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Research on the High-Quality Development of Agricultural Supply Chain Financial Ecosystem Empowered by Science and Technology

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Abstract: A systematic perspective on agricultural supply chain finance can offer fresh insights into its development. The high-quality development of the agricultural supply chain finance ecosystem is crucial for the comprehensive revitalization of rural areas and the realization of agricultural power. Based on the current state of development of this ecosystem, this paper identifies several bottlenecks, such as insufficient policy and technical support in the macro-environment system, weak incentives for independent circulation within the industrial environment system, and inadequate motivation for stakeholders to participate in the micro-environment system. To address these issues, this paper proposes that the visualization, digitalization, and authenticity characteristics of the "blockchain + Internet of Things" technology architecture can effectively resolve these bottlenecks. Additionally, targeted strategies are suggested to promote the high-quality development of the agricultural supply chain finance ecosystem.

Keywords: Agricultural supply chain finance ecosystem; High-quality development; Blockchain + Internet of Things

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1. Introduction

Addressing financing challenges for agricultural business entities, particularly farmers and small- to medium-sized enterprises, is essential for building an agricultural powerhouse. However, traditional agricultural supply chain finance faces problems such as poor sustainability and limited chain extension. This paper reviews the development of agricultural supply chain finance from a systematic perspective, explores how scientific and technological tools can enhance the ecosystem, and examines the application prospects and challenges under existing policy support. The paper provides a reference for further advancing the high-quality development of agricultural supply chain finance.

2. Connotation of the agricultural supply chain finance ecosystem

2.1. Definition of agricultural supply chain finance

Agricultural supply chain finance refers to lending behavior where the capital provider uses the core entity in the agricultural industry chain as the credit party, the capital required by the chain as the credit line, and the collateral and reputation of the core entity as the guarantee. Unlike traditional lending, agricultural supply chain finance transforms a one-on-one contract into a one-to-many relationship, using pre-credit checks, credit supervision, and post-loan controls to promote credit and risk management [1]. In practice, agricultural supply chain finance is typically driven by three models: bank-led financial institutions, core enterprise-led models (with agriculture as the focus), and third-party dominance (mainly by internet finance companies). These three models complement each other in serving the comprehensive revitalization of rural areas.

2.2. Structure of the agricultural supply chain financial ecosystem

When analyzing the financial ecosystem, the first step is to identify the elements within the ecosystem and locate each subsystem. Next, the dependencies or restrictions between each element and subsystem are identified. Finally, the dynamic balance process of the entire ecosystem is described. The agricultural supply chain finance ecosystem is divided into the macro-environment system, industrial environment system, and micro-environment system [2]. The macro-environment system primarily refers to the institutional and technological environments, including laws, regulations, cognitive factors, supply chain technology, and big data technology. The industrial environment system includes agricultural supply chain transaction parties, trading platform providers, transaction risk managers, risk takers, and liquidity providers. The micro-environment system focuses on the procurement, production, distribution, and logistics of agricultural entities, as well as their investment, financial situations, and risk monitoring. For the agricultural supply chain finance ecosystem to operate healthily, it requires the symbiosis and coordination of various subsystems.

3. Development status and bottlenecks of the agricultural supply chain finance ecosystem

The development of agricultural supply chain finance can be examined through factors such as the balance of agricultural loans, financial products, leading agricultural enterprises, and policy support.

3.1. Development status of the agricultural supply chain finance ecosystem

3.1.1. Expansion in the scale of agriculture-related loans

In the first quarter of 2024, the total outstanding agriculture-related loans across the country reached 60.19 trillion Chinese yuan (CNY), reflecting a 13.5% year-on-year increase and a 6.6% rise from the beginning of the year. Of this, loans in key areas such as grain amounted to 4.14 trillion CNY, up 21.46% year-on-year. The balance of loans for agriculture, forestry, animal husbandry, and fisheries reached 6.33 trillion CNY, marking a 14.7% year-on-year increase. Loans for rural infrastructure construction totaled 10.83 trillion CNY, up 11.9% year-on-year, while loans for farmland infrastructure construction were 534.3 billion CNY, up 29.8% year-on-year. Agricultural science and technology loans totaled 116.6 billion CNY, a 16.7% year-on-year increase. Additionally, outstanding loans to rural households reached 17.72 trillion CNY, reflecting an 11.6% year-on-year growth [3].

3.1.2. Continuous innovation in financial products and services

By the end of June 2023, loans to rural enterprises and organizations totaled 29.3 trillion CNY, up 17.7% year-on-year. Financial products and services continue to innovate, guiding non-government capital investments in industries with distinctive advantages. Support has been provided to 142 enterprises, issuing 170.46 billion CNY in rural revitalization bills. Business loan guarantees have been strengthened, with the balance of venture guarantee loans reaching 298.1 billion CNY, up 14.6% from the previous year. Government financing guarantees have been fully utilized to enhance credit availability. With support from the Ministry of Finance, the State Financing Guarantee Fund increased the volume of re-guarantee cooperation business by 1.2 trillion CNY, up 60% year-on-year, with new re-guarantee cooperation businesses reaching 1.39 million, an increase of 91.6% year-on-year [3].

3.1.3. Growth in the number of leading agricultural enterprises

Nationwide, 180 industrial clusters with distinctive advantages, 300 modern agricultural industrial parks, and 1,509 towns with strong agricultural industries have been established. Additionally, 1,952 key national leading enterprises have been identified. There are 6.2 million new agricultural business entities, including 2.193 million farmer cooperatives and 4 million family farms. However, nearly half of the new agricultural business entities have not received loans, with internal financing accounting for approximately 30.8% [3].

3.1.4. Strengthened policy support

In 2019, the China Banking and Insurance Regulatory Commission issued the "Guidance on Supply Chain Financial Services for the Real Economy," encouraging banks and insurance institutions to innovate and develop agricultural supply chain financial services. In April 2021, the "Circular on High-Quality Services for Rural Revitalization in 2021" highlighted the need to innovate services for new types of agricultural business entities and actively develop agricultural supply chain finance, focusing on industries with competitive advantages at the county level. In June 2021, the Ministry of Agriculture and Rural Affairs issued the "Guidance on Accelerating the Development of Agriculture's Full Industry Chain," emphasizing financial support for supply chain finance and urging leading enterprises to provide guarantees and credit services to small farmers and new operators along the entire industry chain. In June 2022, the "Guidelines on Social Capital Investment in Agriculture and Rural Areas" encouraged the development of supply chain finance, exploring methods to continuously increase support for social capital investment in agriculture through investment-loan linkages. In June 2023, the "Guiding Opinions on Financial Support for Comprehensive Rural Revitalization and the Acceleration of Agricultural Power" advocated for core supply chain enterprises to enhance credit and guarantee services for upstream and downstream enterprises. This can be achieved through the establishment of white-list confirmation, accounts receivable verification, and the creation of purchase and sales funds, ultimately improving the financing availability of enterprise farmers and new agricultural business entities within the chain [3].

3.2. Bottlenecks of the agricultural supply chain financial ecosystem

3.2.1. Insufficient attention to agricultural supply chain finance and technology in the macro environment system

National policies support and regulate the financial development of the supply chain. For instance, the "Opinions on Standardizing and Developing Supply Chain Finance to Support the Stable Circulation, Optimization, and Upgrading of the Supply Chain Industry Chain," the "14th Five-Year Plan for Financial Standardization,"

the “Notice on the Banking and Insurance Industry to Comprehensively Promote the Key Work of Rural Revitalization in 2023,” and the “Definition of Technical Standards for Supply Chain Finance” have all introduced new plans and ideas for the development of supply chain finance. However, there is a lack of specific technical documentation and policies targeting agricultural supply chain finance, with a limited focus on driving technological development. The application of supply chain technology also differs significantly between urban and rural areas. While other industries experience widespread and sustained application, the agricultural sector suffers from a lack of universality and sustainability.

3.2.2. Insufficient power for autonomous circulation in the industrial environment system

The necessary and sufficient condition for the development of the agricultural supply chain is the virtuous cycle of the agricultural industrial chain, with resilience and sustainability playing critical roles. Agricultural supply chain finance bridges small farmers and modern agriculture, allowing weak agricultural entities (such as small farmers and agricultural small and midsize enterprises) to access industry cycles and share in economic benefits. This enables coordinated development between the real economy and finance. Additionally, integrating innovation and technology creates a high-level cycle of “technology-finance-industry.” However, in practice, the autonomous circulation power of agricultural supply chain finance remains insufficient. The agricultural industry chain lacks depth and resilience [4], with characteristic agricultural chains being neither prominent nor competitive. Furthermore, the flow of resources and factors to rural areas faces obstructions. Capital, technology, and human resources demand high returns, and the high cost and low return of investments in rural areas severely limit the involvement of financial institutions, social capital, and other entities [5].

3.2.3. The microenvironment system faces challenges as key participants lose momentum

The operation of agricultural supply chain finance relies on the full integration of four key chains. First is the circulation of the capital chain, where the core agricultural entity serves as the credit subject, and the capital required for chain operations is used as the credit line, establishing an interest linkage mechanism between participants. Second, an information-sharing system for “agriculture, rural areas, and farmers” is created, utilizing technologies such as the Internet, 5G, big data, artificial intelligence (AI), and the Internet of Things (IoT) to build agricultural information systems. Digital technologies convert this information into data, becoming input factors. Third, risk management is emphasized from a micro perspective. Big data, blockchain, and intelligent IoT can analyze market information changes and guide the behavior of participants in real time, dynamically monitor behavior changes, predict compliance rates, and adjust strategies accordingly, thereby increasing attractiveness for participants. However, in practice, the development of new agricultural business entities is insufficient in quantity, uneven in quality, limited in scale, and lacks the capacity to drive upstream and downstream agricultural entities. Additionally, participants lack a strong sense of contract, as the explicit and implicit clauses in supply chain finance contracts are poorly designed, the interest linkage mechanism is weak, and the sense of responsibility among participants is low. Consequently, participation in supply chain financing behavior tends to be contingent and inconsistent.

4. Technology empowers the high-quality development of the agricultural supply chain finance ecosystem

To maintain the high-quality development of the agricultural supply chain finance ecosystem, it is essential to

adopt new development concepts and patterns, ensuring the integration of macro and micro perspectives and advancing comprehensive rural revitalization. Scientific and technological innovation has become the most critical aspect of these efforts.

4.1. "Blockchain + Internet of Things" enables the decision-making model of agricultural supply chain finance

The combination of "blockchain + IoT" is employed to build a digital blockchain platform, which is primarily used to maintain relationships among various entities within the macro, industrial, and microsystems of agricultural supply chain finance, as illustrated in **Figure 1**. From a macro operational perspective, the platform includes agricultural core entities, upstream farmers, downstream agricultural retailers, consumers, financial institutions, government departments, and other stakeholders. Once the blockchain platform is established, IoT technology is used to transfer the capital flow, physical flow, and information flow formed between upstream and downstream agricultural entities and consumers onto the blockchain platform. Financial institutions and government departments can grant credit, monitor activities, and perform other functions based on the data stored on the blockchain platform.

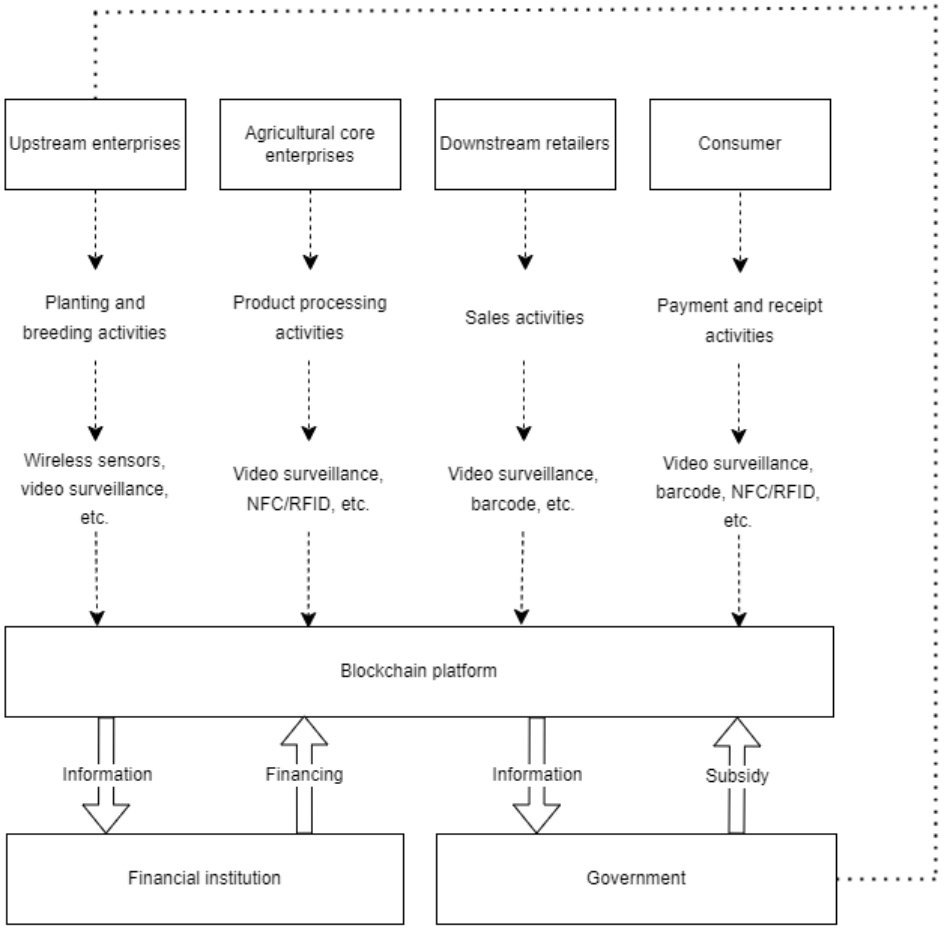

Figure 1. The operating principle of the "blockchain + IoT" model in the agricultural supply chain financial ecosystem

Blockchain technology facilitates the relationships formed between different entities, utilizing tools such as infinite sensing, video surveillance, social frequency sensing, near-field communication (NFC), radio frequency

identification (RFID), and global positioning systems (GPS). Wireless sensors and video monitoring provide farmers with information flow related to production activities. This data, along with the relationships among the various entities, is transferred to the platform via Ethernet, Wi-Fi, and 4G/5G technology. Based on this information, financial institutions and government departments can make informed investment and financing decisions [6].

4.2. Countermeasures for the high-quality development of agricultural supply chain finance enabled by "blockchain + internet of things"

4.2.1. Fiscal policy accuracy: providing system and technology innovation support

First, fiscal policy support for the application of blockchain and IoT technologies in the agricultural supply chain should be increased [7]. The government can establish special funds to encourage agricultural enterprises and technology companies to research and develop blockchain and IoT technologies. These funds should focus on projects that can effectively enhance supply chain transparency, reduce financial risk, and improve overall efficiency. Additionally, the government can use preferential tax policies, such as additional deductions for R&D expenses and corporate income tax relief, to incentivize more companies to participate in innovation. Second, fiscal policy should emphasize building infrastructure to support blockchain and IoT applications. The digitalization and intelligentization of agricultural supply chains require robust technical infrastructure. The government should increase investment in rural network infrastructure, enhance the penetration of IoT devices, and promote the standardization of blockchain technology. Finally, fiscal policy should drive institutional innovation to ensure the safe and effective application of blockchain and IoT technologies in agricultural supply chain finance. The government should expedite the formulation of laws and regulations related to blockchain and IoT, providing a clear legal framework for their application. Additionally, fiscal measures such as subsidies and guarantees can lower the costs and risks for agricultural enterprises participating in supply chain finance, boosting their willingness to engage.

4.2.2. Full integration of agricultural and financial supply chains for high-level circulation

The application of "blockchain + Internet of Things" in the agricultural supply chain finance ecosystem aligns with rural industrial development goals that prioritize the well-being of farmers, market orientation, industry integration, and green growth driven by innovation. First, a transparent and efficient information-sharing platform should be established. The immutability and distributed ledger features of blockchain technology effectively enhance transparency and trust in agricultural supply chains [8]. By recording data from agricultural production, processing, and transportation on the blockchain, the authenticity and traceability of information can be ensured, providing reliable data for financial institutions. This transparency can reduce information asymmetry and financial risk, promoting the efficient flow of financial resources throughout the agricultural supply chain. IoT technology can monitor all aspects of agricultural production in real time, such as soil moisture, climatic conditions, and crop growth, generating accurate production data. These data can be directly linked to financial services, enabling financial institutions to assess agricultural production risks in real time and offer more precise financial products, such as loans with dynamic interest rates. Core agricultural enterprises, financial institutions, and other participants can offer a variety of financial services, including advance financing, order financing, and factoring, ensuring the efficiency and security of capital flow [9]. Blockchain technology can monitor the entire process of fund usage, preventing misuse and ensuring the stable operation

of the supply chain. Smart contracts can dynamically monitor the agricultural supply chain, identify potential risks, and automatically trigger risk control measures.

In summary, all participants in the supply chain can empower agricultural supply chain finance through real data and information enabled by "Blockchain + Internet of Things." This will independently drive the extension and sustainability of the agricultural industry chain, incorporating more agricultural entities. The authenticity and visualization of technology-enabled information, combined with government policy support, will enhance innovation in financial products and services, increasing credit availability and forming a virtuous cycle of "technology-industry-finance" [10].

4.2.3. Participant behavior embedded in digital information and rooted in the spirit of contract

From a data perspective, the business chain (procurement, production, sales, logistics, consumption) is digitized, management activities (investment, accounting, finance) are systematized, and risk management is precise. First, a digital identity authentication system should be established. Blockchain technology can create a unique digital identity for each participant in the agricultural supply chain, including farmers, producers, logistics companies, and financial institutions. Once authenticated, all behavior and transaction records associated with these identities will be recorded on the blockchain [11]. Second, IoT technology can collect real-time data on agricultural production, processing, logistics, and other activities, automatically uploading the information to the blockchain via sensors and network devices to form a complete digital information chain. The transparency and sharing of this data allow all parties to monitor the supply chain's operation in real time and provide accurate risk control data for financial institutions, thereby promoting contract compliance.

From an application perspective, upstream and downstream agricultural entities are inherently vulnerable. However, through large-scale and systematic operations, their awareness of and ability to resist natural and social risks can be improved. With proper guarantees in place, participating agricultural entities will voluntarily adopt and adhere to the spirit of the contract [12]. At the contract level, smart contracts can automatically record and execute transactions, payments, deliveries, and other activities between participants, reducing human intervention and minimizing disputes. This automated, transparent method of contract execution will effectively enhance the spirit of the contract and encourage all parties to strictly fulfill their obligations as agreed.

5. Conclusion

This paper analyzes the existing issues in the traditional agricultural supply chain finance ecosystem, including the lack of institutional and technical support, insufficient power for autonomous chain circulation, and inadequate participation from key chain entities. It finds that the introduction of "blockchain + Internet of Things" in agricultural supply chain finance can effectively address these problems. However, further policy support, capital investment, and technological advancements are needed to ultimately achieve high-quality development.

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Disclosure statement

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