the initial research sample. The year 2012 was chosen as the starting point because, in that year, the State-owned Assets Supervision and Administration Commission (SASAC) issued the "Guiding Opinions on Central

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Enterprises' Management Improvement Activities," which for the first time established corporate social responsibility management as a fundamental function of state-owned enterprises, laying the foundation for the implementation of ESG principles. Based on this, the sample was further processed as follows: (1) financial and insurance companies were excluded; (2) firms with missing financial data were excluded; (3) to control for the influence of outliers, continuous variables were winsorized at the 1% level at both ends. Ultimately, a total of 8,132 firm-year observations were retained. Data were sourced from the CSMAR database and Bloomberg Terminal.

3.2. Model Specification

To test Hypothesis 1, the following regression model was constructed:

$$ESG_{i,t} = a_0 + a_1 DCG_{i,t} + \theta Control_{i,t} + Year + Industry + Code + \varepsilon_{i,t}$$

Where i、t represent firms and years, respectively; $ESG_{i,t}$denotes the ESG performance of firm; $DCG_{i,t}$measures the degree of digital transformation; $Control_{i,t}$represents a set of control variables; $Year$、$Industry$、$Code$ denote year-fixed effects, industry-fixed effects, and firm-fixed effects, respectively; $\varepsilon_{i,t}$is the error term. The primary coefficient of interest is a_1; if a_1>0, it suggests that digital transformation has a positive effect on ESG performance; if a_1<0, it indicates a negative impact; if a_1=0, it implies no significant relationship between the two.

3.3. Definition of Key Variables

3.3.1. Dependent Variable – ESG Performance (ESG)

Following the study by Xu Xiangbing et al. [21], this study employs the Bloomberg ESG comprehensive rating index as the dependent variable. This rating is based on the ESG information disclosure of listed companies and varies within the range of [0,100], where higher scores indicate better ESG performance.

3.3.2. Independent Variable – Degree of Enterprise Digital Transformation (DCG)

Referring to the measurement approach of Wu Fei et al. [16], this study first identifies and categorizes digital transformation keywords from five dimensions: artificial intelligence, cloud computing, big data, blockchain, and digital technology applications. Next, a word frequency statistical analysis is conducted. Finally, the total word frequency count for each firm is calculated to quantify its level of digital transformation.

3.3.3. Control Variables

To improve the precision and accuracy of the study and avoid omitting key variables, several control variables that may influence corporate ESG performance are incorporated, as summarized in Table 1.

Table 1: Definition of Variables

Variable Type	Variable Name	Symbol	Definition
Dependent Variable	ESG Performance	ESG	Bloomberg ESG Rating
Independent Variable	Enterprise Digital Transformation	DCG	Based on Wu Fei et al. [16], constructed from keyword frequency related to artificial intelligence, cloud computing, big data, blockchain, and digital technology applications.
	Firm Size	Size	Natural logarithm of total assets at year-end

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Table 1: (continued).

Control Variables	Operating Cash Flow	Cfo	Net cash flow from operating activities divided by total assets at year-end
	Return on Assets	Roa	Net profit divided by total assets at year-end
	Leverage Ratio	Lev	Total liabilities divided by total assets at year-end
	Firm Age	Age	Log of (current year minus listing year +1)
	Board Size	Board	Natural logarithm of the number of board members
	Board Independence	Indep	Proportion of independent directors on the board
	Growth	Growth	Revenue growth rate
	Auditor Type	Big4	Equals 1 if the firm is audited by a Big Four accounting firm, otherwise 0

4. Empirical Results and Analysis

4.1. Descriptive Statistics

Table 2 presents the descriptive statistics. The mean ESG performance (ESG) score is 30.783, with a minimum of 10.703 and a maximum of 57.781. The mean digital transformation (DCG) score is 1.586, with a minimum of 0 and a maximum of 5.037. Additionally, the mean values for operating cash flow (Cfo), return on assets (Roa), leverage ratio (Lev), and firm age (Age) are 0.069, 0.045, 0.483, and 3.012 years, respectively. These values all fall within reasonable ranges and align with prior research findings, such as those of Song Jing et al. [11], Li Zhijun et al. [12], and Wang Haijun et al. [9].

Table 2: Descriptive Statistics

	Obs	Mean	Sd.	Min	p25	p50	p75	Max
ESG	8132	30.783	9.431	10.703	25.370	29.333	35.097	57.781
DCG	8132	1.586	1.405	0	0	1.386	2.565	5.037
Size	8132	23.339	1.292	20.430	22.450	23.220	24.090	27.020
Cfo	8132	0.069	0.080	-0.169	0.021	0.062	0.110	0.342
Roa	8132	0.045	0.059	-0.177	0.016	0.039	0.074	0.223
Lev	8132	0.483	0.196	0.081	0.333	0.494	0.632	0.890
Age	8132	3.012	0.304	1.957	2.833	3.053	3.226	3.584
Board	8132	2.167	0.200	1.609	2.079	2.197	2.197	2.708
Indep	8132	0.376	0.055	0.300	0.333	0.364	0.429	0.571
Growth	8132	0.163	0.371	-0.493	-0.010	0.106	0.252	2.486
Big4	8132	0.132	0.339	0	0	0	0	1

4.2. Baseline Regression

Table 3 reports the regression results for the impact of enterprise digital transformation on ESG performance. Column (1) presents the results without including control variables or fixed effects for year, industry, and firm. Column (2) incorporates year, industry, and firm fixed effects but excludes control variables. Column (3) further includes control variables. The results in Table 3 indicate that the regression coefficient of digital transformation (DCG) remains significantly positive at the 5% level across all model specifications, regardless of whether control variables are included. This suggests that enterprise digital transformation effectively enhances ESG performance, thus providing empirical support for Hypothesis H1.

DOI: 10.54254/2754-1169/2025.21988

Table 3: Regression Results of the Extent of Firms' Digital Transformation on ESG Performance

	(1)	(2)	(3)
DCG	1.1161***	0.3880***	0.2697**
	(8.73)	(3.61)	(2.53)
Size			1.7075***
			(6.78)
Cfo			0.2841
			(0.29)
Roa			4.5543***
			(3.03)
Lev			-3.3381***
			(-3.71)
Age			0.5416
			(0.24)
Board			0.0056
			(0.01)
Indep			4.8296**
			(2.24)
Growth			0.1174
			(0.67)
Big4			2.8397***
			(3.70)
Constant	29.0132***	30.1306***	-12.0009
	(103.27)	(177.17)	(-1.36)
Year Fixed	NO	YES	YES
Industry Fixed	NO	YES	YES
Code Fixed	NO	YES	YES
N	8132	8098	8098
R^2	0.03	0.84	0.85

Note: ***, **, and * indicate that the coefficients are significant at the 1%, 5%, and 10% levels, respectively, with t-values in parentheses, below.

4.3. Robustness Tests

To mitigate estimation bias caused by endogeneity, this study employs the national big data pilot policy as a grouping criterion and uses the propensity score matching (PSM) method to match control groups to experimental groups. This policy, introduced in 2016 by the National Development and Reform Commission, the Ministry of Industry and Information Technology, and the Cyberspace Administration of China, aims to foster the development and integration of big data across industries by strengthening infrastructure, building industrial ecosystems, and promoting data openness and sharing.

Table 4 presents the matching results. The results of the t-test indicate that there are no significant differences in the mean values of the matching variables between the two groups. According to Rosenbaum and Rubin [22], a well-matched sample should exhibit a bias ratio of no more than 20%. In Table 4, the maximum absolute bias is 4.97%, and the variance ratio V(T)/V(C) falls within the acceptable range of [0.91, 1.31], confirming the robustness of the estimates.

DOI: 10.54254/2754-1169/2025.21988

Table 4: Matching Balance Test Results

Matching variables	Treated	Number	Controls	Number	Mean Diff	|Bias%|
Size	23.272	2125	23.278	2153	-0.007	0.03%
Cfo	0.068	2125	0.067	2153	0.001	1.47%
Roa	0.044	2125	0.045	2153	-0.001	2.27%
Lev	0.481	2125	0.476	2153	0.005	1.04%
Age	3.018	2125	3.018	2153	-0.001	0.03%
Board	2.170	2125	2.175	2153	-0.005	0.23%
Indep	0.375	2125	0.373	2153	0.002	0.53%
Growth	0.161	2125	0.169	2153	-0.008	4.97%
Big4	0.114	2125	0.109	2153	0.005	4.39%

Table 5 reports the regression results after PSM matching. Column (1) includes control variables as well as fixed effects for year, industry, and firm. The regression coefficient of the explanatory variable is 0.6340 and remains significantly positive at the 1% level. This indicates that, compared to listed companies unaffected by the policy, those that increased their focus on digital transformation due to policy shocks experienced significant improvements in ESG performance. These findings, consistent with previous results, further confirm the robustness of the study.

To address potential endogeneity issues caused by reverse causality, this study also re-estimates the main conclusions by lagging all control variables by one period. As shown in Column (2) of Table 5, the coefficient of the explanatory variable is 0.3784 and remains significantly positive at the 1% level. This consistency with previous findings confirms the robustness of the study's conclusions.

Table 5: Regression Results after PSM Matching and Lagged One Period Control Variable Regression Results

	(1)	(2)
	ESG	ESG
DCG	0.6340***	0.3784***
	(4.42)	(3.15)
Controls	YES	YES
Year Fixed	YES	YES
Industry Fixed	YES	YES
Code Fixed	YES	YES
N	4161	6689
R^2	0.86	0.85

4.4. Heterogeneity Analysis

4.4.1. Environmental Regulation (Carbon)

This study uses industry carbon intensity to measure environmental regulation. Theoretically, firms in high-carbon industries have a stronger association between core business activities and carbon disclosure obligations. These firms face greater policy pressure and transformation challenges, leading to potential variations in the impact of digital transformation on ESG performance compared to low-carbon industries [23]. Following Wang Haijun et al. [9], this study classifies high-carbon industries based on the definitions provided by the Chinese Ministry of Ecology and Environment (April 2021) and the Shanghai Environment and Energy Exchange (June 2021). Eight industries

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included in China's carbon trading market—electricity, petrochemicals, chemicals, building materials, steel, non-ferrous metals, paper, and aviation—are assigned a value of 1, while other industries are assigned a value of 0. Regression results in Table 6 show that the interaction term is significantly positive at the 1% level, while the coefficient for DCG is significantly positive at the 10% level. This suggests that the effect of digital transformation on ESG performance is more pronounced in high-carbon industries, indicating a potential substitution effect in environmental governance. Enterprises can leverage digital technologies to simulate and optimize production processes, thereby reducing pollutant emissions. These findings provide insights into how digital technology can enhance ESG performance in high-carbon industries.

4.4.2. Corporate Governance (Report Attention)

There is limited research on the role of analyst report attention in the relationship between digital transformation and ESG performance. This study innovatively incorporates analyst report attention as a measure of corporate governance. Analyst reports serve as a crucial information transmission medium in financial markets. A higher level of analyst report attention indicates greater information dissemination, leading to deeper investor and analyst understanding of the firm [24]. Firms with high analyst report attention are more likely to integrate ESG-related information with digital transformation strategies, effectively communicating their ESG strengths to the market. Conversely, firms with low analyst report attention face greater constraints in information dissemination. This study assigns a value of 1 to firms in the top quartile of analyst report attention and 0 otherwise. Regression results in Table 6 indicate that the interaction term is significantly positive at the 5% level, while the coefficient for DCG is significantly positive at the 1% level. This suggests that the positive impact of digital transformation on ESG performance is more pronounced in firms with higher analyst report attention. These findings provide insights for corporate strategic decision-making and industry development, supporting sustainable economic growth.

4.4.3. Market Competition (Market)

Marketization plays a critical role in shaping the business environment and may significantly influence the relationship between digital transformation and ESG performance. However, existing studies have not systematically examined this issue. In general, higher marketization levels enhance transparency in supply-demand conditions and price signals, enabling firms to better understand market needs and optimize resource allocation. This, in turn, encourages firms to actively fulfill social responsibilities and establish a positive corporate image [25]. Following Wang Xiaolu et al. [26], this study measures marketization levels using the Marketization Index and classifies firms based on their registered location. Firms in provinces with marketization levels above the top quartile are assigned a value of 1, while others are assigned 0. Regression results in Table 6 indicate that both the interaction term and the DCG coefficient are significantly positive at the 1% level. This suggests that, compared to firms in regions with lower marketization levels, digital transformation has a more pronounced effect on improving ESG performance in highly marketized regions. These findings highlight the importance of resource allocation efficiency and suggest that firms in high-marketization regions should prioritize digital transformation investments to maximize ESG benefits.

Table 6: Subgroup Tests for Heterogeneity Analysis

	Subgroup on Environmental Regulation	Corporate Governance Subgroup	Market Competition Grouping
	ESG	ESG	ESG

DOI: 10.54254/2754-1169/2025.21988

Table 6: (continued).

DCG*Carbon	0.8417***		
	(4.84)		
DCG*Report Attention		0.1898**	
		(1.97)	
DCG*Market			0.4426***
			(3.59)
DCG	0.1516*	0.2440***	0.2175***
	(1.90)	(3.14)	(2.82)
Carbon	-0.0254		
	(-0.04)		
Report Attention		-0.0679	
		(-0.30)	
Market			-0.5832**
			(-2.01)
Controls	YES	YES	YES
Year Fixed	YES	YES	YES
Industry Fixed	YES	YES	YES
Code Fixed	YES	YES	YES
N	8099	8099	8099
R^2	0.85	0.85	0.85

5. Research Conclusions and Implications

Against the backdrop of the "dual carbon" strategy, integrating the digital economy with ESG to establish a green governance mechanism is crucial for social sustainability and the development of new productive forces. Using A-share listed companies from 2012 to 2022 as a sample, this study empirically examines the relationship between enterprise digital transformation and ESG performance, as well as its underlying mechanisms. The key findings are as follows: (1) After a series of robustness and endogeneity tests, the results confirm that enterprise digital transformation significantly enhances ESG performance. (2) Mechanism analysis reveals that digital transformation improves ESG performance by strengthening green innovation capabilities, enhancing external supervision, and optimizing resource allocation. (3) Heterogeneity tests incorporating corporate governance (micro-level), environmental regulation (meso-level), and market competition (macro-level) show that the positive effect of digital transformation on ESG performance is more pronounced in firms with high analyst report attention, those operating in high-carbon industries, and those located in regions with high marketization levels.

Based on these findings, this study offers the following insights: (1) Enterprises should embed ESG principles into their digital transformation strategies by developing evaluation metrics aligned with authoritative ESG standards. Digital transformation should be leveraged to support ESG initiatives, prioritizing strategies that enhance ESG outcomes. (2) Enterprises can use digital tools to establish real-time ESG performance monitoring systems, collecting diverse internal and external data to identify weaknesses and optimize strategies in a timely manner. Additionally, firms should utilize digital innovation to explore market demands, driving product, service, and corporate social responsibility innovations. The dynamic and innovative nature of digital transformation can ensure continuous improvement in ESG performance. (3) At the policy level, on the one hand, a special pool

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of funds is set up to provide project funding to enterprises committed to digital transformation and actively practising ESG concepts, helping them to upgrade technology, optimise processes, and digitally empower environmental governance, social responsibility fulfilment and corporate governance enhancement; on the other hand, tax incentives are formulated, and tax relief is provided based on the effectiveness of the enterprise's digital transformation and its ESG ratings, so as to stimulate the enterprise's intrinsic motivation.

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