Economic Society and Humanities Vol. 3 No. 8, 2026

Factors Influencing Low-Carbon Supply Chain Financing of Manufacturing Enterprises from the Perspective of Digital Intelligence Capability

Jie Chen*, Xinke Fu, Ziyi Zhang
Department of Economics and Management, Tianjin Chengjian University, Tianjin, China.
**Corresponding Author*

Abstract: Against the backdrop of the "Dual Carbon" strategy, the low-carbon transformation of manufacturing companies requires greater financial support, and there are still problems of credit shortages in the process of integrated financing for the manufacturing industry. This paper targets manufacturing companies and discusses the relationship between digital and intelligent capabilities and low-carbon supply chain financing performance. It builds a theoretical system of "digital and intelligent capabilities, transparency of low-carbon supply chain information, financing performance" and uses the questionnaire survey data to carry out empirical research, using reliability and validity tests, multiple regression analysis and mediation effect tests. The study also divides the digital and intelligent capabilities into three dimensions: smart manufacturing capabilities, digital and intelligent operational capabilities, and digital and intelligent connectivity capabilities. The findings show that digital and intelligent capabilities have an impact on the LCSC financing performance of manufacturing businesses, especially digital and intelligent connectivity capabilities. Moreover, these capacities make information and enhance the financing results by reducing information asymmetry.

Keywords: Digital and Intelligent Capabilities; Low-Carbon Supply Chain Financing; Information Transparency; Manufacturing Enterprises

1. Introduction

With the constant promotion of the "Dual Carbon" goals, green transformation in the manufacturing industry has become an important means of achieving industrial upgrading, especially for an industry that consumes a large amount of energy and emits a lot of carbon. Energy-saving retrofits, the use of green technologies, the replacement of production equipment must be done continuously by enterprises, but there are still enterprises that cannot solve the financing channels and capital supply problems in the industrial chain. This means that the financing needs associated with low carbon transformation are growing into a significant part. Although there are existing studies on the supply chain finance models and the design of financing mechanisms, the role of a company's internal digital capability in financing and the information transmission mechanism are not well studied. Therefore, from both theoretical and practical aspects, the impact of digital and intelligent functions on performance of manufacturing enterprises is worth studying.

There is a new financing model, which is called low-carbon supply chain financing, in the integrated development of green finance and supply chain finance. It stresses the integration of green production capacity of enterprises, carbon emissions performance and the relationship of enterprise transaction in the supply chain into the financing evaluation system, thereby giving the financial support for enterprises' low-carbon development. But in fact, there is a problem of information sharing among financial institutions and enterprises. Production and operational information of enterprises is not passed on in time and accurately, carbon emission information is not passed on, low-carbon project implementation effect is not passed on. This makes it difficult for financial institutions to evaluate risk, and has a negative impact on financing efficiency. Raising information transparency is emerging as a breakthrough.

With the rapid development of digital technology in recent years, digital and intelligent capabilities have gradually evolved into one of

the important pillars of enterprises to improve their management efficiency and deepen the cooperation of the supply chain. Smart manufacturing, digital operations, and supply chain data integration can help manufacturing enterprises improve their production data collection, make the operational information more transparent, and make the enterprise-financial institution information exchange more efficient. Of these, the smart manufacturing capability helps realize digital management of the production process and enhance the traceability of low-carbon data; the digital and intelligent operational capability can realize digital integration of the internal information of the enterprise and raise the level of enterprise management; the digital and intelligent connectivity capability can improve the connectivity and sharing of the information of upstream and downstream of the value chain of the enterprise, so as to provide more comprehensive information support for financing. According to the existing research, digital and intelligent transformation can help foster corporate innovation and green production; however, there is still a need to further research on its influence on the performance of financing and the role of information transparency in this process.

2. Research Hypotheses

2.1 Direct Impact of Digital and Intelligent Capabilities on the Financing Performance of Low-Carbon Supply Chains

The performance of low-carbon supply chain financing mainly represents the real effect of financing enterprises in obtaining low-carbon supply chain financing, which is manifested in the financing availability, financing cost, financing efficiency and financing structure of manufacturing enterprises in the process of low carbon transition. With the gradual penetration of digital technologies into corporate activities, the corporate financing environment is increasingly influenced by digital and intelligent attributes. Li and Zhan came to the conclusion that the higher is the digitalization and intelligence level of small and medium enterprises (SMEs), the more positive it is to the development of supply chain finance; and the more relieving it is to financing constraint, and this effect is more significant for manufacturing enterprises [1]. The digitalization and intelligence of the enterprise can decrease the opportunistic behavior in the process of supply chain transaction, improve the number of trust of the supply chain participants and promote the financing performance. Besides, Cheng et al.'s study reveals that DSF can assist green the manufacturing enterprise as a result of the development of green technological innovation and also can solve the problem of manufacturing enterprise capital shortage [2].

In this paper, the digital and intelligent capabilities are segmented into three sub capabilities: smart manufacturing capabilities, digital and intelligent operational capabilities and digital and intelligent connectivity capabilities. The effect of these capabilities on the performance of low-carbon supply chain finance can be seen in its levels of production, operations and connectivity. Smart manufacturing capabilities can be achieved through technologies like smart devices and the Industrial Internet to improve data collection and management in the production process, ensure the accuracy and traceability of enterprises' low-carbon production information. Meanwhile, they optimize the production process, lower production costs and enhance the financing capacity of enterprises. Digital and intelligent operational capabilities focus on optimizing the business management, improving information processing efficiency, enhancing the quality of business information and reducing financial institutions' information identification costs, alleviating the information asymmetry in the financing process. Digital and intelligent connectivity capabilities are geared towards information sharing and collaboration between enterprises, upstream and downstream supply chain partners and financial institutions and to achieve greater efficiency in credit transmission in the supply chains by facilitating improved data sharing of transactions. The digital and intelligent functions can not only optimize allocation of enterprises' internal resources, but also promote the "informationization" of the enterprise- enterprise link in the supply chain, reduce the financing uncertainty of enterprises, and promote the financing performance of manufacturing firms. Based on this we can formulate the following hypothesis:

H1: Digital and intelligent capability has positive and significant relationship with low carbon supply chain financing performance of manufacturing enterprise.

2.2 Impact of Digital and Intelligent Capabilities on Information Transparency in Low-Carbon Supply Chains

Transparency in low-carbon supply chains means how much information about a company's low carbon operations and supply chain transactions is available to different stakeholders. It is best seen in the quality of the low carbon disclosures of a company and information sharing. The high transparency of the approach facilitates the exchange of information for supply chain actors to have a better understanding of the company's business performance and progress toward low-carbon transformation, hence minimizing cost of information access and verification. Bian and Lu discovered that the better transparency in the supply chain, the lower the cost of information verification, which means enterprises can get financing support with lower cost of information transmission; digital technology is one way to promote supply chain information transparency [3]. Yu et al. noted that through supply chain information disclosure to effectively reduce enterprises financing constraints, information sharing between enterprises and core customers and suppliers has a positive effect on the financing environment [4]. Li et al. also discovered that information sharing can improve the supply chain financing capacity of a company, reduce the negative impact of the external environmental uncertainties [5].

To enhance the information transparency of low-carbon supply chains, a technological foundation and data support are necessary, which are provided by digital and intelligent capabilities. Through continuous collection and recording of energy consumption, carbon emissions and other data during the production process, enterprises can move beyond the traditional passive disclosure or reporting of low-carbon information, to dynamic management, and enhance the traceability and verifiability of low-carbon information, which can be obtained by the use of smart sensing devices, Internet of Things (IoT) technology and manufacturing execution systems. Digital technologies and data management platforms enable enterprises to link production and operations data with low carbon data, making information more efficient to organise, more good to disclose and more accurate and timely to inform. Meanwhile, supply chain collaboration platforms and fintech platforms link companies, supply chain partners and financial institutions for the real-time exchange of transportation, transaction and carbon emissions data and promote the transition from unidirectional to multi-stakeholder transmission of supply chain information. Digital and intelligent capabilities not only enhance the internal information management of enterprises but also enhance the information sharing among all the supply chain involved. Hence the following hypothesis is formulated:

H2: Digital and intelligent capabilities have a significant positive impact on the transparency of low-carbon supply chain information.

2.3 The Impact of Low-Carbon Supply Chain Information Transparency on Financing Performance and Its Mediating Role

Information transparency, as a key mechanism linking firms to external capital providers, has a significant impact on corporate financing performance. High-quality information disclosure can reduce information asymmetry between firms and financial institutions, lower the costs for financial institutions to obtain and evaluate corporate information, and thereby improve the corporate financing environment. Chen’s research found that improving the quality of information disclosure can effectively reduce information asymmetry and agency costs for firms, thereby alleviating financing constraints [6]. Wei further pointed out that corporate social responsibility (CSR) disclosure can promote the sustainability of corporate innovation by improving financing constraints, with disclosures regarding suppliers, customers, and environmental matters playing equally positive roles [7]. Carbon emissions data and green business information have gradually become key criteria for financial institutions to evaluate a firm’s capacity for green transformation. Gong et al. argue that the effective transmission and feedback of green information among supply chain participants help foster a virtuous cycle between green production and financing for small and medium-sized enterprises [8].

Information transparency primarily influences financing performance by improving information quality and optimizing risk identification mechanisms. Adequate information disclosure enables financial institutions to gain a more comprehensive understanding of a company’s operational status, low-carbon transition progress,

and supply chain transactions, thereby reducing the costs of information search and authenticity verification and increasing the likelihood of corporate access to financing. Transparent low-carbon information enhances financial institutions ability to assess a company's green development capabilities and future risk levels, enabling more accurate financing pricing, reducing risk premiums arising from insufficient information, and consequently lowering financing costs. Enterprises' ongoing disclosure of information regarding low-carbon operations and supply chain collaboration helps signal their commitment to green transformation to capital markets, improves corporate creditworthiness, and further optimizes financing structures. Transparency not only directly improves enterprises' financing terms but may also serve as a key channel through which digital and intelligent capabilities influence the performance. Based on this, the following hypothesis is proposed:

H3: Transparency in low-carbon supply chain information has a significant positive impact on the performance of low-carbon supply chain financing for manufacturing enterprises.

3. Study Design

3.1 Study Design

This study's purpose is to examine how the digital and intelligent abilities of Beijing-Tianjin-Hebei manufacturing businesses affect the performance of low-carbon supply chain financing, and to in-depth analyze the role played by information transparency in low-carbon supply chains in this process. The questionnaire survey was used as a tool to collect sample data, and reliability and validity tests, correlation analysis and regression analysis were carried out using SPSS and Stata software to test the validity of the research hypotheses.

3.1.1 Questionnaire design

The data of this study is microdata obtained by questionnaire survey of manufacturing enterprises in Beijing-Tianjin-Hebei. The questionnaire was designed based on the existing research findings and the focus of this study by using existing and well-established scales with the items appropriate to the subject of low-carbon supply chain financing, and some items in existing scales were re-worded to suit the context of this study. To optimize the wording of the items, experts' comments were taken into account and feedback obtained from enterprise representatives during the design process, and further fine-tuning of the questionnaire's structure and content was done with a pilot survey. The final questionnaire includes 7 modules: mostly enterprise and respondent basic information, sample selection, smart manufacturing capability, digital and intelligent operational capability, digital and intelligent connectivity capability, low-carbon supply chain information transparency, financing performance. The questionnaire was anonymous and explanations for core concepts were given to reduce comprehension errors and to ensure good reliability of the survey data.

3.1.2 Sample acquisition

The target enterprises of this study include manufacturing enterprises in China that are implementing low-carbon programs, which must have held green production, energy-saving retrofits, low-carbon technological innovations, or supply chain emission-reduction activities in the last three years. The sample was gathered using online questionnaire platform, industry association, manufacturing industrial parks and face-to-face survey in the enterprises. Senior executives, financial and financing staff, supply chain management staff and staff in production operations, digital information technology and environmental sustainability related positions within the enterprises were targeted to receive the questionnaires exclusively.

Sample screening criteria:

(1) The companys primary business activity falls within the manufacturing industry;

(2) The respondents are familiar with corporate digital and intelligent transformation, low-carbon management, and supply chain financing operations;

(3) The enterprise has undertaken activities related to energy conservation, emission reduction, and low-carbon transformation in the past three years;

(4) Exclude invalid questionnaires that have uniformly selected all options, were completed within an excessively short time frame, or contain logical inconsistencies.

Following the collection of the questionnaire, data cleaning was first performed by removing invalid samples—those with a high rate of missing responses or those exhibiting discernible response patterns—so that valid samples could be used for subsequent reliability and validity testing, descriptive statistics, correlation analysis,

and regression analysis.

3.2 Variable Design

3.2.1 Dependent variable: low-carbon supply chain financing performance (FP)

The dependent variable is the low-carbon supply chain financing performance, which is a reflection of the overall effect of the manufacturing enterprises in securing low-carbon supply chain financing. This performance is measured based on six dimensions: financing cost (E1), financing amount and needs (E2), financing approval efficiency (E3), financing accessibility (E4), financing maturity (E5) and the supporting effect of financing on low-carbon projects (E6). A composite indicator is then obtained by calculating the average score for these six items, as listed in Table 1:

Table 1. Measurement Items for Low-Carbon Supply Chain Financing

variable	dimension	Item	source
explained variable	Status of Low-Carbon Supply Chain Financing	E1: Compared to other financing options available to the company, low-carbon supply chain financing offers lower overall costs.	Zhang Wei [9]
		E2: The financing quota obtained by this enterprise through supply chain financing is well-matched with its actual funding requirements for low-carbon initiatives.	
		E3: At the process for low-carbon supply chain financing—from application to fund disbursement—is relatively short.	
		E4: This company can relatively easily access low-carbon supply chain financing.	
		E5: The financing term and repayment arrangements of this enterprises financing are well-matched with the capital utilization cycle of low-carbon projects.	
		E6: The supply chain financing secured by this enterprise can sustainably support green production, energy-saving retrofits, and low-carbon technological innovation.	

Source: Compiled by the author

3.2.2 Explanatory variable: digital and intelligent capabilities (DA)

The explanatory variable—digital and intelligent capabilities of manufacturing enterprises—is divided into three sub-dimensions: production and intelligent manufacturing capabilities, digital and intelligent operational capabilities, and digital and intelligent connectivity capabilities, as detailed in Table 2.

Table 2. Three Sub-dimensions of Digital and Intelligent Capabilities

level-one variable	Secondary variable
Digital and intelligent capabilities	Digital and Intelligent Manufacturing
	Digital and Intelligent Operational Management
	Digital and Intelligent Connectivity Capabilities

Source: Compiled by the author.

(1) Intelligent Production Capability (DA1): Corresponding to questionnaire items A1–A4, this metric reflects the enterprises intelligent transformation of its production processes, as well as its capability to monitor production, energy consumption, and carbon emission data; the mean value of these items is calculated.

(2) Digital and Intelligent Operational Capability (DA2): Corresponding to questionnaire items B1–B4, this dimension measures the enterprises capabilities in internal business data integration, operational dynamics monitoring, and data-driven decision-making; the mean score of these items is calculated.

(3) Digital-Intelligent Connectivity Capability (DA3): Corresponds to questionnaire items C1–C4; this metric assesses the interoperability of an enterprises internal systems, as well as its data integration capabilities with upstream and downstream partners in the supply chain and its level of information synergy; the mean score of these items is calculated.

The overall digital and intelligent capability score of the enterprise is obtained by calculating the average of the scores across all three sub-dimension items.

Each of the three sub-dimensions comprises four measurement items, as detailed in Table 3.

3.2.3 Mediating variable: Information transparency of low-carbon supply chains (IT)

The intervening variable is low-carbon supply chain information transparency, which is measured by assessing the completeness, authenticity, timeliness, traceability, verifiability, and ease of access to information regarding

supply chain operations, energy consumption, carbon emissions, and emission reductions, as well as the accessibility of information to partner entities and financial institutions. This measurement employs six items from Questionnaire D1–D6; the average score across these items is taken. The detailed results are presented in Table 4.

Table 3. Measurement Items for Digital and Intelligent Capabilities

variable	dimension	Item	source
explanatory variable	Manufacturing capacity	A1 The company continuously applies digital and intelligent technologies throughout its product design and manufacturing processes.	Zhou Fengqi [10]; Xiao Dingding et al. [11]
		A2: The company utilizes intelligent systems to monitor production progress, equipment operation, product quality, and energy consumption in real time.	
		A3: This enterprise promptly identifies and addresses production anomalies based on real-time production data.	
		A4: This company leverages digital and intelligent technologies to optimize production planning, process flows, and quality control.	
	Digital and intelligent operational capabilities	B1: This enterprise has implemented unified integration of business data across procurement, production, inventory, sales, and finance.	
		B2: The digital and intelligent platform enables the enterprise to provide real-time visualization and dynamic monitoring of its operational activities.	
		B3: The company leverages data analysis to optimize its business processes and resource allocation.	
		B4: Data and intelligent tools provide support for the companys operational decision-making and risk identification.	
	Digital and Intelligent Connectivity Capabilities	C1: Data interoperability has been achieved between the companys internal business units and its various information systems.	
		C2: This enterprise maintains stable data connections with key supply chain entities, including suppliers and customers.	
		C3: The company can promptly access information such as orders, inventory, and logistics data from both upstream and downstream partners in its supply chain.	
		C4: Our company leverages a digital and intelligent platform to facilitate data exchange and business collaboration with supply chain partners.	

Source: Compiled by the author.

Table 4. Measurement Items for Information Transparency in Low-Carbon Supply Chains

variable	dimension	Item	source
metavariable	Information transparency of low-carbon supply chains	D1: This enterprise maintains comprehensive records of energy consumption, carbon emissions, and energy conservation and emission reduction information across all supply chain stages, including procurement, production, and logistics.	Ye Zhiqiang et al. [12]; Chehreh S et al. [13]
		D2: The low-carbon supply chain information established by this enterprise can accurately reflect actual production and operational conditions.	
		D3: The company ensures timely updates to its low-carbon supply chain information provided to financial institutions and key supply chain partners.	
		D4: The energy consumption and carbon emission data of this enterprise can be traced back to specific suppliers, products, orders, or production stages.	
		D5: The information regarding this companys low-carbon supply chain can be verified using business vouchers, green certifications, or relevant data.	
		D6 Financial institutions and key supply chain partners can easily access their companys low-carbon supply chain information.	

Source: Compiled by the author

3.2.4 Control variables

Drawing on existing relevant literature, we define a set of firm-level control variables, primarily including: firm size, firm ownership type, years of firm establishment, the firms position within the supply chain, and the current stage of implementation of the firms low-carbon initiatives.

(1) Enterprise size: assigned based on the number of employees;

(2) Nature of corporate ownership: classification into state-owned and state-controlled, privately-owned, foreign-invested, and mixed-ownership enterprises;

(3) Number of years since establishment of the enterprise: Set according to the questionnaire-based grouping;

(4) Supply chain position: chain leader core enterprise, first-tier supplier, second-tier and lower-tier suppliers;

(5) Low-carbon implementation phase: small-scale pilots, partial business

implementation, and full-scale implementation.

4. Empirical Analysis

4.1 Reliability and Validity Testing

Reliability and validity are prerequisites for the reliability of questionnaire data. Composite reliability (CR) is used to assess internal consistency, with a CR value exceeding 0.8 considered satisfactory; average variance extraction (AVE) is employed to evaluate convergent validity, where an AVE value greater than 0.5 indicates good convergent validity.

As shown in Table 5, the standardized factor loadings for all items exceeded 0.7. The CR values for all variables surpassed the standard threshold of 0.8, and all AVE values exceeded 0.5. These results indicate that the items of the scale exhibit good internal consistency, that the convergent validity has been adequately demonstrated, and that the sample data meet the requirements for subsequent regression analyses.

4.2 Descriptive Statistics

At the level of control variables, the sample consists primarily of small and medium-sized manufacturing enterprises and private enterprises, most of which have a relatively long operational history; suppliers account for a relatively high proportion of the supply chain entities; the mean value of the low-carbon implementation stage is 1.94, indicating that most enterprises have only completed low-carbon pilot projects or partial upgrades, while the proportion of enterprises having achieved comprehensive low-carbon transformation remains limited.

Table 5. Results of Validity Tests for Each Variable

variable	Item	Standardized factor load	CR	AVE
Intelligent production capabilities	A1	0.805	0.881	0.650
	A2	0.805		
	A3	0.857		
	A4	0.754		
Digital and Intelligent Connectivity Capabilities	C1	0.857	0.854	0.661
	C2	0.765		
	C3	0.815		
	C4	0.765		
Digital and intelligent operational capabilities	B1	0.774	0.870	0.626
	B2	0.796		
	B3	0.800		
	B4	0.794		
Information transparency of low-carbon supply chains	D1	0.769	0.857	0.600
	D2	0.760		
	D3	0.821		
	D4	0.747		
	D5	0.758		
	D6	0.813		
Supply Chain Financing Performance in a Low-Carbon Context	E1	0.762	0.916	0.686
	E2	0.860		
	E3	0.884		
	E4	0.799		
	E5	0.831		
	E6	0.797		

Regarding the core variables, the mean values of digital and intelligent manufacturing capability, digital and intelligent operational capability, and digital and intelligent connectivity capability were 3.314, 3.437, and 3.386, respectively, indicating a relatively high level. Within enterprises, the digitalization of internal operations is progressing faster than the intelligent transformation of production processes. The mean values of transparency and financing performance were 3.57 and 3.526, respectively; however, their standard deviations were relatively large, suggesting significant variations in the relationship between an enterprises information transparency level and its financing performance. All variable values fall within the range of 1–5, with no extreme outliers present, making regression analysis feasible. The descriptive statistics for these variables are presented in Table 6.

Table 6. Descriptive Statistics of Variables

Variable	N	Mean	SD	Min	P25	P50	P75	Max
Enterprise size	501	2.17	0.971	1	1	2	3	4
Nature of corporate ownership	501	2.32	1.021	1	2	2	3	5
Number of years the enterprise has been in operation	501	2.93	0.907	1	2	3	4	4
Supply chain position	501	2.38	1.008	1	2	2	3	4
Low-carbon implementation phase	501	1.94	0.747	1	1	2	2.5	3
A (Manufacturing Digitalization and Intelligence)	501	3.314	0.87	1	2.75	3.25	4	5
B (Digital and Intelligent Operations Management)	501	3.437	0.872	1	2.75	3.5	4	5
C (Digital-Intelligent Connectivity Capability)	501	3.386	0.781	1	3	3.5	4	5
D (Low-Carbon Supply Chain Information Management)	501	3.57	0.695	1.167	3.167	3.667	4.167	5
E (Low-carbon supply chain financing)	501	3.526	0.794	1.333	3	3.5	4.167	5

4.3 Multiple Regression Analysis

We employed hierarchical regression analysis to examine the impact of the three sub-dimensions of digitalization and intelligence on the performance of low-carbon supply chain financing; the regression results are presented in Table 7. The results indicate that the coefficient for the number of years the enterprise has been established is significantly positive, suggesting that the longer an enterprise has been in operation, the easier it is for the enterprise to secure financing.

In Models 2–4, we sequentially incorporated digital-intelligent manufacturing capabilities, digital-intelligent operational capabilities, and digital-intelligent connectivity capabilities. The regression coefficients for these three dimensions were 0.290***, 0.261***, and 0.333***, respectively, all showing statistically significant positive effects at the 0.1% level, thereby confirming Hypothesis H1. Comparing the magnitude of these coefficients, the relative impact strength follows the order: digital-intelligent connectivity> digital-intelligent manufacturing> digital-intelligent operational capabilities, with digital-intelligent connectivity exhibiting the strongest driving effect on financing performance. Digital-intelligent connectivity enables data interoperability across the supply chain, facilitates the proper attribution and credit enhancement of orders and accounts receivable, and is particularly critical for low-carbon supply chain financing.

Table 7. Regression Analysis Results of the Impact of Digital and Intelligent Capabilities on Low-Carbon Supply Chain Financing

variable	model 1	model 2	model 3	model 4
Enterprise size	-0.069	-0.081	-0.071	-0.058
Nature of corporate ownership	0.06	0.055	0.063	0.073*
Number of years the enterprise has been in operation	0.136**	0.138**	0.128**	0.125**
Supply chain position	-0.033	-0.023	-0.025	-0.01
Low-carbon implementation phase	0.064	0.054	0.063	0.036
A (Manufacturing Digitalization and Intelligence)		0.290***		
B (Digital and Intelligent Operations Management)			0.261***	
C (Digital-Intelligent Connectivity Capability)				0.333***
R^2	0.031	0.115	0.099	0.141
adjustR^2	0.021	0.104	0.088	0.13
Fprice	3.178**	10.691***	9.065***	13.473***

Note: The values reported in the table are standardized coefficients; ***p<0.001, **p<0.01, *p<0.05.

4.4 Mediation Effect Test

Regarding the initial row, the coefficient of digital and intelligent capabilities regarding the low-carbon supply chain information transparency index is 0.539*, which is markedly positive; consequently, hypothesis H2 is validated: digital and intelligent capabilities can improve the transparency of low-carbon information within the supply chain.

Within the second column of the total effect regression, the coefficient of digital and intelligent capabilities regarding financing outcomes is 0.493***, indicating a statistically significant total impact.

Regarding the third column, both primary predictors and mediators were incorporated; the parameter for the transparency factor reached

0.316***, backing up hypothesis H3; the direct impact coefficient for digital-intelligent capability reduced to 0.323***, maintaining its statistical significance.

The results indicate that information transparency plays a partial mediating role. Specifically, digital and intelligent capabilities can either directly enhance the financing performance of low-carbon supply chains, or indirectly optimize corporate financing performance by improving information transparency in such chains. The detailed findings are presented in Table 8.

Table 8. Results of the Mediation Effect Test of Digital and Intelligent Capabilities on Low-Carbon Supply Chain Financing

variable	IT	FP	FP
Digital and Intelligent Capabilities (DA)	0.539*** (0.044)	0.493*** (0.052)	0.323*** (0.058)
Low-carbon supply chain information transparency (IT)	—	—	0.316*** (0.052)
controlled variable	Under control	Under control	Under control
Sample size N	501	501	501
R^2	0.256	0.194	0.251
adjustR^2	0.231	0.167	0.224
Fprice	10.39***	7.27***	9.50***

4.5 Analysis of Empirical Results

The holistic empirical validation findings demonstrate that the scale utilized in this investigation exhibits excellent reliability and validity, rendering it appropriate for evaluating the primary research propositions. In terms of the digitalization and intelligence of manufacturing enterprises, the development level of digital and intelligent function of manufacturing enterprises in the Beijing-Tianjin-Hebei region is generally moderate, and the application of digital technology in operational governance has made positive progress, but still needs to be further strengthened in the intelligent upgrade of production and manufacturing systems. At the same time, there are certain gaps between firms in terms of information disclosure in low-carbon value chains and credit performance, suggesting gaps in the alignment of green transition and strengthening of credit.

The regression results show that all dimensions of digital and intelligent skills have a significant positive impact on the low-carbon supply chain financing results and the influence of digital and intelligent connectivity is especially prominent. Therefore, it suggests that digital and intelligent transformation in enterprises cannot only focus on optimizing internal processes, but also data sharing and interconnection between enterprises and their upstream and downstream supply chain partners can play an important role.

An in-depth analysis reveals that the openness of the information in low-carbon supply chains partially mediates the relationships between the digital and intelligent capacities and capital efficiency. This helps to reduce the informational identification load for financial organizations as companies increasingly use digital means to enhance their abilities, including around carbon emissions regulation. At the same time, the positive impact of the duration of an organization's existence on capital outcomes is significant, whilst the impact of the party size and the location of its supply chain are small. This implies that the advancement of digital and intelligent capabilities and information openness, to a certain extent, can enhance the capital atmosphere for micro and small-scale manufacturing firms, offering fresh assistance to these businesses to obtain low-carbon supply chain funding.

5. Conclusions and Outlook

5.1 Conclusion

This research selected manufacturing enterprises within Beijing-Tianjin-Hebei as its research subjects, conducting an empirical investigation into how the digital and intelligent capabilities of firms influence the performance of low-carbon supply chain financing. The findings from regression analysis demonstrate that the digital and intelligent capabilities of these firms significantly promote the performance of low-carbon supply chain financing. The empirical evidence further confirms that digital

and intelligent transformation strengthens the information transparency of low-carbon supply chains through a partial mediation mechanism. In addition, digital and intelligent transformation, which signifies both direct and indirect improvements in corporate financing performance, reduces information asymmetry among different stakeholders. Furthermore, regression results suggest a substantial positive relationship between the duration of enterprise operations and financing outcomes, whereas no significant relationship exists between enterprise size and financing performance, nor between a company's position in the supply chain and financing outcomes. These findings hold practical importance as they suggest that small and medium-sized enterprises (SMEs) facing numerous drawbacks can potentially be compensated by the benefits of digital and intelligent transformation and heightened information disclosure.

5.2 Outlook

The selected sample area for this study is mainly in Beijing-Tianjin-Hebei areas, there are geographical limitations, so conclusions may not apply to other parts of the country. Future studies might be carried out or expanded to include more areas, as well as perform heterogeneity analysis by dividing sectors like energy-intensive and equipment manufacturing. This study was conducted using cross-sectional survey data, which is unable to adequately observe the dynamic changes over time caused by the digitalization and intelligent transformation and is not conducive to reflecting the relationship between variables. Additional investigations might involve examining objective evidence such as panel data from publicly traded firms and open carbon reporting. Furthermore, specific boundary constraints within this study were omitted, and the mediation route of information transparency among low-carbon supply chains was solely verified. In the coming period, factors like policy backing and credit ratings of central entities can be incorporated as moderating elements to establish a moderated mediation framework. It could also additionally distinguish between diverse low carbon supply chain financing frameworks, encompassing carbon credit pledges and commercial credit, to determine whether digital and intelligent potentials exert distinct effects on distinct financing systems, and thus examine the mechanisms involved in this sector in a more comprehensive manner.

Acknowledgments

Funding Support: Supported by the Key Accounting Research Project (Y250301) of the Tianjin Municipal Finance Bureau for 2025-2026.

References

[1] Li Wei, Zhan Kaimin. Digital Transformation and Financing Efficiency of Small and Medium-sized Enterprises: Empirical Evidence from Companies Listed on the ChiNext Board. Accounting Friend, 2025, (4): 17–25.

[2] Cheng Cheng, Chen Yanming, Xu Zhaoyi, et al. Digital Supply Chain Finance and Corporate Green Transformation: An Empirical Study Based on the Zhongzheng Accounts Receivable Financing Service Platform. Journal of Financial Theory and Practice, 2026, 47(4): 11–18.

[3] Bian Rui, Lu Jiaxin. Supply Chain Finance, Corporate Market Position, and Commercial Credit Financing. Monthly Journal of Accounting and Finance, 2026, 47(4): 52–59.

[4] Yu Guansheng, Guo Miaomei, Li Tanlin. Supply Chain Information Disclosure and Corporate Financing Constraints: An Empirical Study Based on a Sample of Listed Companies. Contemporary Economic Research, 2024, (12): 90–101.

[5] Li Zhuosong, Zhuang Wenying, Chen Zhu. Unleashing the Value of Data: A Collaborative Innovation Model for Enterprise Data Asset Financing. Accounting and Finance Bulletin, 2026, (10): 145–153.

[6] Chen, S. The Impact of ESG Information Disclosure Quality on Corporate Financing Costs. Friends of Accounting, 2026, (14): 26–35.

[7] Wei Wei. The Impact of the Quality of Corporate Social Responsibility Information Disclosure on Financing Constraints. Accountants, 2025, (15): 4–6.

[8] Gong Hongyu, Chen Jingyi, Cao Yuliang. The Mechanism by Which Supply Chain Finance Empowers Corporate Green Technology Innovation: An Empirical Analysis of Listed Companies on the

Shanghai and Shenzhen A-Shares Markets. Ecological Economy, 2026, 42(8): 49–58.

[9] Zhang Wei. Analysis of Influencing Factors and Optimization Strategies for the Financing Efficiency of Low-Carbon Supply Chains in Enterprises under the Dual Carbon Background. Anhui University of Science and Technology, 2026.

[10] Zhou Fengqi. Research on the Impact of Digital and Intelligent Transformation of Supply Chains on the Performance of Manufacturing Enterprises: A Case Study of Haier Smart Home. Shandong Jianzhu University, 2026.

[11] Xiao Dingding, Hui Peng, Liu Shaoni, et al. Practical Research and Policy Recommendations on the Collaborative Transformation toward Digitalization, Intelligence, and Green Development in Chinas Traditional Manufacturing Industry: A Case Study of Key Traditional Manufacturing Enterprises in Shandong Province . Acta Academiae Scientiarum Sinicae, 2026, 41(8): 1585–1597.

[12] Ye Zhiqiang, Chai Yifan. Can the Integration of Advanced Manufacturing and Modern Services Break the Constraints on High-Quality Innovation in Enterprises?—The Role Mechanism of Financing Constraints, Information Transparency, and Operational Efficiency. Business Research, 2026, (5): 19-30.

[13] Chehreh S, Rezaei M, Salmasnia A. Optimization of sustainable supply chains under uncertainty: integrating Internet of Things and blockchain. Scientific Reports, 2026, 16 (1): 22522-22522.