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Research on the Service Quality Control System of Supply Chain Finance for Small and Micro Enterprises Empowered by Big Data: A Case Study of Hebei Province

Xinyu Wang, Xiaoli Wang

Hebei Oriental University, Langfang 065000, Hebei, China

**Author to whom correspondence should be addressed.*

Abstract: To address the pain points of traditional supply chain finance, such as static indicator limitations, information asymmetry, and low financing efficiency, this paper focuses on the deep integration of big data technology and supply chain finance for small and micro enterprises (SMEs). Combining the practices of manufacturing and service industries in Hebei Province, through literature research, case analysis, and field investigations, it systematically analyzes the technical principles of big data-empowered supply chain finance and the logical reconstruction of subject roles. A service quality control system of "common indicators + industry-specific indicators" and a full-process solution of "data collection and governance-risk quantification and early warning-collaborative service optimization" are constructed. Empirical results show that the system achieved a risk early warning accuracy rate of 89.2% for financial institutions, and the financing success rate of manufacturing SMEs in Hebei Province increased by 37% compared with the traditional model, effectively alleviating the financing dilemma. The industry-adapted model and cross-regional data sharing plan formed by the research provide a replicable "Hebei Experience" for the high-quality development of supply chain finance.

Keywords: Big data; Small and micro enterprises; Supply chain finance; Service quality control; Risk early warning

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1. Introduction

1.1. Research background

As the "capillaries" of the national economy, small and micro enterprises play a key role in stabilizing employment and promoting innovation. However, constrained by small scale, lack of credit records, and low information transparency, they face prominent problems such as difficulty in supply chain finance financing, low product adaptability, and poor service experience. Taking Hebei Province as an example, before the establishment of the

financing coordination mechanism in 2024, the average financing success rate of SMEs in the province was less than 40%, and the approval cycle generally exceeded 15 working days [1]. Among them, problems such as occupied funds for raw material procurement in the manufacturing industry and lack of light asset pledges in the service industry have exacerbated the financing dilemma.

Traditional supply chain finance relies on core enterprise credit endorsement and static financial indicators, which are difficult to match the dynamic operational needs of SMEs. With the strategic deployment of "financial services for the real economy" and "digital transformation" in the "14th Five-Year Plan", big data, with its capabilities of data integration, real-time analysis, and precise profiling, has become a core tool to address the above pain points. It can realize the integration of logistics, capital flow, and information flow, providing full-process data support for service quality control. Against this background, exploring a big data-empowered service quality control system for supply chain finance of SMEs combined with the practice of characteristic industries in Hebei Province has important theoretical and practical value.

1.2. Review of domestic and foreign research status

Relevant research in Hebei Province is in its initial stage. Although it focuses on the service dilemmas of supply chain finance for SMEs, most of them remain at the level of problem description, lacking systematic application research on big data technology. Although cross-regional collaboration in the Beijing-Tianjin-Hebei region has started, a long-term mechanism for information sharing has not yet been formed. In 2024, cross-regional financing accounted for less than 12%, and information barriers restricted the improvement of service quality [2].

Coastal developed regions outside the province have formed mature research and practice models. For example, relying on the financial market and massive samples, Guangdong has identified key influencing factors of service quality through machine learning, increasing the regional SME financing success rate to 68%. However, such research mostly focuses on the local market, has insufficient adaptability to northern manufacturing clusters, and rarely relates to the needs of county-level characteristic industries, leaving room for expansion.

1.3. Research significance and content

1.3.1. Theoretical significance

This study moves beyond the limitations of single-enterprise static indicators commonly adopted in traditional research by introducing a big data perspective and integrating Hebei's industrial practices. It systematically analyzes the logic of technological application, constructs a "dynamic, industry-adapted" quality evaluation model, and proposes a cross-regional data-sharing supervision framework, thereby addressing the gap in systematic research within the province.

1.3.2. Application value

At the enterprise level, the model enhances financing efficiency and reduces capital costs. At the industrial level, it provides targeted credit support for characteristic industrial clusters, thereby strengthening cluster competitiveness and coordinated development. At the educational level, it contributes to the development of a structured case library that supports innovation and entrepreneurship education in higher institutions.

1.3.3. Research content

Constructing an industry-specific quality control indicator system, optimizing the data collection and governance process, establishing industry-specific risk quantification models, designing hierarchical early warning and

collaborative service mechanisms, and verifying the effectiveness of the system through empirical testing.

2. Theoretical mechanism of big data-empowered supply chain finance and Hebei's practice

2.1. Core technical principles

Big data empowers supply chain finance through the full process of "storage-analysis- application", where distributed architecture is adopted for data storage. For example, Hebei Bank's "Tianyuan" risk middle platform is based on the HBase database, storing multi-subject data of the supply chain in 12 nodes, with a data loss rate controlled below 0.03% [3]. Parallel computing mode is used for data analysis. ICBC Hebei Branch processes data of 196 industrial clusters through MapReduce technology, compressing the traditional 3-day workload to 4 hours [4]. Data application relies on decision engines to achieve dynamic risk control. Hebei Bank's system can respond to enterprise overdue warnings within 15 seconds, with a response speed increased by 90% [3].

2.2. Reconstruction of subject roles

Big data promotes the formation of a collaborative ecosystem among supply chain finance subjects: core enterprises have upgraded from "credit endorsers" to "data integrators". For example, Zekai Cable integrates upstream and downstream data to provide credit evidence for suppliers, increasing the financing approval rate by 42%. SMEs have transformed from "passive financiers" to "data value creators". For example, Hebei Hengchi Bicycle obtained a loan of 10 million yuan through transaction data, reducing financing costs by 1.8 percentage points [5]. Financial institutions have transformed from "risk avoiders" to "dynamic monitors", which can adjust credit limits in real time.

2.3. Hebei's practical foundation

Since the establishment of Hebei Province's SME financing coordination mechanism in October 2024, the effectiveness of big data empowerment has been remarkable. By the end of 2024, the province's SMEs had received 270.937 billion yuan in credit and 221.678 billion yuan in credit support, with a bank-enterprise docking rate of 87% [5]. ICBC Hebei Branch has issued 69 billion yuan in inclusive loans to more than 23,000 SMEs in 196 industrial clusters, and the "one industry, one policy" model has become the key to breaking the regional financing deadlock [6].

3. Construction of an industry-specific quality control indicator system

3.1. Design logic

Based on the three-dimensional framework of "data quality-risk assessment-service satisfaction", an adaptive system of "common indicators + industry-specific indicators" is constructed. Common indicators ensure versatility, while specific indicators focus on the characteristics of manufacturing industry such as "heavy assets, strong logistics, and long accounting cycles" and service industry such as "light assets, high cash flow, and strong customer dependence" to improve evaluation accuracy.

3.2. Common quality control indicators

Common indicators are applicable to various SMEs, providing a basic evaluation basis for financial institutions.

This table presents a structured indicator framework for evaluating digital financial services supporting SMEs, covering data quality, risk assessment, and service satisfaction dimensions. It outlines specific indicators, their functional significance, and practical implementation standards based on Hebei Province's experience, demonstrating how big data analytics enhances financial accuracy, risk control, and financing efficiency (**Table 1**).

Table 1. Digital financial evaluation indicators and Hebei province practice standards

Indicator category	Specific indicators	Indicator significance and Hebei's practice standards
Data quality indicators	Data accuracy	Ensure that the collected data is consistent with the actual situation of the enterprise. Hebei Bank controls the data error rate within 3% through cross-validation (such as comparison between tax records and cash flow).
	Data timeliness	Real-time monitoring of capital flow data. The transaction data update frequency of Ningjin cable enterprises is T+0.5, and the response time for abnormal data is ≤1 hour.
Risk assessment indicators	Credit risk indicators	Generate credit scores by integrating enterprise operation data. SMEs in Hebei Province with a credit score ≥75 points can obtain unsecured credit.
	Market risk indicators	Real-time tracking of raw material prices. When the price of copper fluctuates by more than 10%, a risk early warning is triggered for manufacturing enterprises.
Service satisfaction indicators	Financing success rate	The average financing success rate of SMEs in the province increased from 38% in 2023 to 59% in 2024.
	Financing cost reduction rate	After the application of big data, the average financing interest rate of SMEs in Hebei Province decreased from 5.8% to 4.2%, a cost reduction of 27.6%.

3.3. Manufacturing-specific quality control indicators

In view of the characteristics of "heavy assets, strong logistics, and long accounting cycles" of manufacturing clusters such as cables and children's bicycles in Hebei Province, the following indicators are added (**Table 2**).

Table 2. Risk control and service performance indicators in supply chain finance: Practical cases

Category of indicators	Specific indicators	Significance & practical cases
Data quality indicators	Completeness of pledged assets data	Collect data on the specifications, storage location, and price of pledged items, achieving a data integrity rate of 99.2% for new materials.
Risk assessment indicators	Inventory turnover rate	For Ningbo warehousing enterprises, an inventory turnover rate ≥ 6 times/year is deemed low risk; an early warning is triggered if it falls below 3 times/year.
	Stability of cooperation with core enterprises	Cooperate with core enterprises for ≥ 2 years with an annual transaction volume ≥ 5 million yuan to enhance credit limits; the average credit limit for supply chain financing has increased by 35%.
	Realization rate of pledged assets	Prioritize pledged assets with a realization rate ≥ 85% (e.g., copper, steel) to reduce asset impairment risk.
Service satisfaction indicators	Loan disbursement timeliness	The average loan disbursement time for manufacturing enterprises has been shortened from 15 days to 4 days, with the fastest disbursement on the same day (e.g., Hebei Yansheng Fittings).
Raw material financing indicators	Raw material financing coverage rate	The raw material financing coverage rate of Ningbo warehousing enterprises has reached 72%, an increase of 40 percentage points compared with the traditional model.

3.4. Service industry-specific quality control indicators

In view of the characteristics of "light assets, high cash flow, and strong customer dependence" of service industries such as Qinghe cashmere e-commerce and logistics in Hebei Province, the following indicators are added (**Table 3**).

Table 3. Digital risk assessment and inclusive finance service indicators: E-commerce and micro-small enterprise practices

Category of indicators	Specific indicators	Significance & practical cases
Data quality indicators	Completeness of transaction flow data	E-commerce enterprises are required to provide 12 months of complete transaction flow data. The data completeness rate of Qinghe Cashmere E-commerce has reached 83%.
Risk assessment indicators	Accounts receivable collection cycle	For service enterprises, an accounts receivable collection cycle ≤ 90 days is a safe zone; an early warning is triggered if it exceeds 120 days.
	Customer retention rate	An annual customer retention rate ≥ 60% for e-commerce enterprises can improve credit ratings. A Qinghe cashmere e-commerce enterprise thus obtained an additional 5 million yuan in credit.
	Stability of cash flow	Monthly cash flow volatility ≤ 20%; dynamic monitoring is activated if volatility exceeds 30%.
Service satisfaction indicators	Online approval coverage rate	The online approval ratio of service enterprises has reached 78%, 15 percentage points higher than that of manufacturing enterprises. Qinghe cashmere enterprises have achieved full-process online processing for "e-commerce loans".
Service for micro and small enterprises	Renewal loan	81%
	First-time loan	59%

4. Research methods and empirical design

4.1. Research methods

The research methods are as follows:

(1) Literature research method: Sorting out 62 core literatures to construct a theoretical framework;

(2) Case analysis method: Analyzing typical cases from the Pearl River Delta in Guangdong and Ningjin, Pingxiang in Hebei to extract 3 types of replicable models;

(3) Field investigation method: Investigating 87 enterprises in 4 industrial clusters, interviewing 12 financial institutions, and collecting 2,360 valid data;

(4) Model testing method: Using Python to build a risk model, training and verifying based on 1,000 sets of historical data [7–9].

4.2. Empirical design

4.2.1. Data collection and governance

A tripartite network of "government-core enterprises-financial institutions" was established, employing a dual-channel data collection approach combining QR codes and web crawlers, which increased data coverage to 92 [10]. Collected data were stored in MySQL and cleaned using OpenRefine, with monthly random inspections of 5% of samples conducted to ensure data accuracy.

4.2.2. Industry-specific risk models

Taking 126 enterprises in Ningjin cable industry as samples for the manufacturing industry, using logistic regression models with core variables such as inventory turnover rate, the default prediction accuracy rate is 89.2% [11]. Taking 89 Qinghe cashmere e-commerce enterprises as samples for the service industry, classifying risks through decision tree models to provide support for special products [12].

4.2.3. Hierarchical early warning and collaborative mechanism

Three-tiered warning levels were established, "general" (5–10%), "serious" (10–20%), and "critical" (>20%), and the "core enterprise + chain service" model was implemented to enhance risk management and service coordination.

5. Empirical results and innovations

5.1. Empirical results

5.1.1. Significant improvement in financing efficiency

The financing success rate of Ningjin cable enterprises increased from 35% to 72%, and the cost decreased from 5.2% to 3.8%; the approval cycle for Pingxiang children's bicycles was compressed from 12 days to 3 days.

5.2.2. Obvious risk control effects

The non-performing loan rate of Hebei Bank decreased from 2.9% to 1.7%, and the early warning response time was shortened from 24 hours to 15 minutes.

5.2.3. Enhanced industrial synergy effects

The proportion of cross-regional financing in the Beijing-Tianjin-Hebei region increased from 12% to 21%, and the capital turnover efficiency of characteristic industrial clusters was significantly improved.

5.2. Innovations

5.2.1. Methodological innovation

This approach overcomes the limitations of general models by constructing industry-specific risk frameworks and integrating multi-stakeholder dynamic data, enabling the coordinated integration of logistics, capital flow, and information flow.

5.2.2. Application innovation

A Hebei plan was developed based on the framework of "characteristic industry + special products + precise risk control," which has been implemented across 196 industrial clusters [13–15]. A production-university-research collaborative case library was established, covering more than 1,200 students, and Beijing-Tianjin-Hebei data-sharing standards were proposed to overcome cross-regional information barriers.

6. Conclusion and outlook

6.1. Research conclusion

The "common + industry-specific" service quality control system and full-process solution constructed in

this study have effectively improved the financing efficiency of SMEs in Hebei Province and the risk control capabilities of financial institutions. The financing success rate has increased by 37%, and the risk early warning accuracy rate has reached 89.2%, solving the problems of difficult pledges in the manufacturing industry and difficult credit approval in the service industry. The practical model and data sharing plan formed by the research provide replicable experience for the high-quality development of supply chain finance.

6.2. Research outlook

In the future, the integration of big data and blockchain technology can be deepened to improve the traceability efficiency of pledged goods and data credibility. Moreover, the research scope can be expanded to cross-border supply chains, focusing on exchange rate risks and data cross-border compliance, and constructing a quality control system adapted to the "domestic + international" dual circulation.

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