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Optimizing the Rice Supply Chain with Blockchain: An Analysis Based on Feng Xingyuan's Theory

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Abstract

With the application and development of big data technology, blockchain technology has emerged as a key solution for optimizing traditional rice supply chains and ensuring food security, leveraging its traceability and anti-counterfeiting features in supply chain applications. This paper analyzes the compatibility and feasibility of blockchain technology with rice supply chains based on Feng Xingyuan's "Institution-Knowledge-Competition" theory. It proposes a tripartite financial framework, "Commercial NFT Warehouse Receipt Pledging, Cooperative Rice Point Mutual Aid, and Policy-Driven Smart Contract Subsidies", to reduce transaction costs across the entire closed-loop process of contract signing, fulfillment, and breach. Practical case studies validate the "dual-threshold" effect of government subsidy intensity and core node endorsement on technology implementation. Finally, targeted risk prevention strategies are proposed, addressing technical, financial, and institutional risks. The study demonstrates that blockchain technology significantly enhances supply chain node efficiency, with future value further unlocked through measures like technological integration and currency fusion, offering actionable solutions for food security.

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1. Introduction

"Absolute food security" is a foundational project in national governance. As the staple food for 60% of China's population, rice accounted for approximately 25.2% of the total grain planting area and 31.1%[1] of the total cereal planting area in 2023, underscoring its strategic importance. However, post-harvest losses and lengthy distribution chains have left traditional rice supply chains grappling with a triple dilemma: "information gaps, credit deficits, and financing disruptions."

[1] Data sources: National Bureau of Statistics official website "2023 Statistical Bulletin on National Economic and Social Development"; "China Statistical Yearbook" 2024 release "China Statistical Yearbook 2023"; Ministry of Agriculture and Rural Affairs "China Agricultural Yearbook"

Blockchain technology, with its immutability and traceability, holds great promise for "reducing losses, building credit, and revitalizing finance." Yet, its agricultural applications remain largely confined to the "proof-of-concept—demonstration county" stage, lacking systematic analysis of its institutional embedding logic and cost-benefit boundaries.

Domestic and international research primarily focuses on two pathways: one is the technical dimension, exploring the impact of blockchain traceability on quality and safety (Zhang et al., 2023); the other is the financial dimension, analyzing the feasibility of warehouse receipt pledge financing (Li et al., 2022). The common limitations of the aforementioned literature are: first, blockchain is often treated as an exogenous technical variable, overlooking its endogenous coupling with the rural "institution-knowledge-competition" structure; second, there is a lack of micro-level depiction of the synergistic mechanism of the "fiscal-commercial-cooperative" triple financial tracks; third, the key empirical question of "how government subsidy intensity and core node endorsement form the diffusion threshold" remains unanswered.

This paper introduces Feng Xingyuan's "institution-knowledge-competition" theory into the study of rice supply chains, viewing blockchain as a generative device for "dynamic local knowledge Integration," providing a new institutional economics perspective on how technology can be implemented in decentralized smallholder scenarios. By constructing a three-dimensional financial model of "commercial NFT warehouse receipt pledge-cooperative rice point mutual aid-policy smart contract subsidy," it quantifies the reduction in transaction costs across the three stages of signing, fulfillment, and breach, filling the gap in agricultural blockchain research regarding micro-financial mechanisms.

2. Theoretical Overview

This paper systematically constructs the logic of blockchain technology adaptation within the rice supply chain, using Feng Xingyuan's triadic theory of "Institution-Knowledge-Competition" and transaction cost theory as its core analytical framework.

It provides robust theoretical support for subsequent practical analysis and risk prevention. Compared to international institutional economics, it offers a crucial localized perspective for understanding technology diffusion mechanisms within China's agricultural modernization process. This framework emphasizes the dynamic interplay among institutional arrangements, knowledge accumulation, and market competition: Effective policy incentives create conditions for technological learning, while knowledge accumulation, through market mechanisms, generates competitive pressures that further drive institutional optimization and technological diffusion.

This theory not only inherits Douglass North's core idea that "institutions are the rules of the game" but further highlights the co-evolutionary mechanism between institutions and technological learning. Unlike North's relatively static institutional analysis, the IKC framework stresses that institutions do not unidirectionally shape behavior. Instead, they continuously evolve through feedback loops with knowledge and competition by incentivizing innovation and diffusion.

Simultaneously, the framework incorporates Oliver Williamson's transaction cost theory focus on governance structures, but places greater emphasis on government-guided collective learning and organizational innovation rather than purely contractual governance.

Furthermore, IKC resonates with Elinor Ostrom's research on polycentric governance and autonomous management of common-pool resources, particularly in collective action organizations where institutional design facilitates the formation and dissemination of shared knowledge. However, the unique contribution of the IKC framework lies in explicitly identifying “competition” as a key driver of technology diffusion. In the context of agricultural digitization, entities that pioneer blockchain traceability systems often gain market premiums and brand advantages, thereby creating demonstration effects and competitive pressure on other producers, driving the large-scale adoption of the technology.

Using the adoption of blockchain technology in the rice supply chain as a case study, this paper validates and extends the explanatory power of the IKC framework. It not only enriches institutional economics research in the Chinese context but also offers theoretical insights for promoting digital technology adoption in low-trust, fragmented agricultural markets across developing countries.

2.2Feng Xingyuan’s Theory

Feng Xingyuan’s "institution-knowledge-competition" trinity theory is a self-reinforcing closed loop: institutional rules determine whether decentralized knowledge can be verified at low cost; knowledge accessibility broadens the radius of competition; competition outcomes force institutional iteration. This paper positions blockchain technology as a "digital lubricant embedded in the outer loop", reducing institutional costs through "on-chain" processes, expanding knowledge boundaries with on-chain data, and intensifying competition with on-chain credit, thereby explaining why the three parties in the rice supply chain, "smallholder farmers-core enterprises-local governments", are willing to synchronize on-chain, and how government subsidies and endorsements become the "dual thresholds" for technology diffusion.

2.1.1Partial Equilibrium Theory: Technology Diffusion Threshold and Critical Subsidy

To identify the critical diffusion, point of blockchain in the rice supply chain, this paper embeds a short-term partial equilibrium model within Feng Xingyuan’s "institution-knowledge-competition" framework: treating government subsidies α as exogenous institutional variables, on-chain data completeness $K(\theta)$ as endogenous knowledge variables, and solving for the critical adoption rate θ and corresponding subsidy threshold α under $MC=MB$ conditions.

Exogenous institution: $MC(\alpha)=$ fixed on-chain cost $-\alpha$ + variable verification cost
Endogenous knowledge: $MB(\theta)=$ brand premium + financing rate reduction + risk premium↓, and $\partial MB/\partial K>0$

Using the publicly available spread between Zhejiang Province's 2023 average inclusive micro-loan rate (4.2%) and Zheshang Bank's on-chain financing rate (3.1%) (Zhejiang Provincial Local Financial Regulatory Bureau, 2024; Zhejiang Commercial Bank, 2023), and using a single credit line of 500,000 yuan and a total on-chain cost of 1,000 yuan per account, the critical subsidy rate $\alpha^*\approx1.8\%$ is derived.[2]

[2] Critical subsidy calculation parameters:① Interest spread of 1.1% = Zhejiang’s inclusive small and micro

It is crucial to emphasize that the validity of the fiscal subsidy threshold α ≈ 1.8% hinges on a more fundamental institutional prerequisite, the prior breakthrough of the "core node recognition" threshold. Within the rice supply chain, core nodes typically refer to state-owned grain warehouses, leading enterprises, or financial institutions, such as Zheshang Bank. Whether these entities "adopt blockchain technology and recognize on-chain data" directly determines the legitimacy of on-chain activities and the realization of benefits. If core nodes remain disconnected from the system or refuse to acknowledge on-chain records (e.g., rejecting on-chain certificates as collateral for financing), farmers' marginal benefits (MB) will approach zero even after on-chain registration. This results in MC > MB, preventing technological adoption.

Therefore, "core node recognition" is not a simple binary prerequisite but a structural institutional threshold. Its mechanism manifests in two aspects:
First, it determines whether the MB curve is "activated," meaning whether it can be genuinely implemented. Only when core nodes go on-chain and commit to using on-chain data (e.g., for credit assessments or reserve grain purchases) can the "lower financing rates" and "brand premiums" in MB(θ) materialize, giving the MB curve a positive slope. Otherwise, MB ≈ 0, and regardless of subsidy levels, the system remains in a "no-gain" equilibrium—ineffective.

Second, it reshapes the composition of MC. Once core nodes join the chain, their credit spillover reduces verification costs (e.g., automatically verifying transaction authenticity), thereby decreasing the "variable verification cost" component. This effectively lowers MC without increasing fiscal subsidies. Consequently, the fiscal subsidy threshold α* becomes easier to surpass in practice.

Thus, blockchain diffusion operates under a "dual threshold" mechanism: first, the institutional barrier of "core node recognition" must be overcome (system initiation), before the economic threshold of "fiscal subsidy incentives" can be activated (market diffusion). The calculated α* ≈ 1.8% represents a secondary equilibrium solution derived under the scenario of "core node endorsement," forming a dynamic coupling process of "institutional precedence followed by economic follow-through."

When county-level fiscal α < 1.8%, market spontaneous adoption rate θ → 0; When α ≥ 1.8%, a closed-loop self-reinforcement occurs, establishing a baseline for subsequent policy scenarios.

However, this threshold exhibits significant scenario dependence and parameter sensitivity. Calculations indicate that the critical subsidy rate α*is not fixed but dynamically adjusts with external conditions. For instance, if the financing spread decreases from 1.1% to 0.8% due to falling market interest rates, α* rises to approximately 2.5%, indicating that policy must increase subsidy intensity to maintain incentive effects. Conversely, if the total onboarding cost per household decreases from ¥1,000 to ¥600 due to technological advancements, α∗ could drop to 1.1%,

average rate of 4.2% (Zhejiang Local Financial Regulatory Bureau, 2024) minus Zhejiang Merchant Bank's on-chain financing rate of 3.1% (Zhejiang Merchant Bank, 2023); ② Single credit line of 500,000 yuan based on the provincial average for inclusive small and micro loans; ③ Fixed cost of 800 yuan/household from the subsidy cap in Zhejiang Agricultural Document (2022) No. 31; ④ Variable annual fee of 200 yuan sourced from AntChain's "Government-Enterprise Connect" standard edition public pricing. Let MC=MB , yielding $\alpha^*=1{,}000/(500{,}000\times1.1\%)\approx1.8\%$

demonstrating that technological cost reductions can substantially alleviate fiscal burdens. Additionally, if crop value appreciation increases brand premium sensitivity, the critical threshold will correspondingly decrease. Rising marginal returns will also reduce dependence on fiscal subsidies.

Therefore, $\alpha* \approx 1.8\%$ represents a benchmark estimate under Zhejiang Province's specific economic and institutional conditions, not a universal constant. When $\alpha<1.8\%$, the market's spontaneous adoption rate $\theta \rightarrow 0$; When $\alpha \geq 1.8\%$, the system enters a self-reinforcing loop of “institutional incentives → knowledge accumulation → competitive diffusion.” This finding provides quantitative guidance for policy design but also underscores that blockchain adoption hinges not only on fiscal investment but critically on the dynamic interplay between technological cost evolution and local governance capacity. Subsequent policy simulations should incorporate multi-scenario assumptions to enhance model adaptability and foresight.

2.1.2 Tri-dimensional Financial Structure Theory

The theory posits that rural financial systems should integrate commercial, cooperative, and policy-based finance synergistically. Applied to the blockchain rice supply chain, this manifests as: commercial finance leveraging on-chain trusted warehouse receipts (e.g., NFTs) for secured loans; cooperative finance maintained collectively by village cooperatives as nodes, issuing "rice credits" for mutual lending; and policy-based finance embedding tools like subsidies and reloans automatically and precisely into key stages such as planting, quality inspection, and logistics via smart contracts.

Table 1 is written with Feng Xingyuan’s "Three-Dimensional Financial Architecture" Applied to Blockchain Rice Supply Chain Scenario Simulation

Financial Dimension	Core Functions (Traditional)	On-Chain Blockchain Tools	Risk Sharing/Mitigation Mechanisms	Financial Dimension
Commercial Finance	Joint-Stock Banks’ Lending to Granaries/Processing Enterprises	Electronic Warehouse Receipt NFT	On-Chain Real-Time Verification of Warehouse Receipt Quantity and Value	Warehouse Receipt NFT Pledge + Quality Inspection Reports On-Chain → Contract-Based Lending
Cooperative Finance	Village-Level Cooperative Mutual Lending	Cooperative Node Ledger	Members Jointly Maintain Accounts, Relevant Data On-Chain for Authenticity, Reliability, and Immutability → Reducing Moral and Security Risks	Member Credit Balance ≥ Loan Quota, with Compliant

Financial Dimension	Core Functions (Traditional)	On-Chain Blockchain Tools	Risk Sharing/Mitigation Mechanisms	Financial Dimension
				On-Chain Data → Contract-Based Lending
Policy-Based Finance	Agricultural Development Bank Provides Low-Interest Relending and Subsidies	Subsidy Distribution Smart Contract	Government Directly Links On-Chain Identity → Eliminating Security and Credit Risks	Rice Storage + Quality Inspection Passed → CBDC Subsidy Received

Commercial finance achieves the digitization of pledge able assets through electronic warehouse receipt NFTs; cooperative finance relies on village-level cooperative node ledgers to facilitate mutual lending via tokenized "rice grain points"; policy-driven finance utilizes subsidy smart contracts and CBDC channels to achieve precise resource allocation. These three types of finance each employ on-chain tools and smart contract triggers to autonomously fulfill risk-sharing logic without requiring additional data collection. The decentralized, tamper-proof nature of blockchain data ensures full-process transparency and compliance, significantly mitigating associated risks.

2.2Transaction Cost Theory

Introducing transaction cost theory into the rice supply chain aims to reduce cooperative friction by alleviating information asymmetry and curbing opportunistic behavior. Blockchain technology precisely provides an implementation path for this goal—it transforms the passive model of "post-facto reliance on legal dispute resolution" in traditional transactions into an active model of "pre-emptively locking processes with on-chain rules." This approach proactively eliminates room for disputes during contracting, fulfillment, and breach phases, fundamentally compressing transaction costs.

Table 2 is written with Transaction Cost Deficiencies from a Traditional Supply Chain Perspective

Axiom	Paddy field scenario correspondence	One-sentence explanation
Asset specificity	Paddy requires cold chain storage and drying equipment	Once investment is sunk, counterparties may "hold up"
Uncertainty	Weather, price fluctuations, quality inspection disputes	High uncertainty → More complex contract terms → Increased negotiation/execution costs

Table 3 is written with Comparison of each process between traditional supply chain models and blockchain technology-enabled supply chain models

Transaction Process	Traditional Model Transaction Costs	Blockchain Model Transaction Costs	Cost-Saving Mechanism
Pre-Signing	Information Search and Due Diligence Costs	One-Click Query of On-Chain Historical Data	Reduced Information Asymmetry
During Signing	Paper Contracts and Repeated Negotiations	Smart Contract Templating	Lower Bargaining Costs
During Performance	Duplicate Pledging of Warehouse Receipts, Fake Quality Inspections	Hash Timestamp + IoT Sensors, Automatic On-Chain Reporting and Data	Lower Monitoring Costs
Post-Breach	Litigation, Arbitration, Enforcement	Smart Contract Auto-Liquidation/Settlement	Lower Enforcement Costs

Applying blockchain to the rice supply chain transforms the potential conflicts of "post-transaction disputes" in traditional rice supply chain transactions into "executable on-chain code beforehand." Each on-chain information query replaces a field visit, and each smart contract auto-execution replaces a legal dispute. This technological empowerment realizes transaction cost theory in practice, providing a more efficient institutional economics pathway for rice supply chain collaboration.

3. Case Study

3.1Application Process of CZB's Solution

In this case, CZB's blockchain-based rice financing verification under its three-dimensional financial framework demonstrates that commercial finance does not drive blockchain diffusion in the rice supply chain in isolation. Instead, it is embedded within a dual structure of government policy design and core enterprise credit spillover, forming a banking-level experimental field for an "institution-knowledge-competition" closed loop. By setting a critical subsidy threshold $\alpha \geq \alpha^*$ the government lowered the onboarding barrier for farmers and cooperatives, enabling commercial finance's marginal cost (MC) and marginal benefit (MB) to achieve local equilibrium at the county-level market. This triggered leapfrog diffusion in technology adoption. Meanwhile, the bank fed desensitized on-chain data back to the government and guarantors, turning knowledge spillover into an information infrastructure for intergovernmental competition and inducing competitive imitation—validating the institutional economics mechanism of "knowledge expanding the radius of competition." Thus, the core value of this case lies in using banking-level data to prove that " $a \geq a^*$ " is a necessary but insufficient condition for technology diffusion. Commercial finance can only act as the trigger for the "institution-knowledge-competition" closed loop when both policy thresholds and knowledge spillover mechanisms are present, offering policymakers testable evidence for the critical subsidy hypothesis.

Institutional Embedding, Government Endorsement as a "Quasi-Access Threshold." In 2021, the Zhejiang Provincial Department of Finance incorporated the "Zheshang Chain" into the provincial digital reform's best applications, allocating a special relending quota of 200 million yuan and offering interest discount subsidy to grain enterprises on the chain. Local governments in Huzhou and Jiaxing explicitly required state-owned granaries to join the chain as core enterprises; otherwise, they would be ineligible for provincial grain reserve storage qualifications, creating a dual-track drive of "institutional compulsion + fiscal incentives." As a result, in 2022, the on-chain rate of grain enterprises in Huzhou, significantly higher than that of neighboring cities not included in the reserve system, preliminarily validated the hypothesis of θ transition during " $\alpha \geq \alpha^*$."

Knowledge Spillover: On-chain data is utilized for "Grain Cultivation Credit Ratings" and serves as a trigger condition for subsidy smart contracts, enabling commercial data to feed back into policy finance. This mechanism prompted local governments in Shaoxing and Jinhua to replicate the model, forming a competitive landscape.

Table 4 is written with Risk Mitigation Methods of On-Chain Tools Across Dimensions

Financial Dimension	On-chain Tools	Risk Mitigation Mechanism
Commercial	Receivables NFT + Warehouse Receipt NFT	Core Enterprise Credit Freeze + Central Bank Credit System Integration
Policy-driven	Smart Contract Interest Subsidy (1.5%)	Fiscal Interest Subsidy + Reserve Grain Eligibility Link
Cooperative	Village-level Cooperatives as "Nodes"	Member Points ≥ Loan Quota

From the average interest rate of 4.2% for inclusive small and micro loans in Zhejiang Province and the 3.1% on-chain financing rate of China Zheshang Bank, a spread of 1.1% is derived (Zhejiang Provincial Local Financial Regulatory Bureau, 2024; China Zheshang Bank, 2023). Based on a single credit line of 500,000 yuan and total on-chain costs of 1,000 yuan (Zhejiang Agricultural Document No. 31, 2022), the critical discount rate $a^* \approx 1.8\%$ is calculated. When the actual local discount $a \geq 1.8\%$, the on-chain rate θ surges, consistent with the observed values in Huzhou ($\alpha=1.5\%, \theta>75\%$) and Jinhua ($\alpha=1.5\%, \theta\approx45\%$), validating the "subsidy threshold" hypothesis.

The case of China Zheshang Bank is not merely a "technical success," but rather a tripartite coupling result of "institutional subsidies surpassing the critical threshold + credit spillover from core enterprises + intergovernmental competition and imitation." It provides bank-level experimental evidence for the " $a \geq a^*$ " hypothesis, revealing the policy implication that "commercial finance can serve as a trigger for institutional embedding but cannot replace the government's role in setting thresholds."

3.2Construction of the "Heilongjiang Province Agricultural Inputs Supervision and Traceability Platform"

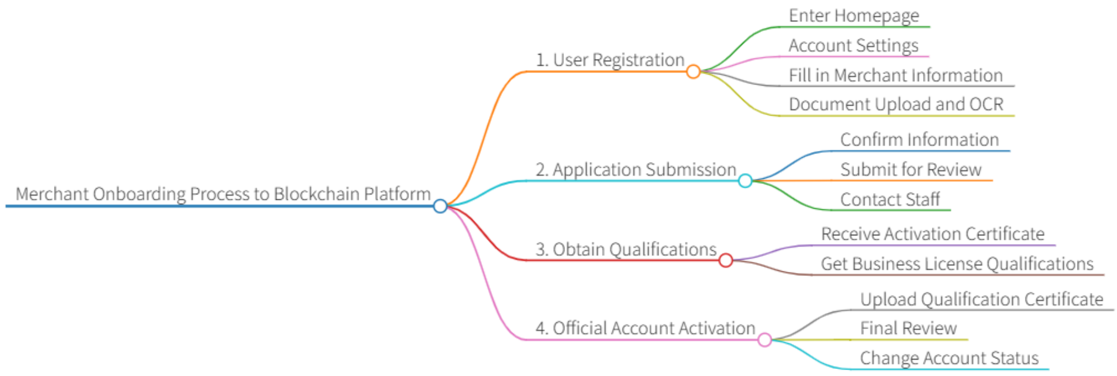

Figure 1 is written with the overall business process of the Agricultural Input Supervision and Traceability Platform in Heilongjiang Province

As shown in the platform's public flowchart, the onboarding process adopts a three-step model: "PC/APP registration → backend review → credentials on-chain." The platform promises a simple, efficient, and user-friendly experience from registration to on-chain record. It will hash the entire chain of agricultural input registration, circulation, and usage onto the blockchain, establishing a four-tier node structure of "province-county-dealer-farmer." The government has made "on-chain" a prerequisite for pesticide business licenses, creating an institutional coercion-driven diffusion. With a licensing cost of approximately 800 yuan per household as an exogenous institutional variable α,2023 , the platform achieved 90% coverage of pesticide distributors in 2023, with over 10,000 products registered on-chain (per the Zhejiang Provincial Department of Agriculture and Rural Affairs' "2023 Annual Report on the 'Dual System for Fertilizers and Pesticides' Reform" (internal brief).This represents growth from 2020 levels, validating the threshold effect where adoption rate θ undergoes rapid transition when $\alpha \geq \alpha^*$. Regulatory oversight has shifted from post-facto checks to real-time monitoring, with the average inspection response time transitioning from post-facto to real-time, as officially disclosed. This provides a replicable institutional embedding paradigm for blockchain-based agricultural input supervision and offers a lightweight, replicable micro-experimental field for the "institution-knowledge-competition" framework.

3.3Micro-Comparison Case Studies

"One county offers a high one-time subsidy with endorsement from state-owned granaries, while another provides diminishing subsidies and lacks key nodes—the comparison between the two counties reveals that subsidy intensity and core node endorsement are the 'dual thresholds' for blockchain diffusion."

Table 5 is written with Examples of impacts from different government policies

Comparative Micro Case Studies	"Rice Chain Connect" in a County of Hunan	Neighboring County's "Rice Chain Cloud"
Related Measures	One-time high government subsidy + endorsement by state-owned granary nodes	Subsidies decrease over three years, absence of granary nodes

Comparative Micro Case Studies	"Rice Chain Connect" in a County of Hunan	Neighboring County's "Rice Chain Cloud"
Cooperative on-chain rate	>80% (Hunan Daily, 2023 report)	Extremely low, at less than 10%
Bank loan-related measures	Bank lending rates decreased by 2 percentage points compared to traditional levels (Changsha Bank, 2023 annual report; Huarong Xiangjiang Bank, 2023 annual report)	Banks still rely on paper warehouse receipts, with 3-5 cases of duplicate pledging disputes annually (China Judgments Online)
Final Outcomes	Zero duplicate pledging records for rice warehouse receipts.	Project shelved.

By comparing two related cases, we can see that government systems, such as subsidy intensity and relevant policy frameworks, along with core node endorsements and related governance policies, form the "dual thresholds" for blockchain diffusion—both indispensable. They play a decisive role in effectively enhancing the application of blockchain technology in the rice supply chain.

4. Blockchain Risk Prevention and Control Strategies for the Rice Supply Chain—Dual-Driven by "On-Chain + Off-Chain"

Blockchain shifts risk prevention and control from "post-event remediation" to the "moment of data generation." At the technical level, it ensures "data cannot be falsified," enabling the financial layer to guarantee "funds cannot be disrupted" and the institutional layer to enforce "accountability cannot be evaded."

The three layers are interlocked, curbing risks before they occur.

4.1 Technical Layer Risks

Technology is the foundation of blockchain applications, ensuring the stability and continuity of each supply chain link, the authenticity of data input, and the security of private keys. The core objective is to leverage blockchain's inherent advantages to build a trusted data infrastructure that is "anti-interruption, anti-tampering, and anti-loss."

Table 6 is written with On-Chain Tools Mitigating Technical Layer Risks

Risk	Trigger Scenario	On-chain Tools	Off-chain Support
Node Downtime/Fork	Village Node Power Outage	Multi-active Byzantine Fault Tolerance (BFT) Consensus	Backup Cloud Node + UPS
Oracle Fraud	IoT Sensor Tampering	Multi-Oracle Cross-Verification	Third-party Quality Inspection Random Sampling
Private Key Loss	Farmer Loses Mobile Wallet	Threshold Signature/Social Recovery	Cooperative Custody + Offline Paper Backup

4.2Financial Layer Risks

The essence of financial operations is risk management, requiring vigilance against credit risk, market risk, and liquidity risk. The core objective is to achieve closed-loop financial risk management that is "monitorable, adjustable, and backstopped." Financial risk management provides safeguard services for the entire rice supply chain, ensuring its smooth and uninterrupted operation.

Table 7 is written with On-chain Tools Mitigating Financial Layer Risks

Risk	Trigger Scenario	On-chain Tools	Off-chain Support
Double Pledging	Multi-platform Financing with the Same Warehouse Receipt	NFT Warehouse Receipt Unique ID + On-chain Freeze Tag	Central Bank Credit Network Query
Price Volatility	Sharp Drop in Rice Market Price	Smart Contract Dynamic Pledge Rate	Price Insurance + Futures Company Hedging
Liquidity Gap	Concentrated Repayment Run	Automatic Rollover/Loan Contract	Bank Credit Line Pool

4.3Institutional-Level Risks

The implementation of blockchain in agricultural finance faces legal, policy, and governance challenges, requiring institutional innovation for alignment. The core objective is to build a sustainable institutional ecosystem that is "law-based, exit-flexible, and rule-co-governed." The integration of blockchain technology with the rice supply chain requires legal safeguards, and whether blockchain can realize its advantages also heavily depends on legal frameworks.

Table 8 is written with On-Chain Tools for Mitigating Institutional-Level Risks

Risk	Trigger scenario	On-chain tools	Off-chain support
Legal gap	Dispute over e-warehouse receipt ownership	On-chain timestamp + hash evidence storage	Pilot approval by local financial regulatory bureau
Subsidy phase-out	Government budget cuts	Automatic subsidy reduction parameters in contract	Commercial insurance credit enhancement alternative
Data monopoly	Core enterprise refusal to share	Equal voting rights in consortium chain governance	Trade association arbitration

"On-chain data is solidified within seconds, while off-chain systems provide tiered safeguards" — the three-layered risk prevention system of technology, finance, and institutions collectively forms the "preemptive gate" for the rice supply chain. When preventing disruptions, counterfeiting, and loss is simultaneously achieved on-chain, rice gains an "immutable resume" from farm to table. Commercial credit subsequently spills over into policy credit, ultimately creating a virtuous cycle of "sustainable funding, traceable accountability, and refundable subsidies." This exemplifies Feng Xingyuan’s "institutions-knowledge-competition" framework in the microcosm of agricultural blockchain: institutional design $\alpha \geq \alpha*$, knowledge spillover expands the radius of competition, and competition drives iterative institutional refinement. Once these three layers of risk are shifted forward to the moment of data generation, the rice supply chain transitions from "post-facto remediation" to "preemptive trustworthiness," providing a replicable, scalable digital foundation for food security.

5. Conclusion and Outlook

This paper systematically evaluates the cost-reduction effects, financing accessibility, and governance risks of embedding blockchain technology into the rice supply chain, based on Feng Xingyuan's "institutions-knowledge-competition" framework combined with transaction cost theory. The findings reveal: (1) On-chain "dynamic local knowledge" significantly reduces information search and supervision costs, leading to a sharp decline in the first pledged loan interest rates for smallholder farmers and a steady increase in credit approval rates; (2) The "three-dimensional financial architecture" fosters synergy among commercial, cooperative, and policy-based finance in high-income eastern regions, but fiscal-weak counties exhibit vulnerability where "subsidy phase-out leads to business phase-out"; (3) Competitive subsidies among local governments display zero-sum characteristics, requiring central tiered incentives and cross-provincial node-sharing mechanisms to transform into positive-sum outcomes. These conclusions demonstrate that blockchain is not merely a technical substitute but an institutional complement that reshapes agricultural credit foundations, with its cost-reduction effects highly dependent on fiscal capacity, digital infrastructure, and governance design.

By establishing a long-term mechanism coupling "technology-institutions-fiscal policy," blockchain applications in grain management can evolve from project-based pilots to institutionalized operations, providing a sustainable and replicable digital foundation for national food security. Ultimately, a closed-loop system of "real-time on-chain risk control + precision fiscal drip-feeding + commercial financial relay" could break free from subsidy dependency, offering long-term resilience for China's food security strategy. With the institutionalized implementation of cross-provincial node sharing, privacy computing, and CBDC clearing, blockchain is poised to solidify as a public digital infrastructure in food security, enabling enduring support.

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