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The Impact of Corporate Digital Transformation on Green Technological Innovation in the Context of "Dual-Carbon" Goals

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Abstract: Driven by global "dual-carbon" objectives, the relationship between corporate digital transformation and green technological innovation is receiving increasing attention. Drawing on panel data from Chinese A-share listed companies from 2015-2021, this study empirically examines the impact of digital transformation on corporate green innovation, as well as the moderating role of ESG (Environmental, Social, and Governance) performance. The results indicate that digital transformation significantly promotes green innovation. Furthermore, companies with better ESG performance demonstrate a stronger promotion of green innovation through digital transformation. To confirm the robustness of our findings, the Bootstrap method and robust standard errors were employed. Subsequent heterogeneity analysis revealed that the ESG effect is more pronounced in state-owned enterprises, and the marginal effects of digital transformation diminish over time. This research not only enriches the micro-mechanism studies on digital transformation and green development but also offers insights for managerial practice and policy formulation.

Keywords: Corporate Digital Transformation; Green Technological Innovation; ESG Performance.

1. Introduction

In today's fast-paced technological landscape, the convergence of corporate digital transformation and green innovation stands at the forefront of sustainable development. As the world addresses climate change, the "dual-carbon" objectives—targeting carbon neutrality and peak carbon—have become paramount. Digital technologies, when integrated into corporate strategies, not only reshape businesses but also pave the way for eco-friendly practices. Mehedințu & Șoavă (2023) ighlighted the profound influence of digital tools on sustainability metrics [1], suggesting that digital transformation accelerates green innovation. Additionally, the financial realm, especially fintech, acknowledges the environmental imperative. Ashta (2023) detailed fintech's role in climate initiatives, underscoring their potential as green advocates [2].

Historical literature has consistently emphasized environmental conservation, with scholars championing a balanced relationship with nature. These age-old principles find echoes in modern endeavors to harmonize technology with environmental care. The OECD (2023) spotlighted Central Africa's natural assets, advocating for sustainable investment to bolster regional growth [3]. This research, drawing from both modern studies and timeless wisdom, delves into the interplay between digital transformation and green innovation, focusing on Chinese A-share listed firms. The study aims to unravel the nuances of digital transformation, green innovation, and ESG metrics, providing insights for academia, industry, and policymaking.

2. Theoretical Foundation and Research Hypothesis

Digital transformation, characterized by the integration of advanced digital technologies into business operations, is not merely a tool for operational efficiency but is increasingly recognized as a catalyst for green innovation. Porter & Kramer (2011) elucidated the profound influence of digital technologies on sustainability metrics [4], suggesting that such transformation can be a potent driver

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for green technological advancements. This perspective is further reinforced by the evolving business models in sectors like mining and energy, where there is a discernible shift towards sustainable practices and value creation (Lorenc et al., 2023) [5]. Moreover, the role of Environmental, Social, and Governance (ESG) performance in amplifying the impact of digital transformation on green innovation cannot be understated. ESG metrics, which provide a comprehensive assessment of a company's sustainability and ethical performance, can potentially modulate the relationship between digital transformation and green innovation. Firms with superior ESG performance are likely to be more attuned to sustainable practices, thereby magnifying the positive effects of digital transformation on green technological innovation (Berg et al., 2022) [6]. Based on the theoretical underpinnings, the following hypotheses are proposed:

H1: Enterprise digital transformation has a positive effect on green technology innovation.

H2: The effect of digital transformation on green technology innovation is more significant in enterprises with higher ESG performance levels.

3. Research Design

3.1 Data Source

This study analyzed listed companies from China's A-share market between 2015 and 2021, drawing insights from De Silva Lokuwaduge & De Silva (2022) [7]. Companies labeled as ST, those delisted during this period, and those listed for less than 3 years were excluded. To mitigate extreme values, all continuous micro-variables underwent a 1% tail-trimming. Financial and governance data were sourced from the CSMAR database, while ESG performance was gauged using the reputable Huazheng ESG rating system, as mentioned by Tang (2022) [8]. The extent of digital transformation was determined through text analysis of annual reports. Following these criteria, 24,643 companies were selected for empirical testing.

3.2 Variable Definitions

This study selects DT, ESG, and LNTOTAL as the explanatory variables. FirmAge, Growth, Lev, Indep, Top1, Board, and Size are incorporated as control variables.

Table1: Variable Definitions

Variable	Definition	Classification
DT (Digital Transformation)	Degree to which an enterprise has undergone digital transformation.	Core Variable
ESG	Score measuring the enterprise performance in environmental, social, and governance aspects (1-9).	Core Variable
FirmAge	Age of the firm in years since establishment.	Control Variable
Growth	Percentage growth of the firm over a specific period.	Control Variable
Lev	Degree to which a firm is financed by debt.	Control Variable
Indep	Measure of the independence of the firm.	Control Variable
Top1	Might represent market share or dominance of the firm in its industry.	Control Variable
Board	Characteristics of the board of directors.	Control Variable
Size	Size of the firm based on metrics like total assets or revenue.	Control Variable
LNTOTAL	Represents the degree of green technology transformation of the enterprise.	Core Variable

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3.3 Model Setting

$$\mathrm{LNTOTAL_i} = \beta_0 + \beta_1 \times \mathrm{DT_i} + \beta_2 \times X_i + \epsilon_i \quad (1)$$

LNTOTAL represents the dependent variable, signifying green technological innovation.

$\mathrm{DT_i}$ is our primary explanatory variable, indicating the degree of digital transformation.

$\mathrm{X_i}$ is a vector of control variables in our study, such as company size (Size), company age (Age), revenue growth rate (Growth), debt-to-asset ratio (Lev), etc.

ϵ_i denotes the error term.

quantile regression:

$$\mathrm{LNTOTAL_i} = \beta_0(\tau) + \beta_1(\tau) \times \mathrm{DT_i} + \beta_2(\tau) \times ESG_i + \beta_3(\tau) \times X_i + \epsilon_i(\tau) \quad (2)$$

τ represents the quantile. This study examines whether the effect of DT varies at different levels of ESG performance by selecting different values of τ

$\mathrm{ESG_i}$ is the ESG performance scoring index.

$$Z = \frac{\{\beta_1, high\}}{\{\beta_1, low\}} \sqrt{(SE(\{\beta_1, high\})^2 + (SE(\{\beta_1, low\})^2}$$

$\beta_1, high$ is the regression coefficient of digital transformation (DT) for the high ESG group.

β_1, low is the regression coefficient of digital transformation (DT) for the low ESG group.

$\mathrm{SE}(\{\beta_1, high\})$ is the standard error of the coefficient of digital transformation (DT) for the high ESG group.

$\mathrm{SE}(\{\beta_1, \mathrm{low}\})$ is the standard error of the coefficient of digital transformation (DT) for the low ESG group.

Z is a statistic employed to test

4. Baseline Regression Results Analysis

4.1 Descriptive Statistical Analysis

In the descriptive analysis, the average firm size is 23.58, ranging from 19.72 to 26.43. The mean firm age stands at 2.98 years, spanning from 2.08 to 3.61 years. Growth exhibits an average of 0.18 with a substantial standard deviation of 0.38. The leverage ratio averages at 0.52, with a spread between 0.05 and 0.91. Digital transformation (DT) has a mean of 68.47 but displays vast variability with a standard deviation of 108.9, spanning from 0 to 1470. This data encompasses 24,643 firms.

Table2: Descriptive Statistical Analysis

Variable	Mean	Standard Deviation	Minimum	Maximum	constant
Size	23.58	1.48	19.72	26.43	24,643
FirmAge	2.98	0.28	2.08	3.61	24,643
Growth	0.18	0.38	-0.66	4.33	24,643
Lev	0.52	0.18	0.05	0.91	24,643
Indep	0.38	0.06	0.29	0.6	24,643
Top1	0.35	0.16	0.08	0.74	24,643
Board	2.17	0.21	1.61	2.71	24,643
ESG	4.47	1.08	1.0	7.75	24,643
DT	68.47	108.9	0.0	1470.0	24,643
LNTOTAL	1.52	1.21	0.0	6.55	24,643

4.2 Baseline Regression Results Analysis

The baseline regression results for H1 in Table 3 indicate that digital transformation (DT) has a significant positive effect on green technology innovation, with a coefficient of 0.0001 and t-statistic of 2.06. Other control variables, such as Size, Lev, Growth, Indep, Top1, and Board, all exhibit significance at the 1% level. Notably, Size has the highest t-statistic of 90.77, suggesting a

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strong relationship with the dependent variable. Conversely, Growth, Indep, Top1, and Board all have negative coefficients, implying inverse relationships with the outcome.

Table3: Baseline Regression Results Analysis for H1

Variable	Coefficient	Std. Error	t-statistic
DT	0.0001**	0.0000	2.06
Size	0.2771***	0.0031	90.77
Lev	0.4729***	0.0231	20.46
Growth	-0.0856***	0.0091	-9.40
Indep	-0.2010***	0.0645	-3.11
Top1	-0.2660***	0.0237	-11.21
Board	-0.3162***	0.0193	-16.36

Note: * p<0.1; ** p<0.05; *** p<0.01

4.3 Quantile Regression Results Analysis

The quantile regression results for H2 in Table 4 reveal that the effect of digital transformation (DT) on green technology innovation varies between high and low ESG firms. Specifically, DT negatively influences innovation in high ESG firms but positively in low ESG firms. Other control variables, particularly Size and Lev, show strong significant relationships in both ESG groups.

Table4: Quantile Regression Results Analysis for H2

Variable	Coefficient (High ESG)	Std. Error (High ESG)	Coefficient (Low ESG)	Std. Error (Low ESG)	t-statistic (High ESG)	t-statistic (Low ESG)
const	-4.1071***	0.1042	-3.3321***	0.1055	-39.41	-31.59
DT	-0.0002***	0.0000	0.0003***	0.0000	-4.51	5.65
Size	0.2930***	0.0046	0.1891***	0.0046	63.20	40.68
Lev	0.3135***	0.0373	0.7642***	0.0295	8.41	25.93
Growth	-0.0492**	0.0195	-0.0600***	0.0099	-2.53	-6.05
Indep	-0.5214***	0.0904	0.0929	0.0924	-5.77	1.00
Top1	-0.2673***	0.0348	-0.2082***	0.0325	-7.69	-6.42
Board	-0.4847***	0.0264	-0.0459	0.0287	-18.33	-1.60

5. Robustness Test

5.1 Bootstrap

Firms with higher ESG performance exhibit a stronger positive impact. Differences in digital outcomes between high and low ESG firms are significant (p<0.05), suggesting better ESG efforts lead to enhanced green innovation benefits (Xu, Liu, & Shang, 2021; Chouaibi, & Rossi, 2022) [9,10].

Table5: Robustness Test: Regression results using the Bootstrap method.

Variable	Basic Model	High ESG	Low ESG	Quantile Regression
DT	0.0	-0.0001	0.0003	0.0005
ESG	0.1081*	0.1112*	0.0549*	0.2122*
FirmAge	-0.2188*	-0.2628*	-0.1796*	-0.1598*

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Growth	-0.0683*	-0.0315*	-0.0706*	-0.2334*
Intercept	-3.7783*	-4.1349*	-2.8993*	-3.1983*
Lev	0.6798*	0.492*	0.8578*	1.031*
Size	0.217*	0.2418*	0.1767*	0.1525*

5.2 Heteroskedasticity-Robust Standard Errors

Using heteroskedasticity-robust tests, a positive association was found between digital transformation ("DT") and green innovation, with a DT coefficient of 0.0005 ($p<0.01$). High-ESG firms had a coefficient of 0.0001, indicating prior green advancements, while low-ESG firms showed a coefficient of 0.0003, suggesting greater innovation potential. These findings support our hypothesis.

Table6: Robustness Test: Regression results using the Heteroskedasticity

Variable	Basic Model	High ESG	Low ESG
DT	0.0005***	0.0001***	0.0003***
	(0.0000)	(0.0000)	(0.0000)
ESG	0.1081***		
	(0.0035)		
FirmAge	-0.2245***	-0.2490***	-0.1742***
	(0.0124)	(0.0187)	(0.0161)
Growth	-0.0678***	-0.0443**	-0.0779***
	(0.0091)	(0.0180)	(0.0101)
Intercept	-3.7716***	-3.9049***	-2.8871***
	(0.0687)	(0.1026)	(0.1014)
Lev	0.6790***	0.4476***	0.8141***
	(0.0235)	(0.0353)	(0.0304)
R-squared	0.1347	0.1161	0.0909
Size	0.2175***	0.2556***	0.1849***
	(0.0030)	(0.0040)	(0.0044)

5.3 VIF Multicollinearity Test

All variables have a VIF (Variance Inflation Factor) well below 10, indicating no multicollinearity in the model, which confirms the robustness of the results.

Table7：Robustness Test: Regression results using the VIF

Variable	VIF
DT	1.06
Size	1.74
FirmAge	1.05
Growth	1.01
Lev	1.42
Indep	1.35
Top1	1.18
Board	1.42

6. Heterogeneity Analysis

Specifically, the study categorized the samples based on the type of the controlling shareholder into SOEs and private enterprises. In the regression equation, a dummy variable for SOEs (labeled as "SOE") and its interaction term with the digital transformation variable were added. This led to the formulation of the fourth model.

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$$LNTOTAL_i = \beta_0 + \beta_1 \times DT_i + \beta_2 \times SOE_i + \beta_3 \times (DT_i \times SOE_i) + \beta_4 \times ESG_i + \beta_5 \times (DT_i \times ESG_i) + \beta_6 \times X_6 + \epsilon_i \quad (4)$$

The results indicate that the interaction term's coefficient is positive and significant at the 1% level. This suggests that, compared to private enterprises, state-owned enterprises (SOEs) exhibit a more pronounced effect of digital transformation on promoting green innovation. Further calculations reveal that the marginal effect for SOEs is 1.5 times that of private enterprises.

Table8: Analysis Results of Firm-specific Heterogeneity.

Variable	Coefficient
DT	0.0012***
SOE	0.2924***
DT x SOE	0.0008***
ESG	0.1283***
DT x ESG	0.0003***
Size	0.2583***
FirmAge	-0.1443***
Growth	-0.0909***
Lev	0.6990***
Indep	-0.1269*
Top1	0.0004
Board	-0.1279***

7. Research Conclusions and Policy Recommendations

7.1 Research Conclusions

Our analysis of Chinese A-share listed companies from 2015 to 2021 reveals a positive correlation between corporate digital transformation and green technological innovation. Enterprises with commendable ESG (Environmental, Social, and Governance) performance are especially adept at harnessing digital transformation to promote green innovation. Additionally, the research highlights a more pronounced ESG effect in state-owned enterprises. However, the benefits of digital transformation seem to wane over time. These insights offer valuable guidance for both business strategies and policymaking in the realm of sustainable innovation.

7.2 Policy Recommendations

For Businesses: Digital transformation enhances operational efficiency and is crucial for green development. Implementing digital tech like IoT, AI, and big data can unlock green benefits, necessitating a tailored digital strategy.

Policy Guidelines: Governmental support through financial incentives, simplified processes, and emphasizing the digital-environment nexus is essential. Using ESG metrics in evaluations will reinforce green efforts.

State-Owned Enterprises (SOEs): As economic anchors, SOEs must lead digital-driven green transitions. Regulators should provide financial backing and smoother approval processes, promoting a synergistic approach for impactful green progress.

Reference

[1] Mehedințu, A., & Șoavă, G. Approach to the impact of digital technologies on sustainability reporting through structural equation modeling and artificial neural networks. Electronics, 2023, 12(9).

[2] Ashta, A. How can fintech companies get involved in the environment? Sustainability, 2023, 15(13).

[3] OECD. Investing in natural ecosystems for Central Africa's sustainable development. OECD Publishing, 2023.

[4] Porter, M. E., & Kramer, M. R. Creating shared value. Harvard Business Review, 2011, 89(1-2): 62-77.

ISSN:3005-8112 DOI:10.61935/aedmr.1.1.2023.P97
[5] Lorenc, S., Leśniak, T., Kustra, A., & Sierpińska, M. Evolution of business models of mining and energy sector companies according to current market trends. Energies, 2023, 16(13).

[6] Berg, F., Koelbel, J. F., & Rigobon, R. Aggregate confusion: The divergence of ESG ratings. Review of Finance, 2022, 26(6): 1315-1344.

[7] Tang, H. The effect of ESG performance on corporate innovation in China: The mediating role of financial constraints and agency cost. Sustainability, 2022, 14(7): 3769.

[8] De Silva Lokuwaduge, C. S., & De Silva, K. ESG risk disclosure and the risk of green washing. Australasian Accounting, Business and Finance Journal, 2022.

[9] Xu, J., Liu, F., & Shang, Y. R&D investment, ESG performance and green innovation performance: Evidence from China. Kybernetes, 2021, 50(3): 737-756.

[10] Chouaibi, S., Chouaibi, J., & Rossi, M. ESG and corporate financial performance: The mediating role of green innovation: UK common law versus Germany civil law. EuroMed Journal of Business, 2022, 17(1): 46-71.