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The Impact of Digital Transformation on Corporate ESG Performance--Dual Path Analysis Based on Financing Constraints and Government Regulation

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Abstract: Against the backdrop of rapidly accelerating digital transformation, corporate performance in the areas of Environment, Social and Governance (ESG) has become a key indicator of corporate sustainability and long-term competitiveness. This paper explores the intricate mechanism of digital transformation on corporate ESG performance, utilizing the data of Chinese A-share listed companies from 2013 to 2023. By constructing a two-path analytical framework and a panel regression model, this study finds that corporate digital transformation significantly enhances the overall corporate ESG performance through the mediating channels of alleviating financing constraints and strengthening government regulation. The impact is particularly prominent among state-owned enterprises and firms with relatively low market competitiveness. The results provide a theoretical basis for policy makers to optimise the efficiency of resource allocation. They also offer practical guidance for enterprises to implement differentiated digital transformation strategies, which is of practical guidance value for regions with high financing constraints and policy-supported industries.

Keywords: Digital transformation, corporate ESG, financing constraints, government regulation, dual path analysis

1. Introduction

In the context of a global sustainable development agenda, ESG framework has become a strategic element of corporate core competitiveness. The three core elements of sustainable development, social justice and economic prosperity are compatible with China's macro-development strategy. Multiple stakeholders, including public institutions and business, have realised that addressing climate change, realizing social value and building a modern governance system are crucial for future development [1]. Additionally, the interplay between digital transformation and ESG performance has triggered dual attention from academia and industry.

Studies have shown that digital technology can promote corporate environmental management efficiency and social responsibility, but there is significant heterogeneity in practice [2]. PricewaterhouseCoopers 2022 survey shows that the ESG return dispersion coefficient for digital transformation of Chinese listed companies is as high as 0.83, implying that institutional environment and resource endowment have a key mediating role. Differences in financing constraints may trigger

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divergent economies of scale effects in technology adoption, while changes in the government regulation intensity can reshape firms' digital investment priorities.

Drawing on data from Chinese A-share listed companies from 2013 to 2023, this study empirically investigates how digital transformation affects corporate ESG performance, emphasizing the mediating contributions of the two transmission paths: alleviating financing constraints and synergizing government regulation. It also analyses the boundary of the effect through the heterogeneity of property rights and market environment. This study offers offers a foundation for enterprises to optimise the resource allocation for digital transformation, as well as for policy makers to design precise incentive tools.

2. Theoretical review and research hypothesis

2.1. Impact of digital transformation on corporate ESG performance

Existing research confirms that digital transformation reconfigures the enterprise operation mode through technological empowerment, positively impacting ESG performance in multiple dimensions. In the environmental dimension, digital technology optimises resource utilisation efficiency and reduces carbon emissions, driving the transformation of green production. In the social dimension, digital tools enhance the efficiency of stakeholder communication and increase the transparency of social responsibility. In the governance dimension, big data analysis and algorithmic decision-making strengthen risk management capabilities and optimise governance structures [3]. The Resource-Based View (RBV) states that digitalisation builds ESG capability barriers by improving resource utilisation efficiency, while the stakeholder theory emphasises that it facilitates multi-stakeholder value co-creation [4]. Although initial technology investment may crowd out ESG resources, the long-term technology diffusion effect dominates the positive effect.

Building on this, Hypothesis H1 is proposed: Digital transformation can improve the ESG performance of companies across environmental, governance and social responsibility dimensions.

2.2. Mediating effects of financial constraints

The inhibitory impact of financing constraints on corporate ESG is supported by cross-country empirical evidence: credit rationing and high financing costs force firms to cut back on long-run ESG investments [5]. Digital transformation presents a dual moderating function. First, supply chain finance and blockchain technologies alleviate information asymmetry and broaden financing channels to support ESG practices [6]. Second, the collateral attributes of digital assets enhance balance sheet resilience. However, traditional industries may exacerbate financing pressure due to sunk costs [7]. Dynamic capabilities theory suggests that financing constraints limit firms' digital agility, which in turn weakens the effectiveness of ESG strategic alignment.

Based on this, hypothesis H2a is proposed: Financing constraints mediate the relationship between digital transformation and firms' ESG performance.

2.3. Mediating effects of government regulation

Institutional theory reveals that government regulation drives firms to align digitalization with ESG objectives through legitimacy pressure. Specific mechanisms include mandatory regulations that raise costs of environmental violations, incentives that lower the cost of transformation, and guiding measures that regulate responsible practices [8-10]. Cross-country comparisons show that strong regulatory environments can strengthen the positive interaction between digitalisation and ESG, but excessive reliance may induce strategic greenwashing [11]. The effects of digital transformation are

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moderated by regulatory intensity. Policy signals are translated into corporate actions through digital tools, while the speed of regulatory iteration affects resource allocation priorities [12].

Based on this, hypothesis H2b is proposed: Government regulation mediates the relationship in the relationship between digital transformation and firms' ESG performance.

Integrating the resource-based view and institutional theory, this study constructs a dynamic dual-path model where digital transformation improves ESG performance through "technological empowerment-resource and institutional adaptation-strategic response upgrading". Among them, financing constraint alleviation (internal resource optimisation) and government regulation synergy (external institutional response) constitute the core intermediary path, and their effects are regulated by the combination of the industry's digital maturity and the speed of policy iteration. The framework breaks away from traditional static analyses to reveal how technology-institution co-evolution shapes the heterogeneity of ESG improvement paths.

3. Research design

3.1. Data sources

The data utilized in this study comprises information from Chinese A-share listed companies from 2013-2023. The data were processed to exclude companies with missing variables, those in the financial industry, and samples of ST and *ST companies, resulting in 21,112 observations. The ESG data are sourced from the CSI ESG rating system, the corporate green technology innovation data are from the China Research Data Service Platform, and additional data are from the Cathay Pacific database. This study uses Stata 17.0 software for statistical analysis of data.

3.2. Definition of variables

The explanatory variable is ESG performance (ESG). This study assigns values from 1 to 9 based on the CSI ESG rating system for listed companies, according to C, CC, CCC, B, BB, BBB, A, AA, and AAA from low to high. The degree of digital transformation (DT) is measured by extracting the frequency of terms related to digitalisation, from corporate annual reports, using the natural logarithm of the frequency plus one as the variable for DT [13]. The mediating variables are financing constraint (FC) and government regulation (GR). Financing constraint (FC) is measured using the SA index to assess corporate financing constraints. For government regulation, this paper used the method of Chen Shiyi and Chen Dengke and adopts the proportion of the word frequency related to environmental regulation in local government work report compared to the total word count. This approach serves as a proxy variable for environmental governance. It reflects the strength of the government regulation of the environment, and helps alleviate the endogeneity problem, as the local government working report typically occurs at the beginning of the year, while economic activities take place throughout the year [14]. Control variables related to corporate governance and operation level include firm size (Size), board size (Board), shareholding concentration (Top1), net profit growth rate (Growth), part-time appointment (Dual), gearing ratio (Lev), audit quality (Big4), and the proportion of sole director (Indep). Time and industry fixed effects are also controlled for in the analysis.

3.3. Modelling

To verify the relationship between corporate digital transformation and ESG performance, as well as to explore the role mechanism of corporate financing constraints and government regulation, this study establishes the following model [15].

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$$ESG_{i,t} = \beta_0 + \beta_1 DT_{i,t} + \beta_2 Controls_{i,t} + \sum year + \sum industry + \varepsilon_{i,t} \quad (1)$$

$$M_{i,t} = \beta_0 + \beta_1 DT_{i,t} + \beta_2 Controls_{i,t} + \sum year + \sum industry + \varepsilon_{i,t} \quad (2)$$

$$ESG_{i,t} = \beta_0 + \beta_1 DT_{i,t} + \beta_2 M_{i,t} + \beta_3 Controls_{i,t} + \sum year + \sum industry + \varepsilon_{i,t} \quad (3)$$

Where model (1) is the regression equation to verify the relationship between firms' digital transformation and ESG performance. Models (2) and model (3) are the mediation effect test equations. Here, i and t stand for firms and year, respectively, while M represents FC and GR. The variables for year and industry represent fixed effects and ε is the random error term.

4. Analysis of empirical results

4.1. Descriptive statistics

The descriptive statistics of the main variables are shown in Table 1:

Table 1: Descriptive statistics

VarName	Obs	Mean	SD	Min	Median	Max
ESG	21112	4.1817	0.935	1.0000	4.00	6.00
DT	21112	1.9970	1.690	0.0000	1.95	5.97
FC	21112	-3.8543	0.261	-5.3971	-3.86	-3.18
GR	21112	4.0303	0.331	1.7918	4.08	4.75
Size	21112	22.3333	1.300	19.5850	22.16	26.15
Lev	21112	0.4098	0.203	0.0349	0.40	0.88
Growth	21112	0.1395	0.331	-0.6535	0.09	1.74
Board	21112	2.1186	0.191	1.6094	2.20	2.56
Indep	21112	37.6755	5.455	28.5700	36.36	57.14
Dual	21112	0.2818	0.450	0.0000	0.00	1.00
Top1	21112	0.3354	0.149	0.0760	0.31	0.72
Big4	21112	0.0700	0.255	0.0000	0.00	1.00

Table 1 shows that the standard deviation of corporate ESG performance is 0.935, with a mean of 4.1817, suggesting notable gaps in the environmental, social responsibility and governance performance among the firms. Although the ESG performance is more concentrated, there remains room for improvement. The degree of digital transformation (DT) has a standard deviation of 1.690, and a mean of 1.997, indicating a generally low level of digital transformation with considerable variation among firms. The standard deviation of financing constraints (SA) is 0.261, and the mean value is -3.8543, highlighting significant differences in financing barriers among the sample enterprises. The standard deviation of government regulation (GR) is 0.331, with a mean of 4.0303, indicating less variation in regulatory intensity across firms. Other control variables such as firm size (Size) with a standard deviation of 1.300 and a mean of 22.3333 indicate moderate size differences. Leverage (Lev) with a standard deviation of 0.203 and a mean of 0.4098 indicates moderate differences in financial leverage. The growth rate (Growth) with a standard deviation of 0.331 and a mean of 0.1395 indicates significant growth disparities among firms. Overall, the distribution characteristics of the variables are consistent with the existing literature, providing a reliable basis for the subsequent regression analyses.

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4.2. Baseline regression analysis

Table 2: Baseline regression analysis

	(1) ESG	(2) ESG	(3) FC	(4) ESG	(5) GR	(6) ESG
DT	0.0432*(9.84)	0.0195*(4.01)	-0.0248*(-19.67)	0.0270*(5.52)	0.0137*(6.71)	0.0217*(4.37)
Size		0.182*(18.96)	-0.0432*(-15.62)	0.197*(20.03)	0.0219*(5.57)	0.183*(18.46)
Lev		-0.895*(-19.54)	0.0112 (0.94)	-0.893*(-19.44)	-0.0545*(-2.85)	-0.859*(-18.22)
Growth		-0.0295*(-1.91)	0.0311*(9.27)	-0.0428*(-2.76)	0.0372*(5.89)	-0.0260 (-1.63)
Board		0.279*(5.70)	0.0926*(6.93)	0.255*(5.19)	-0.0293 (-1.43)	0.278*(5.48)
Indep		0.0151*(9.68)	0.00114*(2.72)	0.0148*(9.48)	0.00146 (2.26)	0.0141*(8.75)
Dual		-0.0374 (-2.46)	0.0194*(4.88)	-0.0395*(-2.60)	0.00805 (1.28)	-0.0375 (-2.44)
Top1		0.486*(7.92)	0.364*(20.74)	0.360*(5.78)	-0.0296 (-1.15)	0.435*(6.88)
Big4		0.156*(4.54)	0.115*(9.64)	0.120*(3.47)	0.00499 (0.34)	0.138*(3.84)
FC				-0.317*(9.31)		
GR						0.0737*(4.13)
_cons	4.062*(415.64)	-0.916*(-3.78)	-3.233*(-45.53)	0.0705 (0.27)	3.548*(36.71)	0.587 (2.25)
N	26620	24634	24538	24538	23640	23640
r2	0.479	0.522	0.684	0.525	0.347	0.527
year	Yes	Yes	Yes	Yes	Yes	Yes
industry	Yes	Yes	Yes	Yes	Yes	Yes

Note: tstatisticsinparentheses
*p<0.1, p<0.05, *p<0.01

Table 2 show the regression results of firms' digital transformation on ESG performance. Columns (1) and (2) show that Column (1) controls only for year and industry fixed effects, while Column (2) adds control variables to column (1). The regression coefficients for digital transformation are positive and significant at the 1% level in both columns. This suggests that enterprises' undertaking digital transformation can improve their environmental performance, strengthen social responsibility, enhance internal governance, and promote the ESG performance of enterprises. Therefore, Hypothesis H1 is verified.

4.3. Mediating effect mechanism test

The regression results for financing constraints as mediators are presented in Column (3) of Table 2. The coefficient for financing constraints and ESG ratings is -0.0248, significantly negative at the 1% level, indicating that financing constraints inhibit ESG ratings. Column (4) shows a positive correlation between digital transformation (DT) and ESG performance with a coefficient of 0.027, also at the 1% level. This confirms that the significance conditions for testing the mediation effect are met, thus verifying Hypothesis H2a.

Column (5) Column (6) of Table 2 show the impact of government regulation on the relationship between digital transformation and ESG performance. In Column (5), the regression coefficient for digital transformation is 0.0137, significantly positive at the 1% level. Column (6) incorporates government regulation as a mediating variable, showing a regression coefficient of 0.1547 for government regulation, significant at 1% level. After adding government regulation, the coefficient for digital transformation changes increases from 0.0195 in Column (2) to 0.0217, indicating that government regulation mediates the relationship between corporate digital transformation and ESG performance, thereby confirming Hypothesis H2b.

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5. Further studies

5.1. Robustness tests

First, this study employs a systematic GMM approach to mitigate potential endogeneity problems of the model, especially estimation bias caused by omitted variables or bidirectional causality. In the dynamic panel setting, the first-order lagged term (L.ESG1) of the explanatory variable (ESG_LP) is introduced into the model as an instrumental variable, while controlling for year and individual fixed effects. The coefficient of L.ESG1 is 0.824 and significant at the 1% level (z=17.60), indicating significant dynamic persistence in firms' ESG performance. The coefficients of other control variables such as firm size (Size) and leverage (Lev) do not pass the significance test, probably because their marginal impact on ESG is disturbed by path complexity or industry heterogeneity. The validity of the System GMM estimation is supported by statistical tests. The p-value of AR(1) test is 0.118, which is not strictly lower than 0.1, but in combination with p-value of AR(2) test of 0.006 (significant rejection of the original hypothesis of second-order autocorrelation), indicating first-order serial correlation but no higher-order autocorrelation. The Hansen over-identification test (p=0.681) confirms the validity of the instrumental variables, suggesting no over-identification problem. These results indicate that the model effectively mitigates endogeneity bias, enhancing the robustness of the findings.

Second, in the robustness test, the assignment method is replaced and a new explanatory variable ESG1 is constructed and regressed again. When the CSI ESG ratings in the sample are assigned a value of 3 for A to AAA, a value of 2 for B to BBB, and a value of 1 for C to CCC. As presented in Column (1) of Table 3, the regression results show that the regression coefficient of DT remains positively significant at the 1% level, confirming the robustness of the original findings.

Third, to address the issue of bidirectional causality in the model, this study lags the core explanatory variable—enterprises' degree of digital transformation—by one period, and regresses with the ESG performance of enterprises. As presented in Column (3) of Table 3, the regression coefficient of the lagged one-period explanatory variable L.DT is 0.0265, significantly positive at the 1 percent statistical level, aligning with the initial findings.

Table 3: Robustness test

	(1) ESG1	 F. ESG	(3) ESG
DT	0.0224* (3.93)	0.0250* (4.06)	
Size	0.194* (17.33)	0.157* (12.74)	0.189* (15.42)
Lev	-0.878* (-16.27)	-0.844* (-14.27)	-0.803* (-13.42)
Growth	-0.0177 (-0.93)	0.141* (7.04)	0.00821 (0.42)
Board	0.297* (5.06)	0.155 (2.43)	0.286* (4.49)
Indep	0.0155* (8.45)	0.0111* (5.47)	0.0142*(7.28)
Dual	-0.0301* (-1.68)	-0.0359* (-1.81)	-0.0355* (-1.84)
op1	0.474* (6.60)	0.249* (3.10)	0.446*(5.51)
Big4	0.181* (4.44)	0.152* (3.46)	0.214* (5.03)

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Table 3: (continued)

L. DT			0.0265*(4.49)
_cons	-1.237* (-4.31)	0.103 (0.32)	-1.076* (-3.42)
N	19626	16160	16160
r2	0.475	0.551	0.554
year	Yes	Yes	Yes
province			

Lastly, The Bootstrap method is used to assess the mediating effect, with 1000 iterations and a 95% confidence interval. Results indicate the presence of mediating effects, as the confidence interval for the indirect effect does not include 0, while the direct effect's confidence interval suggests a fully mediated effect. The test results are presented in Tables 4 and 5.

Table 4: Further tests of the mediating effect of financing constraints

	Observedcoefficient	Bootstrapstd.err.	z	P>|z|	Normal-based [95%conf. interval]	
_bs_1	-.0012358	.0002441	-5.06	0.000	-.0017143	-.0007573
_bs_2	.0523113	.0032054	16.32	0.000	.0460288	.0585937

Table 5: Further tests of the mediating effect of government regulation

	Observedcoefficient	Bootstrapstd.err.	z	P>|z|	Normal-based [95%conf. interval]	
_bs_1	-.0007735	.0001919	-4.03	0.000	-.0011495	-.0003974
_bs_2	.051849	.003313	15.65	0.000	.0453556	.0583424

5.2. Heterogeneity test

The results of the heterogeneity test are shown in Table 6:

Table 6: Further tests of the mediating effect of government regulation

	state-owned business ESG1	Non-State-owned Enterprises ESG1	Higher market competition ESG1	Less competitive market ESG1
DT	0.0321* (3.66)	0.0194*(2.83)	0.0119* (1.96)	0.0578* (4.92)
Size	0.202* (12.66)	0.167* (11.50)	0.191* (15.32)	0.165* (7.32)
Lev	-0.765* (-9.76)	-0.908* (-13.29)	-0.896* (-15.10)	-0.673* (-6.07)
Growth	-0.00342 (-0.12)	-0.0326 (-1.39)	-0.0258 (-1.27)	-0.00337 (-0.09)
Board	0.277* (3.25)	0.282* (3.87)	0.292* (4.52)	0.278 (2.50)
Indep	0.0186* (7.03)	0.0121*(5.24)	0.0152*(7.63)	0.0131* (3.56)
Dual	-0.0456 (-1.58)	-0.0186 (-0.89)	-0.0286 (-1.49)	-0.0145 (-0.39)
Top1	0.457* (4.11)	0.452* (5.18)	0.481* (6.13)	0.403* (2.80)
Big4	0.138 (2.36)	0.217* (4.20)	0.140* (3.18)	0.260* (3.16)

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Table 6: (continued)

_cons	-1.552* (-3.81)	-0.449 (-1.20)	-1.107* (-3.45)	-0.626 (-1.11)
N	7274	11981	14659	4578
r2	0.544	0.494	0.520	0.526
year	Yes	Yes	Yes	Yes
industry	Yes	Yes	Yes	Yes

Columns (1) and (2) of Table 6 present the regression results for state-owned and non-state-owned firms. The findings indicate that corporate digital transformation is significantly positive at the 1 percent statistical level in both groups. However, the regression coefficient changes from 0.0321 in Column (1) to 0.0194, suggesting that the effect of corporate digital transformation on ESG performance is more pronounced in state-owned firms. This may be due to SOEs having greater financial support and access to modern technology compared to non-state-owned enterprises (non-SOEs), enabling them to adapt more effectively to the digital economy. Additionally, SOEs may have a higher social responsibility to practice ESG concepts and promote corporate ESG performance. Compared with SOEs, non-SOEs may focus mainly on the daily operation and development of the enterprise, and may neglect the fulfilment of corporate ESG responsibilities, so the impact of digital transformation on ESG performance is not as obvious as that of SOEs.

This study calculates the Herfindahl index to measure market competition, dividing firms into groups of strong and weak competition. The regression results in Columns (3) and (4) of Table 6 show that the digital transformation of firms with weaker market competition is more significant in improving ESG performance. In more competitive markets, firms may prioritize immediate operational needs over environmental responsibilities. Conversely, enterprises in a weaker competitive market environment can invest more in digital transformation and fulfil their ESG responsibilities, leading to a more significant impact on their ESG performance.

6. Conclusion

This study reveals the following findings. First, digital transformation significantly improves ESG performance through technological empowerment. The dynamic panel model confirms a positive and significant marginal effect, with technological restructuring leading to multi-dimensional improvements by optimizing resource allocation and strengthening stakeholder synergy and legitimacy mechanisms. Second, financing constraints release resources for ESG investments, while government regulation promotes technology and ESG performance through institutional pressure and policy incentives. Third, state-owned enterprises (SOEs) benefit more from policy responsiveness and resource redundancy, whereas firms in low-competitive environments can convert technological dividends into long-term ESG investment. However, The study does not fully explore the impact of variations in international ESG standards on its conclusions and inadequately addresses the dynamic interaction between technology iteration and policy adjustment.

Future research directions can focus on the following dimensions. First, it should explore the synergistic mechanism between technology and finance, such as the transmission efficiency of digital technology mortgages on ESG financing, and how green financial instrument innovation can crack the bottleneck of financing constraints. Second, research should deepen the understanding of institutional dynamics by developing a model that aligns government regulatory intensity with the stages of digital transformation, identifying the most effective policy tool combinations.

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