

Corporate Digital Transformation and Environmental Performance--Based on the Mediating Role of Internal Control

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Abstract: Ensuring harmony between economic growth and ecological preservation is an undeniable societal responsibility for companies. The widespread incorporation of digital technology has had a profound effect on their green strategies, making it imperative to explore ways to enhance their green performance. By analyzing data from Chinese A-share listed companies from 2013 to 2022, this study provides insights into the effects of enterprise digital progress on environmental performance. Our research findings indicate that a higher level of corporate digital transformation is linked with better environmental performance. Digital transformation boosts environmental performance By enhancing the standard of corporate internal control. Notably, this improvement effect is more evident in non-state-owned enterprises compared to state-owned enterprises, and it is even more significant in high-carbon-emitting enterprises than in those with lower carbon emissions. Additionally, media attention serves as a beneficial mediator in boosting the impact of digital transformation on environmental performance. This paper furnishes empirical evidence supporting the advancement of industrial digital transformation and the active improvement of corporate internal control quality as means to elevate green performance. These discoveries contribute to advancing the comprehension of how digital technology can facilitate more sustainable business practices.

Keywords: digital transformation, environmental performance, internal control, media attention

1. Introduction

With the deepening international climate crisis, environmental governance has become a pivotal problem in economic development of each nation. Enterprises, as the core body of economic activities, have a direct influence on society's sustainable development. Over the past many years, China's mode of high-grade growth has led to enterprises overreliance on resource consumption and a 'high energy consumption and high emission' vicious cycle. Digital transformation, as one of the biggest innovation paths, can promote economic benefit while factoring in environmental benefits in the process through technological innovation and transformation. Therefore, exploring how digital transformation contributes to environmental performance is of extreme practical relevance as well as value in terms of theoretical findings and presents a novel perspective for advocating green transformation.

Digital transformation has been a prominent trend across all industries in recently due to the extensive usage of digital technologies like cloud computing, big data, and artificial intelligence. Digital transformation is transforming the production pattern of firms, which is widely believed to be the master key to the solution of the environmental governance puzzle. According to some studies, it is demonstrated that not only can digital technology promote the sustainability by enhancing the efficiency of resource allocation [1], but also facilitate green technological innovation and allow enterprises to pursue a greener and more sustainable production mode [2]. In this context, the influence of corporate digital transformation on ecological sustainability remains a significant area requiring in-depth exploration.

Therefore, does the digital transformation of enterprises enhance environmental performance? Once this effect is verified, what underlying mechanisms drive it? How do the characteristics of individual firms influence the effect of their digital transformation on sustainability? While existing research has concentrated on the immediate environmental consequences of digital transformation, like optimizing resource distribution and decreasing energy use and emissions, the specific mechanisms at play remain largely unexplored. Regarding transmission mechanisms, the current body of literature linking digital transformation to environmental performance predominantly examines exogenous factors, such as technological advancements and supply chain coordination [3]. [4], relatively neglecting the mediating role of the internal governance system of organisations. Internal control, as the core framework of enterprise risk management, enhances the degree of intelligence and automation of the enterprise internal control system through information technology in the digitalisation process, thus helping enterprises to better monitor and manage the use of resources, reduce environmental risks, and promote the sustainability [5]. Therefore, the mechanism of the role of internal control quality under digital transformation deserves further study.

The following are the marginal contributions of this paper: (1) The study enriches the exploration of the mechanism. Enterprise digital transformation influences environmental performance by revealing the intermediary role of internal control. While existing literature primarily emphasizes the direct technical impact of digital transformation on environmental performance, this study incorporates the quality of internal control into the analysis of the mediation process. (2) It not only focusing on internal control, but also exploring the role of external supervision, and the moderating role of media attention between digital transformation and environmental transformation, the internal and external dual perspective expands the analytical framework of the study of corporate environmental performance. (3) Practically, it serves as a valuable instrument for crafting digital support policies and refining enterprises' green transformation pathways. This is particularly enlightening for the sustainable progression of high-carbon emitting corporate and non-state-owned corporate.

2. Theoretical analysis and research hypotheses

2.1. Digital transformation and environmental performance

Digital transformation activates the innovation potential within enterprises and strongly promotes green technological innovation. Digital transformation refers to the deployment and application of technology by enterprises to carry out all-round and systematic changes to their business models, organisational structures, and operational processes, while technological innovation is an important force driving the development of enterprises and society. Digital transformation changes the business model, organisational structure and value creation of enterprises by integrating digital technologies, thus significantly enhancing the innovation ability and efficiency of enterprises [6]. Green technology innovation, as a direct driving force to enhance corporate environmental performance, covers a wide range of fields from efficient pollution control technologies to renewable energy utilisation

technologies [7]. By developing and applying these green technologies, enterprises can effectively mitigate adverse effects of production activities on the environment.

Digitalization has the capacity to optimize use of enterprise resources and facilitate green production. Digital condition enables the realization of intensive management of production process through assistance of big data analysis as well as technology of artificial intelligence. The potential exists for digital transformation to augment enterprise green total factor productivity on a large scale, and this mainly takes place by means of modes such as propagation of green investment, improvement in the efficiency of management and growing green innovation power [8]. By making accurate market demand forecasts, companies can pragmatically plan their production to avoid squandering of resources and environmental pollution through excessive production. Through the support of digital technology, companies can choose environmentally friendly options to reduce the creation of pollutants at its origin and improve resource utilization efficiency [9].

In the perspective of resource-based theory, the competitive strength of businesses comes from the combination of resources and capabilities [10]. The digitalization of businesses has ushered in a series of highly valuable digital resources to businesses, and these resources are an entirely new force to promote the green development of businesses. By deeply mining and analysing huge amounts of accurate data, enterprises can optimize production processes in a targeted manner, precisely adjust resource inputs, and significantly reduce pollutant emissions [11]. Transaction cost theory states that the economic activities of enterprises will generate transaction costs [12], and digital transformation can reduce these costs. During the green development of enterprises, digital transformation has the capability to decrease expenses associated with obtaining environmental information, the communication cost of cooperation with external parties, and so on. Digitalisation enables enterprises to obtain environmental information more efficiently, break through the limitations of traditional information collection, and avoid resource waste and environmental problems caused by information asymmetry [13].

Building on the above analysis, this paper proposes research hypothesis 1: digital transformation prompts enterprises to improve environmental performance

2.2. The intermediary role of internal control

Internal control, as an important mechanism of corporate internal governance, aims to ensure the compliance of the enterprise's operating activities, the safety of its assets and the dependability of its financial reports. The optimisation of corporate internal control helps to reduce operational risks, improve management efficiency and ensure the implementation of environmental protection measures, thus promoting green performance.

On the one hand, internal control provides institutional assurance for the digital transformation of firms and enhances the transparency and accuracy of enterprises in environmental management. A well internal control system can clarify the duties and powers of each department of the enterprise in digital transformation and ensure the orderly progress of digital transformation [14]. Utilizing the internal control framework as a foundation, enterprises can set specific green performance targets and incorporate them into digital transformation strategic planning. Through internal control's monitoring and evaluation functions, enterprises can ensure that the operations in the digital transformation process meet the demands of green development.

On the other hand, internal control can enhance the enterprise's ability to manage environmental risks in the process of digital transformation and stabilise sustainability performance. Although digital transformation brings many opportunities for enterprises, it is also accompanied by new risks, such as data security risks and technology application risks [15]. These risks may affect the stability of an enterprise's green performance. A perfect internal control system can effectively identify, assess and respond to the environmental risks during the digital transformation process [16]. Through the

establishment of risk early warning mechanisms and contingency plans, enterprises can identify and deal with risk events that may affect green performance promptly, and safeguard the sustainability of the enterprise's sustainable development [17].

Building on the above analysis, this paper proposes research hypothesis 2: Enterprise internal control plays a mediating role between digital transformation and green performance.

3. Research design

3.1. Data source and processing

This paper selects Chinese A-share listed companies as samples over the period from 2013 to 2022 and applies the following procedures: (1) companies operating in the financial and real estate sectors are excluded. (2) samples with ST and PT statuses are excluded. (3) samples containing significant missing data are removed; (4) to mitigate the impact of extreme values, the main continuous variables involved shrinking at the 1 per cent and 99 per cent levels (Winsorize) treatment. After the above screening, 6,495 research samples were finally obtained. The data is sourced from CSMAR database and annual reports of relevant enterprises.

3.2. Model setting

With the aim of test the effect of corporate digitalisation on environmental performance, the following econometric model is set up:

$$EP_{i,t} = \beta_0 + \beta_1 DIG_{i,t} + \beta_2 Controls_{i,t} + Ind_k + Year_t + \varepsilon_{i,k,t} \quad (1)$$

The subscripts i and t represent the enterprise and time separately. $EP_{i,t}$ denotes the explanatory variable environmental performance, $DIG_{i,t}$ is the explanatory variable enterprise digital transformation degree, and $controls_{i,t}$ denotes an array of control variables. ind_k and $year$ denote the enterprise fixed effect and year fixed effect respectively, and $\varepsilon_{i,k,t}$ is a random perturbation term.

In order to test the mediating role of enterprise internal control, this paper sets up the following mediating effect model:

$$IC_{i,t} = \alpha_1 DIG_{i,t} + \alpha_2 Controls_{i,t} + Ind_k + Year_t + \varepsilon_{i,k,t} \quad (2)$$

$$EP_{i,t} = \varphi_0 + \varphi_1 DIG_{i,t} + \varphi_2 IC_{i,t} + \varphi_3 Controls_{i,t} + Ind_k + Year_t + \varepsilon_{i,k,t} \quad (3)$$

where $IC_{i,t}$ denotes the quality of corporate internal control. If α_1 and φ_2 are significant, it suggests that the mediation effect of enterprise internal control is established. On this basis, if φ_1 is significant, it indicates that there is partial mediation effect of enterprise internal control, otherwise it is full mediation effect.

3.3. Definition of variables

(1) Enterprise digital transformation (DIG). The present article tallies the keywords pertaining to digitalization found in the annual reports of listed companies. More precisely, the keywords associated with enterprise digitalization are delineated based on the following five facets: technology in artificial intelligence, big data, blockchain, cloud computing, and digital technology, and the statistics of keyword frequency in each aspect are calculated using Python, and the total word frequency is summed up finally [18]. Given the 'right-biased' nature of the data, the paper adopts the logarithmically processed total word frequency as the measurement index for enterprise digital transformation. Furthermore, the disclosure counts of keywords across four domains—digital technology application, Internet business models, intelligent manufacturing, and modern information

statistics—has been standardized [19]. To ascertain the weights of each index, the entropy method was employed, culminating in the derivation of the digital transformation index for robustness testing.

(2) Environmental performance (EP). This paper adopts the environmental score in the CSI ESG rating to measure environmental performance, specifically, the constituents of the CSI 300 Index are evaluated on their ESG performance, which is categorized into nine grades ranging from C to AAA and these grades are sequentially assigned scores from 1 to 9, respectively.

(3) Internal control (IC). To gauge the quality of internal control for listed companies, it employs the natural logarithm of the Dibble database's internal control index (ICI), incremented by 1. A higher IC value indicates superior internal control quality for the company.

(4) Control variables. This paper controls the key variables affecting enterprise digital transformation as much as possible based on existing research. The control variables include: enterprise size, gearing ratio, profitability, equity concentration, enterprise age, and cash flow ratio.

3.4. Descriptive statistics

Table 1 presents the statistical attributes of the key variables for listed companies. One can observe that the average value of environmental performance stands at 60.743., the maximum value is 45.760, and the minimum value is 80.310, which means that there are some differences in the environmental performance of firms; the mean value of the degree of digital transformation (logarithmic value) is 1.267, and the standard deviation is 1.242. All other control variables possess values that fall within an acceptable range.

Table 1: Descriptive statistics of main variables of listed companies

Variable	Mean	Sd	Min	Max
EP	60.743	6.806	45.760	80.310
DIG	1.267	1.242	0	5.011
Size	22.410	1.206	20.240	26.050
Lev	0.428	0.196	0.068	0.892
Top	0.335	0.142	0.088	0.708
Roa	0.038	0.064	-0.209	0.220
Age	2.989	0.315	2.079	3.555
Cashflow	0.051	0.067	-0.144	0.248
IC	2673	1567	1	5453

4. Analysis of empirical results

4.1. Benchmark regression results

Table 2 reports the results of the regression of the level of climate risk disclosure and stock price volatility. Column (1) does not control for time fixed effects, industry fixed effects, and control variables, column (2) incorporates time fixed effects and industry fixed effects, and column (3) incorporates control variables on top of that. The regression coefficients of enterprise digital transformation are 0.786, 0.621, and 0.307, respectively, which pass the 1% significance test. Digital transformation of enterprises has a positive impact on environmental performance and research hypothesis 1 was tested. The feasible explanation is that digital transformation can effectively break through the technical bottlenecks and synergy barriers of the traditional environmental governance model, improve energy utilisation, effectively control pollution sources, and at the same time lead to a reduction in the level of carbon emissions in the whole chain, thus promoting the improvement of green performance.

Table 2: The impact of enterprise digital transformation on carbon emissions

	EP		
	(1)	(2)	(3)
DIG	0.786*** (0.067)	0.621*** (0.075)	0.307*** (0.074)
Controls		Yes	
Ind	No	Yes	Yes
Year	No	Yes	Yes
N	6495	6495	6495
R ²	0.021	0.165	0.223

4.2. Robustness tests

To guarantee the dependability of the conclusions, this paper undertakes the subsequent robustness tests. (1) Replacement of explanatory variables. Substitution of explanatory variables. Utilizing an alternative standard metric for digital transformation keywords, this paper derives a replacement digital transformation index to gauge the extent of digital transformation. As depicted in Column (1) of Table 3, the coefficient for digital transformation is positive at the 1% significance level, aligning with the benchmark regression results, which suggests that a higher degree of digital transformation in enterprises leads to enhanced environmental performance. (2) Lagged one-period digital transformation. In order to address the endogeneity issue arising from reverse causality, this paper employs a one-period lagged regression for digital transformation. As illustrated in Column (2) of Table 3, the impact of digital transformation on environmental performance remains significant at the 1% level, thereby confirming the core conclusion of this paper. (3) Inclusion of control variables. In order to reduce the error caused by omitted variables, drawing on previous literature, this paper adds new corporate governance level control variables Board size and Dual, on the basis of which the impact of corporate digital transformation on environmental performance is examined. Column (3) of Table 3 reports the regression results after the addition of control variables, and the digital transformation coefficient is 0.321, which is significant at 1% and consistent considering the benchmark regression outcomes.

Table 3: Robustness tests

	EP		
	(1)	(2)	(3)
DIG	0.307*** (0.074)		0.321*** (0.074)
L_DIG		0.315*** (0.085)	
Controls		Yes	
Ind		Yes	
Year		Yes	
N	6495	6495	6495
R ²	0.506	0.225	0.224

4.3. Mediating effects

This study aims to investigate how firms' digital transformation impacts their environmental performance by examining the intermediary role of internal control mechanisms. Column (1) of Table

4 presents the baseline regression, incorporating control variables and fixed effects. Column (2) reveals a significantly positive coefficient of 35.46 for digital transformation at the 5% level, suggesting a notable positive impact of digital transformation on firms' internal control. Column (3) introduces firms' internal control into the benchmark regression model, showing that the coefficient for digital transformation stands at 0.307, but when internal control is introduced into the model, this coefficient decreases to 0.303, a value that remains positive and significant at the 1% level. Consequently, it becomes evident that internal control plays a partial mediating role in the relationship between digital transformation and green performance, implying that digital transformation boosts green sustainability by strengthening internal control, thereby confirming Hypothesis 2.

Table 4: Mediation effect test

	(1)	(2)	(3)
	EP	IC	EP
DIG	0.008*** (0.000)	35.46** (16.59)	0.303*** (0.0735)
IC			0.001* (0.000)
Controls		Yes	
Ind		Yes	
Year		Yes	
N	6495	6495	6495
R ²	0.223	0.254	0.216

4.4. Heterogeneity analysis

4.4.1. Heterogeneity analysis based on enterprise ownership type

This paper regresses the sample data separately for state-owned enterprises and non-state-owned enterprises, taking into account their respective ownership types. Columns (1) and (2) of Table 5 show the estimated results of the impact of digital transformation on environmental performance for enterprises with different ownership natures. The coefficient estimate for digital transformation among state-owned companies is 0.299, which is significant at the 5% level. In contrast, private enterprises exhibit a coefficient estimate of 0.342, significant at the 1% level. This underscores the varying impacts of digital transformation on the environmental performance of enterprises with differing ownership structures. Notably, non-state-owned enterprises show a more significant effect of digital transformation on their environmental performance. The reason could be that private enterprises confront greater market competition., and therefore more actively use digital technology to optimise their production processes in the course of digital transformation to significantly improve environmental performance. Besides, state-owned enterprises have relatively complex decision-making processes and are subject to institutional and other constraints, and although they can also improve environmental performance through digital transformation, they do not do so to the same extent as non-state-owned enterprises.

4.4.2. Heterogeneity analysis based on the industry to which the enterprise belongs to

To investigate whether the influence of enterprise digital transformation on environmental performance varies between highly polluting and non-highly polluting enterprises, this paper refers to the secondary industry classification division outlined in the 2012 Guidelines for Industry Classification of Listed Companies, amended by the China Securities Regulatory Commission, which

categorizes heavily polluting industries. Table 8, Columns (3) and (4), present the impact of a firm's classification as highly polluting on the correlation between digital transformation and environmental performance. The coefficient estimates indicate that for highly polluting firms, the coefficient for digital transformation is 0.445, and for non-highly polluting firms, it is 0.259, both of which are statistically significant at the 1% level. Chow's test shows that the coefficients are significantly different between groups. The possible reason for this result is that high-polluting firms are facing stricter environmental regulation and pressure from public opinion, and digital transformation has become a key way to break through the environmental dilemma. In addition, high-pollution enterprises usually have larger business scale and complex production process, the scale effect brought by digital transformation is more significant, and the integration of industrial chain through digitalisation can effectively reduce the waste of resources.

Table 5: Heterogeneity analysis

	EP			
	(1)	(2)	(3)	(4)
	SOEs	Non-SOEs	Heavy Pollution	Non-Heavy Pollution
DIG	0.299** (0.132)	0.342*** (0.090)	0.445*** (0.167)	0.259*** (0.082)
Controls			Yes	
Ind			Yes	
Year			Yes	
ChowTest		2.93 ***		2.07 ***
N	6495	6495	6495	6495
R ²	0.261	0.231	0.197	0.247

5. Further discussion

To uncover how corporate digital transformation contributes to improving environmental performance, this paper examines the moderating role played by media attention in digital transformation for environmental performance enhancement. Media attention measures the degree of exposure and level of attention a company receives on media platforms. Drawing on existing literature, The following econometric model is developed to examine the moderating effect of media attention:

$$EP_{i,t} = \lambda_0 + \lambda_1 DIG_{i,t} + \lambda_2 Media + \lambda_3 Media * DIG + \lambda_4 Controls_{i,t} + Ind_k + Year_t + \varepsilon_{i,k,t} \quad (4)$$

where $Media_{i,t}$ denotes the moderating variables, and the rest of the variables are set the same as in equation (1). In this paper, we calculate the natural logarithm of the aggregate number of reports from online media and newspapers after adding 1 to measure media attention [20]. If the coefficients λ_2 and λ_3 in equation (4) are significant, it indicates that the $Media_{i,t}$ variable moderates the relationship between digital transformation and green performance.

Column (1) of Table 6 demonstrates that media attention positively moderates the connection between firms' digital transformation and their green performance, reaching statistical significance at the 1% level. As media attention intensifies, the positive impact of corporate digital transformation on green performance becomes more pronounced. This positive moderation effect can be theoretically justified through the dual lens of stakeholder theory and signalling theory. Stakeholder theory points out that the media, as an important subject of social supervision, its continuous attention essentially constitutes a source of institutional pressure to which enterprises must respond [21]. When media exposure increases, the environmental behaviour of enterprises will be exposed to wider social supervision, and this 'visibility pressure' will strengthen the intrinsic motivation of enterprises to

implement green innovation through digital transformation, prompting them to more systematically apply digital technology to pollution monitoring, energy optimization and other environmental management scenarios. Signal transmission theory shows that the ‘information amplification effect’ formed by high media attention can enhance the signal display function of enterprises' green technology application [22], so that the ecological benefits brought by digital transformation can be more easily recognised by investors, consumers and other stakeholders, and then form a positive feedback mechanism in the market. Under this dual role, enterprises will increase the substantive input of digital technology to environmental governance, and strengthen the role of enterprise digital transformation in promoting green performance.

Table 6: Moderating effects test

	EP	
	(1)	(2)
DIG	0.288*** (0.075)	0.281*** (0.075)
Media	0.273*** (0.0985)	0.224** (0.099)
Media*DIG		0.170*** (0.048)
Controls		Yes
Ind		Yes
Year		Yes
N	6495	6495
R ²	0.227	0.228

6. Conclusions and implications

As the digital economy grows, Chinese enterprises are embarking on a significant phase of digital transformation, presenting an opportunity to enhance their environmental performance. This paper establishes a theoretical framework to analyze the influence of corporate digital transformation on environmental performance and empirically tests it using data from listed Chinese companies. The results reveal that digital transformation positively affects companies' environmental performance, with internal control quality partially mediating and external media attention positively moderating these effects. Further heterogeneity analysis shows that private enterprises and highly polluting firms experience more significant improvements in environmental performance through digital transformation. The discoveries of this research offer the following policy insights for promoting enterprise digital transformation and enhancing environmental performance: (1) Promote deep integration of enterprise digital transformation and green performance. The government need to increase its support for digital transformation, i.e., green technology and sustainable development, through policy promotion and financial support, in order to enable enterprises to adopt sustainable production modes in digital transformation, in order to attain a mutually beneficial outcome in terms of both economic and environmental benefits. (2) Enhance the quality of control from the inside and strengthen social supervision from the outside. Therefore, firms should strengthen the internal system, and the public opinion supervision on the environmental protection behaviour of enterprises should be strengthened in the external environment. (3) Provide differentiated support for green performance improvement according to enterprise characteristics. For non-state-owned, highly-polluting enterprises, the focus should be on promoting the introduction as well as upgrading of green

technologies, so that enterprises can enhance resource utilisation efficiency and achieve sustainable goals through digital means.

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