

Research on the Application of Blockchain in Supply Chain Finance in Hainan

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Abstract: This paper explores the application of blockchain in Hainan's supply chain finance, analyzing its impact on enhancing market transparency, optimizing processes, and addressing challenges like information asymmetry and inefficient credit transmission. It examines technical and security issues such as scalability and cross-chain interoperability, proposing solutions like layered architectures and privacy computing. The study highlights blockchain's role in empowering cross-border trade, tropical agriculture, and SME financing, aiming to provide a reference for Hainan Free Trade Port's financial digital transformation.

Keywords: Blockchain; Hainan Free Trade Port; Supply chain finance; Cross-border trade

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1. Introduction

With the acceleration of global trade, digital transformation, and the complexity of supply chain finance, traditional financial models face issues such as information asymmetry, lack of trust mechanisms, and redundant processes, particularly pronounced in the financing of small and medium-sized enterprises (SMEs). Blockchain technology, as a distributed ledger technology, offers a novel solution to these supply chain finance pain points by leveraging its characteristics of decentralization, immutability, and transparency with traceability^[1].

Hainan Free Trade Port, as a significant platform for national strategic deployment, has its supply chain finance development deeply intertwined with the construction of the free trade port. Relying on its four leading industries—tourism, modern services, high-tech industries, and tropical high-efficiency agriculture—Hainan has cultivated a unique cross-border supply chain ecosystem. However, challenges such as difficulties in SME financing, low efficiency in cross-border settlements, and risks of trade document forgery hinder industrial upgrading^[2]. Integrating blockchain technology into Hainan's supply chain finance not only enhances the capital flow efficiency of the local industrial chain but also aids in fostering an international, rule-of-law-based, and facilitative financial environment for the Free Trade Port^[3].

This paper focuses on the application of blockchain technology in Hainan's supply chain finance. By

analyzing the compatibility of technical features with Hainan's industrial needs, it explores the application advantages, challenges, and countermeasures, providing theoretical references for supply chain finance innovation in Hainan Free Trade Port. The research combines the policy dividends of Hainan Free Trade Port with the potential of blockchain technology, aiming to construct an optimized supply chain finance path that aligns with regional characteristics ^[4].

2. Blockchain technology and the overview of supply chain finance in Hainan

2.1. Characteristics of blockchain technology

The application of blockchain technology within supply chain finance has garnered increasing scholarly attention, emphasizing its potential to enhance transparency, security, and efficiency in supply chain operations. Zhang and Peng ^[5] specifically investigated how blockchain can be integrated into supply chain finance, highlighting its capacity to streamline financial transactions and improve trust among stakeholders. Similarly, Liu reviewed existing literature on blockchain-based supply chain finance, underscoring its emergence as a significant research hotspot and emphasizing the transformative potential of blockchain in this domain ^[6].

The features of blockchain technology are fundamental to understanding its transformative potential across various sectors. Several studies highlight key characteristics such as decentralization, transparency, immutability, and security as core features that underpin its applications ^[7].

Decentralization is a prominent feature, facilitating distributed data management without reliance on a central authority. This characteristic is particularly advantageous in energy systems, as discussed, where blockchain enables secure energy distribution and trading within microgrids, addressing issues of centralized control and enhancing user autonomy ^[8]. The open nature of blockchain also fosters transparency, which is crucial in supply chain environments. Alabaddi et al. ^[2] demonstrated how blockchain enhances supply chain transparency and resilience, especially in healthcare, by providing an immutable record of transactions accessible to all stakeholders.

Immutability, a feature where once data is recorded, it cannot be altered, is central to blockchain's trustworthiness ^[9]. This feature supports applications requiring high levels of data integrity, such as in trust accounting, where it examines whether blockchain can substitute or complement traditional trust agents by providing a tamper-proof ledger. Furthermore, the technology's ability to manage data in a sequential, chronological manner is highlighted by ^[8], reinforcing its suitability for real-time data management and auditability.

Blockchain's features also extend to enhancing security in Internet of Things (IoT) environments, as discussed, where blockchain's cryptographic and consensus mechanisms bolster IoT security frameworks ^[10]. In the context of cryptocurrencies, describe how interconnected computers form a chain of blocks containing transaction data, illustrating the decentralized and secure nature of blockchain in digital currency systems.

Overall, these studies collectively underscore that blockchain's core features—decentralization, transparency, immutability, security, and open data management—are instrumental in enabling innovative applications across supply chains, energy, healthcare, IoT, and financial sectors. These features not only facilitate enhanced trust and data integrity but also open avenues for replacing traditional intermediaries and improving operational resilience in various industries.

2.2. General situation of supply chain finance in Hainan

Under the grand context of the free trade port construction, the development of supply chain finance in Hainan is

exhibiting a favorable trend, with robust policy support, active market participation, gradually expanding business scale, and continuous emergence of innovative models. However, it also faces numerous challenges.

The continuous enhancement of policy support provides a solid foundation for the development of supply chain finance in Hainan. The Action Plan for Promoting High-Quality Development of Inclusive Finance in Hainan Province (2024–2028) explicitly states the need to deepen the application of the accounts receivable financing service platform, guide “two chains” core enterprises and provincial state-owned enterprises to leverage their “chain leader” advantages in conducting accounts receivable verification, and enhance financing convenience for small and micro enterprises within the supply chain. The development of supply chain finance in Hainan is driven by policy innovation, leveraging the openness advantages of the Free Trade Port and the empowerment of digital technology, and gradually constructing a multi-level service system. According to the 14th Five-Year Development Plan for the Financial Industry in Hainan Province, the provincial government explicitly proposes accelerating supply chain finance innovation, promoting movable property financing services, supporting the real economy and small and micro enterprises, and establishing an accounts receivable financing incentive mechanism (up to 2 million yuan) to stimulate financial institutions’ enthusiasm. The 2025 document Building an Important Practice Base for New Qualitative Productivity further proposes carrying out the “Artificial Intelligence +” initiative, promoting AI-enabled collaborative development of industrial and supply chains, and strengthening technical support.

In terms of business model innovation, Hainan has broken through traditional credit dependencies, forming three typical practices. First is the innovation in credit guarantee models. In 2023, the Industrial and Commercial Bank of China Hainan Branch collaborated with the Hainan Financial Guarantee Fund to launch the first “credit + supply chain financing guarantee” business, issuing 2.9 million yuan in “Hainan Supply Chain Purchase Loans” to a technology company. This model eliminates the need for core enterprise counter-guarantees, using real transaction data as the credit basis to achieve “signing and lending simultaneously.” Second is the breakthrough in asset securitization. In 2023, Ping An Bank Haikou Branch issued Hainan’s first supply chain finance ABS project, with a shelf scale of 2 billion yuan and an initial priority rate as low as 4.98%, dedicated to serving upstream and downstream enterprises in the Sanya Yazhou Bay Science and Technology City, significantly reducing financing costs within the supply chain. Third is the deepening of scenario-based finance. For example, Sunshine Credit Finance introduced an e-commerce supply chain guarantee product, integrating merchant transaction flows and return rates to shorten the capital recovery cycle for small and medium sellers from one month to 1–2 days, cumulatively serving thousands of small and micro e-commerce enterprises.

Cross-border finance has become a prominent feature. Hainan leverages the combined advantages of RCEP and Free Trade Port policies to promote the facilitation of cross-border capital flows. In 2025, enterprises such as Hainan Natural Rubber Group were approved as the first batch of cross-border capital centralized operation centers, achieving coordinated scheduling of domestic and international funds; Zhonglian International Investment Company, relying on the “Cross-border Investment and Financing Connect” digital platform, integrated investment, financing, and settlement services for Chinese-ASEAN enterprises, accelerating its Southeast Asian market layout after receiving 3 million yuan in angel round financing in 2025, and cumulatively facilitating transactions exceeding 50 million yuan. Meanwhile, the optimization of QFLP/QDLP pilot programs and the expansion of EF accounts further enhance cross-border investment and financing capabilities.

Digital infrastructure serves as the underlying support. The Hainan Provincial Smart Financial Integrated Service Platform integrates government data and core enterprise order information to provide a whitelist and risk control service for downstream enterprises in the industrial chain, such as jointly issuing a 1.5 million

yuan loan with Hainan Bank to downstream distributors of Yuehai Feed. Blockchain and AI technologies are deeply integrated into risk control processes, such as data verification rules and cross-border payment big data applications, providing technical assurance for supply chain finance.

3. Impact of blockchain technology application on Hainan's supply chain finance

3.1. Enhancing market transparency and trust

Leveraging core features such as distributed ledgers, immutability, and smart contracts, blockchain technology has established a technology-driven trust mechanism for Hainan's supply chain finance market ^[11]. It fundamentally addresses long-standing issues in traditional models, including information asymmetry and inefficient credit transmission, while systematically enhancing market transparency and trust in multi-party collaboration.

In cross-border trade supply chain finance scenarios, under the traditional model, documents like customs declarations and bills of lading rely on manual verification, which is highly vulnerable to forgery and inefficient in transmission ^[12]. This leads financial institutions to reduce credit limits or extend approval cycles due to doubts about information authenticity. Blockchain digitizes and uploads these documents to the chain, ensuring immutability through hash encryption and timestamps, allowing participants to query in real-time based on their permissions. All data related to products, transportation, and other relevant aspects are stored on the chain, enabling financial institutions to confirm transaction authenticity without on-site verification. This not only reduces risk control costs but also provides small and medium-sized trading enterprises with equal access to financing opportunities.

Targeting the characteristics of Hainan's tropical agricultural supply chains, traditional live collateral valuation relies on manual assessment, resulting in subjective data and delayed supervision. Financial institutions are reluctant to lend or restrict loan amounts due to difficulties in controlling the value of collateral. Additionally, there is a lack of a reliable basis for agricultural product traceability. Blockchain collects real-time growth data (such as weight and health status) of live pigs and deep-sea fish through IoT devices (e.g., smart ear tags and water quality sensors) and uploads it to the chain, with smart contracts automatically updating valuation models. When fluctuations in collateral value exceed thresholds, smart contracts automatically issue warnings, prompting both parties to adjust financing plans. Meanwhile, data on the cultivation, processing, and transportation of fresh products like lychees and durians is fully traceable on the chain. Consumers can verify the entire process by scanning codes, and financial institutions evaluate enterprises' performance capabilities based on traceability data, forming a virtuous cycle of "consumer trust–brand value enhancement–financing convenience."

In the field of SME financing, under the traditional model, core enterprises' payment commitments hardly reach the end of the supply chain, leaving small and medium-sized suppliers struggling with financing due to a lack of credit endorsements. Blockchain, through platforms like "Haikin Cloud Chain," uploads core enterprises' accounts payable confirmation information onto the chain, generating tamper-proof electronic creditor's rights certificates. Small and medium-sized suppliers can secure financing using these on-chain certificates without requiring core enterprises to reconfirm, and enterprises use the platform to confirm rights for upstream and downstream small and medium-sized suppliers, effectively easing their financial pressure.

Moreover, blockchain's hierarchical permission mechanism ensures data security: core enterprises can view the entire chain of creditors' rights circulation, SMEs only access their own transaction data, and financial institutions verify data authenticity via encryption algorithms without gaining access to commercial secrets. This balance between privacy protection and information sharing not only dispels enterprises' concerns about data leakage but also provides financial institutions with a sufficient risk control basis, significantly improving SMEs'

access to financing.

Blockchain also optimizes the overall credit ecosystem through credit information sharing. In the traditional model, enterprises' credit-related data, such as tax payment records, social security contributions, and customs violations, are scattered across various departments, leading financial institutions to underestimate their creditworthiness due to incomplete information. Hainan has integrated government affairs data with on-chain transaction data to build a "government + business" dual-dimensional credit model. For example, after integrating a company's VAT records, on-chain order fulfillment rates, and logistics delivery rates, its credit score is significantly higher than that evaluated based solely on financial data, enabling it to successfully obtain unsecured credit loans. This multi-source data cross-validation model allows well-operated small and medium-sized enterprises lacking collateral to secure financing based on their credit, thereby improving the credit system of supply chain finance.

3.2. Optimizing business processes and efficiency

Blockchain technology, leveraging its decentralized architecture and the automated nature of smart contracts, systematically reconstructs the business processes of supply chain finance in Hainan ^[1]. It breaks the constraints of information silos and manual intervention in traditional models, enabling efficient collaboration throughout the entire financing chain.

In terms of the financing approval process, under the traditional model, SMEs have to go through cumbersome procedures such as confirmation by core enterprises, multi-level reviews by financial institutions, and repeated transmission of paper documents, which are time-consuming and prone to delays due to human errors ^[10]. Blockchain stores trade contracts, order vouchers, logistics records, and other documents on the chain to form tamper-proof digital archives. Smart contracts automatically complete qualification verification and condition matching according to preset rules ^[13]. For example, when a processing enterprise applies for accounts receivable financing, the blockchain platform directly retrieves the on-chain confirmation information of the core enterprise, and smart contracts quickly complete transaction verification and credit calculation without manual document review, significantly shortening the approval process that originally took several days. All parties in the supply chain share data in real-time through the blockchain, avoiding the inefficiency of multiple parties repeatedly entering the same data, and the connection efficiency of each link is significantly improved.

The process innovation in cross-border settlement is particularly crucial. As a free trade port, Hainan's cross-border trade involves multi-currency settlement, multi-department supervision, and adaptation to rules in multiple jurisdictions ^[4]. The traditional model requires layers of verification by correspondent banks, resulting in long document transmission and clearing cycles and high handling fees. The cross-border trade financing platform built on blockchain digitizes and puts letters of credit, bills of lading, foreign exchange verification documents, etc., on the chain to achieve full network visibility ^[7]. When goods arrive at the port, customs inspection data is automatically synchronized to the blockchain, and smart contracts immediately trigger the bank's letter of credit negotiation process, which greatly shortens the settlement time that originally took several days and eliminates intermediate agency fees. This on-chain direct connection model, combined with Hainan's policy of exempting tariffs for processed products with an added value of 30%, accelerates the turnover of cross-border funds and helps foreign trade enterprises seize opportunities.

In the traditional model, enterprises applying for government-supported financing need to submit multiple paper materials such as business licenses and tax certificates, and some certificates need to be issued on-site by multiple departments, resulting in redundant processes and being prone to expired materials. Blockchain puts

government data, such as enterprise operation qualifications, credit ratings, and policy matching degrees, on the chain, and financial institutions can directly retrieve and verify them with authorization, without the need for enterprises to submit repeatedly. When an enterprise applies for a loan, the blockchain platform automatically links its on-chain data to tax or related departments, and smart contracts quickly calculate indicators such as the proportion of R&D investment and the number of patents to match the interest subsidy policy, significantly shortening the total time from application to loan disbursement. This model significantly reduces institutional transaction costs.

In response to the personalized needs of Hainan's characteristic industries, blockchain, combined with the Internet of Things and big data, promotes the upgrading of processes to be scenario-based and dynamic. In the scenario of living collateral, blockchain connects with IoT devices to collect real-time growth data of live pigs and deep-sea fish. Smart contracts dynamically adjust the financing amount according to weight and health indicators, avoiding the rigid data in the traditional model, where one evaluation is used for the whole year^[14]. When the value of the collateral fluctuates beyond the threshold, the system automatically issues an early warning, prompting both parties to adjust the repayment plan, which not only ensures the capital security of financial institutions but also provides financing flexibility for enterprises. In the tourism supply chain, after the transaction data of hotels, scenic spots, and travel agencies are put on the chain, smart contracts can automatically adjust the proportion of advance payment financing according to the passenger flow during peak and off-seasons, making the capital scheduling of small and medium-sized tourism enterprises more in line with the business cycle.

The distributed collaboration feature of blockchain also realizes the process integration of the entire supply chain^[15]. From order generation, raw material procurement to finished product delivery and capital payment, information of each link is uploaded to the chain in real-time and forms a unified data caliber, avoiding reconciliation disputes caused by inconsistent information in the traditional model. Core enterprises store data such as production plans, supplier stockpiles, and logistics scheduling on the chain. When core enterprises adjust the number of orders, smart contracts automatically trigger adjustments in suppliers' financing limits and optimization of logistics routes, improving the response speed of the supply chain. After the goods are inspected and accepted, the system automatically initiates the payment process without manual transfer, achieving seamless connection.

4. Strategies for the application of blockchain technology in Hainan's supply chain finance

4.1. Technical and security challenges faced

Although blockchain technology holds great potential in the application of Hainan's supply chain finance, it also faces a series of technical and security challenges that require systematic solutions. Firstly, scalability is the biggest bottleneck for the large-scale application of blockchain in Hainan's supply chain finance. Despite the certain advantages of consortium blockchains in cross-border trade scenarios of Hainan Free Trade Port, their throughput (TPS) still cannot meet the needs of high-frequency transactions. For instance, the peak transaction volume of cross-border trade in Hainan can reach 12,000 transactions per day, while the performance of existing consortium blockchains (such as Hyperledger Fabric with 3,500 TPS) may fail to ensure the timeliness and reliability of transactions during peak hours. In addition, the balance between the complexity of smart contracts and transaction speed needs further optimization to adapt to the diverse supply chain financial scenarios in Hainan.

Secondly, the issue of cross-chain interoperability is particularly prominent in the multilateral trade of the Hainan Free Trade Port. As an important hub connecting RCEP member states, Hainan's cross-border supply chain

involves data interaction across multiple jurisdictions. The cross-chain technology between different blockchain platforms is not yet mature, especially with conflicts in data formats, privacy protection, and compliance requirements. For example, cross-border data sharing between Hainan and the Guangdong-Hong Kong-Macau Greater Bay Area needs to take into account both the Data Security Law and the privacy protection regulations of Hong Kong and Macau, but there is currently a lack of unified technical and institutional standards.

Thirdly, data privacy and security are of great importance in blockchain applications. Although the decentralized nature of blockchain can enhance transparency, sensitive commercial data and cross-border transaction information still face the risk of leakage. In 2023, global DeFi platforms suffered losses of up to 1.86 billion US dollars due to security vulnerabilities, highlighting the importance of smart contract code auditing and system protection. If the supply chain financial platforms in Hainan Free Trade Port fail to effectively protect enterprises' commercial secrets and transaction data, it may lead to the loss of competitive advantages and legal disputes.

Finally, the issue of energy consumption and sustainability cannot be ignored. The high energy consumption of blockchain consensus mechanisms (such as Proof of Work, PoW) conflicts to a certain extent with the “dual carbon” goals of Hainan Free Trade Port. For example, the annual energy consumption of the Bitcoin network is equivalent to that of a small country, which is inconsistent with Hainan's strategic direction of promoting a green economy. Therefore, priority should be given to energy efficiency and sustainability requirements when selecting blockchain technologies.

4.2. Corresponding solutions and recommendations

To address the aforementioned technical and security challenges, this paper proposes the following specific measures to promote the sustainable application of blockchain in Hainan's supply chain finance.

First, adopt a layered architecture to enhance system performance. At the core transaction layer, Hainan can introduce a “Layer 1 (main chain) + Layer 2 (lightning network)” architecture, diverting high-frequency transactions to the second-layer network to alleviate pressure on the main chain. For example, state channel technology can enable atomic settlement of cross-border payments, reducing transaction confirmation time to seconds. Meanwhile, to meet the demand for complex smart contracts in supply chain finance, a modular design is recommended to separate core logic from auxiliary functions, improving code maintainability and operational efficiency.

Second, improve cross-chain interoperability and data sharing mechanisms. Hainan Free Trade Port should actively promote the application of cross-chain protocols (such as Polkadot's relay chain and parachain architecture) in cross-border trade scenarios to achieve “one chain for multiple uses and multi-chain collaboration.” Specifically, Hainan can collaborate with the Guangdong-Hong Kong-Macau Greater Bay Area to build a “multi-chain interconnection” demonstration project, exploring zero-knowledge proof (ZKP)-based data sharing solutions to realize information mutual recognition among customs, taxation, and financial institutions while protecting privacy. Additionally, it is advisable to formulate the Hainan Free Trade Port Blockchain Data Sharing Standards to clarify cross-chain data formats, transmission rules, and security requirements.

Third, strengthen smart contract security and privacy protection measures. Hainan's supply chain finance platforms should establish strict smart contract code review mechanisms and introduce third-party auditing institutions to detect vulnerabilities in contract logic. For data privacy, multi-party computation (MPC) and homomorphic encryption technologies are recommended to ensure that cross-border transaction data is “usable but not visible.” For instance, in the offshore duty-free supply chain, MPC can enable collaborative data verification among suppliers, logistics enterprises, and banks, reducing the risk of commercial secrets leakage.

Fourth, promote the research, development, and application of green blockchain technologies. Hainan should prioritize low-energy consensus mechanisms such as Proof of Stake (PoS) and Proof of Authority (PoA), gradually phasing out high-energy-consuming PoW algorithms. Furthermore, Hainan can explore the integration of blockchain with digital renminbi, leveraging the controllable anonymity of digital renminbi to enhance payment efficiency and security in supply chain finance. Finally, Hainan Free Trade Port can pilot “green supply chain finance” in Yangpu Bonded Port Area, uploading carbon emission data to the blockchain to promote in-depth integration of carbon credits and financial assets.

The implementation of these solutions will enable Hainan to effectively overcome technical and security barriers in blockchain applications, creating an efficient, secure, and sustainable supply chain finance ecosystem that provides strong technical support for the high-quality economic development of the free trade port.

5. Conclusion

With the characteristics of decentralization and non-tampering, blockchain technology provides an innovative path for Hainan supply chain finance to solve pain points such as information asymmetry and process redundancy. The research shows that it has achieved remarkable results in improving market transparency and trust, and through the construction of a distributed ledger, the data traceability of the whole process of the supply chain can be realized, providing credible support for scenarios such as live mortgage of tropical agriculture and cross-border trade document verification, and helping small and medium-sized enterprises to obtain financing by relying on on-chain credit. In terms of optimizing business processes, the automated execution of smart contracts greatly shortens the financing approval cycle, promotes the efficiency of government financing and cross-border settlement, and promotes the “three-stream” collaboration of the supply chain. Although it faces challenges such as scalability, cross-chain interoperability, and data security, it can be gradually resolved through countermeasures such as hierarchical architecture, cross-chain protocol, and privacy-preserving computing. In the future, with the advancement of the construction of the Hainan Free Trade Port, blockchain technology will be applied in more scenarios, promoting the intelligent and green upgrading of supply chain finance, injecting impetus into the development of the real economy, and providing a practical example for the digital transformation of supply chain finance.

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