

How Corporate Digital Capabilities Drive ESG Performance: A Study Based on Low-Carbon Innovation

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Abstract. Against the backdrop of the rapid development of the digital economy, how enterprises can improve their ESG performance through digital capabilities has become a vital topic for high-quality development. This paper constructs a mediating effect model focusing on the correlations among corporate digital capabilities, low-carbon innovation and corporate ESG performance, and empirically tests the influencing mechanism of digital capabilities on corporate ESG performance. The research results show that corporate digital capabilities can significantly boost corporate ESG performance, which indicates that the accumulation of data assets and the improvement of digital capabilities help enterprises elevate their ESG performance; digital capabilities can prominently facilitate corporate low-carbon innovation, and low-carbon innovation exerts a partial mediating effect in the process where digital capabilities affect corporate ESG performance. From the perspective of low-carbon innovation, this paper reveals the internal path through which digital capabilities empower corporate ESG performance, and provides references for enterprises to advance the coordinated development of digitalization and green transformation.

Keywords: Digital Capabilities, Low-Carbon Innovation, Corporate ESG Performance

1. Introduction

Under the dual backdrop of the "Dual Carbon" goals, the advancement of the digital economy and the deepening of ESG concepts, corporate ESG performance has turned into a core criterion for measuring high-quality corporate development. In reality, enterprises are confronted with pressures including green transformation as well as the fulfillment of environmental and social responsibilities, alongside organizational restructuring and resource allocation reforms brought by digital capabilities. Therefore, how to leverage digital tools to enhance corporate ESG performance has become a practically worthy research issue.

Existing studies generally hold that digital capabilities can affect corporate development quality by lifting information processing efficiency, optimizing resource allocation and strengthening corporate innovation capacity [1]; meanwhile, low-carbon innovation is regarded as a critical path for enterprises to realize green transformation and sustainable development [2]. Nevertheless, most prior literature analyzes the direct impacts of digital capabilities on corporate financial performance, innovation output or ESG performance, while insufficient attention has been paid to the functional mechanism through which digital capabilities shape corporate ESG performance.

On this basis, this paper incorporates digital capabilities, low-carbon innovation and corporate ESG performance into a unified analytical framework. It mainly examines whether digital capabilities can improve corporate ESG performance, and further analyzes whether low-carbon innovation plays a mediating role therein.

2. Research hypotheses

2.1. Digital capabilities and corporate ESG performance

Digital capabilities exert positive impacts on corporate ESG performance by optimizing corporate resource allocation, elevating governance efficiency and improving the quality of external information disclosure. First, digital capabilities enable enterprises to utilize data resources to raise production, management and decision-making efficiency, cut resource waste and operating costs, and thereby strengthen long-term operational capacity [3]. Second, digital capabilities can reshape the internal governance framework of enterprises, substantially improve corporate information transparency, and boost enterprises' responsiveness to environmental, social, governance and other multi-dimensional requirements. Third, the application of digital tools helps enterprises timely identify changes in external markets and demands from stakeholders. Accordingly, Hypothesis 1 is proposed:

H1: Digital capabilities can significantly improve corporate ESG performance.

2.2. Digital capabilities and low-carbon innovation

Digital capabilities drive corporate low-carbon innovation by lowering information search costs, boosting R&D efficiency and facilitating knowledge integration. First, digital technologies strengthen enterprises' perception of environmental policies, market demands and technological trends, making it easier for enterprises to identify green innovation opportunities. Second, digital capabilities help enterprises integrate data resources across R&D, production, supply chain and other links, lifting the efficiency and precision of green R&D activities [4]. Third, higher digitalization promotes internal knowledge sharing and external knowledge acquisition within enterprises, facilitates information exchange and knowledge integration among different departments, enterprises and external entities, and thus lays a knowledge foundation for low-carbon innovation. Accordingly, Hypothesis 2 is proposed:

H2: Digital capabilities can significantly promote corporate low-carbon innovation.

2.3. The mediating effect of low-carbon innovation

Low-carbon innovation acts as a vital transmission mechanism through which digital capabilities influence corporate ESG performance. First, digital capabilities enhance enterprises' information processing and technology application capacity, providing fundamental conditions for enterprises to carry out low-carbon innovation. Second, low-carbon innovation can reduce corporate energy consumption, cut pollution emissions and upgrade green production capacity, thereby improving corporate environmental performance [5]. Third, low-carbon innovation can also strengthen enterprises' competitive edges and social recognition amid the green development trend, lifting enterprises' overall ESG performance. Accordingly, Hypothesis 3 is proposed:

H3: Low-carbon innovation plays a mediating role between digital capabilities and corporate ESG performance.

3. Variable definition

3.1. Explanatory variable

Digital capabilities (logData) refer to the process where enterprises reshape production and operation, organizational management and resource allocation by relying on data resources, digital technologies and digital management modes, so as to boost operational efficiency and development quality. Current research mainly measures corporate digital capabilities via the scale of data assets, investment in digital technologies, digital-related intangible assets, textual analysis and other approaches. Among these metrics, the quantity and scale of data assets can directly reflect the data resource foundation accumulated by enterprises during digital transformation [6]. This paper adopts the total data asset value of enterprises (unit: ten thousand yuan) after logarithmic transformation to measure the level of corporate digital capabilities, so as to alleviate skewed distribution of variables.

3.2. Explained variable

Corporate ESG performance (ESG) represents enterprises' comprehensive capacity to achieve long-term stable development by balancing environmental responsibility, social responsibility and corporate governance while pursuing economic benefits [7]. Existing research commonly measures corporate ESG performance through corporate ESG ratings, sustainability report disclosure quality, environmental performance, social responsibility performance or comprehensive evaluation indices. Among these indicators, ESG scores can comprehensively reflect enterprises' overall performance across environmental, social and governance dimensions. A higher score indicates stronger comprehensive corporate performance in environmental responsibility, social responsibility and corporate governance. For this reason, this paper adopts the annual average of Huazheng ESG total scores over the research period as the explained variable to measure corporate ESG performance.

3.3. Mediating variable

Low-carbon innovation (Green) refers to technological R&D and innovative activities conducted by enterprises targeting energy conservation, emission reduction, pollution control, resource recycling and green production. Existing studies generally measure the level of corporate low-carbon innovation by the number of green patent applications, green patent authorizations, green invention patents or green innovation indices. Among these metrics, the number of green patent applications can reflect enterprises' enthusiasm for green innovation and corresponding innovation outputs [8].

3.4. Control variables

To mitigate the impacts of other factors on corporate ESG performance, this paper incorporates firm-level control variables into the model. Specifically, two control variables are selected: (1) Total corporate assets (ten thousand yuan) (Eco): to control for disparities in firm size; (2) Proportion of independent directors (Num): to control for differences in corporate governance structures.

4. Empirical analysis

This paper selects A-share listed companies on the Shanghai and Shenzhen Stock Exchanges from 2020 to 2024 as research samples to explore the correlation between digital capabilities and corporate ESG performance. To guarantee data validity and research rigor, the initial samples are

screened and cleaned. First, samples with missing values of core variables are eliminated to ensure complete data for regression analysis. Second, core continuous variables are standardized to reduce biases caused by extreme values, and abnormal samples with $|Z|>3$ are excluded. Finally, 10,779 valid observations are retained, and the descriptive statistics are presented in Table 1.

Table 1. Descriptive statistics

Variable	Symbol	Observations	Mean	Standard Deviation	Minimum	Maximum
Total Assets (Ten Thousand Yuan)	Eco	10191	15661960.4	166651580	25584	5.E+9
Proportion of Independent Directors	Num	10191	38.13	5.808	15	80
Total Green Patent Applications (Low-Carbon Innovation)	Green	10191	22.95	83.644	0	1759
Annual Average of Huazheng ESG Scores (Corporate ESG Performance)	ESG	10191	4.26	0.985	1	9
Logarithm of Corporate Data Assets (Digital Capabilities)	logData	10191	23.29	1.363	17	31
Total Corporate Data Assets (Ten Thousand Yuan)	Data	10191	7882942.23	59300645.6	-1313756	2.E+9

4.1. Analysis of empirical results

This paper follows the standard mediating effect testing framework to examine the relationships among digital capabilities, low-carbon innovation and corporate ESG performance. As shown in Table 2, in Model 1, the logarithm of corporate data assets (logData) exerts a significantly positive impact on the annual average of Huazheng ESG scores (ESG) ($\beta=0.281$, $t=25.786$, $p<0.001$), which verifies that digital capabilities can significantly improve corporate ESG performance and supports Hypothesis 1. In Model 2, the logarithm of corporate data assets (logData) shows a significantly positive coefficient for total corporate green patent applications (Green) ($\beta=0.316$, $t=29.142$, $p<0.001$), demonstrating that digital capabilities can significantly boost corporate low-carbon innovation and supporting Hypothesis 2. Further examining Model 3, after both the logarithm of

corporate data assets (logData) and total corporate green patent applications (Green) are included, total corporate green patent applications (Green) have a significantly positive effect on the annual average of Huazheng ESG scores (ESG) ($\beta=0.034$, $t=3.442$, $p<0.001$), indicating that low-carbon innovation can lift corporate ESG performance. Meanwhile, the coefficient of the logarithm of corporate data assets (logData) remains significantly positive ($\beta=0.270$, $t=23.832$, $p<0.001$) yet declines compared with the coefficient in Model 1 ($\beta=0.281$). This outcome proves that low-carbon innovation plays a partial mediating role in the impact of digital capabilities on corporate ESG performance, thereby supporting Hypothesis 3. The regression results are displayed as follows:

Table 2. Mediating effect test

Variable	Model 1 ESG	Model 2 Green	Model 3 ESG
Mediating Variable			
Total Green Patent Applications (Green)			0.034*** (3.442)
Independent Variable			
Logarithm of Corporate Data Assets (logData)	0.281*** (25.786)	0.316*** (29.142)	0.270*** (23.832)
Control Variables			
Total Assets (Ten Thousand Yuan) (Eco)	0.080*** (7.359)	0.057*** (5.311)	0.078*** (7.172)
Proportion of Independent Directors (Num)	0.070*** (7.509)	0.009 (0.991)	0.070*** (7.479)
Number of Samples	10191	10191	10191
R ²	0.112	0.121	0.113
Adjusted R ²	0.112	0.121	0.113
F-statistic	430.065***	469.425***	325.853***

Note: Values in parentheses are t-statistics; ***, **, and * denote significance at the 1%, 5%, and 10% levels.

4.2. Robustness test

To verify the robustness of the above empirical results, this paper revises the measurement of control variables: the firm size variable (total assets in ten thousand yuan, Eco) is replaced by the logarithm of total assets (logEco), and regression analysis is re-conducted. The results show that after adjusting the measurement of firm size, the logarithm of corporate data assets (logData) still imposes a significantly positive impact on the annual average of Huazheng ESG scores (ESG) ($\beta=0.330$, $t=19.324$, $p<0.001$); total green patent applications (Green) also exert a significantly positive effect on the annual average of Huazheng ESG scores (ESG) ($\beta=0.052$, $t=5.053$, $p<0.001$). When both logData and Green are incorporated into the model simultaneously, logData maintains a significantly positive coefficient for ESG ($\beta=0.326$, $t=19.060$, $p<0.001$), and Green still has a significantly positive impact on ESG ($\beta=0.040$, $t=3.967$, $p<0.001$). It can be concluded that the correlations among digital capabilities, low-carbon innovation and corporate ESG performance remain valid after replacing the measurement indicator of firm size.

Table 3. Robustness test

Variable	Model 1 ESG	Model 2 ESG	Model 3 ESG
Mediating Variable			
Total Green Patent Applications (Green)		0.052*** (5.053)	0.040*** (3.967)
Independent Variable			
Logarithm of Corporate Data Assets (logData)	0.330*** (19.324)		0.326*** (19.060)
Control Variables			
Logarithm of Total Assets (logEco)	-0.010 (-0.567)	0.247*** (24.017)	-0.021 (-1.229)
Proportion of Independent Directors (Num)	0.072*** (7.661)	0.079*** (8.261)	0.071*** (7.572)
Number of Samples	10191	10191	10191
R ²	0.108	0.077	0.109
Adjusted R ²	0.107	0.077	0.109
F-statistic	409.956***	284.583***	311.847***

Note: Values in parentheses are t-statistics; ***, **, and * denote significance at the 1%, 5%, and 10% levels.

5. Conclusions

This paper conducts research on the correlations among digital capabilities, low-carbon innovation and corporate ESG performance. Empirical results demonstrate that corporate digital capabilities can significantly improve corporate ESG performance and prominently facilitate corporate low-carbon innovation; low-carbon innovation further generates positive impacts on corporate ESG performance. It can be seen that digital capabilities can not only directly upgrade corporate governance efficiency and sustainable development performance, but also indirectly advance corporate green and sustainable development by stimulating vitality in low-carbon innovation. Based on the above conclusions, enterprises should further attach importance to the coordinated advancement of digital capacity building and green transformation. While improving data resource management and digital technology application capacity, enterprises should embed digital capabilities deeper into green R&D, green production and green governance processes. Meanwhile, enterprises should raise awareness of investment in low-carbon innovation, and convert the efficiency advantages brought by digital capabilities into long-term ESG performance by perfecting internal innovation mechanisms, optimizing resource allocation and upgrading ESG management standards.

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