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Published in:

Journal of Global Information Management

Published: 01/01/2024

Document Version:

Final Published version, also known as Publisher's PDF, Publisher's Final version or Version of Record

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Publication record in CityU Scholars:

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Published version (DOI):

[10.4018/JGIM.335905](https://doi.org/10.4018/JGIM.335905)

Publication details:

Zhang, L., Ye, Y., Meng, Z., Ma, N., & Wu, C.-H. (2024). Enterprise Digital Transformation, Dynamic Capabilities, and ESG Performance: Based on Data From Listed Chinese Companies. *Journal of Global Information Management*, 32(1). <https://doi.org/10.4018/JGIM.335905>

Citing this paper

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Enterprise Digital Transformation, Dynamic Capabilities, and ESG Performance: Based on Data From Listed Chinese Companies


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ABSTRACT

Digital transformation improves the operational efficiency and perceptual capabilities of businesses and creates a foundation for fulfilling ESG responsibilities. The authors use the theories of technological innovation and dynamic capabilities and select a sample of 4054 listed companies with commercial integration of ESG rating data to explore the mechanisms through which digital transformation affects ESG performance. Dynamic capabilities are further divided into innovation changeability (IT), coordination integration capability (CI), and learning absorption capability (LA) to investigate the mediating effects and summarize the causal path of “digital transformation - dynamic capabilities - ESG performance.” The research focuses on the impact of digital technology on ESG performance with the aim of helping businesses utilize technology more effectively to build dual competitive advantages in digitization and ESG.

KEYWORDS

Digital Transformation, Dynamic Capabilities, ESG

INTRODUCTION

Given the rise of the fourth Industrial Revolution, the pace of enterprises’ transformation to Industry 4.0 is gradually accelerating. The emergence of novel and powerful digital technologies, digital platforms, and digital infrastructure has greatly changed innovation and entrepreneurship (Satish et al., 2019). Digital transformation is defined as the use of new digital technologies, such as mobile, AI, cloud, blockchain and internet of things (IoT) technologies, to achieve significant business improvements, enhance customer experiences, streamline operations, or create new business models

DOI: 10.4018/JGIM.335905

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(Karl, et al., 2019). As a new enterprise development model, digitization is of great significance to the development of contemporary economy and society. Digital transformation is urgently needed for businesses to overcome survival challenges and to plan for future development. Digital transformation possesses powerful capabilities to innovate traditional business forms, operational methods, and profit models. Digital transformation's technological, innovative, intelligent, and unique characteristics enable companies to gain new competitive advantages and become one of the factors influencing their environmental, social, and governance (ESG) responsibilities. Digital transformation brings more possibilities and opportunities for businesses to explore the positive impact of technology.

The ESG concept focuses on environmental management, social responsibility, and corporate governance. ESG considers both economic and social benefits and adapting to green, low-carbon objectives. ESG serves as a guiding principle for sustainable development and a practical tool for greening capital markets. In the new stage of economic development, companies not only need to enhance their own development quality and improve operational efficiency but also pay more attention to environmental protection, carbon emissions reduction, long-term development, and sustainability. ESG is an advanced approach that comprehensively evaluates a company's sustainable development from the three dimensions of environment (E), society (S), and governance (G). ESG also represents an important standard used by the international community to measure corporate green sustainability levels (Baker et al., 2021). Today's connected environment is characterized by ESG, a network of people, and organizations and equipment that constantly interact, talk and exchange information. These forms of communication show that information sharing, signaling, and brand value creation have evolved over the past decade (Lee et al., 2022). ESG performance, as a corporate evaluation standard and investment concept that focuses on corporate environmental, social and governance performance rather than financial performance, to a certain extent measures whether listed companies have sufficient social responsibility, reflects enterprises' potential in sustainable development, and provides important support for the country to achieve green development. Given the rapid growth of global ESG investments, ESG has become a hot topic for policy makers, regulators, and investors and has been gradually included in the decision-making process of investment and financing (Wu et al., 2023).

Regarding the microeconomic consequences of corporate digital transformation, scholars have mainly explored the impact of corporate digital transformation on financial performance, corporate performance, and operational performance. Fadi et al. (2022) proposed that CTTI4.0 disclosure has a positive impact on financial performance. In addition, the study found that ESG practices moderated the relationship between CTTI4.0 disclosure and financial performance, suggesting that firms with better ESG performance tend to be more actively involved in CTTI4.0 disclosure and simultaneously have better financial performance (2022). Qi and CAI (2020) note that many derivative management costs are generated in the enterprise digital transformation process, which seriously weakens its effect on driving enterprise performance. Chen et al. (2019) note that the unique rhythm and trajectory of digital technology enables enterprises to carry out innovation and transformation, thus improving economic performance. He and Liu (2019) concluded through empirical research that enterprise digital transformation can significantly improve a company's business performance.

The digital revolution has profoundly changed people's lifestyles. In the face of uncertainty and change, it has become increasingly challenging for enterprises to adapt, respond quickly, and maintain business continuity and stability. To overcome these challenges, companies need to rely on their internal capabilities but must make them dynamic and modify them when necessary to respond to or anticipate external changes. Nastaran (2023) proposed a business model innovation (BMI) model with the goal of pursuing sustainability to adapt to changes in the principle of pursuing dynamic capabilities in the digital era. Feroz et al. (2023) identified the dynamic capabilities of SDT and preliminarily determined 28 capabilities based on the hybrid method. Consensus (> 70% agreement) was reached on 19 capabilities, which were classified as the sustainable capture, perception, and

transformation capabilities of organizations. The dynamic capabilities outlined provide insights for organizations seeking sustainable digital transformation. Most studies have used digital technology as a resource to enhance dynamic capabilities through improved forecasting, decision making, and data-driven innovation. A large body of literature has focused on the leading role of digital technologies in promoting circular business model innovation. However, to date, little attention has been paid to the dynamic capabilities involved in the digital enabling of the transition from linear to circular (van Eechoud et al., 2023).

The impact of digital transformation on ESG performance of enterprises is mainly reflected in two aspects: enhancing external legitimacy pressure and mitigating information asymmetry. First, from the perspective of legitimacy theory, enterprises implementing digital transformation strategies face greater legitimacy pressure and are more inclined to improve their ESG performance. Digital transformation significantly enhances the ability of enterprises to collect and process information, allowing them to output information as standardized and structured data, making them more willing to proactively “push” information to the market, thus facilitating market scrutiny of their production and operational conditions. At the same time, digitally transformed enterprises seize the opportunities of the era and have better development prospects, attracting more attention from media and the public (Huang et al., 2021). Media attention itself can serve as a supervision mechanism for corporate behavior, promoting green innovation (Li et al., 2018), fulfilling social responsibilities (Jia et al., 2014), and improving governance levels (Dai et al., 2011). From the perspective of information asymmetry theory, digital transformation enables enterprises to effectively reduce the degree of information asymmetry, alleviate financing constraints, and address agency problems, thereby improving their ESG performance. On one hand, information asymmetry is an important factor affecting enterprise financing costs. Capital providers are constrained by information asymmetry and demand higher returns on investment to compensate for the risk they bear, leading to increased financing costs for enterprises. On the other hand, information asymmetry is also a fundamental cause of agency problems. The exacerbation of agency problems can lead to managerial “short-sighted behavior.” Unfortunately, thus far, the impact of enterprise digital transformation on ESG performance using dynamic capabilities as a driving factor has not been explored. Therefore, we explore how Chinese listed companies promote ESG performance based on corporate digital innovation and use multiple mediation analysis to test this relationship. This relationship is mediated by the parallel effects of three dynamic capabilities: innovation and change capability, coordination and integration capability, and learning and absorption capability.

Compared to previous research, we make several marginal contributions. First, we analyze new potential paths for improving corporate ESG performance from the perspective of digital transformation, providing a fresh angle for the research on sustainable development and inclusive growth, thus serving as an important supplement to the literature on ESG. Second, we explore the mechanism by which digital transformation promotes corporate ESG performance from the perspective of dynamic capabilities and conduct a heterogeneous analysis of companies from various sectors and of various natures, thereby revealing the theoretical logic, connections, and internal and external influences among them in a systematic and in-depth manner. This exploration enriches and expands the research on the noneconomic effects of digitization and digital transformation. Third, we provide a new perspective on the factors influencing corporate ESG performance and offer theoretical references for companies to achieve good governance through digital technology utilization. Our research focuses on the impact of digital technology on ESG performance, with the aim of helping enterprises better manipulate technology.

Theoretical Analysis and Research Hypothesis

Enterprise Digital Transformation and ESG Performance

Enterprise ESG performance is closely related to enterprise development. Given the emergence of many foreign scholars conducting ESG research in recent years, the field of ESG has become a

concern in various domestic academic circles. Most of the mainstream models of traditional ESG research have comprehensively evaluated enterprises from the aspects of the environment, society and corporate governance. Enterprise digital transformation uses digital technology and capabilities to drive enterprise business model innovation and business ecosystem reconstruction, connect the “chimney system” and “information island” under traditional enterprises, turn all businesses online and digital, support all businesses with data, and generate value after data correlation. The upgrading of production technology resulting from the digital transformation of enterprises creates demand for high-skilled labor and squeezes out some low-skilled labor to optimize the human capital structure (Xiao et al., 2022). Equipment and technology upgrades resulting from digital transformation can help enterprises establish resource barriers and form sustainable competitive advantages (Chen et al., 2023).

ESG rating results can greatly influence the decisions made by investors (Avramov et al., 2022). As an important strategy for the high-quality development of enterprises in the new era, digital transformation can affect enterprise ESG performance. On the one hand, enterprises bear environmental responsibility, and when social civilization has developed to a certain degree, enterprises should fulfill the obligation to protect the environment. By changing the industrial structure, digital transformation provides a steady stream of power for improving the environment and can reduce carbon productivity (Li et al., 2017). Moreover, high-tech products brought about by digital transformation reduce enterprises’ dependence on energy consumption and improve environmental quality. Technological innovation empowers traditional industries to improve resource utilization, which is a key means of achieving sustainable economic development. Digital transformation, as the deep integration of production and digital technology in enterprises, is an innovative process that comprehensively enhances operational efficiency and undoubtedly has a significant impact on a company’s pollution emissions. Continuous technological innovation can strengthen a company’s comparative advantage, improve energy efficiency, enhance product cleanliness, and thereby reduce pollution emissions in the production process, providing possibilities for green development in enterprises.

In the social responsibility dimension, after scholars conducted research on corporate social responsibility in the digital age (Wruk et al., 2019) and other theoretical perspectives, some researchers have begun to explore the impact of digital transformation on corporate social responsibility and its underlying pathways. Digital transformation in enterprises can enhance their level of social responsibility by improving internal management mechanisms, enhancing production methods (Shen et al., 2022), increasing internal control information disclosure, and reducing earnings management tendencies (Xiao et al., 2021). Aguinis and Glavas (2012) believe that corporate social responsibility encompasses various aspects, including environmental, social, and economic responsibilities. As companies gradually grow and develop, it is important to consider their stakeholders, including governments, investors, media, and the public, in order to establish a positive social image. Digital transformation in business operations can lower production costs, increase product value, and expand market share. This not only enables owners and investors to achieve higher profits but also effectively motivates employees and enhances recognition from various sectors (Fernandes et al., 2021). Moreover, as the level of digital transformation increases during the process, companies are more likely to adopt more aggressive strategies (Wang et al., 2022), requiring greater resource support. Companies integrate resources and complement advantages while utilizing the internet for cross-industry cooperation. This leads to the emergence of business ecosystems (Jacobides, 2019; Fuller et al., 2022). Companies also pay more attention to relationships with external stakeholders and actively fulfill their social responsibilities. Companies undergoing digital transformation face greater legitimacy pressure. In order to meet external legitimacy requirements, they are inclined to enhance their performance in terms of social responsibility.

In terms of corporate governance, at the theoretical level, digital governance theory advocates the role of “data-driven decision-making” and emphasizes that data information is a key factor

in improving corporate governance (Vikas, 2003). The evolution of digital technology enables economic organizations to capture and obtain massive amounts of data, including richer governance frameworks, checks and balances mechanisms, benefit allocation, equity incentives, stakeholder demands, and the like, laying the foundation for breaking down governance data barriers between different departments and re-integrating the governance system. In other words, under the guidance of digital transformation strategies, economic organizations leverage their scale data information and technological advantages to promote governance decision-making and behavioral changes (Li et al., 2014), thereby enhancing corporate governance levels. Asymmetric information theory suggests that different stakeholders possess differentiated information, and these “digital divides” significantly hinder the effective operation of corporate governance (Clarkson et al., 2007). Asymmetric information is a key variable affecting differences in the level of economic organizations’ governance. Breaking the “digital islands” helps mitigate biases in delegation, agency relationships, and other stakeholder information deviations, enhancing mutual supervision and checks among different stakeholders. From a practical perspective, during the process of digital transformation, when digital technology is applied to various aspects of enterprise management processes, it involves internal governance structures and external information disclosure. First, digitalization allows managers to have a more objective understanding of internal company information, thereby enhancing corporate governance levels. Second, external media are easily attracted by digital transformation, leading external stakeholders to pay more attention to a company’s operational status and financial information for supervision purposes (Shao & Wang, 2023). The improvement in corporate governance levels occurs during the process of enterprise digital transformation. Furthermore, digital transformation also enhances corporate governance levels in driving innovation in operational management processes. Through interaction with market elements, enterprise innovation capabilities can achieve information interaction and sharing, reducing external environmental uncertainties (Mohsen & Eng, 2016), and providing a favorable governance environment for companies. For example, Haier Group, in the context of digitalization, has built a “shared empowerment platform” to complement its incentive model and enable employees to effectively utilize the company’s segmented resources, seize market opportunities, and increase revenue.

According to existing research, digital transformation greatly improves enterprise performance and stimulates the motivation for enterprise innovation. Reducing costs, increasing revenue, improving efficiency, and encouraging innovation are the main ways for digital transformation to promote enterprise development (Peng et al., 2022). The digital transformation index is significantly positively correlated with economic development (Aly, 2020). Among them, the development of digital inclusive finance has significantly promoted improvements in enterprise ESG performance, and the impact of digital inclusive finance on enterprise ESG performance has a marginal decreasing effect, while enterprise green technology innovation has a marginal increasing effect on enterprise ESG performance (Li, 2023).

Based on the above analysis, digital transformation can promote enterprise ESG performance. Therefore, hypothesis 1 is proposed:

H1: Enterprise digital transformation can improve enterprise ESG performance.

The Mediating Role of Enterprise Dynamic Capability

The digital revolution has profoundly changed people’s way of life. Due to uncertainty and change, many enterprises face challenges to adapt, respond quickly, and maintain business continuity and stability. To overcome these challenges, businesses need to rely on their internal capabilities while ensuring they remain dynamic in order to modify capabilities as necessary to respond to or anticipate external changes. Dynamic capability theory points out that leading enterprises in various industries have flexible innovation capabilities, the ability to coordinate and integrate internal and

external resources, and the ability to learn knowledge and skills (Teece et al., 1997; Zahra et al., 2006; Barreto, 2010). If an enterprise has dynamic capabilities, it can manage the uncertainty and complexity of the market through continuous upgrading and restructuring to maintain its competitive advantage. When exploring the impact of digital development on the service innovation of advanced manufacturing enterprises, Zhang et al. (2023) divided the dynamic capability of enterprises into the three subdimensions of innovation and change capability, coordination and integration capability, and learning and absorption capability.

First, regarding innovation and change capability, enterprises embed digital transformation into the innovation research and development process. He Fan et al. (2019) found that enterprises reduce the cost of information acquisition and transmission through digital transformation, increase the efficiency of resource allocation, promote the improvement of total factor productivity of enterprises, and thus improve ESG performance. At the same time, enterprises can integrate fragmented information, connect the needs of both suppliers and marketers, improve the operational efficiency of enterprises, and then improve the level of marginal innovation. Second, regarding coordination and integration capability, enterprise digital transformation can effectively manage data resources and achieve dynamic updates. Digital transformation can improve the information asymmetry in the operation process of enterprises, release the information dividend trapped inside enterprises, form an efficient communication mechanism, promote enterprises to build a green image, and have a positive impact on ESG performance. Research has shown that the role of dynamic capabilities in perceiving and grasping digital cycle business model innovation, particularly supply chain collaboration, lean methods, and project management (Van Eechoud et al., 2023). Finally, regarding learning and absorption capability, based on the ability of innovation and change, the development of digital inclusive finance is found to improve the green technology innovation ability of enterprises, and this innovation can improve the green sustainable ability and the ESG performance of enterprises (Li, 2023). Matarazzo et al. (2021) studied the relevance of perception and learning capabilities as triggers for digital transformation and concluded that digital transformation uses dynamic capabilities to create value. Therefore, perception and learning capabilities are the pillars of digital transformation. Enterprise digital transformation can broaden the knowledge source of enterprises and enable the absorption of new external knowledge and its application to their business process.

Based on the above analysis, hypothesis 2 is proposed.

H2: Enterprise dynamic capability plays a mediating role between digital transformation and ESG performance.

H2a: Enterprise innovation and change capability plays a mediating role between digital transformation and ESG performance.

H2b: Enterprise coordination and integration capability plays a mediating role between digital transformation and ESG performance.

H2c: Enterprise learning and absorption capability plays a mediating role between digital transformation and ESG performance.

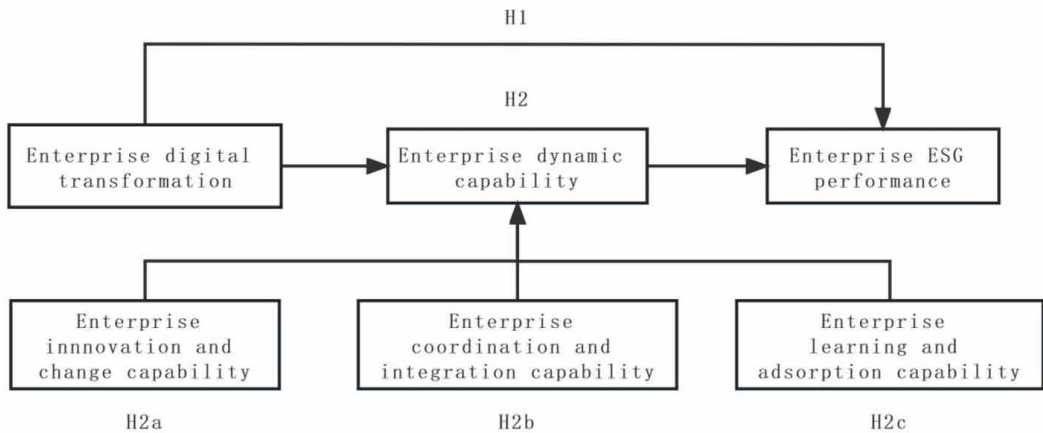
Based on the above assumptions, the theoretical model diagram shown in Figure 1 can be obtained.

RESEARCH DESIGN

Data Source

We use data on Shanghai and Shenzhen A-share listed companies from 2015 to 2022 as the initial research sample; retaining samples with a SynTao Green Finance ESG Rating, excluding ST and ST* samples, delisted companies, and companies with a significant lack of core data, we

Figure 1. Theoretical model



obtain 4,862 samples. The data are from the SynTao Green Finance ESG, CSMAR databases and Bloomberg database.

Variable Definition

Explained Variables

The explained variable of this study is firm ESG performance (ESG). Since the ESG rating system of SynTao Green Finance includes both positive and negative indicators to measure the ESG performance of enterprises, it is more robust and comprehensive than other databases in terms of index selection, and more detailed and effective in terms of corporate governance evaluation indicators, which helps investors to have an effective understanding of its sustainable development ability, and the data is also easier to obtain. With reference to the findings of Danny et al. (2021), Long et al. (2022) and Zhou Pin et al. (2023), this paper uses the data of the ESG rating system of SynTao Green Finance to assign scores to the ESG performance level of enterprises. Specifically, the sample base score of the rating grade D is marked as 1 point, and 1 point is added for each of D, C-, C, C+, B-, B, B+, A-, A, and A+ successively. The rating grade A+ is the highest score and is marked as 10 points.

Explanatory Variable

The explanatory variable of this study is the degree of digital transformation (DIG). Based on the literature (Li, 2008; Loughram et al., 2011; Yang et al., 2019), we extract the keywords related to digital transformation in the annual report through Python, calculate the word frequency and take the logarithm to obtain the measured value. Digital transformation keywords include digital technology application, internet business model, intelligent manufacturing, and modern information system in four categories. Digital technology application is divided into data, digital and digitization; internet business model is divided into internet and e-commerce; and intelligent manufacturing is divided into intelligence, intellectualization, automation, numerical control, integration and integration. Modern information systems are divided into information, informatization, and networking (Zhao et al., 2021).

Intermediate Variable

The intermediate variable of this study is enterprise dynamic capability. Based on the above discussion, enterprise dynamic capability can be divided into three sub-dimensions (Wang & Ahmed, 2007; Mo Dongyan et al., 2023): innovation and change capability (IT), coordination and integration capability (CI) and learning and absorption capability (LA). The innovation and change capability is measured by

the logarithm of the total number of patent applications. The coordination and integration capability is based on the coefficient of variation of the intensity of R&D, advertising and capital expenditure, that is, the ratio of the standard deviation of the three to the average; learning and absorption capacity is measured as a ratio of R&D expenditure to operating income.

Control Variables

We consider the factors affecting the ESG performance of enterprises and refer to the literature of Liu et al. (2022) to select enterprise size, asset-liability ratio, enterprise performance, ownership concentration, and enterprise age as the control variables. The specific measurement methods are shown in Table 1.

Model Setting

To verify H1, that is, to explore the causal relationship between the degree of enterprise digital transformation and enterprise ESG performance, we develop the following baseline regression model:

$$ESGi,t = \alpha_0 + \alpha_1 DIGi,t + \alpha_2 Controlsi,t + Year_t + Indi + \epsilon_{i,t} \quad (1)$$

where *i* indicates the industry and *t* indicates the year. α_1 reflects the total effect of the degree of digital transformation ($DIG_{i,t}$) on enterprise ESG performance ($ESG_{i,t}$), $Controls_{i,t}$ represents all control variables, $Year_t$ and $Indi$ represent the year and industry fixed effects, respectively, and $\epsilon_{i,t}$ represents the random interference term. If α_1 is significantly positive, it indicates that enterprise digital transformation can positively promote improvements in enterprise ESG performance.

To verify H2, this study adopts the stepwise mediation testing method proposed by Baron et al. (1986), Wen and Ye (2004). Three sub-dimensions – innovative change capability, coordination and integration capability, and learning and absorption capability – are included in the model. The specific settings are as follows:

Table 1. Variable definition table

Type	Name	Symbol	Definition
Explained variable	Enterprise ESG performance	ESG	ESG ratings from D to A+ are assigned 1 to 10 points according to the SynTao Green Finance database
Explanatory variable	Degree of digital transformation	DIG	Logarithmic keyword frequency
Intermediate variable	Innovation and Change capability	IT	Logarithm of the total number of patent applications for each year
	Coordination and Integration capability	CI	Coefficient of variation for R&D, advertising and capital expenditure intensity
	Learning and Absorption capability	LA	R&D expenditure/operating income
Control variables	Enterprise size	Size	Natural logarithm of total asset
	Enterprise performance	Roa	Net profit margin on total assets = net profit/total assets
	Asset-liability ratio	Lev	Total corporate liabilities/total corporate assets
	Ownership concentration	Top1	The proportion of the largest shareholder
	Enterprise age	Age	Logarithm of the number of years a company has been listed
	Year	Year	Year dummy variable
Industry	Ind	Industry dummy variable	

$$IT_{i,t} = \beta_0 + \beta_1DIG_{i,t} + \beta_2Controls_{i,t} + Year_t + Indi + \epsilon_{i,t} \quad (2)$$

$$ESG_{i,t} = \gamma_0 + \gamma_1DIG_{i,t} + \gamma_2IT_{i,t} + \gamma_3Controls_{i,t} + Year_t + Indi + \epsilon_{i,t} \quad (3)$$

$$CI_{i,t} = \delta_0 + \delta_1DIG_{i,t} + \delta_2Controls_{i,t} + Year_t + Indi + \epsilon_{i,t} \quad (4)$$

$$ESG_{i,t} = \zeta_0 + \zeta_1DIG_{i,t} + \zeta_2CI_{i,t} + \zeta_3Controls_{i,t} + Year_t + Indi + \epsilon_{i,t} \quad (5)$$

$$LAI_{i,t} = \eta_0 + \eta_1DIG_{i,t} + \eta_2Controls_{i,t} + Year_t + Indi + \epsilon_{i,t} \quad (6)$$

$$ESG_{i,t} = \theta_0 + \theta_1DIG_{i,t} + \theta_2LAI_{i,t} + \theta_3Controls_{i,t} + Year_t + Indi + \epsilon_{i,t} \quad (7)$$

Models (2), (4) and (6) are designed to verify the significance of the impact of the degree of digital transformation on innovation and change capability, coordination and integration capability and learning and absorption capability, respectively. Models (3), (5) and (7) verify the mediating role of innovation and change capability, coordination and integration capability and learning and absorption capability in the relationship between enterprise digital transformation and enterprise ESG performance, respectively.

EMPIRICAL RESULTS AND ANALYSIS

Descriptive Statistics

As shown in Table 2, according to the descriptive statistical results of each variable, the mean value of ESG performance (ESG) of enterprises is 5.400, the median value is 5, and the standard deviation is 1.090, indicating that the ESG performance of enterprises varies greatly, and half of enterprises' ESG performance is at or below the medium level. The mean value of the degree of digital transformation (DIG) is 1, the median value is 0.690, and the standard deviation is 1.180, indicating that the degree of digital transformation of enterprises varies greatly.

Correlation Analysis and Collinearity Diagnosis

Correlation Analysis

From the following analysis results shown in Table 3, it can be seen that at the 90% confidence level, the explained variables, explanatory variables and intermediary variables all pass the significance test, and the next analysis can be carried out.

Table 2. Descriptive statistics

Variables	N	mean	sd	min	max	p50
ESG	4826	5.400	1.090	3	9	5
DIG	4826	1	1.180	0	6.020	0.690
IT	4862	2.980	2.290	0	7	3
CI	4862	-0.910	0.270	-1.410	-0.0300	-0.910
LA	4862	38.08	61.63	0	2089	20.63
Size	4862	24.41	1.620	20.97	31.31	24.10
Lev	4862	0.510	0.210	0.0100	1.060	0.520
ROA	4862	0.0500	0.220	-14.30	0.640	0.0400
Top1	4862	36.52	16.57	3.970	89.99	35.06
Age	4862	2.440	0.770	0	3.430	2.640

Table 3. Statistical table of correlation analysis

Variables	ESG	DIG	IT	CI	LA	Size	Lev
ESG	1						
DIG	0.0180	1					
IT	-0.054***	-0.0100	1				
CI	-0.0110	0.097***	0.138***	1			
LA	-0.0140	0.173***	0.149***	0.233***	1		
Size	0.281***	0.0230	0.00400	-0.186***	-0.346***	1	
Lev	0.116***	0.030**	-0.038***	-0.208***	-0.337***	0.700***	1
ROA	0.00300	-0.00500	0.024*	0.040***	0.0140	-0.056***	-0.135***
Top1	0.042***	-0.142***	0.092***	-0.064***	-0.164***	0.067***	-0.030**
Age	0.064***	-0.095***	0.051***	0.00100	-0.146***	0.144***	0.065***
	ROA	Top1	Age				
ROA	1						
Top1	0.052***	1					
Age	-0.043***	-0.033**	1				

Collinearity Diagnosis

Before the hierarchical regression analysis, collinearity diagnosis was carried out on the sample data, and the results are shown in Table 4. The VIF of each variable is less than 2, and the mean VIF is far less than the reasonable value of 10, indicating that there is no multicollinearity problem among the variables, and regression analysis can be carried out.

Direct Effect Test and Intermediate Effect Test

The direct effect test is the premise and research basis of the intermediate effect test. Therefore, we first examine the direct effects of digital transformation on ESG performance. The test results are shown in Table 5. Column (1) shows that the regression coefficient α_1 between digital transformation

Table 4. Collinear diagnosis

Variables	VIF	1/VIF
DIG	1.07	0.933359
IT	1.06	0.942818
CI	1.10	0.906077
LA	1.31	0.763527
Size	2.09	0.478254
Lev	2.10	0.476428
ROA	1.03	0.974415
Top1	1.09	0.921293
Age	1.06	0.944204
Mean	1.32	

Table 5. Direct effect and intermediate effect test

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	ESG	IT	ESG	CI	ESG	LA	ESG
DIG	0.020*	0.136***	0.017	0.020***	0.018	4.000***	0.017
	(1.657)	(6.449)	(1.391)	(6.438)	(1.496)	(3.638)	(1.374)
IT			0.023**				
			(2.563)				
CI					0.097*		
					(1.672)		
LA							0.001***
							(2.716)
Size	0.251***	0.470***	0.240***	0.001	0.251***	-3.714***	0.254***
	(19.460)	(21.618)	(17.614)	(0.407)	(19.421)	(-6.436)	(19.598)
Lev	-0.209**	0.079	-0.211**	-0.197***	-0.190**	-44.552***	-0.171*
	(-2.193)	(0.512)	(-2.216)	(-7.837)	(-1.973)	(-7.098)	(-1.783)
ROA	-0.003	-0.020	-0.003	-0.004	-0.003	-5.444	0.001
	(-0.126)	(-0.494)	(-0.111)	(-0.611)	(-0.112)	(-0.659)	(0.039)
Top1	0.004***	0.004***	0.003***	0.001***	0.004***	-0.287***	0.004***
	(3.902)	(2.929)	(3.784)	(3.124)	(3.826)	(-8.083)	(4.146)
Age	0.036**	-0.087***	0.038**	0.011**	0.035*	-8.024***	0.043**
	(1.992)	(-2.646)	(2.101)	(2.270)	(1.930)	(-5.477)	(2.348)
_cons	-1.374***	-9.178***	-1.161***	-1.219***	-1.256***	149.439***	-1.500***
	(-4.431)	(-17.783)	(-3.581)	(-14.912)	(-3.943)	(10.989)	(-4.773)
Age	-0.163	-0.129	-0.166	0.0403	-0.161	0.000566	-0.164
	(-1.24)	(-0.78)	(-1.26)	(1.40)	(-1.22)	(0.17)	(-1.24)
year	Yes	Yes	Yes	Yes	Yes	Yes	Yes
industry	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	4862	4862	4862	4862	4862	4862	4862
r2	0.273	0.598	0.274	0.266	0.274	0.346	0.275
r2_a	0.268	0.595	0.269	0.261	0.268	0.341	0.269

Note: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$ indicates statistical significance; standard error in parentheses.

and enterprise ESG performance is 0.020, $p < 0.05$. The results show that the degree of digital transformation positively affects enterprise ESG performance, and hypothesis H1 is verified.

Based on the establishment of a direct effect, we examine the mediating effect between the degree of digital transformation and the ESG performance of enterprises. According to columns (2), (4) and (6), when $p < 0.001$, the degree of digital transformation has a positive impact on innovation and change capability, coordination and integration capability, and learning and absorption capability. Hypothesis H2 is preliminarily verified. The results in columns (3), (5) and (7) show that, based on the direct effect model, after controlling for the innovation and change capability, coordination and integration capability and learning and absorption capability of the intermediary variables, the regression

coefficient between the degree of digital transformation and ESG performance is significantly less than 0, and the degree to which the model variables explain is also improved. Therefore, the test results show that enterprise dynamic capability plays a partial mediating role between the degree of digital transformation and enterprise ESG performance, and hypothesis H2 can be basically tested.

To verify H2, this study adopts the stepwise mediation testing method proposed by Baron et al. (1986), Wen and Ye (2004), and the test steps for setting mediation variables are shown in Table 6.

The examination steps for the mediation variables are presented in Table 6. By incorporating the results from Table 5 into the examination steps, the mediation effects of dynamic capabilities are determined in Table 7. The results in Table 7 indicate that both Step 1 and Step 2 meet the criteria. In Step 3, where the degree of digital transformation, dynamic capabilities, and ESG performance are included in the same model and tested separately, the coefficients for dynamic capabilities are significant while the coefficients for the degree of digital transformation on ESG performance are both smaller than $\alpha 1$ and not significant. Therefore, it can be concluded that dynamic capabilities (innovative change capability, coordination and integration capability, learning and absorption capability) fully mediate the relationship between the degree of digital transformation and ESG performance, thus validating Hypothesis 2.

Endogeneity Test

Previous studies have suggested that there may be a reciprocal relationship between enterprise digital transformation and ESG performance, meaning that better ESG performance may lead to proactive digital transformation by companies, seeking better channels for innovation. To address endogeneity concerns, lagged one-period enterprise digital transformation is used as an instrumental variable in the two-stage least squares estimation. Considering the comprehensive impact of enterprise digital transformation on ESG performance, when companies formulate their digital transformation strategies, the driving effect takes some time to materialize. Therefore, a one-period lag is applied to enterprise digital transformation to further mitigate endogeneity interference. The specific results are shown in Table 8. In the first column, the regression coefficient of enterprise digital transformation is 0.0612 and significant at the 5% level, indicating a significant driving effect of enterprise digital transformation on ESG performance, and suggesting a stable relationship between the two. The results in the second column show a significant positive correlation between enterprise digital transformation and ESG performance. In conclusion, it can be robustly and reliably stated that enterprise digital transformation positively influences ESG performance.

Robustness Test

Replace the Explained Variable

Bloomberg is a well-known provider of global business, financial information, and economic news. It not only possesses a vast amount of corporate fundamental data but has also established unique

Table 6. Test steps of intermediate variables

Steps			Coefficient (Take β as an Example)	Establishment Condition
Step 1	Independent variable	Dependent variable	$\beta 1$	$\beta 1$ should be significant
Step 2	Independent variable	Intermediate variable	$\beta 2$	$\beta 2$ should be significant
Step 3	Independent variable Intermediate variable	Dependent variable	$\beta 3$ $\beta 4$	1. $\beta 4$ should be significant 2. $\beta 1 > \beta 3$ 3. When $\beta 3$ is not significant, it is completely mediating, while when $\beta 3$ is significant, it is partially mediating

Table 7. Test results of mediating effect of dynamic capability

Step	Explanatory Variable	Explained Variable		Coefficient	Establishment condition
Step 1	Independent variable	Dependent variable		α_1	α_1 should be significant
	Degree of digital transformation DIG	ESG performance		0.020*	DIG showed a positive and significant correlation with ESG
Step 2	Independent variable	Intermediate variable (Dynamic capability)		$\beta_1, \delta_1, \eta_1$	$\beta_1, \delta_1, \eta_1$ should be significant
	Degree of digital transformation DIG	Innovation and change ability IT		0.136***	DIG was positively correlated with IT, CI and LA
		Coordinate and integrate capabilities CI		0.020***	
		Learning absorptive capacity LA		4.000***	
Step 3	Independent variable	Intermediate variable	Dependent variable	coefficient	γ_2 should be significant; $\alpha_1 > \gamma_1$; If γ_1 is not significant, it is completely mediating, and if it is significant, it is partially mediating
	Degree of digital transformation DIG	Innovation and change ability IT	ESG performance	The coefficient of DIG: $\gamma_1 = 0.017$ The coefficient of IT: $\gamma_2 = 0.023^{**}$	γ_2 was significant, $\alpha_1 > \gamma_1$, γ_1 was not significant Innovation and change ability has complete mediating effect
	Independent variable	Intermediate variable	Dependent variable	coefficient	ζ_2 should be significant; $\alpha_1 > \zeta_1$; If ζ_1 is not significant, it is completely mediating, and if it is significant, it is partially mediating
	Degree of digital transformation DIG	Coordinate and integrate capabilities CI	ESG performance	The coefficient of DIG: $\zeta_1 = 0.018$ The coefficient of CI: $\zeta_2 = 0.097^*$	ζ_2 was significant, $\alpha_1 > \zeta_1$, ζ_1 was not significant Coordination and integration ability has complete mediating effect
	Independent variable	Intermediate variable	Dependent variable	coefficient	θ_2 should be significant; $\alpha_1 > \theta_1$; If θ_1 is not significant, it is completely mediating, and if it is significant, it is partially mediating
	Degree of digital transformation DIG	Learning absorptive capacity LA	ESG performance	The coefficient of DIG: $\theta_1 = 0.017$ The coefficient of LA: $\theta_2 = 0.001^{***}$	θ_2 was significant, $\alpha_1 > \theta_1$, θ_1 was not significant Learning absorptive capacity has a complete mediating effect

Note: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$ indicates statistical significance; standard error in parentheses.

Table 8. Endogeneity tests with a one-stage lag

Variables	(1)	(2)
	first stage	Second stage
	DIG	ESG
L.DIG	0.0612* (0.0248)	
DIG		0.0516** (0.0211)
Constant	-3.933* (0.5936)	5.502*** (0.078)

Note: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$ indicates statistical significance; standard error in parentheses.

models and methods for data processing. Bloomberg's ESG scores are based on a bottom-up, model-driven approach, primarily relying on publicly disclosed information from companies such as ESG

reports, CSR reports, annual filings, mandates, corporate governance reports, and company websites. The aim is to facilitate a transparent and parameterized scoring system. Bloomberg’s ESG disclosure score includes scores for environmental (E), social (S), and governance (G) factors, ranging from 0 to 100, with close to 100 being the best achievable score for a company. To enhance the credibility of the main effect in this study and make the research conclusion of this paper can be extended to different markets, this paper substitutes the dependent variable with Bloomberg’s database ESG rating data and incorporates it into Model (1). The coefficient is 0.490 with $p < 0.01$, supporting the robustness of hypothesis H1.

Replace the Core Explanatory Variable

To ensure the stability of the research conclusions, we refer to Wu et al. (2021) to replace the core explanatory variable DIG and select specific keywords representing the degree of enterprise digital transformation from the practical application of technologies such as artificial intelligence, internet, big data, blockchain, cloud computing, e-commerce, and intelligent manufacturing. Finally, the total word frequency statistics were calculated using Python. On this basis, the above data processing steps were repeated to obtain the replacement core explanatory variable data and perform a regression test, as shown in Table 9. Digital technology and digital technology application have a significant impact on the service innovation of advanced manufacturing enterprises, and the test results are still valid in the intermediary effect. Therefore, the regression results from replacing the core explanatory variables remain consistent with the previous results.

RESEARCH CONCLUSIONS AND POLICY RECOMMENDATIONS

Research Conclusion

Emerging digital changes, such as “artificial intelligence” and “big data”, provide a technical way to improve ESG performance and improve company value. At the same time, ESG performance

Table 9. Regression test results for replacing core explanatory variables

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	ESG	IT	ESG	CI	ESG	LA	ESG
DIG1	0.0475*	0.00830*	0.0475*	6.421 *	0.0480*	-0.402*	0.0475*
	(2.32)	(0.36)	(2.33)	(1.30)	(2.35)	(-0.79)	(2.32)
IT			-0.00603				
			(-0.38)				
CI					-0.0000886		
					(-1.18)		
LA							-0.00000736
							(-0.01)
_cons	4.823***	2.838***	4.840***	489.3**	4.867***	27.25	4.823***
	(7.72)	(3.99)	(7.72)	(3.23)	(7.77)	(1.75)	(7.71)
year re	Yes	Yes	Yes	Yes	Yes	Yes	Yes
industry re	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	3972	3972	3972	3972	3972	3972	3972

Note: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$ indicates statistical significance; standard error in parentheses.

can improve enterprise value by winning financial support from stakeholders and promoting green innovation. We draw the following conclusions. (1) Digital transformation can improve enterprise ESG performance. We study the relationship between digital transformation and enterprise ESG performance by establishing a regression model. The conclusion is that digital transformation can significantly improve enterprise ESG performance. In the face of uncertainty and change, digital transformation not only enables enterprises to adapt and respond quickly but also maintains business continuity and stability. (2) Dynamic capabilities play a mediating role. Based on the theory of dynamic capabilities, we construct a mediation model to explore the relationship between dynamic capabilities and enterprise ESG performance in digital transformation. For digital transformation, dynamic capability and ESG performance are simultaneously included in the regression model, and the following conclusions are drawn according to the empirical test results: Digital transformation can improve the dynamic capability of enterprises, further promoting improvements in enterprise ESG performance, and dynamic capability plays a mediating role between digital transformation and ESG performance.

Policy Recommendations

Policy Recommendations at the Government and Regulatory Agency Levels

First, the government should actively create an institutional environment to help enterprises with digital transformation and give them effective guidance and incentives. For example, through the introduction of relevant preferential policies, certain subsidies and tax incentives are given to enterprises undergoing digital transformation to reduce the cost of enterprise transformation. Simultaneously, relevant policies and supporting measures are formulated and improved to further enhance the willingness of enterprises to carry out digital transformation. Second, it is necessary to provide positive guidance to enterprises' digital transformation and issue relevant policies to escort traditional enterprises through their digital transformation. In addition, government departments can accelerate and promote the digital transformation of enterprises by formulating special plans and strategies for such transformation to optimize production modes, operation modes and governance systems of enterprises as a whole. Third, in the process of promoting digital transformation in the company, each department should attach importance to the company's own digital capabilities and provide better management support for the company's relevant matters. During this process, relevant staff should go deep into the enterprise, strengthen communication with the enterprise, understand the characteristics of each enterprise and the difficulties of digital transformation, and provide targeted help. Creating a good external environment is necessary for enterprises to implement digital transformation, strengthen the construction of big data platforms and sharing factories, reduce financing costs and taxes during the development of their digital transformation, and guide the development of this transformation. Relevant departments can promote improvements in enterprises' ESG performance through both rewards and punishments. The reward measures include increasing bank credit, reducing taxes and fees, and increasing government subsidies. The punishment measures include inclusion in the negative list, administrative penalties, and reducing the scale of loans. At the same time, relevant departments should also establish a comparable and comprehensive ESG rating system based on the current various ESG rating methods and the specific situation in China to force enterprises to enhance their understanding of ESG responsibilities and improve ESG performance.

Policy Recommendations at the Financial Institution Level

Banks and other financial institutions should strongly support enterprises in improving their ESG performance and development of digital transformation. First, for enterprises adhering to the ESG development concept and undergoing digital transformation, banks and other financial institutions should provide credit support, reduce the financing constraints and financing costs of these enterprises, and play the guiding role of financial intermediaries in sustainable development.

Furthermore, it is necessary to deepen the development of digital finance, promote the implementation of digital finance projects, and better serve the real economy to stimulate vitality in entities. Traditional finance should embrace the development of digital technology in a more open manner, strengthen and improve infrastructure construction such as big data and cloud computing, and deepen their integration with the financial sector. On one hand, by promoting digitization in the financial sector, it is possible to meet the financing needs of enterprises as much as possible and provide more small and medium-sized enterprises with funds for ESG development and technological research. On the other hand, utilizing digital technology can help identify promising enterprises and achieve precise fund allocation since these enterprises often possess more vitality and focus on technological research and development. This way, the effects of financial support and technological assistance can better contribute to ESG development in companies.

Moreover, it is important to create a favorable financing environment for ESG development in companies. The securities market should place greater emphasis on ESG report disclosure systems, strengthen supervision over ESG report disclosure, promote the improvement and development of ESG investment concepts. This will enhance companies' subjective willingness to engage in ESG initiatives and enable the development of digital finance to better support ESG development through financial support and technological assistance, thereby enhancing overall ESG performance.

Last, supportive financing policies related to ESG should be formulated reasonably. Particularly for non-state-owned enterprises, financing projects and channels corresponding to environmental governance, social responsibility commitments, and internal governance should be introduced to provide targeted support for ESG development in companies. At the same time, it is important to improve tracking and supervision systems for relevant financing projects to avoid issues such as misallocation or misuse of funds.

Policy Recommendations at the Corporate Level

The first recommendation is to accelerate the company's digital transformation and promote the deep integration of digital technology into the real economy. In the context of "digital power," digital transformation has become an important standard for measuring whether a company can develop rapidly. The data show that in the digital transformation process, physical enterprises are the main battlefield in which manufacturing is the foundation and industrial integration is the core. Manufacturing enterprises should use their own industry characteristics as the basis, make full use of the digital dividend, and accelerate the digital transformation process. The enterprise's products and services should be optimized through comprehensive coverage, enabling digitalization to penetrate into all areas of the enterprise. Problems arising in the transformation process should be actively addressed. Enterprises can learn from each other and actively promote the digital transformation of the manufacturing industry in a deeper and broader way to improve their performance.

Second, investments in innovative research and development should be increased to enhance the company's competitiveness. When achieving digital transformation, R&D and innovation investment are critical factors and important measures for promoting the high-quality development of the manufacturing industry. Therefore, it is necessary to increase R&D investments, conduct regular training for researchers, introduce technical talents to comply with trends in digital development, and improve innovation efficiency. Given the continuous progress of open automation, open source design, and automation systems that are easier to implement and are more flexible, digital innovation has provided manufacturing companies with a better user experience. Digitalization provides companies with more innovation opportunities and simultaneously brings new challenges. Manufacturing enterprises should actively respond, break down barriers, improve reforms and innovation capabilities, and rank at the forefront of high-quality development.

Third, enterprises should strengthen their awareness of energy conservation, emission reduction, and green innovation; purchase pollution control equipment; vigorously invest in green innovation projects; actively build a green supply chain; strengthen information disclosure in green development;

and embark on the path of green transformation and development. In terms of corporate governance, it is necessary to optimize the management system, improve the company's operational efficiency, increase the size of the board of directors and the equity concentration, strengthen the functions of the board of directors, improve the risk management mechanism, and strengthen the internal control and supervision. At the same time, enterprises should accelerate the digital transformation process and the application and innovation of digital technology in various aspects of marketing, management, production, and operation. Enterprises should also strengthen the construction of the information infrastructure, create an efficient information sharing platform, and achieve efficient transmission and communication of information. On this basis, enterprises should explore the path of digital transformation to transform the traditional production mode, close the distance between them and employees and consumers with the help of digital technology, optimize production processes and business methods according to their own production and customer needs, improve enterprise performance, and then enhance their values.

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