The Impact of the Dual Synergy of Digital Transformation and Green Transformation on Enterprise Performance

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Abstract. Based on data from Chinese A-share listed firms on the Shanghai and Shenzhen Stock Exchanges from 2005 to 2022, this study applies text analysis and the coupling synergy model to measure the synergy level of corporate digital and green transformation, and examines its impacts on firm's financial and environmental performance. Results show that digital-green synergistic transformation significantly promotes both types of performance through the mediating role of corporate reputation, and this positive effect is strengthened by higher regional marketization. Heterogeneity tests indicate that state-owned enterprises benefit more in financial performance while non-state-owned enterprises improve more in environmental performance. Digital-green synergy benefits small firms more in profitability and environmental performance, but only significantly enhances large firms' market valuation. Regarding life cycle, declining firms gain higher short-term returns, whereas growth and mature firms achieve greater market value; mature firms also show significant improvement in environmental performance. This study possesses theoretical worth and practical importance for establishing a modern industrial system and attaining the "carbon peaking and carbon neutrality" objective.

Keywords: Digitalization; Greening; Synergistic transformation; Enterprise performance; Corporate reputation

1 Introduction

Facing the challenges posed by digitalization and the green transition, a growing number of countries are adopting synergistic strategies as a pivotal approach. In response to the dual-carbon goals, China has incorporated the synergistic transformation of digitalization and greening into its 14th Five-Year Plan, explicitly proposing a two-way penetration path of "practicing the green-oriented transformation in the digital industry" and "digitally upgrading the environmental industry".

As an important economic entity in the macroeconomy, the business operations of enterprises are closely related to macroeconomic fluctuations. Utilizing government policies effectively is also an inevitable choice for enterprises to promote their own

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economic development[1]. A new paradigm for enterprise development has emerged from the synergy of digital and green transformation. However, research on either digital or green transformation in isolation is abundant, the collaborative mechanisms arising from their interaction remain theoretically limited.

This paper focuses on the impact of the digital–green synergy on enterprise performance, exploring how companies can leverage this cooperative effect to achieve enhanced outcomes. Enterprise performance can be divided into financial performance and environmental performance. To maintain and enhance an enterprise's competitive edge, a win-win situation between financial and environmental performance should be achieved[2]. It is recognized that the deep integration of digitalization and green transition can achieve a synergistic effect of "1+1>2". Specifically, green technologies can mitigate the environmental impacts of digital technologies[3], while digital technologies can facilitate the green transition by optimizing systems and raising consumer environmental awareness[4-5].

Against this backdrop, this study draws on data from A-share listed companies on the Shanghai and Shenzhen stock exchanges from 2005 to 2022 to construct an empirical analytical framework. Concurrently, the study conducts a deeper investigation on the mediating role of corporate reputation. With regard to the moderating effect, this paper finds that enterprises with higher degree of marketization derive greater benefits from the dual synergy in enhancing their performance. Given that enterprise characteristics may influence the performance-enhancing effect of the dual synergy, we conduct a heterogeneity analysis from three perspectives: ownership, firm size, and life cycle. In terms of ownership, state-owned enterprises demonstrate a stronger synergistic effect of digital and green transformation on financial performance, while non-state-owned enterprises achieve greater improvements in environmental performance. In terms of firm size, the interaction between digital and green transformation more significantly enhances both profitability and environmental performance among small enterprises, while its impact on market valuation is only significant for large enterprises. Across life cycle stages, declining firms experience notable increase in short-term returns from digital-green synergy. Conversely, growth-stage and maturity-stage companies demonstrate significant progress in market value. When it comes to environmental performance, firms in the maturity phase indicate significant enhancement through synergistic transformation.

The marginal contribution of this paper is as follows: Firstly, it categorizes corporate performance into financial performance and environmental, providing a more comprehensive examination than a single-angle approach. Secondly, this paper enriches the research on digital-green synergy. We analyze how digital and green transformation jointly affect enterprise performance, examining the moderating role of marketization and the mediating mechanism of corporate reputation. Heterogeneity analysis across ownership, firm size, and life cycle enhance the practical implications of the empirical findings.

The remainder of this paper is structured as follows. Section 2 reviews the relevant literature. Section 3 constructs the theoretical framework and presents the research hy-

potheses. Section 4 describes the data sources, variable definitions, and empirical models. Section 5 reports and discusses the empirical results. Section 6 concludes the paper and presents the corresponding implications.

2 Literature Review

2.1 Enterprise Digital Transformation and Enterprise Performance

Digital transformation is widely recognized as a key driver of firm performance, primarily through pathways of cost reduction, operational efficiency, and innovation enhancement[6]. Empirical studies confirm that digital initiatives optimize resource allocation and mitigate information asymmetry, thereby supporting new business models and revenue streams[7]. However, the relationship is not uniformly positive. Significant implementation hurdles, such as organizational resistance and substantial learning costs, can stifle innovation and erode potential gains[8]. Furthermore, evidence suggests a non-linear dynamic: while moderate digitalization improves performance, excessive investment may lead to resource redundancy and governance complexity, resulting in an inverted U-shaped relationship[9-10]. The strength of digital transformation's impact is also moderated by contextual factors including firm size, ownership structure, and market conditions[11-12].Thus, while digital transformation holds clear performance potential, its realization is contingent on strategic execution and organizational adaptability.

2.2 Enterprise Green Transformation and Enterprise Performance

The literature presents a nuanced picture regarding the performance implications of corporate green transformation. On one hand, green practices—particularly eco-innovation and strong ESG performance—are associated with enhanced long-term financial outcomes, attributed to lower capital costs, improved stakeholder trust, and reduced regulatory risks[13-14].

On the other hand, green initiatives often entail substantial upfront investments and operational adjustments, which can dampen short-term profitability and operational efficiency[15]. Some studies further identify a non-linear effect, where the intensity of green activities exhibits an inverted U-shaped relationship with firm efficiency, indicating the presence of optimal implementation levels[16]. These divergent findings underscore the role of firm-specific factors, such as size, industry, and resource flexibility, in mediating the green-performance link[17-19].

Despite ongoing debate, a prevailing consensus acknowledges that green transformation aligns with both social responsibility and strategic resilience, though its financial returns may unfold over varying time horizons.

2.3 The "Dual Synergy" Relationship Between Digital and Greening Transformation of Enterprises

Existing research has sufficiently explored how digitalization and greening independently affect enterprise performance. However, the interaction between the two remains underexamined. Current studies primarily focus on the one-way enabling role of digitalization in advancing green objectives—such as through IoT and data analytics improving resource efficiency and supporting low-carbon transitions[20-21].Emerging work also notes that green imperatives can drive digital advancement, yet the bidirectional and synergistic mechanisms remain poorly understood.[22-23].

Few studies have empirically investigated how the synergy of digital and green transformations jointly enhances enterprise performance, particularly at the firm level. Most existing synergy analyses rely on regional or provincial indices[24] , leaving a gap in micro-level mechanism and pathway analysis. Specifically, the processes through which digital and green transformations interact to improve environmental and financial performance are not fully articulated.

While the literature offers multifaceted insights into the individual pathways and economic consequences of digital or green transformation, a significant gap remains. The specific mechanisms and implementation paths through which their synergy enhances business performance are underexplored. As China's economy transitions from rapid growth to a stage of high-quality development, fostering corporate dual synergy has become an imperative. Investigating its impact on firm performance thus carries substantial theoretical and practical significance. Therefore, this study aims to address this gap by examining the specific mechanisms and implementation paths through which the synergy between digital and green transformation affects enterprise performance.

3 Theoretical Analysis and Hypotheses

3.1 The Dual Synergy of digital transformation and Green Transformation on the Performance of Enterprises

Drawing on the resource-based view[25] and dynamic capability theory[26], this study constructs a theoretical framework to analyze how the dual synergy of digital and green transformations enhances enterprise performance.

The resource-based view posits that competitive advantage stems from valuable, rare, inimitable, and non-substitutable resource combinations. Digital-green synergy enables firms to build such distinctive resources. Digital technologies (e.g., cloud computing, IoT, big data) enhance the acquisition, integration, and real-time monitoring of resources, reducing waste and operational costs[27-28]. Concurrently, green technologies improve energy efficiency and reduce emissions. Their integration creates novel, complementary resource sets that optimize production processes, enable waste resource utilization[29], and support green product innovation, thereby improving both financial and environmental outcomes[30-31].

Dynamic capability theory emphasizes a firm's ability to integrate, build, and reconfigure resources to address rapidly changing environments. The dual transformation strengthens these capabilities. Digital tools provide real-time data on markets and environmental regulations, enhancing the speed and quality of decision-making and strategic adaptability[32]. Green transformation fosters environmental adaptability, helping firms comply with and exceed regulatory standards, thereby building market credibility(Song and Yu, 2018). Their synergy amplifies innovation capacity: digital technology shortens R&D cycles for green innovation[33], while green objectives guide digital optimization toward sustainable outcomes, shifting firms from "end-of-pipe treatment" to "source prevention"[34]. This collaborative dynamic capability enables efficient resource reallocation, rapid response to green market demands, and sustained competitive advantage in a green economy.

This synergy drives financial performance through dual pathways. First, it generates cost-reduction benefits: integrated monitoring and intelligent adjustment of production and energy use lower operational expenses and improve total factor productivity[35]. Second, it enhances revenue generation: deep market insights and digital marketing allow precise targeting of green consumer segments, fostering green brand building and market share expansion[36-37].

Simultaneously, the synergy elevates environmental performance. It enriches environmental monitoring and internal control mechanisms, reducing negative externalities. By improving resource lifecycle tracking and conversion efficiency, it minimizes the environmental footprint. Moreover, it establishes a foundational framework for green innovation, reducing associated costs and risks, and promoting sustainable competitiveness[38-39].

Based on the above integration of theoretical perspectives, the following hypotheses are proposed:

H1: The dual synergy of digital transformation and green transformation will significantly promote the improvement of corporate financial performance.

H2: The dual synergy of digital transformation and green transformation will significantly promote the improvement of corporate environmental performance.

3.2 The Path to Enhancing Enterprise Performance Through Dual Synergy: Analysis Based on Enterprise Reputation

The synergy between digital and green transformation enhances informational transparency, facilitating more effective signaling to external stakeholders. For instance, digital tools enable the real-time disclosure of environmental data (e.g., carbon emissions, energy consumption), which mitigates information asymmetry and bolsters the credibility of corporate environmental commitments among customers and shareholders[40]. Furthermore, this synergy reinforces corporate social responsibility (CSR). While green transformation fosters the development of low-carbon products, digital technology leverages precise marketing to communicate sustainable brand value, thereby enhancing corporate reputation.

Enterprise financial performance

A positive feedback loop exists between corporate reputation and financial performance: Strong financial performance enhances reputation, which in turn further strengthens financial outcomes, enabling sustained high performance[41]. First, a stronger reputation contributes to cost reduction through several channels. For instance, a favorable reputation mitigates information asymmetry for investors, improving credit ratings and expanding access to lower-cost financing[42]. It aids in attracting high-quality talent, which enhances operational efficiency and reduces human capital costs[43]. Meanwhile, reputation lowers transaction costs by fostering reliable partnerships. Suppliers are more willing to engage in enduring cooperation with reputable firms, as concerns over contractual risks are diminished[44].

Beyond cost reduction, reputation enhances financial performance by driving revenue growth. It signals product quality and reliability, which strengthens customer loyalty and increases consumers' willingness to pay, thereby enhancing pricing power[40]. Furthermore, positive media coverage amplifies brand influence and attracts new customers, contributing to market share gains[45].

Thus, the following theories are put out in this paper:

H3: Dual synergy promotes the enhancement of an enterprise's financial performance by enhancing its reputation.

Enterprise environmental performance

Reputation pressure serves as a catalyst for environmental innovation, compelling firms to increase R&D investment in green technologies. High-reputation firms are subject to sustained stakeholder scrutiny; to maintain their reputational capital, they must continually demonstrate commitment through green innovation[46]. Beyond this pressure mechanism, a strong reputation attracts partners and investors, securing essential financial and technical resources[44]. This support directly enables greater investment in the research and application of environmental technologies, elevating firms' green standards.

Thus, the following theories are put out in this paper:

H4: The dual synergy of digital transformation and green transformation drives enhancements in a firm's environmental performance by boosting its reputation.

The moderating role of the degree of marketization

A higher degree of marketization facilitates corporate digital transformation, which helps reduce costs and improve operational efficiency[47]. This improved institutional environment reflects healthier markets and more robust competitive dynamics, which in turn significantly enhance firms' capacity for technological innovation[48]. Such innovation directly contributes to greater economic value and expected returns. Furthermore, well-developed markets broaden firms' access to resources and increase the likelihood of obtaining lower-cost financing. This access is conducive to cost reduction, efficiency gains, and ultimately, enhanced firm performance[49].

Furthermore, marketization encourages corporate green transformation, thereby promoting sustainable and high-quality development[50]. This effect operates through two primary channels. First, as established, marketization facilitates digital transformation, and the digital economy is a significant driver of green economic development[51]. Second, a market-oriented environment intensifies competitive pressures, increasing firms'

imperative to optimize costs. In this context, environmental taxes act as a further catalyst, effectively compelling regional enterprises to pursue green innovation[52].

Additionally, a high degree of marketization positively influences the dual synergy between digital and green transformation. The marketization of data elements enhances corporate ESG performance by accelerating digital evolution. Robust ESG performance, in turn, improves financial outcomes and strengthens long-term corporate viability[53-54]. Moreover, marketization amplifies this synergistic effect institutionally. Regions with advanced market mechanisms typically implement more comprehensive digital and environmental policies—such as carbon emission trading systems and data-sharing standards. These institutional frameworks reduce compliance costs for firms and enhance the performance benefits derived from integrating digital and green initiatives.

H5: The stronger the degree of marketization, the more significant the contribution of the dual synergy of digital transformation and green transformation on enterprise performance.

The theoretical model is illustrated in Fig.1.

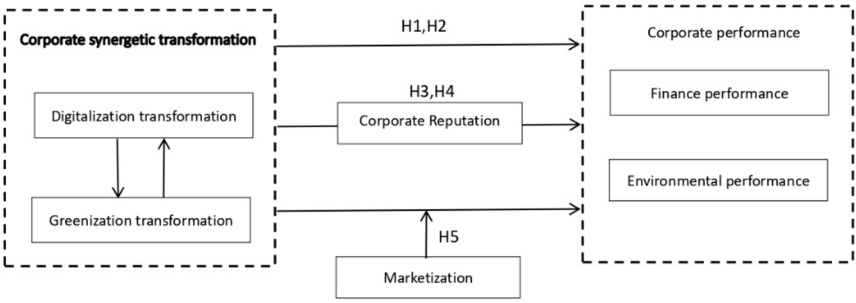

Fig. 1. Theoretical model of corporate synergetic transformation's impact on corporate performance

4 Research Design

4.1 Sample Selection and Data Sources

Our study utilizes yearly observational data from Chinese A-share companies that are publicly traded in the Shanghai and Shenzhen stock exchanges, covering the period from 2005 to 2022. The sample was selected depend on several criteria: (1) financial firms were excluded. (2) Firms designated as ST or PT were removed. (3) firms with missing key data were excluded. This selection process resulted in 36,951 observations. The data primarily from the CSMAR and WIND databases, with environmental performance (E scores) sourced from the Huazheng Index.

4.2 Variable Definition

Core Explanatory Variable: Digital-Green Synergy Level (DG)

The core explanatory variable is the degree of digital-green synergy (DG) within firms. To assess the mutual influence and development of digitalization and greenization transformations, a coupling synergy degree model is employed for quantitative analysis. This model is advantageous because it both captures the connection between digitalization and greening transformation and measures the extent of their interaction.

For measuring digitalization transformation (D), this study adopts a commonly used approach in academic research. Specifically, annual report text analysis is utilized to evaluate the digitalization transformation level of firms. The process is as follows: First, a digitalization transformation keyword library is constructed. Drawing from the approach proposed by[55], in this research, the frequencies of digital-related terms are divided into two categories: basic technical applications and practical technical operations. Next, Python web scraping techniques are employed to gather annual report data from A-share listed companies. Textual data is extracted from these documents using the Java PDFBox library to assemble a corpus. The Python program is used to search, count, and categorize the keywords from the digital transformation library within the dataset, resulting in a total frequency count for key technological directions. To mitigate scale differences across variables, the frequency data is log-transformed to build an indicator system for firm digitalization transformation. For robustness, alternative methods for measuring digital transformation are also used for validation in subsequent analysis.

In measuring the level of greening transformation (G), adopts the method outlined by[56], using textual analysis approach to evaluate the green transformation status of companies. Compared to content analysis, text analysis combines natural language processing (NLP) techniques, enabling more accurate extraction of information from unstructured text in large datasets. This significantly lowers error margins and enhances analytical reliability.

Building on previous research, the research set 113 keywords associated with corporate greenization transformation, categorized into five key areas: advocacy and promotion, strategic planning, green innovation, pollution control, and supervision management. By calculating the frequency of keywords within the annual report texts, the overall count of terms related to greenization is obtained. To quantify the level of green transformation, the study applies a logarithmic transformation of the keyword frequency, adding one to each value for the analysis.

Coupling Synergy Model for Digital-Green Synergy(DG)

After measuring the extent of digitalization transformation (D) and greening transformation (G), we utilize a coupling synergy degree model to evaluate the synergetic level of DG. Since the DG represents a strategic relationship of mutual reinforcement and promotion, this model is well-suited to capture the overall effectiveness and interaction of multiple subsystems in a holistic manner[57-58]. The first step is developing the model to compute the coupling degree (C) between digital and green transformations:

$$C = 2 \times \left[\frac{D \times G}{(D+G)^2}\right]^{\frac{1}{2}} \tag{1}$$

We further calculates the synergy degree (T) of digitalization and greening, which is then used to derive the coupling synergy degree (DG) of the two transformations. The specific calculation formulas are as follows:

$$T=a\times D+b\times G \tag{2}$$

$$DG=\sqrt{C\times T} \tag{3}$$

In Equation (2), a and b represent the weight coefficients for digitalization and greening. Considering that digitalization and greening are equally important for the dual transformation, here we set a = b= $\frac{1}{2}$. Finally, the coupling synergy degree DG, calculated according to Equation (3), will be used to measure the synergetic transformation of the firm.

Dependent Variable: Corporate Performance

The dependent variable is corporate performance, which is divided into two dimensions: financial performance and environmental performance.

Financial performance is represented by two proxies: the TobinQ ratio and the return on assets (ROA). TobinQ reflects a company's market value, while ROA serves as a comprehensive financial indicator, encompassing various factors such as production efficiency, sales capacity, profitability, and financial leverage.

In recent years, the evaluation of environmental performance has expanded beyond traditional metrics like air and water quality to include broader social aspects such as education. The ESG indicators have become a vital tool for assessing environmental performance due to their alignment with sustainable development principles and China's dual-carbon goals. The Huazheng ESG rating index considers various factors in a company's daily operations, including pollutant emission management, clean energy utilization, and waste disposal. It also applies differentiated weightings based on industry characteristics. Due to its comprehensive coverage, strong data traceability, and precise calculation methods, this index has become one of the most important and authoritative metrics for evaluating environmental performance. Therefore, this study uses the annual average environmental score (E score) from the Huazheng ESG rating as a proxy for environmental performance.

Mechanism analysis: Corporate Reputation

Refer to the research of Zhang and Jiang[59],this study collects all news reports of sample companies from various media outlets such as television, the internet, and newspapers for each year. These reports are then classified into three categories: positive, neutral, and negative. To measure each company's public reputation (Reputation) for a specific year, we add 1 to the number of positive news and take the natural logarithm of the result.

4.3 Model Construction

Building upon the theoretical framework, a multiple linear regression model is developed to test Hypothesis 1 and Hypothesis 2, which examine the direct effects of digitalization and greenization synergetic transformation on corporate financial and environmental performance. The model is constructed as follows:

$$ROA_{i,t}=\alpha_1+\beta_1 DG_{i,t}+\gamma_1 Controls+\sum firm+\sum Year+\varepsilon_{i,t} \quad (4)$$

$$TobinQ_{i,t}=\alpha_2+\beta_2 DG_{i,t}+\gamma_2 Controls+\sum firm+\sum Year+\varepsilon_{i,t} \quad (5)$$

$$E\text{-}score_{i,t}=\alpha_3+\beta_3 DG_{i,t}+\gamma_3 Controls+\sum firm+\sum Year+\varepsilon_{i,t} \quad (6)$$

The (i) and (t) represents the firm and the year respectively. The dependent variables (ROA) and (TobinQ) represent the firm's financial performance, and the (E-score) represents the firm's environmental performance. The core explanatory variable (DG) measures the level of synergetic transformation, with the parameter β depicting the impact of (DG) on corporate performance. (Controls) refers to other firm-level control variables. To control for macroeconomic factors and other unmeasurable influences, fixed effects for both year and firm are included.

The mechanism test model is as follows:

$$Reputation_{i,t}=\alpha_4+\beta_4 DG_{i,t}+\gamma_4 Controls+\sum firm+\sum Year+\varepsilon_{i,t} \quad (7)$$

We introduces the interaction term between the synergetic transformation and marketization into models (4) to (6) to test the moderating effect:

$$ROA_{i,t}=\alpha_8+\beta_8 DG_{i,t}+\mu_8 DG\times market+\nu_8 market+\gamma_8 Controls+\sum firm+\sum Year+\varepsilon_{i,t} \quad (8)$$

$$TobinQ_{i,t}=\alpha_9+\beta_9 DG_{i,t}+\mu_9 DG\times market+\nu_9 market+\gamma_9 Controls+\sum firm+\sum Year+\varepsilon_{i,t} \quad (9)$$

$$E\text{-}score_{i,t}=\alpha_{10}+\beta_{10} DG_{i,t}+\mu_{10} DG\times market+\nu_{10} market+\gamma_{10} Controls+\sum firm+\sum Year+\varepsilon i,t_t \quad (10)$$

5 Empirical Results

5.1 Descriptive Statistics

Table 1 reports the descriptive statistics. The DG measure ranges from a minimum of 0 to a maximum of 0.945, with a mean value of 0.359 and a standard deviation of 0.302. These figures reveal substantial heterogeneity in the extent of synergistic development across the sample of listed companies.

Table 1. Descriptive Statistics

VarName	Obs	Mean	SD	Min	Median	Max
DG	36951	0.359	0.302	0.000	0.488	0.945
ROA	36951	0.040	0.062	-0.965	0.039	0.786
TobinQ	36951	2.003	1.207	0.625	1.619	9.998
Escore	36951	60.437	7.348	29.460	60.250	95.160

size	36951	22.186	1.322	18.702	21.984	28.636
invt	36951	0.052	0.050	0.000	0.037	0.642
lnage	36951	2.039	0.920	0.000	2.197	3.497
DirectorNumber1	36951	8.553	1.707	0.000	9.000	18.000
top1	36951	34.545	15.090	0.290	32.330	89.990
big4	36951	0.061	0.239	0.000	0.000	1.000
cr	36951	0.576	0.205	0.014	0.593	1.000
lev	36951	0.419	0.206	0.007	0.412	0.997
cflow	36951	0.048	0.074	-0.744	0.047	0.771

5.2 Baseline Regressions

The baseline regression results for the effect of synergistic transformation on corporate performance is reported on Table 2.

Column (1) and (2) indicate that DG has a positive impact on ROA and TobinQ, at the 1% and 5% significance level, respectively. Both of these results confirm that synergistic transformation positively influences financial performance, thus supporting Hypothesis 1. Moreover, Column (3) indicates that the DG coefficient is significantly positive at the 1% level, highlighting that dual integration synergy substantially enhances environmental performance, thereby confirming Hypothesis 2.

Specifically, the results suggest that for every 1-unit increase in DG, ROA increases by 0.00522 units and TobinQ rises by 0.0531 units. Additionally, environmental performance improves by 0.831 units.

Table 2. Baseline regressions

	(1)	(2)	(3)
VARIABLES	roa	tobin	Escore
DG	0.00522***	0.0531**	0.831***
	(0.00134)	(0.0220)	(0.148)
size	0.0182***	-0.558***	1.047***
	(0.00105)	(0.0169)	(0.0808)
invt	0.111***	1.090***	-3.524***
	(0.00746)	(0.121)	(0.743)
lnage	-0.00134	0.687***	-1.641***
	(0.000873)	(0.0165)	(0.116)
DirectorNumber1	0.000488	-0.00333	-0.0748**
	(0.000343)	(0.00492)	(0.0327)
top1	0.000498***	-0.00254***	-0.00994*
	(4.87e-05)	(0.000808)	(0.00511)
big4	0.00376	0.0799*	0.433
	(0.00244)	(0.0469)	(0.300)
cr	0.0749***	0.395***	-1.303***
	(0.00367)	(0.0575)	(0.325)
lev	-0.142***	0.0230	-0.475
	(0.00460)	(0.0550)	(0.310)
cflow	0.194***	1.039***	0.562
	(0.00660)	(0.0847)	(0.448)
Constant	-0.382***	12.73***	42.32***

	(0.0227)	(0.366)	(1.753)
Year FE	Y	Y	Y
Firm FE	Y	Y	Y
Observations	36,950	36,950	36,950
R-squared	0.527	0.634	0.567

Note(s):

This research uses robust standard errors, which are reported in parentheses, *p < 0.1, **p < 0.05 and ***p < 0.01.

5.3 Endogeneity Test

In empirical research, reverse causality can lead to endogeneity issues. Specifically, better-performing firms may be more inclined to promote synergistic transformation, meaning that improved performance could be the cause of synergistic transformation rather than its effect. To address this concern and confirm the robustness of the findings, we conducted endogeneity tests.

First, acknowledging the possibility of time lags in the effect of DG, the core explanatory variable was lagged by one period (L1DG). As presented in Table 3, the estimated coefficients for synergistic transformation continue to exhibit statistically significant positive values, reinforcing the consistency of our findings over time.

On the other hand, we addressed endogeneity using an instrumental variable (IV) approach. Borrowing from[60], we used the cubic difference between the synergistic transformation index and the average value of synergistic transformation indicators categorized by industry and province as the instrument variable. This instrument is valid because synergistic transformation exhibits peer effects—firms within the same industry and region tend to influence each other's transformation efforts—while a firm's performance is unlikely to be directly affected by the transformation activities of peers. Consequently, the instrument satisfies both relevance and exogeneity requirements.

Column (1) of Table 4 reports the first-stage effect of the instrument on the independent variable (DG), with a coefficient of 4.642, and is significantly positive at the 1% level, passing the weak instrument test. Columns (2) to (4) display the second-stage results, where the coefficients for synergistic transformation are 0.005, 0.057, and 1.207.

These findings confirm that after addressing the endogeneity issue, the conclusion that synergistic transformation significantly positively impacts corporate performance remains valid.

Table 3. Results of first-order lag regression

	(1)	(2)	(3)
Variable	ROA	TobinQ	E score
L1DG	0.00382***	0.0384*	1.345***
	(0.00146)	(0.0228)	(0.159)
Controls	Y	Y	Y
_cons	-0.393***	11.07***	39.00***
	(0.0243)	(0.363)	(2.041)
Year FE	Y	Y	Y

Firm FE	Y	Y	Y
N	31,152	31,152	31,152
R^2	0.529	0.656	0.594

Note(s):
This research uses robust standard errors, which are reported in parentheses, *p < 0.1, **p < 0.05 and ***p < 0.01.

Table 4. Instrumental Variable Method

	(1) DG	(2) ROA	(3) TobinQ	(4) E score
lewbel_IV	4.642***			
	(0.044)			
DG		0.005***	0.057*	1.207***
		(0.002)	(0.031)	(0.197)
controls	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
Firm FE	Y	Y	Y	Y
N	36950	36950	36950	36950
R^2		0.188	0.123	0.014
F	11043.011	294.618	291.109	39.921
CD Wald F	53119.813			
SW S stat.	42.403			

Note(s):
This research uses robust standard errors, which are reported in parentheses, *p < 0.1, **p < 0.05 and ***p < 0.01.

5.4 Robustness Test

High-dimensional Fixed Effects

Given the impact of changing macroeconomic conditions on corporate performance within specific periods and regions, we conduct regressions using both year-city interaction fixed effects and firm fixed effects. As reported in Table 5, even after considering these interaction effects, the synergistic transformation continues to exert a statistically significant and positive effect on both financial and environmental performance. This further strengthens the robustness of our findings.

Table 5. High-dimensional Fixed Effects

VARIABLES	(1) ROA	(2) TobinQ	(3) Escore
DG	0.00557***	0.0451*	0.746***
	(0.00145)	(0.0242)	(0.162)
size	0.0184***	-0.555***	1.020***
	(0.00111)	(0.0180)	(0.0902)
invt	0.105***	0.980***	-3.398***
	(0.00801)	(0.131)	(0.830)
lnage	-0.00147	0.687***	-1.581***
	(0.000946)	(0.0182)	(0.129)

DirectorNumber1	0.000533	-0.00384	-0.0829**
	(0.000378)	(0.00519)	(0.0365)
top1	0.000464***	-0.00245***	-0.00897
	(5.19e-05)	(0.000876)	(0.00565)
big4	0.00446*	0.0595	0.400
	(0.00250)	(0.0493)	(0.325)
cr	0.0705***	0.317***	-0.835**
	(0.00393)	(0.0607)	(0.358)
lev	-0.137***	0.00720	-0.526
	(0.00473)	(0.0599)	(0.346)
cflow	0.186***	0.934***	0.538
	(0.00702)	(0.0899)	(0.493)
Constant	-0.386***	12.72***	42.62***
	(0.0242)	(0.391)	(1.965)
Firm FE	Y	Y	Y
Year-City FE	Y	Y	Y
Observations	35,065	35,065	35,065
R-squared	0.577	0.670	0.608

Note(s):

This research uses robust standard errors, which are reported in parentheses, *p < 0.1, **p < 0.05 and ***p < 0.01.

Substitution of Key Explanatory Variable

In light of the distinctive nature of digitalization, this study adopts an approach based on[61], using the proportion of digitization-related intangible assets relative to total intangible assets as an indicator of digitalization(D2).

For measuring green transformation, there is no universally accepted standard. We further use the share of green patent applications within a firm's total patent applications as a proxy for green transformation (G2).

Building upon this, we recalibrate the degree of synergistic transformation as (DG2) and incorporate it into the regression model. In Table 6, the results manifest that the synergy measured by digital technology intangible assets and green patents significantly enhances corporate performance, further confirming the robustness of our conclusions.

Table 6. Substitution of Key Explanatory Variable

VARIABLES	(1) ROA	(2) TobinQ	(3) Escore
DG2	0.00692***	0.0428*	1.411***
	(0.00114)	(0.0257)	(0.187)
size	0.0107***	-0.366***	1.644***
	(0.000343)	(0.00758)	(0.0394)
invt	0.126***	1.394***	-2.239***
	(0.00613)	(0.129)	(0.761)
lnage	-0.00568***	0.294***	-0.601***
	(0.000353)	(0.00766)	(0.0490)
DirectorNumber1	0.000279*	-0.0103***	0.0669***
	(0.000164)	(0.00324)	(0.0219)

top1	0.000208***	-0.000214	-0.00433*
	(1.80e-05)	(0.000371)	(0.00253)
big4	-0.00505***	0.304***	0.240
	(0.00102)	(0.0239)	(0.162)
cr	0.0695***	0.437***	-0.143
	(0.00199)	(0.0386)	(0.234)
lev	-0.111***	-0.445***	0.0825
	(0.00224)	(0.0373)	(0.220)
cflow	0.287***	1.910***	1.889***
	(0.00646)	(0.0973)	(0.484)
Constant	-0.210***	9.365***	24.65***
	(0.00716)	(0.159)	(0.822)
Industry FE	Y	Y	Y
Year FE	Y	Y	Y
Observations	36,849	36,849	36,849
R-squared	0.351	0.322	0.188

Note(s):

This research uses robust standard errors, which are reported in parentheses, *p < 0.1, **p < 0.05 and ***p < 0.01.

5.5 Mechanism Test

To test the underlying mechanism, we utilize a two-stage regression approach. In Table 7, the findings demonstrate that the synergistic transformation enhances corporate reputation, thereby confirming the mechanism: synergistic transformation improves corporate performance by strengthening corporate reputation.

Table 7. Mechanism Test

Variable	(1) Reputation
DG	0.0840***
	(0.0208)
controls	Y
_cons	-5.310***
	(0.104)
Year FE	Y
Industry FE	Y
N	36,458
R2	0.444

Note(s):

This research uses robust standard errors, which are reported in parentheses, *p < 0.1, **p < 0.05 and ***p < 0.01.

5.6 Moderating Effect of Marketization

This study introduces an interaction term between the degree of synergistic transformation and marketization (DG_M). In Table 8, the interaction terms DG_M are significantly positive at the 1% level, indicating that marketization significantly enhances the

positive effect of synergistic transformation on corporate performance, thereby confirming Hypothesis 5.

Table 8. Moderating Effect

VARIABLES	(1) ROA	(2) TobinQ	(3) Escore
DG_M	0.00182***	0.0326***	0.324***
	(0.000574)	(0.0103)	(0.0743)
market	0.000392	0.0201*	-0.115
	(0.000662)	(0.0118)	(0.0738)
DG	0.00460***	0.0562**	0.753***
	(0.00129)	(0.0222)	(0.151)
size	0.0172***	-0.541***	1.066***
	(0.00106)	(0.0167)	(0.0839)
invt	0.103***	1.031***	-3.777***
	(0.00722)	(0.124)	(0.764)
lnage	-0.00172**	0.682***	-1.714***
	(0.000863)	(0.0166)	(0.118)
DirectorNumber1	0.000350	-0.00235	-0.0622*
	(0.000338)	(0.00488)	(0.0334)
top1	0.000416***	-0.00184**	-0.00903*
	(4.65e-05)	(0.000810)	(0.00528)
big4	0.00357	0.0787*	0.527*
	(0.00251)	(0.0477)	(0.308)
cr	0.0732***	0.403***	-1.302***
	(0.00364)	(0.0575)	(0.338)
lev	-0.133***	0.0151	-0.548*
	(0.00470)	(0.0569)	(0.329)
cflow	0.194***	1.042***	0.450
	(0.00658)	(0.0869)	(0.467)
Constant	-0.361***	12.13***	43.03***
	(0.0237)	(0.377)	(1.966)
Firm FE	Y	Y	Y
Year FE	Y	Y	Y
Observations	35,643	35,643	35,643
R-squared	0.532	0.636	0.571

Note(s):

This research uses robust standard errors, which are reported in parentheses, *p < 0.1, **p < 0.05 and ***p < 0.01.

5.7 Heterogeneity Analysis

Ownership Heterogeneity Analysis

This research categorizes the sample into state-owned and non-state-owned enterprises, employing regression analysis to explore the connection between synergistic transition and financial and environmental performance across different ownership types. According to Table 9, columns (1)–(2), the beneficial impacts of synergistic

transformation on ROA are significant in both state-owned and non-state-owned enterprises. However, the effect is more pronounced in the former case. Probably because state-owned enterprises are the beneficiaries of a number of advantages, including greater government support, access to resources and stable management. With these advantages, state-owned enterprises can improve their ROA more efficiently when adopting positive transformation methods. Conversely, heightened market competition may leave non-state-owned enterprises stretched too thin, resulting in relatively limited gains in ROA from synergistic transformation.

The beneficial impact on financial performance is significant exclusively in state-owned enterprise when measured by TobinQ. When state-owned enterprises adopt the dual synergy, they are not only capable of using various forms of support such as policies for accelerating profits but also convey a positive signal to the public: they shoulder the responsibilities of digital innovation and environmental protection. Therefore, the market may place a higher value assessment and establish elevated expectations on them. However for non-state-owned enterprises, the long-term effect of synergy requires continuous technological iteration and market validation and it may be difficult for the market to fully price them in such a short term.

Besides, the results in columns (5)–(6) reveal that synergistic transformation significantly enhances the environmental performance for both types of enterprises, with a higher coefficient for non-state-owned enterprises. State-owned enterprises themselves are under an obligation to respond to national policy directives and are subject to more stringent requirements with regard to the control of environmental pollution. Consequently, the capacity for enhancing environmental performance through synergistic transformation may be constrained. But for non-state-owned enterprises, they may have had relatively loose environmental controls in the early stages. In the context of mounting regulatory pressures and heightened societal scrutiny on corporate environmental responsibility, non-state-owned enterprises are increasing investments in integrating digitalization with sustainable development. This initiative may bring about more significant performance improvement.

Table 9. Heterogeneity Analysis of Enterprise Ownership

VARIABLES	(1) SOEs ROA	(2) NSOEs ROA	(3) SOEs TobinQ	(4) NSOEs TobinQ	(5) SOEs Escore	(6) NSOEs Escore
DG	0.00433**	0.00395**	0.0561*	0.00920	0.667***	0.940***
	(0.00188)	(0.00186)	(0.0302)	(0.0304)	(0.238)	(0.190)
size	0.0126***	0.0222***	-0.548***	-0.559***	1.315***	0.976***
	(0.00128)	(0.00152)	(0.0247)	(0.0234)	(0.132)	(0.111)
invt	0.109***	0.105***	1.060***	1.102***	-0.295	-4.767***
	(0.0121)	(0.00959)	(0.185)	(0.153)	(1.254)	(0.933)
lnage	0.00174	-0.000619	0.484***	0.757***	0.416	-2.231***
	(0.00140)	(0.00121)	(0.0315)	(0.0223)	(0.271)	(0.144)

Director-Number1	0.000111	0.00124**	-0.000509	0.00290	-0.0320	-0.101**
	(0.000389)	(0.000537)	(0.00635)	(0.00740)	(0.0480)	(0.0469)
top1	0.000192***	0.000782***	-0.00180*	-0.00312**	-0.0249***	-0.00336
	(6.13e-05)	(7.54e-05)	(0.00108)	(0.00122)	(0.00792)	(0.00714)
big4	0.000168	0.00572	-0.00696	0.222***	0.0379	0.869*
	(0.00266)	(0.00409)	(0.0491)	(0.0859)	(0.397)	(0.477)
cr	0.0741***	0.0727***	0.390***	0.496***	-1.669***	-1.303***
	(0.00515)	(0.00532)	(0.0884)	(0.0776)	(0.542)	(0.423)
lev	-0.142***	-0.139***	-0.0880	0.0917	-0.0729	-0.685*
	(0.00582)	(0.00659)	(0.0855)	(0.0729)	(0.524)	(0.399)
cflow	0.180***	0.201***	0.651***	1.207***	0.746	0.547
	(0.00884)	(0.00891)	(0.115)	(0.111)	(0.720)	(0.576)
Constant	-0.251***	-0.484***	12.84***	12.64***	31.56***	44.69***
	(0.0292)	(0.0331)	(0.546)	(0.509)	(2.966)	(2.401)
Observations	13,185	23,697	13,185	23,697	13,185	23,697
R-squared	0.570	0.522	0.669	0.631	0.582	0.576

Note(s):

This research uses robust standard errors, which are reported in parentheses, *p < 0.1, **p < 0.05 and ***p < 0.01.

Scale Heterogeneity Analysis

This part examines how synergistic transformation differentially affects corporate performance with firm size as a moderating factor. The dataset is partitioned into large-sized and small-sized enterprises and the results are presented in Table 10.

Regarding TobinQ, synergistic transformation conduces to large enterprises significantly yet the efficacy of this measure for small businesses is uncertain. This indicates that larger companies leverage synergistic transformation enabling them to quickly enhance market expectations. In contrast, smaller companies experience limited incremental benefits from these synergies.

In terms of Escore, small enterprises exhibit a slightly stronger improvement than large companies. By adopting synergistic transformation, small enterprises can quickly address loopholes in environmental protection, with considerable room for marginal improvement in environmental performance. Large-scale enterprises have relatively sound environmental compliance and governance systems, which may result in less obvious benefits from synergistic transformation.

When it comes to ROA, the effect of synergistic transformation is significantly stronger for small enterprises compared to large ones. Small businesses are characterized by their small-scale nature and relatively simple production processes. It suggests that in the process of undergoing transformation, the costs associated with activities in small companies may be lower so that the achievement of improved financial performance within a short period of time is more obvious.

Table 10. Heterogeneity Analysis of Enterprise Scale

VARIABLES	(1) Small-sized ROA	(2) Large-sized ROA	(3) Small-sized TobinQ	(4) Large-sized TobinQ	(5) Small-sized Escore	(6) Large-sized Escore
DG	0.0137***	0.00855***	0.0311	0.0763***	0.888***	0.832***
	(0.00202)	(0.00152)	(0.0341)	(0.0220)	(0.203)	(0.236)
size	0.0240***	0.0142***	-1.055***	-0.151***	0.914***	1.430***
	(0.00215)	(0.00143)	(0.0321)	(0.0202)	(0.150)	(0.171)
invt	0.0993***	0.109***	1.011***	0.972***	-5.873***	0.463
	(0.00947)	(0.0121)	(0.174)	(0.132)	(0.959)	(1.293)
lnage	-0.00721***	-0.00122	0.924***	0.360***	-2.409***	0.904***
	(0.00130)	(0.00139)	(0.0263)	(0.0266)	(0.156)	(0.270)
Director-Number1	0.00154***	-0.000258	3.73e-05	0.000183	0.0160	-0.156***
	(0.000587)	(0.000350)	(0.00887)	(0.00525)	(0.0507)	(0.0492)
top1	0.000615***	0.000356***	-0.00934***	-0.00189***	-0.00988	-0.0106
	(9.32e-05)	(5.69e-05)	(0.00156)	(0.000807)	(0.00929)	(0.00824)
big4	0.00305	0.00223	0.107	-0.00532	-0.415	0.399
	(0.00516)	(0.00275)	(0.138)	(0.0426)	(0.664)	(0.376)
cr	0.0727***	0.0814***	0.287***	0.490***	-0.873*	-2.591***
	(0.00534)	(0.00558)	(0.0863)	(0.0652)	(0.446)	(0.621)
lev	-0.108***	-0.171***	0.234***	-0.272***	-0.00287	-1.856***
	(0.00689)	(0.00556)	(0.0819)	(0.0665)	(0.433)	(0.581)
cflow	0.173***	0.175***	0.735***	1.060***	0.414	0.785
	(0.00878)	(0.00805)	(0.122)	(0.0857)	(0.591)	(0.745)
Constant	-0.513***	-0.273***	23.10***	4.056***	44.74***	29.97***
	(0.0459)	(0.0327)	(0.672)	(0.467)	(3.168)	(3.900)
Observations	20,396	15,783	20,396	15,783	20,396	15,783
R-squared	0.551	0.631	0.669	0.714	0.610	0.581

Note(s):

This research uses robust standard errors, which are reported in parentheses, *p < 0.1, **p < 0.05 and ***p < 0.01.

Lifecycle Heterogeneity Analysis

Companies at different stages of their lifecycle manifest marked discrepancies in their business objectives, resource endowments, market environment, and competitive strategies. The influence of synergistic transformation, served as an indicator of the integration of digital and sustainable development, is closely associated with a company's lifecycle stage. Accordingly, this research adopts Dickinson's methodologies to

assess how synergistic transformation influences corporate performance across the growth, maturity, and decline stages[62].

According to Table 11, although growth-stage enterprises are in an expansion phase, the impact of synergistic transformation on ROA is not significant. This could stem from the conflict between substantial investment costs and limited resources, which hinders the full realization of digital greening synergy benefits in the short term. As enterprises enter the maturity phase, the effect of synergistic transformation on ROA remains not significant. This suggests that with accumulated resources and market stability, it may be hard for mature enterprises to reorganize their structure. Adopting the synergistic strategy costs a lot, resulting that short-term effect of financial enhancement is not significant. The beneficial effect of digital-green synergies on ROA is most pronounced during the decline phase of the enterprise. Particularly under China's "dual carbon" strategy, green transformation and digital optimization may provide significant financial recovery which has a immediate positive impact on companies in financial crisis during a recession.

Table 11. Heterogeneity Analysis of Enterprise Life Cycle -ROA

VARIABLES	(1) growth ROA	(2) maturity ROA	(3) decline ROA
DG	0.00524	0.00368	0.0122**
	(0.00470)	(0.00226)	(0.00505)
size	0.0159***	0.0152***	0.0252***
	(0.00295)	(0.00198)	(0.00414)
invt	0.0867***	0.131***	0.209***
	(0.0333)	(0.0166)	(0.0413)
lnage	-0.00425	0.00301	0.00746
	(0.00301)	(0.00214)	(0.00483)
DirectorNumber1	0.00248*	0.000268	0.000806
	(0.00127)	(0.000578)	(0.00129)
top1	0.00101***	0.000449***	0.000336**
	(0.000195)	(9.29e-05)	(0.000158)
big4	0.00801	0.00101	0.00715
	(0.00603)	(0.00404)	(0.00773)
cr	0.0558***	0.0763***	0.0912***
	(0.0132)	(0.00689)	(0.0119)
lev	-0.151***	-0.152***	-0.169***
	(0.0147)	(0.00856)	(0.0149)
cflow	0.000545	0.330***	0.136***
	(0.0152)	(0.0138)	(0.0154)
Constant	-0.347***	-0.332***	-0.565***
	(0.0628)	(0.0424)	(0.0925)
Observations	3,687	12,177	5,944
R-squared	0.600	0.667	0.538

Note(s):

This research uses robust standard errors, which are reported in parentheses, *p < 0.1, **p < 0.05 and ***p < 0.01.

According to **Table 12**, in the growth and maturity phase, the positive effect of dual integration synergies on TobinQ is pronounced. This reflects that mature enterprises are not only able to sustain the current business model, but they can also rapidly integrate dual resources and convert them into market value. During the growth phase, the beneficial influence is slightly weaker. Growing enterprise are able to promote market value through innovation and resource optimization through dual integration synergies while the beneficial effect has not been fully released due to limited scale and resources. In the decline phase, the positive effect on TobinQ is not significant. Probably because the advantages of dual transformation are postponed. The market lacks confidence in recessive companies so notwithstanding any efforts to effect a transformation, it is challenging to effect a change in the market's valuation of the brand in the short term without immediate profit performance.

Table 12. Heterogeneity Analysis of Enterprise Life Cycle -TobinQ

VARIABLES	(1) growth TobinQ	(2) maturity TobinQ	(3) decline TobinQ
DG	0.108*	0.105**	0.0797
	(0.0652)	(0.0423)	(0.0672)
size	-0.695***	-0.484***	-0.863***
	(0.0645)	(0.0326)	(0.0489)
invt	-0.0572	1.371***	2.185***
	(0.477)	(0.324)	(0.612)
lnage	0.544***	0.730***	0.675***
	(0.0492)	(0.0455)	(0.0669)
DirectorNumber1	-0.0154	-0.00261	0.0203
	(0.0162)	(0.00951)	(0.0141)
top1	-0.00414	-0.00242	-0.00104
	(0.00300)	(0.00163)	(0.00234)
big4	-0.0242	0.0693	0.0884
	(0.107)	(0.0934)	(0.150)
cr	-0.137	0.509***	0.250*
	(0.200)	(0.125)	(0.151)
lev	0.136	-0.0262	0.134
	(0.166)	(0.110)	(0.149)
cflow	0.171	2.648***	0.329*
	(0.388)	(0.215)	(0.192)
Constant	16.46***	10.71***	19.02***
	(1.499)	(0.712)	(1.035)
Observations	3,687	12,177	5,944
R-squared	0.739	0.684	0.750

Note(s):

This research uses robust standard errors, which are reported in parentheses, *p < 0.1, **p < 0.05 and ***p < 0.01.

According to Table 13, the empirical findings indicate that synergistic transformation significantly enhances a firm's environmental performance in the mature phase.

In the case of mature enterprises, the market share has stabilized and business growth has decelerated. Companies are willing to seek novel competitive advantages and sustainable development paths like synergistic transformation, so improvements can be achieved over a relatively brief period. For growing enterprise, corporate entities prioritize the augmentation of business operations, the attainment of market dominance, and the enhancement of market competitiveness. They allocate a significant proportion of their resources to the domains of production, marketing, and other pertinent areas so the beneficial effect of synergistic effects may be limited. The reason why companies undergoing a decline phase do not show significant improvement in environmental performance when employing a dual-coordination strategy may be similar to those in the growing phase——the company's strategic focus is pivotal. When companies are confronted with a critical challenge to their survival, their priority is on stopping losses and seeking survival. It often hinders the implementation of coordination strategies, resulting in suboptimal resource allocation and outcomes.

Table 13. Heterogeneity Analysis of Enterprise Life Cycle -E Score

VARIABLES	(1) growth Escore	(2) maturity Escore	(3) decline Escore
DG	0.847	1.088***	0.190
	(0.537)	(0.284)	(0.402)
size	0.712**	1.302***	0.681***
	(0.292)	(0.174)	(0.244)
invt	-2.779	-0.408	-6.195*
	(2.684)	(1.832)	(3.589)
lnage	-3.019***	1.087***	-0.225
	(0.370)	(0.284)	(0.442)
DirectorNumber1	0.0575	-0.0420	-0.163*
	(0.123)	(0.0615)	(0.0930)
top1	-0.0288	0.0167*	0.00908
	(0.0208)	(0.0101)	(0.0150)
big4	1.615*	-0.310	0.564
	(0.969)	(0.514)	(0.717)
cr	-0.443	-1.219*	-2.688***
	(1.179)	(0.693)	(0.833)
lev	0.358	-1.211*	-0.144
	(1.063)	(0.670)	(0.810)
cflow	1.137	-0.470	2.600***
	(1.903)	(1.123)	(1.006)
Constant	50.70***	29.79***	47.87***
	(6.377)	(3.841)	(5.357)
Observations	3,687	12,177	5,944
R-squared	0.683	0.646	0.675

Note(s):

This research uses robust standard errors, which are reported in parentheses, *p < 0.1, **p < 0.05 and ***p < 0.01.

6 Conclusions and Policy Implications

It is evident that digitalization and sustainability represent two key global development trends. In this context, their synergy offers enterprises a strategic pathway to overcome resource constraints and achieve sustainable development. The practice of dual digital-green transformation is crucial not only for corporate competitiveness but also for national high-quality development.

Using data from Chinese listed companies from 2005 to 2022, this paper examines the impact of digital-green synergy on corporate performance and elucidates its underlying mechanisms. The results show that the synergistic effect promotes both financial performance and environmental performance and this effect remains significant after a series of robustness tests. Marketization level positively moderates this effect, indicating that a more developed market environment helps firms better leverage the synergistic effect. Moreover, we find that corporate reputation serves as an important mediating channel.

Heterogeneity analysis reveals differentiated effects: state-owned enterprises experience stronger financial performance improvements, while non-state-owned firms achieve greater environmental gains. Small firms benefit more in profitability and environmental outcomes, whereas larger firms see more pronounced effects on market valuation. Across life cycle stages, declining firms gain notable short-term returns, while growth- and maturity-stage firms exhibit significant market value improvements.

This study offers several policy implications. First, governments should strengthen policy guidance and institutional support for digital-green synergistic transformation. Second, as marketization level enhances the synergy's positive effect. In eastern regions with higher marketization levels, efforts should focus on integration and innovation to achieve advanced synergistic development and provide a model for less developed regions. For latecomer regions with relatively low levels of marketization, governments should increase investment in digital infrastructure and green energy networks, and introduce appropriate policy support to stimulate market competitiveness and promote balanced regional development. Third, enterprises should voluntarily enhance their sense of subjectivity and assume the responsibility for collaborative transformation.

Despite the valuable conclusions drawn by this study, there are still some limitations. First, the measurement of enterprise performance focuses on financial and environmental indicators, excluding social dimensions such as employee welfare and community impact. In the future, more factors can be further considered to explore the comprehensive influence of the dual synergy. Second, in terms of the moderating effect, the explanation for the regulatory role of "degree of marketization" may be overly macroscopic, as it lacks an examination of enterprises' micro-level decisions, such as managerial perceptions. Subsequent research could incorporate specific micro-level decision-making factors to enrich the research perspective on moderating effects.

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