Academic Education Publishing House

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

Digital Intelligence-Driven Enhancement of Low-Carbon Supply Chain Financing Capability in Manufacturing Enterprises

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Abstract: The evolution of digital and intelligent potentials within industrial manufacturing firms to bolster supply chain finance for low-carbon transition capacity represents a vital route toward high-quality economic growth and realizing the objectives of financial support for new industrialization. This article centers on manufacturing businesses, classifying digital and intelligent potentialities into three facets: smart manufacturing, digital and intelligent operations, and digital and intelligent connectivity. It presents green supply chain information transparency as a mediating factor to establish a theoretical framework, utilizes structural equation modeling and the Bootstrap approach for empirical investigation, and utilizes financing performance to gauge financing capability. The investigation reveals that every facet of digital and intelligent potentialities positively advances low-carbon supply chain financing efficiency while concurrently boosting low-carbon supply chain information transparency; green supply chain information transparency positively affects financing efficiency and functions as a partial mediating factor. This study extends the existing body of research regarding how digital and intelligent technologies empower low-carbon supply chain financing and offers theoretical references and practical guidance for manufacturing firms, banking organizations, and governmental agencies in promoting the green transition of the industrial sector.

Keywords: Digital Intelligence; Low-Carbon Supply Chain; Manufacturing Enterprises; Financing Capability

1. Introduction

Manufacturing is the base of the real economy and a key sector for creating high-quality economic development and modern industrial systems. In July 2025, the People's Bank of China and other government ministries and departments, including the Ministry of Industry and Information Technology, the National Development and Reform Commission, the Ministry of Finance, and others, released the Guiding Opinions on Financial Support for New Industrialization. The document stressed the need to enhance the crossover between financial and industrial policies and make financial system more suitable for the intelligent and green upgrading of the manufacturing sector. Set against this backdrop, the implementation of low-carbon supply chains requires investments in green technologies, process optimisation and coordination between upstream and downstream partners, investments that are typically high capital-intensive and with longer payback periods. Digital finance and technological advancements can improve funding environments, alleviate funding limitations and provide financial assistance for corporate green transitions. Consequently, the pursuit of remedies for conventional financing frameworks and bolstering the financial capacity of low-carbon supply chains has emerged as a challenge within the green evolution of the manufacturing sector [1].

The digital and intelligent transformation of manufacturing enterprises can improve the quality of information disclosure, reduce information asymmetry, ease financing constraints, and give financial support to the transformation and upgrading of real-economy enterprises [2]. According to some studies, digital and intelligent transformation is a process through which digital technologies are being tightly coupled with business processes and organizational resources to achieve data value extraction, optimize resource use, and boost organizational capacity [3]. Other research has suggested that digital transformation can facilitate the synergies between digital technologies and production processes and

organisational management to improve production efficiency and innovation capacities [4]. Digital technologies enable the supply chain, foster information sharing and cooperation between businesses and improve the efficiency of the supply chain operations [5]. A lot of studies have concentrated on the effects of digital and intelligent transformation in business performance, supply chain efficiency and capability of organizations but there is little detailed understanding on how these capabilities can be used in the context of financing low carbon supply chains.

To sum up, this paper concentrates on manufacturing companies. Through theoretical analysis and the use of structural equation modeling, it examines the impact of digital and intelligent capabilities on the low-carbon supply chain financing capabilities of manufacturing enterprises from three dimensions—smart manufacturing capabilities, digital and intelligent operational capabilities, and digital and intelligent connectivity capabilities—as well as the mediating role of low-carbon supply chain information transparency. Moreover, the paper examines how digital and intelligent capabilities are linked to the enhancement of low-carbon supply chain financing performance. Given the fact that capacity in the supply chain is hard to measure in itself, this paper adopts the low carbon supply chain financing performance to measure the capacity in the supply chain. This study builds a framework to analyze how digital and intelligent capabilities and low-carbon supply chain information transparency influence the low-carbon supply chain financing capacity of manufacturing enterprises, enriches the research literature on the ability of digital and intelligent technologies to empower manufacturing enterprises to enhance their low-carbon supply chain financing capacity, and provides theoretical support and guidance for how enterprises can optimally leverage digital and intelligent technologies to improve low-carbon supply chain financing capacity.

2. Theoretical Analysis and Hypothesis Development

2.1 Digital Intelligence Capability and Low-Carbon Supply Chain Financing Performance of Manufacturing Enterprises

The digital and intelligent capabilities of manufacturing enterprises are divided into three dimensions—smart manufacturing capabilities, digital and intelligent operational capabilities, and digital and intelligent connectivity capabilities—which collectively support the digital and intelligent development of manufacturing enterprises [6]. Smart manufacturing capabilities rely on intelligent equipment and the Industrial Internet to enable real-time collection and analysis of production data, enhance information transparency, and provide a foundation for supply chain risk identification and collaborative decision-making; digital and intelligent operational capabilities integrate multidimensional business data to improve information completeness and the efficiency of dynamic updates, strengthen debt-repayment capacity and financial risk identification, and reduce judgment errors caused by information lag; Digital and intelligent connectivity capabilities facilitate the exchange of internal and external information and the sharing of resources through digital and intelligent platforms, thereby improving the flow of supply chain information and the level of collaboration [7]. Although these three dimensions operate at different stages, they all reduce the difficulty of information identification and financing risks for financial institutions, while improving the availability, amount, term, and efficiency of financing, thereby promoting the enhancement of low-carbon supply chain financing performance. Based on the above analysis, the following hypotheses are proposed:

H1: The digital and intelligent capabilities of manufacturing enterprises are positively correlated with the performance of low-carbon supply chain financing.

H1a: Smart manufacturing capabilities are positively correlated with the performance of low-carbon supply chain financing.

H1b: Digital and intelligent operational capabilities are positively correlated with the performance of low-carbon supply chain financing.

H1c: Digital and intelligent connectivity capabilities are positively correlated with the performance of low-carbon supply chain financing.

2.2 Digital Intelligence Capability and Low-Carbon Supply Chain Information Transparency

Transparency in low-carbon supply chains is an

extension of traditional supply chain transparency. It refers to the degree to which manufacturing enterprises disclose and share information regarding suppliers, production, logistics, and other aspects of supply chain operations, with a particular focus on the completeness, accuracy, and traceability of environmental information such as energy consumption and emissions reduction. This enables stakeholders to access operational information, reduces information asymmetry, and provides a basis for external assessments of a company's performance [8]. Compared to general corporate environmental disclosure, the scope of this disclosure extends to the entire supply chain, encompassing not only the company's own low-carbon information but also the transmission and sharing of information between upstream and downstream partners in the supply chain [9]. Digital and intelligent capabilities optimize the supply chain information environment through the generation, processing, and transmission of low-carbon data, smart manufacturing capabilities enable the continuous collection and traceability of production, energy consumption, and carbon emissions data; digital and intelligent operational capabilities drive the integration, standardization, and dynamic updating of cross-departmental low-carbon data; and digital and intelligent connectivity capabilities facilitate information sharing and cross-verification among supply chain participants. These three types of capabilities work in concert to enhance the transparency of low-carbon supply chain information. Based on the above analysis, the following hypothesis is proposed:

H2: There is a positive correlation between digital and intelligent capabilities and information transparency in low-carbon supply chains.

H2a: There is a positive correlation between smart manufacturing capabilities and information transparency in low-carbon supply chains.

H2b: There is a positive correlation between digital and intelligent operational capabilities and information transparency in low-carbon supply chains.

H2c: There is a positive correlation between digital and intelligent interconnectivity capabilities and information transparency in low-carbon supply chains.

2.3 Low-Carbon Supply Chain Information Transparency and Low-Carbon Supply Chain Financing Performance

Low-carbon supply chain financing depends not only on a company's financial condition and supply chain transaction relationships but also on financial institutions' ability to identify low-carbon-related information, such as energy consumption, carbon emissions, green certifications, and emissions reduction projects. Such information is scattered across multiple operational and supply chain activities and is typically highly specialized and difficult to verify, which exacerbates information asymmetry between manufacturing companies and financial institutions and complicates risk assessment [10]. Improving the transparency of low-carbon supply chain information can enhance the accessibility and reliability of such information, enabling financial institutions to gain a more comprehensive understanding of corporate operations and supply chain conditions. This helps reduce information asymmetry, lower the costs of information acquisition and risk assessment, improve access to financing, and optimize the scale, cost, and efficiency of financing. Therefore, transparency in low-carbon supply chain information helps facilitate the alignment of financial resources with enterprises' financing needs for low-carbon transformation, thereby enhancing the performance of low-carbon supply chain financing. Based on the above reasoning, the following hypotheses are proposed:

H3: There is a positive correlation between information transparency in low-carbon supply chains and the performance of low-carbon supply chain financing.

2.4 The Mediating Role of Low-Carbon Supply Chain Information Transparency

Manufacturing enterprises must translate their digital and intelligent capabilities into information that financial institutions can access and verify, thereby influencing financing decisions. Existing research has confirmed that digital transformation can enhance information transparency, alleviate information asymmetry in supply chains, and serve as a key channel for transmitting information transparency [11]. In low-carbon supply chain financing, operational and environmental information is scattered across various links in the supply chain, making it difficult to integrate and verify. By leveraging

three-dimensional capabilities, manufacturing firms can improve the collection, integration, and transmission of low-carbon data, enhance the transparency of low-carbon supply chain information, transform their internal digital and intelligent advantages into information advantages recognizable by financial institutions, and thereby improve financing performance [12]. Existing research primarily focuses on general corporate information transparency and supply chain financing; this paper extends the concept of information transparency to low-carbon supply chains and examines its mediating role between digital and intelligent capabilities and financing performance. Based on this, the following research hypotheses are proposed:

H4: Low-carbon information transparency mediates the relationship between digital and intelligent capabilities in manufacturing enterprises and low-carbon supply chain financing performance.

H4a: Low-carbon information transparency mediates the relationship between smart manufacturing capabilities and low-carbon supply chain financing performance.

H4b: Low-carbon information transparency mediates the relationship between digital and intelligent operational capabilities and low-carbon supply chain financing performance.

H4c: Low-carbon information transparency mediates the relationship between digital and intelligent connectivity capabilities and low-carbon supply chain financing performance.

Based on the above theoretical analysis, the conceptual model of this study is presented in Figure 1.

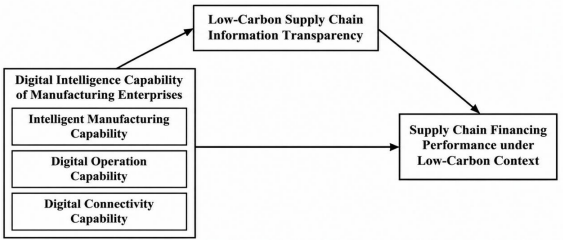


Figure 1. Theoretical Mode

3. Variable Definitions and Research Design

3.1 Variable Definitions

The dependent variable is the low-carbon supply chain financing capacity of manufacturing enterprises. To convert this capacity into quantifiable indicators, a total of five observation items were established. The independent variable is the digital and intelligent capabilities of manufacturing enterprises; this study subdivides these into smart manufacturing capabilities, digital and intelligent operational capabilities, and digital and intelligent connectivity capabilities, with observation items established for each. The mediating variable is the transparency of information in low-carbon supply chains, for which a total of four observation items were established.

3.2 Data Collection

3.2.1 Scale development

The current research utilizes a survey instrument to gather pertinent information, categorizing the digital and intelligent capacities of industrial firms as the primary latent factor, evaluated through the three dimensions previously mentioned; the transparency of data within low-carbon supply networks is regarded as the secondary latent factor, functioning as the mediating variable within the conceptual model; and the financing potential of low-carbon supply chains is assessed through the supply chain financing outcomes throughout the data analytical stage. Throughout the scale construction procedure, relevant academic sources were examined. The entire framework of the survey instrument was founded on the respondents' endorsement levels for every constituent, ultimately yielding a particular scale, as depicted in Table 1.

3.2.2 Sample collection

This investigation utilized a questionnaire-based data collection approach to gather participant information. The investigation focused primarily on the Beijing-Tianjin-Hebei area, and the research population comprised manufacturing firms which had executed green manufacturing, energy conservation improvements, low-carbon technological breakthroughs, or logistics emission mitigation programs within the preceding three years and had utilized corresponding supply chain credit financing. The questionnaire respondents mainly consisted of top company directors, alongside staff involved in finance and investment, logistics and procurement management, and manufacturing execution.

Before launching the official survey, a pilot investigation was performed to improve the design of the questionnaire. Within this pilot phase, 50 questionnaires were handed out, and 48 were submitted, indicating a total response rate of 96%. Feedback provided by participants

during the pilot trial was considered and integrated into the comprehensive version of the survey.

This structured inquiry was executed via an online platform; after a month of dissemination and retrieval, 580 responses were sent, and 569 were submitted. Following the exclusion of responses marked with unusual latency or illogical responses, 501 trustworthy responses were identified, achieving a 86.4% return rate. The tabular summaries of these data are provided in Table 2.

Table 1. Measurement Items of Low-Carbon Supply Chain Financing Capability in Manufacturing Enterprises

Latent Variable	Code	Measurement Item	Source of Indicators
Intelligent Manufacturing Capability	A	A1 Our company continuously applies digital and intelligent technologies in product design and production processes.	Zhang et al [6]. Chi et al [13]. Lü et al [14].
		A2 Our company uses intelligent systems to monitor production progress, equipment operation, product quality, and energy consumption in real time.	
		A3 Our company identifies and handles production abnormalities based on real-time production data.	
		A4 Our company optimizes production planning, processes, and quality control through digital intelligence technologies.	
Digital and Intelligent Operation Capability	B	B1 Our company integrates business data related to procurement, production, inventory, sales, and finance.	
		B2 Our company uses digital platforms to monitor and present operational activities in real time.	
		B3 Our company optimizes business processes and resource allocation through data analysis.	
		B4 Our company uses data and intelligent tools to support operational decision-making and risk identification.	
Digital and Intelligent Connectivity Capability	C	C1 Our company maintains stable data connections with key supply chain partners, such as suppliers and customers.	
		C2 Our company can obtain information on upstream and downstream orders, inventory, and logistics in a timely manner.	
		C3 Our company carries out data exchange and business collaboration with supply chain partners through digital platforms.	
Low-Carbon Supply Chain Information Transparency	D	D1 The low-carbon supply chain information provided by financial institutions and key suppliers is updated in a timely manner.	Zhao et al [15]. Chi et al [16]. Liu et al [17].
		D2 Our company's energy consumption and carbon emission information can be traced to specific suppliers, products, orders, or production stages.	
		D3 Low-carbon supply chain information can be verified through business vouchers, green certifications, or relevant data.	
		D4 Financial institutions and key supply chain partners can conveniently access and understand our company's low-carbon supply chain information.	
Low-Carbon Supply Chain Financing Performance	E	E1 Our company can obtain financing resources from supply chain finance to effectively meet actual financing needs.	Lu et al [14]. Wang et al [18].
		E2 Our company's supply chain financing applications are efficiently reviewed and funds are released within an appropriate period.	
		E3 Our company faces relatively low difficulty in obtaining supply chain financing and has high financing accessibility.	
		E4 The financing amount obtained by our company and the maturity structure of financing instruments effectively match production and operational cycles.	
		E5 The financing obtained by our company effectively meets the funding requirements for green production, energy conservation, emission reduction, and low-carbon technology innovation.	

Source: Compiled and drawn by the authors.

Table 2. Descriptive Statistics of Sample Characteristics (N = 501)

Item	Category	Frequency	Percentage (%)
Working Experience	Less than 1 year	35	7.0
	1–3 years	95	19.0

	4–6 years	121	24.2
	7–10 years	115	23.0
	More than 10 years	135	26.9
Enterprise Industry	Equipment and Machinery Manufacturing	106	21.2
	Electronic Information Equipment Manufacturing	85	17.0
	Automobile and Parts Manufacturing	78	15.6
	Petroleum, Chemical and Pharmaceutical Manufacturing	64	12.8
	Metal and Non-metal Product Manufacturing	59	11.8
	Food, Textile and Other Consumer Product Manufacturing	68	13.6
	Others	41	8.2
Job Position	Senior Management	90	18.0
	Finance and Financing Related	105	21.0
	Procurement and Supply Chain Related	92	19.0
	Production and Operations Management Related	81	16.2
	Digitalization and Information Technology Related	55	16.2
	Low-Carbon Sustainable Development Related	45	9.0
	Others	30	6.0
Enterprise Size	Fewer than 100 employees	140	27.9
	100–499 employees	195	38.9
	500–999 employees	106	21.2
	1,000 employees and above	60	12.0
Ownership Type	State-owned and state-controlled enterprises	90	18.0
	Private enterprises	260	51.9
	Foreign-invested and Hong Kong/Macao/Taiwan-invested enterprises	65	13.0
	Mixed-ownership enterprise	71	14.2
	Others	15	3.0
Enterprise Location	Beijing	170	33.9
	Tianjin	136	27.1
	Hebei	195	38.9

Source: Compiled and drawn by the authors.

4. Empirical Analysis

4.1 Reliability and Validity Analysis

This study employs the CITC index and Cronbach's α to evaluate the consistency of the sample dataset. The CITC score reflects the level of association among a particular question and the remaining elements following its exclusion; a CITC ratio exceeding 0.4 implies that the component maintains sufficient correlation with the comprehensive scale, whereas a Cronbach's α figure above 0.7 signifies excellent internal uniformity for the entire assessment. According to Table 3 presented below, the CITC scores for the measured variables within 501 participant responses exceeded 0.4, and the Cronbach's α scores surpassed 0.7, demonstrating that the research data satisfied the standards for reliability investigations.

The KMO sampling adequacy test and Bartlett's sphericity test were used to determine whether the data were suitable for factor analysis. A KMO value greater than 0.7 indicates a strong common factor among the variables, and a significant Bartlett's sphericity test indicates a significant correlation among the observed items. As shown in Table 4, the KMO value is 0.896, which is higher than 0.8; the significance level of Bartlett's sphericity test is $0.00 < 0.05$. Therefore, the data from the 501 valid questionnaires are suitable for factor analysis.

Table 3. Reliability Analysis Results (N = 501)

Latent Variable	Observed Variable	CITC	Cronbach's α if Item Deleted	Cronbach's α for Subscale	Overall Cronbach's α
Intelligent Manufacturing Capability	A1	0.768	0.846	0.886	0.873
	A2	0.746	0.855		
	A3	0.786	0.839		

	A4	0.702	0.871		
Digital and Intelligent Operation Capability	B1	0.712	0.838	0.870	
	B2	0.726	0.832		
	B3	0.729	0.831		
	B4	0.722	0.834		
Digital and Intelligent Connectivity Capability	C1	0.757	0.763	0.853	
	C2	0.693	0.822		
	C3	0.724	0.794		
Low-Carbon Supply Chain Information Transparency	D1	0.608	0.714	0.769	
	D2	0.589	0.714		
	D3	0.611	0.725		
	D4	0.602	0.711		
Low-Carbon Supply Chain Financing Performance	E1	0.729	0.908	0.916	
	E2	0.810	0.891		
	E3	0.830	0.887		
	E4	0.764	0.901		
	E5	0.786	0.896		

Source: Compiled and drawn by the authors.

Table 4. Validity Analysis Results (N = 501)

Latent Variable	Observed Variable	Factor Loading	KMO Test	Bartlett's Test	Significance
Intelligent Manufacturing Capability	A1	0.839	0.839	1086	0.00
	A2	0.861			
	A3	0.887			
	A4	0.829			
Digital and Intelligent Operation Capability	B1	0.841	0.834	942	0.00
	B2	0.851			
	B3	0.852			
	B4	0.848			
Digital and Intelligent Connectivity Capability	C1	0.898	0.726	663	0.00
	C2	0.860			
	C3	0.879			
Low-Carbon Supply Chain Information Transparency	D1	0.813	0.826	860	0.00
	D2	0.805			
	D3	0.828			
	D4	0.805			
Low-Carbon Supply Chain Financing Performance	E1	0.760	0.899	1681	0.00
	E2	0.760			
	E3	0.770			
	E4	0.750			
	E5	0.740			

Source: Compiled and drawn by the authors.

4.2 Exploratory Factor Analysis

Principal component analysis was applied to evaluate the exploratory factor analysis of the scale, investigating the connections among observed indicators and underlying constructs. Factors were identified according to the rule that eigenvalues should exceed 1, while factor loadings were refined using the maximum variance rotation technique. A total of five common factors were derived, representing 70.223% of the total variance. These five factors comprehensively represent the data from the initial observed variables. Based on the rotated factor loading matrix, the loadings of every test item on its relative common factor are all higher than 0.5, implying that the scale possesses excellent structural validity. The findings are presented in Table 5.

Table 5. Results of Exploratory Factor Analysis

	Intelligent Manufacturing Capability	Digital and Intelligent Operation Capability	Digital and Intelligent Connectivity Capability	Low-Carbon Supply Chain Information Transparency	Low-Carbon Supply Chain Financing Performance
A1	0.875				
A2	0.861				

A3 A4	0.887 0.829				
B1 B2 B3 B4		0.841 0.851 0.852 0.848			
C1 C2 C3			0.898 0.860 0.879		
D1 D2 D3 D4				0.835 0.829 0.860 0.821	
E1 E2 E3 E4 E5					0.824 0.884 0.897 0.851 0.867

Source: Compiled and drawn by the authors.

4.3 Mediation Effect Analysis

In this research, we utilize the Bootstrap technique to evaluate the mediating role of Green supply chain finance information disclosure. By conducting 5,000 bootstrap resampling experiments, we investigate the underlying mechanisms of various aspects of digital intelligence capability regarding sustainable supply chain finance financing outcomes. The findings are summarized in Table 6.

Table 6. Mediation Effect Test Results

Category	Path	Effect	SE	Bias-corrected 95%CI	
				Lower	Upper
Direct Effect	Intelligent Manufacturing Capability → Carbon-conscious supply chain finance Performance	0.193	0.045	0.103	0.283
	Digital and Intelligent Operation Capability → Carbon-conscious supply chain finance Performance	0.188	0.045	0.099	0.276
	Digital and Intelligent Connectivity Capability → Carbon-conscious supply chain finance Performance	0.253	0.058	0.138	0.368
Indirect Effect	Intelligent Manufacturing Capability → Low-Carbon Supply Chain Information Transparency → Carbon-conscious supply chain finance Performance	0.073	0.018	0.042	0.110
	Digital and Intelligent Operation Capability → Low-Carbon Supply Chain Information Transparency → Low-Carbon Supply Chain Financing Performance	0.062	0.015	0.035	0.092
	Digital and Intelligent Operation Capability → Low-Carbon Supply Chain Information Transparency →Carbon-conscious supply chain finance Performance	0.105	0.032	0.043	0.168
Total Effect	Intelligent Manufacturing Capability → Carbon-conscious supply chain finance Performance	0.266	0.045	0.178	0.354
	Digital and Intelligent Operation Capability → Carbon-conscious supply chain finance Performance	0.249	0.045	0.161	0.337
	Digital and Intelligent Connectivity Capability → Carbon-conscious supply chain finance Performance	0.358	0.049	0.261	0.454

Source: Compiled and drawn by the authors.

The findings demonstrate that direct impacts of intelligent manufacturing capability, digital and intelligent operational capability, and digital and intelligent connectivity capability on Carbon-conscious supply chain finance outcomes are substantial, with their bias-corrected 95% confidence bands excluding zero. This suggests that every facet of digital intelligence capability can directly enhance the elevation of supply chain financing performance. Additionally, the confidence bands of the indirect effects regarding green supply chain finance information transparency likewise do not contain zero, indicating that sustainable supply chain

finance information transparency serves as a crucial mediating function between various aspects of digital intelligence capability and green supply chain finance financing performance. Given that both the direct and indirect effects across three pathways are significant, low-carbon supply chain information transparency functions as a partial mediating mechanism.

4.4 Structural Equation Modeling and Hypothesis Testing

4.4.1 Structural equation model

This structural equation framework was developed utilizing AMOS 29.0 tools to empirically evaluate the connections and causal links among latent indicators, and additionally quantify their strength of influence. Grounded on the conceptual model, a preliminary structural equation model was designed to explore the routes through which digital intelligence fosters the improvement of supply chain financing capacity in manufacturing firms, as depicted in Figure 2.

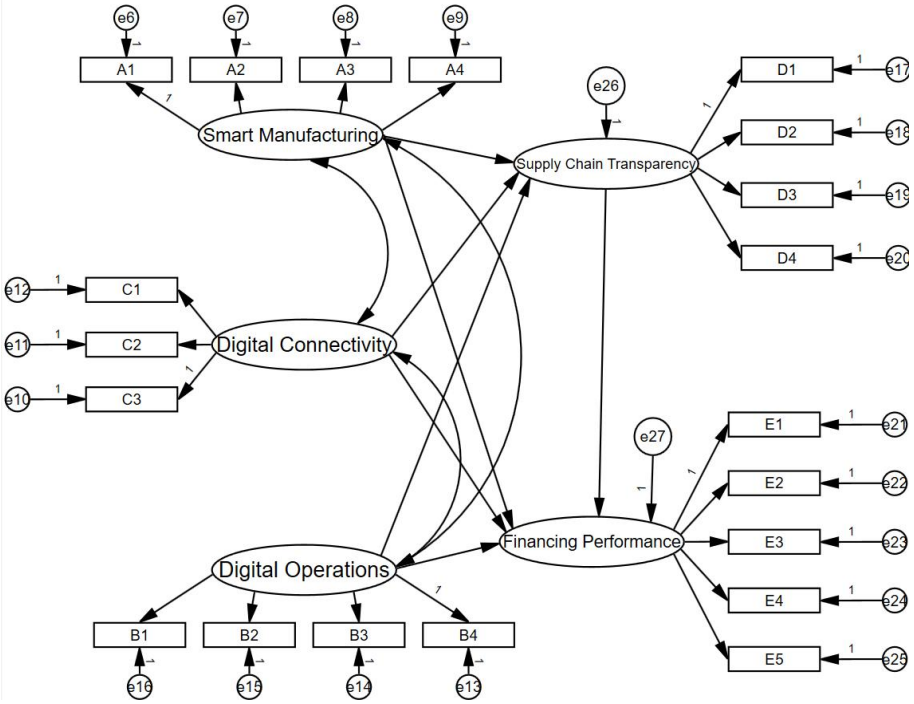


Figure 2. Initial Structural Equation Model

(1) Model Fit Assessment

The comprehensive fit of the primary framework was examined utilizing AMOS 29.0 applications. Following the evaluation metrics outlined by prior studies, absolute fit metrics, value-added fit metrics, and parsimony fit metrics were utilized to evaluate the model's coherence. The particular test outcomes are presented in Table 7; these findings suggest that the system performs excellently.

Table 7. Model Fit Indices

Indicator	Absolute Fit Indices			Incremental Fit Indices			Parsimonious Fit Indices	
Specific Category	X2/df	GFI	RMSEA	NFI	TLI	CFI	PGFI	PNFI
Criteria	<3	>0.8	<0.08	>0.9	>0.9	>0.9	>0.5	>0.5
Initial Model	0.804	0.975	0.001	0.977	1.007	1.000	0.743	0.823
Conclusion	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass

Source: Compiled and drawn by the authors.

(2) Model Analysis Results

The AMOS tool was employed to estimate the structural equation model parameters and perform path analysis. The path coefficients between latent constructs were derived from the model outputs. These research hypotheses were evaluated by integrating the path estimates with their standard errors (S.E.), critical ratios (C.R.), and significance levels (P-values). Specifically, C.R. signifies the ratio of a path estimate to its standard error, serving as a criterion for identifying if the relationship is statistically significant. This study further examines the direct impacts of distinct facets of manufacturing

enterprise digital intelligence on low-carbon supply chain financing capability, as well as the mechanism through which low-carbon supply chain information transparency influences this association. The detailed model outcomes are illustrated in Figure 3.

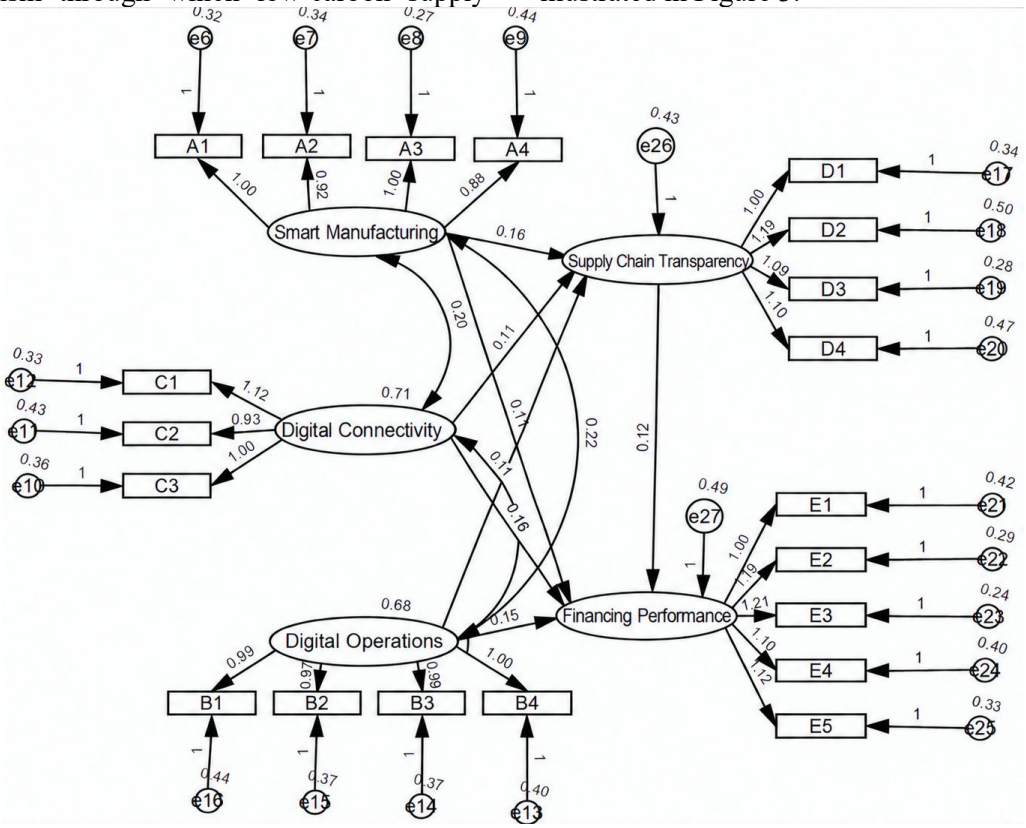


Figure 3. Standardized Model

4.4.2 Hypothesis testing

In order to verify the research hypotheses outlined within this dissertation and examine the mechanisms by which diverse facets of manufacturing firm's digital intelligence capability impact supply chain financing capacity, standardized path coefficients were employed to indicate the magnitude of impact among variables. These coefficients, along with their standard errors, critical ratios, and significance levels were integrated to assess whether the path connections were validated.

If the C.R. index exceeds 1.96 and the P-value falls below 0.05, a significant association is deemed to exist among these factors. The precise hypothesis evaluation outcomes are outlined in Table 8.

4.4.3 Analysis of research results

According to the data presented in the table, the path coefficients for smart manufacturing capabilities, digital and intelligent operational capabilities, and digital and intelligent connectivity capabilities are 0.195, 0.129, and 0.136, respectively, with all P-values exceeding the stipulated thresholds. By gathering data from multiple sources, manufacturing firms can elevate the transparency of information within low-carbon supply chains, validating Hypothesis H2a; within industrial organizations, data amalgamation and data exchange among supply chain actors are realized via digital and intelligent operational capabilities and digital and intelligent connectivity capabilities; consequently, Hypotheses H2b and H2c are validated. Regarding the examination of the influence of low-carbon supply chain information transparency on low-carbon supply chain financing performance, the p-value is 0.024, suggesting a highly significant finding. Strengthening supply chain information disclosure improves the information environment among firms and banks while reducing information asymmetry during lending; consequently, Hypothesis H3 is supported. Concerning the evaluation of the impacts of three dimensions of digital and intelligent manufacturing transformation on supply chain financing outcomes, all P-values met the significance threshold, with standardized path coefficients of 0.152, 0.159, and 0.187, respectively. Hypotheses H1a, H1b, and H1c are thus confirmed.

Table 8. Results of Hypothesis Testing

			Standardized Path Coefficient	Path Coefficient	S.E.	C.R	P	Label
Low-Carbon Supply Chain Information Transparency	<--	Intelligent Manufacturing Capability	0.195	0.158	0.044	3.59	***	Supported
Low-Carbon Supply Chain Information Transparency	<--	Digital and Intelligent Operation Capability	0.129	0.109	0.046	2.390	0.017	Supported
Low-Carbon Supply Chain Information Transparency	<--	Digital and Intelligent Connectivity Capability	0.136	0.112	0.044	2.544	0.011	Supported
Financing Performance	<--	Low-Carbon Supply Chain Information Transparency	0.114	0.125	0.055	2.255	0.024	Supported
Financing Performance	<--	Intelligent Manufacturing Capability	0.152	0.135	0.046	2.940	0.003	Supported
Financing Performance	<--	Digital and Intelligent Operation Capability	0.159	0.148	0.048	3.116	0.002	Supported
Financing Performance	<--	Digital and Intelligent Connectivity Capability	0.187	0.170	0.046	3.681	***	Supported

Source: Compiled and drawn by the authors. Note: *** indicates significance at the 0.1% level.

5. Conclusions and Implications

5.1 Research Conclusions

This article divides the electronic and intelligent capacities of industrial organizations into three categories: smart manufacturing skills, digital and intelligent operational capacities, and digital and intelligent connectivity skills. By incorporating carbon supply chain information transparency as a mediating factor and utilizing structural equation modeling along with the Bootstrap mediation analysis technique, this research investigates the mechanism by which electronic and intelligent capacities affect the supply chain financing outcomes of industrial firms. The primary outcomes are as follows:

(1) The three categories of digital and intelligent potentials—production potential, digital and intelligent operational potential, and digital and intelligent connectivity potential—remarkably and positively boost the supply chain financing efficacy. Through utilizing smart instruments to gather energy utilization and carbon discharge information, comprehensive operational data, and cross-verifying supply chain records, industrial firms minimize the risk management expenses for banking entities.

(2) Digital and intelligent attributes can profoundly improve the transparency of supply chain data. Smart manufacturing potentials allow for the gathering and monitoring of low-carbon metrics at manufacturing sites; digital and intelligent operations enable the revision of internal low-carbon records; and digital and intelligent connectivity encourages data exchange and validation across supply chain stakeholders. Consequently, these three capacities boost the thoroughness, traceability, and veracity of low-carbon records.

(3) Clear visibility within the low-carbon supply chain reveals a substantial beneficial effect on financing outcomes. Low-carbon supply chain data bridges the informational divide among various firms, lowers the evaluation expenses for banking organizations, and enhances the congruence between capital assets and companies' capital requirements for low-carbon upgrades.

(4) Clarification of carbon reduction supply chain data offers a significant mediator. Technological and automated potential affect lending outcomes through transforming primary manufacturing and logistics information into

verifiable data for banks, thus indirectly resolving companies' capital limitations.

5.2 Research Implications

Within corporate contexts, manufacturing firms should intensively utilize these three aspects of their digital and intelligent capacities. They must bolster information governance within low-carbon supply chains and accelerate the transition of data assets. Financial institutions, while assessing initiatives, should evaluate the veracity of low-carbon endeavors alongside the underlying operational hazards. Considering the specific requirements of manufacturing businesses transitioning toward low-carbon transformation, it is essential to streamline approval procedures for carbon emission information and adjust financing conditions to match the project durations of low-carbon renovations; live supply chain data may further be utilized for digital post-loan surveillance of financial expenditure and emission reduction results.

At the administrative tier, facilitative measures ought to be established to foster the concurrent evolution of digitalization alongside low-carbon transitions within manufacturing corporations, while helping small and micro-enterprises in resolving deficiencies in technological integration. Regulations supporting credit assistance for modernization are required, and inducement and risk-sharing frameworks should be improved to channel financial assets toward industrial units constructing sustainable supply networks, thus driving superior progress within the manufacturing industry.

Acknowledgments

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

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