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Mechanisms of the Impact of Digital Transformation on Corporate Sustainability Performance

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Abstract: Under the "dual-carbon" strategic framework, corporate digitalization emerges as a pivotal driver for advancing sustainable development and facilitating high-quality economic and social development. This investigation employs a dataset of Chinese A-share listed companies (2014-2023) to systematically examine the mechanism through which digital transformation enhances sustainability. The empirical analysis found that digital transition elevates sustainable development outcomes through dual mediation pathways: green technological innovation and greening transformation. Specifically, digital transformation fosters the development and adoption of green technologies and promotes organizational and operational changes, which in turn enhance sustainability performance. Heterogeneity analysis reveals significant differential impacts that digital transformation exerts a greater dominant effect on the sustainability performance of state-owned firms, heavily polluting industry firms, and those in the central and western regions. These findings provide empirical evidence for optimizing digital transformation pathways, theoretical references for the implementation of sustainable development strategies, and actionable insights for enterprises to achieve carbon neutrality through technological innovation and green transformation.

Keywords: digital transformation, sustainability performance, green technology innovation, greening transformation

1. Introduction

Amid escalating global environmental degradation and heightened ecological crises, China's ambitious targets of "reaching carbon peak by 2030 and attaining carbon neutrality by 2060" represent a pivotal strategy not only for fostering high-quality domestic development but also for demonstrating its commitment to global sustainable development. Enterprises, as the primary actors in achieving these "dual carbon" objectives, play a crucial role, making their sustainable development strategies immensely significant. The performance in sustainable development serves as a comprehensive metric to evaluate the sustainability progress of these enterprises.[1].

As digital technology develops rapidly, digital economy has emerged as a pivotal engine for economic advancement. In the 14th Five-Year Plan period, digital transition has been clearly defined as a national strategic task, and has become an important direction for enterprises to change in the future. By optimizing resource allocation, promoting technological innovation, and improving operations, digital transformation enhances the economic performance while affecting environmental performance, providing new opportunities for sustainable development.

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China is accelerating green technological innovation, promoting the greening transformation, and providing technological support for building a beautiful China. Green technological Innovation is a vital route to achieve sustainability for corporations, an increasingly critical force for transforming the mode of economic development. Greening transformation requires enterprises to reduce resource consumption and negative impact on the environment while output growth[2], which is an inevitable choice for green development. Active green innovation practices and green transformation in business contribute to higher sustainability performance.

So, what is the impact of digital transition on sustainability performance? Can it increase the sustainability outcomes by driving green technology innovation and facilitating greening transformation? To address these questions, this study examines the effectiveness of digital transformation in improving sustainability performance and the mediating effects of green technology innovation and greening transformation, leveraging data from listed companies spanning 2014 to 2023.

This paper represents a contribution to the existing literature in several areas: first, it positions digital transformation as the central focus, examining its relationship with sustainability outcomes, while highlighting variations across ownership structures, industrial sectors, and geographic locations. Second, the research elucidates the dual-channel mechanism through which technological adoption influences sustainable development metrics. By empirically validating the mediating roles of innovation capabilities and environmental transition processes, the study provides a new research perspective on the complex link between digital transformation and sustainability performance enhancement.

2. Theoretical framework and hypothesis development

2.1. Digital transition and sustainability

Digital transition is a phenomenon of strategic upgrading under the premise of technology development, in order to obtain long-term performance improvement. Contemporary research frameworks analyze this evolution through three dimensions of economic efficiency, environmental enhancement, and their reciprocal reinforcement mechanisms.

From an economic perspective, digital adoption drives financial optimization through dual operational levers: cost savings and productivity improvements. Study proved that many enterprises prioritize digital transformation, and this transformation initiative can enhance enterprise performance and promote them to be competitive in the market[3].Research shows that Digital transformation promotes collaborative innovation among all elements of manufacturing enterprises by reducing costs, improving human capital efficiency and promoting technological innovation, while empowering R&D, production, sales and other links through technologies such as AI, IoT, and big data to improve financial performance in all aspects[4].

The environmental dimension manifests through promotion of utilization efficiency of resources and the environmental performance. The empirical study shows that digital transformation facilitates greening by introducing digital technologies to replace traditional elements and enables precise decision-making to reduce pollutant emissions from production, thus improving environmental performance[5]. Scholars believe that digital technology empowers supervision, improving environmental management and preventing environmental risks by using information acquisition and violation warning; in addition, digital technology optimizes internal and external environmental communication, enhances information transfer efficiency, reduces information asymmetry, and thus improves environmental performance[6].

Some studies point out that digital transformation facilitates the balancing of economic and environmental objectives. The study of scholars proves that digital transformation improves financial

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and environmental performance, especially for environmental performance, and becomes a key force to realize the win-win situation between economy and environment[7]. Recent empirical research by scholars demonstrates that digital transformation improves the total factor productivity and ESG performance by enhancing the innovation capacity and human resource allocation efficiency. Furthermore, the study identifies critical moderators, showing that the developmental impact of digital adoption is amplified in a favourable business environment and marketization process[8].

In view of the preceding analysis, the following hypotheses are formulated:

H1: Digital transformation improves business sustainability performance.

2.2. The mediating role of green technology innovation

Digital transformation significantly enhances sustainability performance by facilitating eco-friendly technological advancements. This technological shift empowers organizations to achieve innovative technological breakthroughs while accelerating the development and implementation of sustainable solutions. The research shows that digital transition enhances production efficiency and resource utilization efficiency by optimizing human capital structure, strengthening market expectations, improving corporate governance, and with the help of information circulation and public opinion supervision, prompts enterprises to increase green investment, which effectively promotes green technology innovation[9]. Scholars pointed out that the improvement of infrastructure development, application implementation and digital development level can promote the efficient sharing of information, enhance information transparency, optimize resource allocation efficiency and technological innovation rates, and create favorable conditions for sustainable technological breakthroughs[10].

Promoting green technology innovation can help to enhance the implementation of sustainable development strategies. The research shows that green technology innovation improves growth efficiency and reduces environmental pollution, and is an endogenous source of sustainable economic growth and green transformation of industries[11]. Through green technology innovation, enterprises are able to increase market share and economic efficiency while reducing pollution emissions and enhancing environmental performance. Scholars analyzed that enterprises use clean energy to reduce pollution at the source, and end-of-pipe pollution control technologies can minimize the adverse impact on the environment, and from a financial perspective, green technology innovation can reduce production costs, and a good green reputation can win the trust of consumers and promote the growth of financial performance[12].

In view of the preceding analysis, the following hypotheses are formulated:

H2: Green technology innovation mediates between digital transformation and sustainability performance.

2.3. The mediating role of the greening transition

The adoption of digital technologies serves as a powerful catalyst for corporations to green their transformation and boost their economic and environmental results. Digital transformation brings new opportunities for enterprise greening transformation. The empirical study shows that digital transformation has led to increased supervision of enterprises, prompting them to boost the willingness of green transformation. It also improves the information environment and optimizes resource allocation while easing financing constraints and acquiring resources for green transformation. It can also promote the intelligence of production and improve the capacity for green transformation. Scholars empirically found that digital technology characterized by technological sophistication and minimal environmental costs, improves production efficiency and facilitates a

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paradigm shift from traditional high-pollution practices to low-carbon operational models, and realizes green transformation[13].

Greening transformation has the effect of environmental protection and resource efficiency enhancement, which can improve the sustainable development performance. Scholars believe that this transition is an operational paradigm rooted in sustainability principles, led by the concept of green development, driven by green innovation, running through the entire production process, taking into account economic and environmental performance, and ultimately promoting the improvement for both ecological system regeneration and premium economic growth.[14].Green transformation in input, production and emission can not only enhance the efficiency of resource utilization, reduce waste, manage emission and improve environmental performance, but also bring green reputation, gain financing advantages, expand market share and drive the enhancement of their economic performance.

Building on this theoretical foundation, we propose:

H3: Greening transformation mediates between digital transition and sustainable development performance.

Building upon the established propositions, Figure 1 illustrates this study's conceptual framework. For different enterprises, industries and regions, digital transformation may function differently, and hence, this article takes the above three aspects further to examine the different consequences of digital transition on capacity for sustainable development from a heterogeneous perspective.

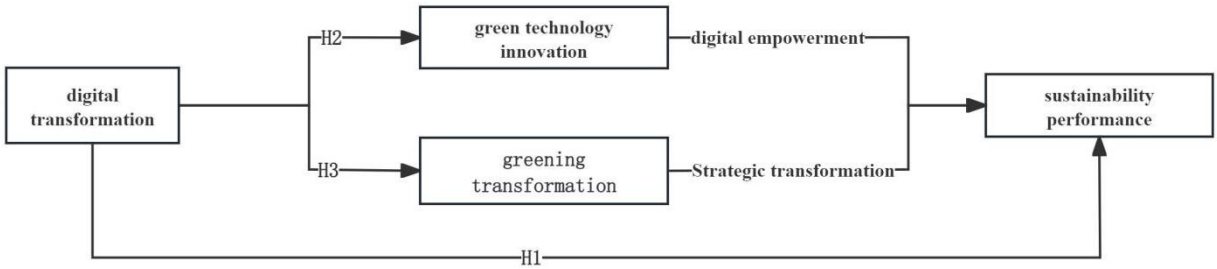

Figure 1: Theoretical model

3. Modeling

3.1. Sample construction and data sources

The analysis employs data from A-share listed firms spanning 2014–2023.To ensure the robustness of the data, the initial dataset was rigorously processed: (1) removal of ST and *ST companies; (2) exclusion of financial institutions; (3)elimination of incomplete records; (4) winsorization of all continuous variables at the 1% and 99% levels. After the above treatments, 34,185 observations are finally obtained, sourced from the CSMAR database and the CNRDS database.

3.2. Definition of variables

3.2.1. Explained variable

Sustainability performance (TDP). It is operationalized as a composite index integrating financial and environmental dimensions, adapting methodologies from scholars[15]. Return on assets (Roa) is a canonical profitability metric, so it is chosen as a measure of financial performance. The environmental score (Esg_e) in the CSI ESG scoring system reflects the performance of in environmental protection, resource utilization, pollution prevention and other aspects of environmental sustainability, so it is chosen to measure the environmental performance. Following

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scholars' normalization framework, both indicators are standardized to a 0–1 scale via transformation:$m^* = (m - \min)/(\max - \min)$, and the standardized financial and environmental performance is turned into a composite index of sustainable development performance (TDP) with the formula:$TDP = [(1 - |Roa - Esg\_e|) \times \sqrt{Roa \times Esg\_e}]/1$.

3.2.2. Explanatory variable

Digital transformation (Dig). This study examines digital transformation (Dig) by developing indicators derived from the annual reports of listed companies, following the methodology established by scholars[16]. Utilizing Python-based text analysis, the research identifies characteristic terms associated with digital transformation across two dimensions: underlying technology application and practical application of technology. The frequency of these keywords serves as the primary metric for assessing the level of digital transformation. To address the right skewed distribution characteristics of the dataset, the study applies a natural logarithmic transformation after incrementing the values by 1.

3.2.3. Mediating variables

This paper selects green technology innovation (Gti) and greening transformation (Gre) as mediating variables. For Gti, the study employs the methodology outlined by scholars[17] , measuring it through the combined count of green patent applications, including both green invention patents and green utility model patents. These values are adjusted by adding 1 and applying the natural logarithm. For the measurement of green transformation, this paper follows the approach of scholars[18], which adds up the frequency of green transformation-related keywords in annual reports and adds 1 to take the natural logarithm to process it.

Table 1: Variable definitions

variant	name	symbol	instructions
explained variable	Sustainable Development Performance	TDP	calculation of standardized processed financial and environmental performance
explanatory variable	Digital Transformation	Dig	ln(total word frequency of digital transformation + 1)
mediating variables	Green Technology Innovation	Gti	ln(number of green patent applications + 1)
	Greening Transformation	Gre	ln(frequency of green transformation + 1)
control variables	Enterprise size	Size	ln(total assets)
	Solvency	Lev	total liabilities / total assets
	Development Capacity	Growth	(current year's operating income/previous year's operating income)-1
	Number of years listed	Age	ln(the number of years since establishment)
	Capital Intensity	Cap	total assets / operating revenues
	Board Size	Board	ln(total number of board members)

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3.2.4. Control variables

In line with prior research on corporate sustainability performance, the study includes several control variables: enterprise size (Size), solvency (Lev), development capacity (Growth), number of years listed (Age), capital intensity (Cap), and board size (Board). The definitions of the variables are shown in Table 1.

3.3. Modeling

To investigate the influence of digital transformation on corporate sustainability performance, this paper establishes the following benchmark model:

$$TDP_{it} = \alpha_0 + \alpha_1 Dig_{it} + \alpha_2 Controls_{it} + \mu_i + \lambda_t + \varepsilon_{i,t} \quad (1)$$

Where the explained variable TDP is the organizations' sustainability performance; Dig is the degree of digital transition; Controls is the control variables; i denotes firm and t denotes year. The model accounts for individual fixed effects, time fixed effects, and incorporates a random error term.

In order to explore in depth the potential mediating mechanisms through which green technology innovation and greening transformation influence the link between digital transformation and corporate sustainable development performance, this study constructs the following mediation models:

$$Gti_{it} = \beta_0 + \beta_1 Dig_{it} + \beta_2 Controls_{it} + \mu_i + \lambda_t + \varepsilon_{i,t} \quad (2)$$

$$TDP_{it} = \varphi_0 + \varphi_1 Dig_{it} + \varphi_2 Gti_{it} + \varphi_3 Controls_{it} + \mu_i + \lambda_t + \varepsilon_{i,t} \quad (3)$$

Where Gti denotes the level of green technology innovation.

$$Gre_{it} = \gamma_0 + \gamma_1 Dig_{it} + \gamma_2 Controls_{it} + \mu_i + \lambda_t + \varepsilon_{i,t} \quad (4)$$

$$TDP_{it} = \delta_0 + \delta_1 Dig_{it} + \delta_2 Gre_{it} + \delta_3 Controls_{it} + \mu_i + \lambda_t + \varepsilon_{i,t} \quad (5)$$

Where Gre denotes the degree of greening of the transition.

4. Empirical analysis

4.1. Descriptive statistics

The specifics of each variable can be clearly understood through descriptive statistics, with detailed results presented in Table 2. The sustainable development performance (TDP) exhibits a mean of 0.4, a median of 0.39 and a standard deviation of 0.12, indicating that the overall realization of enterprise sustainable development goals is at a medium level. However, the wide range between maximum and minimum values highlights that wide disparities exist between the sustainability outcomes of different organizations. For digital transformation (Dig), the average score of 1.68, coupled with a standard deviation of 1.42, reflect uneven adoption levels, with some of firms demonstrating advanced digital capabilities, accelerated progress and more applications of digital technology.

Table 2: Results of descriptive statistics

variant	number	mean	sd	minimum	median	maximum
TDP	34185	0.400	0.120	0.170	0.390	0.760
Dig	34185	1.680	1.420	0	1.610	5.240
Gti	34185	0.370	0.780	0	0	3.690
Gre	34185	2.030	0.840	0	2.080	4.090

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Table 2: (continued)

Size	34185	22.25	1.310	19.87	22.06	26.35
Lev	34185	0.410	0.200	0.0600	0.400	0.920
Growth	34185	0.160	0.550	-0.840	0.0800	3.770
Age	34185	2.080	0.950	0	2.200	3.400
Cap	34185	2.570	2.070	0.410	1.980	13.30
Board	34185	2.100	0.200	1.610	2.200	2.640

4.2. Multiple regression analysis

The findings from the multivariate regression analysis examining the relationship between digital transition and sustainability are presented in Table 3. All estimations employ a fixed-effects model, incorporating controls for both individual and year-specific effects. The baseline regression results, displayed in column (1), reveal a statistically significant positive coefficient for Dig at the 1% level. This suggests a strong positive association between digital transformation and corporate sustainability performance. Quantitatively, a 1% increase in digital transition correlates with a 0.003% rise in sustainability. These results provide empirical support for hypothesis H1 and digital transformation empowers firms to amplify sustainability outcomes through optimized deployment of digital technologies.

Table 3: Benchmark regression, mechanism regression results and robustness check

variant	return to baseline	Regression of mechanisms				robustness check
	(1)	(2)	(3)	(4)	(5)	(6)
	TDP	Gti	TDP	Gre	TDP	TDP
Dig	0.00298*** (0.000550)	0.0477*** (0.00361)	0.00233*** (0.000549)	0.0362*** (0.00345)	0.00195*** (0.000541)	0.0154*** (0.00175)
Gti			0.0137*** (0.000821)			
Gre					0.0287*** (0.000848)	
_cons	-0.236*** (0.0155)	-3.216*** (0.102)	-0.192*** (0.0156)	-1.703*** (0.0971)	-0.187*** (0.0153)	0.333*** (0.0512)
Controls	Yes					
ind	Yes					
year	Yes					
N	34185	34185	34185	34185	34185	29627
adj. R2	0.191	0.186	0.198	0.368	0.217	0.222

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

4.3. Mechanism analysis

The mediating role of green technology innovation is examined in columns (2) and (3) of Table 3, where the coefficients are consistently positive and statistically significant at the 1% level, confirming the validity of H2. Digital transformation enhances sustainability performance by fostering advancements in green technology innovation. The reason for this is that digital transformation empowers green technology innovation breakthroughs to reduce resource waste and pollution in the

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whole process from source to emission. Digital transformation drives green transformation, improves resource utilization efficiency and environmental performance, saves costs and enhances economic performance, as demonstrated in columns (4) and (5) of Table 3. The coefficients in these columns are also significantly positive at the 1% level, validating H3. This confirms that green transformation serves as a mediating mechanism through which digital transition enhances corporate sustainability performance.

4.4. Robustness tests

To confirm the robustness of the results, this study takes an alternative approach by replacing the explained variable. Drawing on the methodology of scholars[19], a corporate sustainability index is constructed using the following formula: corporate sustainability = net sales rate× earnings retention rate× (1+equity ratio)/(1/total asset turnover - net sales rate× earnings retention rate× (1+equity ratio)).The regression results, as shown in column (6) of Table 3, indicate that digital transformation continues to retain its statistically significant positive contribution to the sustainability index. This consistency in findings across alternative measures further confirms the robustness of the study's conclusions.

4.5. Heterogeneity analysis

4.5.1. Firm heterogeneity

Table 4: Heterogeneity analysis

variant	(1)	(2)	(3)	(4)	(5)	(6)
	state-owned	non-state-owned	heavy pollution	non-heavy pollution	easternt	Central and Western
Dig	0.00658***	0.00192***	0.00542***	0.00227***	0.00281***	0.00304***
	(0.00111)	(0.000635)	(0.00109)	(0.000640)	(0.000643)	(0.00106)
_cons	-0.259***	-0.211***	-0.135	-0.219***	-0.257***	-0.169***
	(0.0254)	(0.0213)	(0.106)	(0.0181)	(0.0215)	(0.0251)
Controls	Yes					
ind	Yes					
year	Yes					
N	10701	23484	10823	23362	24645	9516
adj. R2	0.238	0.174	0.221	0.178	0.180	0.249

As shown in columns (1) and (2) of Table 4, state-owned enterprises demonstrate a more pronounced implication on improving continuous development capacity through digital transformation, which can be attributed to policy support, resource advantages and development strategies. State-owned enterprises can get more financial subsidies and low-interest loans to cover the cost of digital transformation. State-owned enterprises have larger human and material capital and higher levels of digital infrastructure, and can invest more development resources in digital transition. In addition, nationalized business place a stronger emphasis on long-term social value and actively respond to the national strategic goals.

4.5.2. Industry heterogeneity

The sample is categorized into heavy-polluting and non-heavy-polluting industries for group test. The results, presented in columns (3) and (4) of Table 4, reveal that the facilitating role of digital

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transformation on the sustainable development performance is more obvious in heavy pollution industry enterprises. This is because they urgently need to reduce resource consumption and pollution through digital transformation. In addition, they often face stricter environmental regulations, so they will conduct environmental protection activities to minimize the cost of non-compliance and promote sustainable development.

4.5.3. Regional heterogeneity

Uneven development between regions may result in varying impacts of digital transformation. As illustrated in columns (5) and (6) of Table 4, firms in the central and western regions exhibit a stronger influence of utilizing digital technologies to advance sustainable development. The development of technology in the east is relatively well-developed, and the central and western regions can introduce mature technology and develop rapidly with the advantage of latecomer to improve the sustainable development performance. And they have low environmental carrying capacity, fragile ecological environment, more room for improving resource utilization efficiency, and greater marginal benefits of digital transformation on sustainable development performance.

5. Conclusion

Leveraging the enterprise sample data from 2014-2023, this paper theoretically and empirically examines how digital transformation influences corporate sustainability performance, with a focus on the mediating roles of green technology innovation and greening transformation. The key findings are summarized as follows: (1) digital transformation exhibits a statistically significant positive effect on corporate sustainability performance. The adoption of digital technologies can align corporate business practices with the sustainable development goals. (2) The mediating effect shows that digital transformation affects sustainable development performance through both technological empowerment and strategic transformation. Specifically, enterprise digital initiatives enhance sustainable development performance by promoting green technology innovation and greening transformation. (3) heterogeneity analysis indicates that the benefits of digital transformation are unevenly distributed across firm types industries and regions. This positive effect is more pronounced in state-owned business, heavy-polluting industries, and firms located in the central and western regions.

Drawing on the research findings, this study puts forward the following recommendations: (1) Enterprises should actively adopt digital transformation strategies to drive sustainable development. This involves integrating digital transformation principles into all operational aspects, including R&D, production, and management processes. By automating and intellectualizing enterprise operations, establishing a digital management platform, and enhancing operational efficiency, enterprises can reduce costs and improve overall performance. (2) Governments should incentivize and support enterprises in accelerating digital transformation to foster sustainable economic and social development. This can be achieved through increasing policy support for digital transformation, such as loan incentives and tax exemptions, to lower the cost of digital transformation and broaden financing channels. Additionally, governments should refine the systematic system of environmental regulation, increase the punishment of environmental violations and flexibly adjust the fiscal policy and regulatory measures for the actual situation of different regions and different enterprises to ensure that the policy accurately falls into place.

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