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Research on the Efficiency Enhancement and Risk Prevention in Cross-Border Payments Through Blockchain Technology

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Abstract: In the context of global cross-border payments exceeding $150 trillion, traditional mediation architectures, such as SWIFT, face challenges due to high costs, inefficiencies, and fraud risks. However, blockchain technology become an important driver of innovation in cross-border payments with the characteristics of decentralization, real-time and immutable. This paper aims to answer two core questions: Blockchain technology how to improve the efficiency of cross-border payments through smart contracts, cross-chain protocols and other technical features? How to identify and prevent key risks such as private key security and regulatory conflicts? Through the logical framework of "technical basis - efficiency analysis - risk identification - prevention and control strategy", combined with case comparison (such as RippleNet and SWIFT) and quantitative data (such as Stellar network $0.01 / transaction cost). This paper systematically analyzes the role of blockchain in disintermediation, cost compression, and transparency optimization. Besides, the risks of technological vulnerabilities, regulatory fragmentation and market volatility are revealed. Then, this paper proposes a collaborative governance scheme of hybrid architecture, zero-knowledge proof and multilateral regulatory sandbox. Research finding, blockchain technology can reduce cross-border payment time to seconds and reduce costs by more than 90%, but it needs to deal with challenges such as throughput constraints, conflicting regulatory standards and the volatility of digital currencies. It is suggested that future research focus technology optimization, multilateral regulatory collaboration and market ecological integration, provide theoretical and practical support for building an efficient and secure global payment system.

Keywords: Blockchain, cross-border payment, efficiency improvement, risk prevention and control, collaborative governance

1. Introduction

In the context of deep integration of the global economy and rapid expansion of digital trade, cross-border payment has become the core link to maintain international business activities. In 2023, the global cross-border payment scale will exceed 150 trillion US dollars. However, the intermediation architecture which traditional financial systems rely on, such as SWIFT, is facing serious challenges: The hierarchical clearing process requires 5 intermediary nodes, takes 3-5 days on average, and the handling fee is as high as 5-7% of the transaction amount [1]. Such high frictional costs and inefficiencies not only restrict the growth of global trade, but also create information silos

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and fraud risks. In this context, blockchain technology has become a key driver for reconstructing the cross-border payment paradigm with its decentralized, real-time settlement and immutable characteristics. For example, RippleNet uses distributed ledger technology to enable peer-to-peer transactions between banks, reducing cross-border remittance time to 10 seconds and reducing the cost to 1/10 of the traditional model (Santander bank case).However, technological innovation comes with significant risks: Volatility in cryptocurrency prices, such as XRP lost 60% of its market value due to SEC lawsuits, lack of cross-chain interoperability like the differences between Bitcoin and Ethereum protocols, and regulatory fragmentation such as conflicting central bank standards for digital currencies call for systematic research to balance efficiency and security.

In this context, this paper aims to answer two core questions: First, how can blockchain technology improve the efficiency of cross-border payments through technical features such as smart contracts, cross-chain protocols? Second, how to identify and prevent key risks in technology applications such as private key security, regulatory conflicts? The significance of the study provides the decision basis for the technology adoption of financial institutions, promote international regulatory collaboration and standardization, such as the Bank for International Settlements' (BIS) mBridge project which through multilateral central bank digital currency bridge trials to explore new paths for cross-border payments.

Based on the logical main line of "technical basis - efficiency analysis - risk identification - prevention and control strategy", this paper firstly analyzes the core principles of distributed ledger, smart contracts (such as IBM Trade finance platform), and cross-chain interoperability (Polkadot), and compares the application scenarios of public, consortium, and private chains. Second, it quantified blockchain's contribution to disintermediation (SWIFT GPII vs. RippleNet), cost compression (Stellar network $0.01 / transaction), and transparency (Everledger traceability), and explained its role in improving efficiency. Besides, focus on technical vulnerabilities, regulatory conflicts and market volatility. Finally, this paper proposed the collaborative governance model of hybrid architecture (J.P. Morgan Quorum), zero-knowledge proof (Zcash) and multilateral regulatory sandbox (Project Ubin). By covering Europe and the United States (Ripple, Project Dunbar), Southeast Asia (mBridge) and multilateral cooperation cases, this paper avoids regional bias and reveals common problems of technology landing from a global perspective. According to the data, this paper combines McKinsey (B2B cost reduction of 40%), BIS (mBridge trial), and enterprise practice (IBM, Santander) to ensure that the demonstration is rigorous. The research finally points to the "technology-regulation-market" three-dimensional collaborative path, providing theoretical reference and practical guidance for building an efficient, secure and inclusive global payment ecology.

2. The Basics of Blockchain Technology

2.1. Principles of Blockchain Technology

The core of blockchain technology is to achieve multi-node synchronous verification and data sharing through distributed ledgers, eliminating the traditional financial system's dependence on centralized institutions. Take Ripple's XRP Ledger for example, which uses consensus algorithm (RPCA) to support direct interbank transactions, bypassing SWIFT's five intermediary layers and reducing cross-border remittance time from 3-5 days to 10 seconds (as in the case of Santander Bank).Smart contracts automatically enforce the terms of the agreement through programmable code, significantly increasing process efficiency: IBM and Maersk's Trade Lens platform uses smart contracts to automate the letter of credit process in trade finance, reducing the traditional seven-day manual review cycle to one hour. In addition, cross-chain interoperability protocols (such as Polkadot's parallel chain architecture and Cosmos's IBC protocol) solve the problem of data and asset

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interoperability between different blockchain networks, such as enabling cross-chain transactions between Bitcoin and Ethereum, providing the technical basis for multi-currency cross-border payments.

2.2. Blockchain Technology Classification and Characteristics

According to the different access rights and participating nodes of the blockchain, it can be divided into public chain, alliance chain and private chain, which have their own unique characteristics and application scenarios in cross-border payment. The difference between different types in different scenarios can be seen in Table 1.A public chain is a fully open blockchain network that anyone can participate in without authorization. As the most representative public chain, Bitcoin has a high degree of decentralization and strong security, but its performance has certain limitations, and its transaction processing capacity is low, only 7TPS (Transactions Per Second), which is difficult to meet the needs of large-scale and highly concurrent cross-border payments [2]. A consortium chain is a blockchain network that is managed and maintained by a number of specific institutions or organizations, and only authorized nodes can join. R3 Corda is a typical representative of the alliance chain, which has significant advantages in the cross-border payment scenario between financial institutions. The alliance chain can balance efficiency and privacy to a certain extent, and achieve relatively efficient transaction processing through the collaboration and consensus mechanism among members, while meeting the strict requirements of financial institutions for data privacy and security [2]. A private chain is a blockchain network built and used within a business or organization that only internal members can access and participate in. Hyperledger Fabric is a common private chain platform, which has the characteristics of high throughput, can support enterprise-level large-scale transaction processing, suitable for B2B (Business-to-Business) cross-border payment scenarios, providing enterprises with a highly customized and secure and reliable solution [2].

Table 1: Technical comparison and data support

Technological Type	Represent Item	Throughput (TPS)	Applicable Scene	Typical Case
Public blockchain	Bitcoin	7	Decentralized payment	Cross-border small remittance
Consortium blockchain	R3 Corda	1,000+	Interinstitutional clearing	SWIFT GPII Blockchain Integration
Private blockchain	Hyperledger Fabric	10,000+	Enterprise high frequency trading	J.P. Morgan Chase JPM Coin

2.3. Application Scenarios in Cross-Border Payment

With RippleNet, Santander has been able to send money across borders from the UK to Spain in just 10 seconds, a significant efficiency boost thanks to blockchain's distributed ledger and real-time consensus mechanism. Under the RippleNet system, transaction data can be quickly synchronized at each node, without the need for layers of transfer and confirmation as in the traditional model, so as to realize the instant arrival of funds. This is of great significance for enterprises and individuals with high requirements for the timeliness of funds, which can effectively improve the efficiency of the use of funds and reduce the risk of funds in transit. By adopting a disintermediated architecture, the Stellar network has successfully reduced the cost of a single transaction to $0.01, a 99% reduction compared to SWIFT. The Stellar network takes advantage of the distributed nature of blockchain to eliminate intermediaries in traditional payments and reduce unnecessary expenses. This makes small cross-border payments more affordable and provides more cost-effective payment options for smes

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and individual users, helping to promote the development of cross-border trade. Everledger uses blockchain to track the diamond supply chain, recording traceability data for more than 2 million diamonds, reducing illegal transactions and insurance fraud. In the cross-border payment scenario, such transparency can effectively reduce the occurrence of fraud and enhance the trust of both sides of the transaction. When the transaction information is recorded on the blockchain, all participants can view the transaction status and fund flow in real time, and any abnormal operations can be detected and traced in time.

3. Blockchain Technology to Improve the Efficiency of Cross-border Payments

3.1. Decentralization and Process Optimization

In the traditional cross-border payment system, SWIFT system is widely used, but it has obvious defects. Scholars Qiu et al pointed out in their research in 2018 that a cross-border remittance usually goes through multiple links such as remitter bank, intermediary bank and agent bank, which takes 3-5 working days on average. In this process, the intermediaries need to carry out information verification, fund clearing and other operations, which not only extends the transaction time, but also increases the complexity of the operation [1]. The distributed ledger characteristics of blockchain technology have brought breakthrough changes to cross-border payments. It supports point-to-point transmission and can effectively reduce the involvement of intermediaries. According to the research results of Islam et al. in 2022, RippleNet connects global financial institutions with the alliance chain model, directly connects the remittance bank and the receiving bank, greatly reduces the transaction level from the traditional 5 to 2, and the transaction time is reduced from the traditional model of several days to 10 seconds [3]. As can be seen from Figure 1, traditional payments need to go through intermediary banks for transactions, while the cross-border payment process of blockchain technology is greatly shortened compared with traditional payments. This change not only simplifies the cross-border payment process, but also reduces the risk of transaction failure due to insufficient liquidity of intermediaries. Tests by the Bank for International Settlements (BIS) have also confirmed that blockchain technology can reduce the settlement time of cross-border payments by 80%, fully demonstrating its great potential to improve the efficiency of cross-border payments [4].

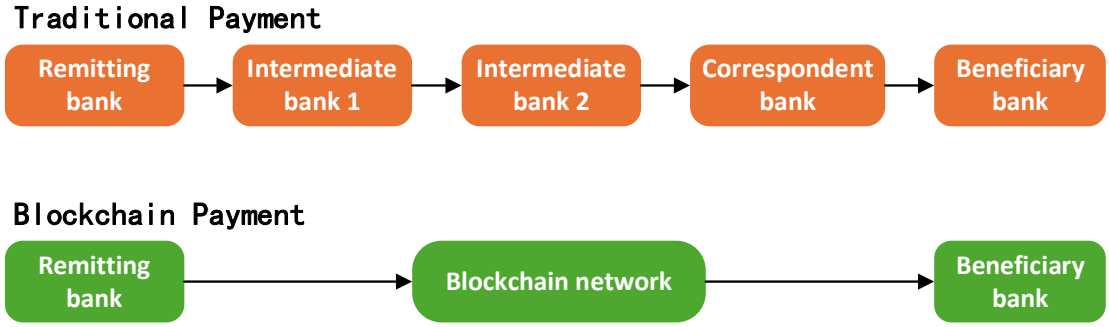

Figure 1: Cross-border payment process comparison (Picture credit: Original)

3.2. Cost and Transparency Benefits

From a cost perspective, blockchain technology has a significant effect on reducing the cost of cross-border payments. As can be seen from Figure 2, blockchain technology has a great degree of efficiency improvement in terms of time cost and number of nodes. According to a study by McKinsey in 2016, blockchain technology can reduce B2B cross-border payment costs by 40%, and the cost compression advantage is more prominent in small-scale high-frequency trading scenarios,

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which is mainly due to the elimination of intermediary fees and manual audit costs by blockchain technology. Take Ripple as an example, its XRP as a "bridge currency", can achieve instant exchange, effectively reduce exchange rate losses, a single transaction fee of only 0.001%, greatly reducing the cost of cross-border payments [5]. In terms of transparency, blockchain technology's full-node recording mechanism plays a key role. Everledger's success in using blockchain to track the diamond supply chain has shown that the risk of illegal transactions has been reduced by 90 percent by linking the flow of each diamond to the chain [6]. In the cross-border payment scenario, the SWIFT system only transmits instruction information, while the blockchain technology can synchronously record the flow of funds and information, and all parties can verify the transaction status in real time. In a 2024 study, Bayram et al. noted that this feature significantly reduces fraud and compliance risks, making cross-border payments more secure and reliable [7].

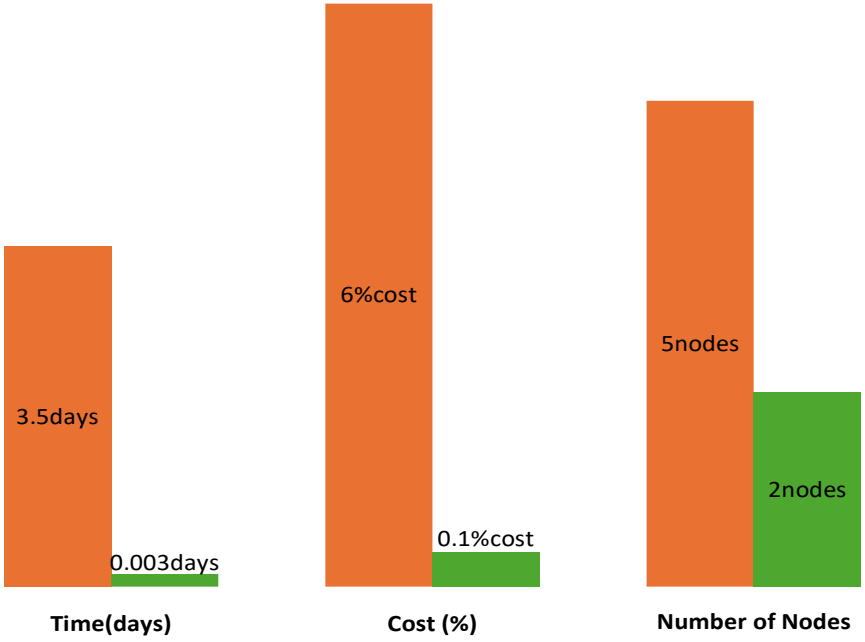

Figure 2: Quantitative comparison of efficiency improvement

3.3. Real-time and Technology-driven Path

The smart contract function of block-chain technology provides strong support for the real-time performance of cross-border payments. Traditional cross-border payments rely on manual audits and are less efficient, while smart contracts enable automated execution of payment conditions. For example, in HSBC's block-chain letter of credit trial, iot devices automatically triggered smart contracts after goods arrived in Hong Kong to achieve instant payment settlement, dramatically reducing the trade finance cycle from 5-10 days to within 24 hours [4]. From the perspective of technological development path, block-chain cross-border payments show phased characteristics. In a 2020 study, Deng pointed out that its development can be divided into three stages: The primary phase focuses on direct account connection and digital currency exchange, such as Ripple's X Rapid; At the intermediate stage, standardized smart contracts are introduced, such as the real-time tracking function of SWIFT GPII [5]. The mature stage is committed to building a full-chain collaborative payment ecology, and the integration of China's CIPS system and block-chain is a typical representative. The "Multi-access Cross-border Payment Trial" of the Bank for International Settlements (BIS) shows that block-chain technology can support the atomic settlement of multi-national central bank digital currencies (CBDC), achieving "transaction as clearing", providing

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a seamless technical basis for the global payment system. This trial points the way for the future development of cross-border payments, and is expected to promote deep changes in the global cross-border payment system.

4. Risk and Prevention Strategy of block-chain Technology Application

4.1. Risk and Challenge

Although block-chain technology has brought many innovations and opportunities for cross-border payments, it also faces a series of risks and challenges in the practical application process, covering multiple levels such as technology, regulation and compliance, market and system. An in-depth analysis of these issues is essential to comprehensively evaluate the application prospects of block-chain in the field of cross-border payments and formulate countermeasures.

4.1.1. Technical Risk

The security foundation of block-chain technology lies in private key management, yet this aspect is fraught with numerous risks. In the Solana wallet attack in 2022, hackers exploited system vulnerabilities to successfully steal digital assets worth 190 million US dollars, which fully exposed the vulnerability of private keys during storage and transmission. Even systems like Ripple, which adopt a consortium chain model and have private keys managed centrally by financial institutions, seemingly enhancing security, are not immune to risks. If the node servers are attacked, the consequences could be disastrous. Financial institutions' servers often store a large amount of users' private key information. If compromised, it would not only lead to users' asset losses but also potentially cause a halt in the entire network's transactions, seriously affecting the normal operation of cross-border payments [3]. Moreover, design flaws in the consensus mechanism may trigger systemic risks. For instance, the Ethereum Classic network was once subject to a 51% attack, where attackers manipulated transaction records by controlling the majority of the computing power, leading to double-spending issues [4]. In the context of cross-border payments, the high frequency of transactions places extremely high demands on the throughput and scalability of block-chain. However, the current mainstream public chains' throughput is insufficient to support the high-frequency cross-border payment requirements. Bitcoin, as a typical representative of block-chain technology, has a processing capacity of only 7 TPS (transactions per second), which is a significant gap compared to Visa's peak processing capacity of 24,000 TPS [7]. Although Ripple Net has increased its processing speed to 1,500 TPS by optimizing the consensus algorithm, its coverage is only 37.5% of SWIFT's, and it still faces performance bottlenecks in high-concurrency scenarios. While consortium chains improve efficiency through node access mechanisms, the complexity of cross-chain interactions may lead to data silo problems [5].

4.1.2. Regulatory and Compliance Risk

The regulatory attitudes of countries around the world towards digital currencies show a significant divergence trend. The European Central Bank's Project Stella and the Bank of Japan's CBDC experiment represent two different approaches to regulation. The euro zone focuses on the central bank-led account model, emphasizing strict controls on the issuance and circulation of digital currencies; Japan, on the other hand, prefers a public-private partnership structure that focuses more on the participation and innovation of market players. This difference in regulatory stance makes it difficult to form a uniform standard for cross-border payments [8]. Such differences make it difficult to unify cross-border payment standards. For example, there are significant differences between China's CIPS system and SWIFT GPII in message format and clearing rules [4]. In addition, the

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contradiction between privacy protection and regulatory transparency is prominent. Privacy coins such as Monero, for example, use ring signature technology to achieve complete anonymity of transactions, which is in direct conflict with the "travel rule" advocated by the FATF (Financial Action Task Force against Money Laundering), that is, the principle of traceability of transaction information. This conflict has led to bans on privacy coins in countries such as South Korea and Australia, reflecting the difficulty of block-chain technology in meeting the needs of privacy protection while balancing regulatory compliance requirements in the current regulatory environment [7]. The transnational nature of block-chain technology poses a serious challenge to traditional legal frameworks. In the US SEC lawsuit against Ripple in 2020, the court ruled that XRP was an "unregistered security", causing its price to plummet by 60% in a single day, bringing huge losses to Ripple and related investors [4]. Such regulatory uncertainty has intensified the application concerns of financial institutions, and some banks have suspended block-chain payment pilots due to high compliance costs [5].

4.1.3. Markets and Systemic Risk

Fluctuations in the value of digital currencies directly affect the stability of cross-border payments. In 2021, XRP lost 75% of its value in a single month due to litigation, causing liquidity to dry up for cross-border transactions using it as a bridging currency [1]. While stablecoins (such as USDC) mitigate volatility through fiat anchoring mechanisms, the lack of transparency in their reserve assets remains controversial. Tether (USDT) was indicted by New York State prosecutors for misrepresenting its dollar reserves, exposing the vulnerability of anchoring mechanisms [4]. The first-mover advantage of traditional payment systems forms ecological barriers. With 11,000 member institutions in 200 countries, SWIFT creates a positive protocol-user-data loop [7]. In contrast, the emerging Ripple Net only has access to more than 100 banks, which is difficult to break through the network effect threshold. Moreover, the sunk costs of existing cross-border infrastructure, such as the correspondent bank model, have led to a lack of institutional willingness to transform. Over the long term, banks have invested significant resources in building and maintaining relationships with correspondent banks. According to McKinsey's survey, 73% of banks have delayed the deployment of block-chain technology in cross-border payments due to concerns about compatibility with the SWIFT system and the high cost of transition [5]. This path dependence makes the promotion of block-chain technology in the field of cross-border payments face huge resistance.

4.2. Risk Prevention and Control Strategy

While block-chain technology brings a lot of convenience to cross-border payments, the risks it faces cannot be ignored. In order to effectively deal with these risks, prevention and control strategies need to be formulated from many aspects, such as technological innovation, regulatory cooperation and market ecological optimization, to ensure the steady development of block-chain technology in the field of cross-border payments [9,10].

4.2.1. Technological Innovation Path

To balance efficiency with compliance, financial institutions are adopting a hybrid block-chain architecture. For example, J.P. Morgan's private chain platform Quorum enables transaction data encryption in cross-border payments by integrating zero-knowledge proof technology, while supporting on-demand audits by regulators [4].The R3 Corda consortium chain allows only authorized banks to participate in ledger synchronization through a node access mechanism, ensuring transaction privacy while meeting the requirements of the General Data Protection Regulation (GDPR) [7].This "private chain + alliance chain" model has been widely used in cross-border trade

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financing, reducing document verification time from seven days to four hours [3].The contradiction between privacy protection and regulatory transparency can be solved by zero-knowledge proof (ZKP) technology. Zcash uses the zk-SNARKs protocol, which allows both parties to verify the validity of a payment without revealing the amount of the transaction or the identity of the participant [5].In the cross-border payment scenario, J.P. Morgan Chase applied it to the JPM Coin system, making the inter bank clearing information only open to the audit authority of the central bank, which not only prevents commercial data leakage, but also meets the FATF anti-money laundering requirements [1].Tests by the European Central Bank's Project Stella show that ZKP technology can improve the efficiency of cross-border payment data disclosure by 50% [8].

4.2.2. Regulatory Collaboration Framework

To explore the boundaries of compliance, multinational regulators jointly set up experimental sandboxes. Project U bin, initiated by the UK's FCA and Singapore's MAS, verified the feasibility of the "real-time total settlement" (RTGS) system by simulating the cross-border settlement of distributed ledgers, and formulated the White Paper on cross-border Payment Agreements to clarify the legal effect of smart contracts [4]. In the second phase of the project, the transaction failure rate of participating institutions was reduced to 0.2%, much lower than the 1.5% of traditional systems [7]. The m Bridge project, led by the Bank for International Settlements (BIS), connects the central banks of Hong Kong, Thailand and the United Arab Emirates to build a multi-access (central bank digital currency) clearing network. Atomic settlement of Hong Kong dollar, Thai baht and dirham through hash time-locked contracts (HTLC) eliminates the risk of exchange rate fluctuations [8]. In the 2023 pilot, the cost of a single cross-border payment was reduced from $30 to $2.50, and the settlement time was reduced from 2 days to 10 seconds [3]. This pattern provides a standardized template for global CBDC interoperability.

4.2.3. Market Ecological Optimization

Fiat anchored stablecoins become a key tool to reduce volatility. USDC, through the joint supervision of Circle and Coin base, ensures the transparency of 1:1 USD reserves, and has been included in the cross-border settlement network by Visa, accounting for 15% of the processing volume [5].DAI, a decentralized stablecoin, maintains its value through over-collateralized crypto assets such as ETH, and MakerDAO applies it to cross-border remittance scenarios in Africa, where the fee is only 1/3 of that of traditional channels [1]. SWIFT GPII (Global Payments Innovation Initiative) partnered with Ripple to pilot the "SWIFT+Ripple Net" dual-track system. While traditional SWIFT messages are used for compliance checks, Ripple Net is responsible for real-time fund settlement, increasing the success rate of cross-border payments from 87% to 99% [7]. In addition, Visa's B2B Connect platform uses the Hyper ledger Fabric consortium chain to seamlessly integrate a pis with banking systems in 200 countries and handle more than 100,000 transactions per day [4].

5. Conclusion

This paper systematically discusses the application potential and limitations of block-chain technology in cross-border payments from three dimensions: technical characteristics, efficiency improvement paths, risk challenges and prevention and control strategies. The study found that block-chain technology significantly optimizes the inter mediation process of traditional cross-border payments through distributed ledgs, smart contracts, and cross-chain protocols, enabling exponential compression of transaction times (such as Ripple Net's 10-second delivery) and significant cost reductions (such as Stellar's $0.01 / transaction).At the same time, its immutability and full-node logging mechanism enhance transaction transparency and effectively curb the risk of fraud (such as

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Ever ledger's diamond traceability case). However, technology adoption still faces multiple challenges: At the technical level, private key security vulnerabilities (such as the Solana wallet attack), low throughput (Bitcoin 7 TPS), and lack of cross-chain interoperability restrict large-scale adoption; At the regulatory level, national policy divergence (e.g., XRP's security attributes dispute) and privacy compliance conflicts (e.g., Monero vs. FATF conflict) impede standardization. At the market level, the volatility of digital currencies (e.g., the shrinking market value of XRP) and the path dependence of traditional payment systems (e.g., the ecological barriers of SWIFT) exacerbate systemic risks.

This paper validates the practical value of block-chain technology through case studies (such as the m Bridge multilateral central bank digital currency trial) and quantitative comparisons (such as the efficiency difference between SWIFT and Ripple Net). It also proposes collaborative governance schemes such as Quorum, zero-knowledge proof (Z cash) and multilateral regulatory sandbox (Project U bin).However, the research still has the following shortcomings: First, most cases focus on Europe, the United States and Southeast Asia, and the applicability of emerging markets such as Africa and Latin America is not discussed enough; Secondly, the quantitative analysis relies on the public data of enterprises, and lacks the dynamic tracking of the long-term operation effect; Third, the impact of technological iterations (such as quantum computing threats) and geopolitical factors (such as CBDC competition) is not fully developed.

In order to break through the current bottleneck of block-chain technology in cross-border payment applications, future research can be carried out from multiple dimensions. In terms of technology optimization and innovation, high-throughput consensus algorithms (such as sharding technology) are developed to support high-frequency trading, and quantum resistant encryption technology is explored to deal with potential security threats; Promote the standardization of cross-chain protocols (such as the integration of Polka dot and Cosmos) to improve multi-chain collaboration. At the same time, build a multilateral regulatory framework (such as expanding the BIS m Bridge model) to harmonize the rules for issuing digital currencies with anti-money laundering standards; Explore "regulation-friendly" privacy technologies (such as auditable zero-knowledge proofs) that balance transparency with privacy needs. In terms of market ecology construction, deepen stablecoin mechanism research (such as DAI's excess mortgage model) to reduce volatility risk; Promote the integration of traditional systems and block-chain (such as SWIFT+Ripple Net dual-track system), using existing infrastructure to accelerate the technology landing. Second, strengthen empirical research on the pain points of cross-border payments in Africa, Latin America and other regions, and explore low-cost block-chain solutions; Expand technology application scenarios, such as supply chain finance and cross-border tax automation, to enhance ecological inclusiveness. In terms of long-term impact assessment, establish a dynamic assessment model to track the long-term stability and risk evolution path of the block-chain payment system; The competitive cooperation between CBDC and private stablecoins is studied to predict the restructuring effect of CBDC on the global monetary system. The process of block-chain technology reshaping cross-border payments is still in its early stages, and its full implementation requires deep coordination of technology, policy and market. Future research should focus on interdisciplinary integration, combining the perspectives of economics, law and computer science to provide more solid theoretical and practical support for the construction of an efficient, secure and inclusive global payment network.

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