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Blockchain Electronic Bills of Lading in Cross-Border Trade: Development, Challenges, and Governance Responses

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Abstract: With the sustained advancement of digital trade and the digital transformation of international shipping, blockchain electronic bills of lading, characterized by decentralization, immutability, traceability, and efficient circulation, have gradually become an important direction for the digital replacement of traditional paper bills of lading. However, the promotion of blockchain electronic bills of lading in cross-border trade still faces multiple practical obstacles. On the one hand, existing legal norms lack clear provisions on their legal nature, function as documents of title, and negotiability, resulting in insufficient institutional support. On the other hand, the transparency and multi-party data-sharing mechanism of blockchain have also brought risks such as the leakage of trade secrets, inadequate privacy protection, and difficulties in cross-border data governance. Meanwhile, the coexistence of real-time cross-border capital flows and reliance on intermediary platforms has posed challenges to traditional financial regulation, including delayed regulatory responses, insufficient rule coordination, and weak collaborative supervision. In light of this, coordinated efforts should be made in improving legal rules, strengthening data security governance, and enhancing cross-border financial regulatory cooperation, so as to promote the standardized application and sound development of blockchain electronic bills of lading in cross-border trade.

Keywords: blockchain electronic bill of lading; legal regulation; data security; financial regulation

1. Introduction

With the rapid development of digital trade, the digital transformation of international cargo transport documents has become a major trend in global shipping and cross-border trade (Pang et al., 2026). In recent years, the international shipping industry has significantly accelerated the standardization, platformization, and interoperability of electronic bills of lading. In 2022, BIMCO, DCSA, FIATA, ICC, and SWIFT jointly established the Future International Trade Alliance (FIT Alliance) to promote a unified-standard electronic bill of lading system and enhance data interconnectivity and institutional coordination across platforms and stakeholders. According to the 2024 Global Electronic Bill of Lading Survey released by ICC and other organizations, the overall adoption rate of electronic bills of lading increased from 33.0% in 2022 to 49.2% in 2024, while the proportion of "dual-track users" using both paper and electronic bills of lading rose from 28.0% to 41.7%. Among respondents still using only paper bills of lading, 74.7% indicated plans to switch to electronic bills of lading. This shows that electronic bills of lading

have entered a stage of accelerated adoption, although their further development remains constrained by institutional and governance conditions. The implementation of blockchain electronic bills of lading in cross-border trade is not merely a technical issue; it also involves complex matters such as the determination of legal attributes, data security protection, and cross-border financial regulatory coordination. Therefore, on the basis of reviewing their current development status, it is necessary to further analyze the practical dilemmas of blockchain electronic bills of lading and propose corresponding improvement paths.

2. Challenges in the Application of Blockchain Electronic Bills of Lading in Cross-Border Trade

2.1. Inadequate Legal Framework and Unclear Legal Nature of Electronic Bills of Lading

As a product of the deep integration of information technology and international trade, blockchain electronic bills of lading are still at an exploratory stage of development in China (Fu & Zhang, 2025). By contrast, the Maritime Code of the People's Republic of China (hereinafter the "Maritime Code"), adopted in 1992 and brought into force in 1993, was enacted well before the emergence of such technologies as blockchain, smart contracts, and electronic bills of lading. Given the inherent lag of the law and the fact that blockchain electronic bills of lading involve emerging technologies (Liu, 2020), the traditional legal framework has difficulty accommodating their technical features. Consequently, the Maritime Code does not provide explicit definitions of blockchain, electronic bills of lading, or related new technological concepts, leaving the legal regulation of blockchain electronic bills of lading largely underdeveloped (Shan & Hu, 2024). Article 71 of the Maritime Code provides that a bill of lading is a document serving as evidence of the contract of carriage of goods by sea, the receipt of the goods by the carrier, or the loading of the goods on board, and by which the carrier undertakes to deliver the goods against surrender of the document. This provision does not specify the form in which a bill of lading must exist; rather, it only establishes that the bill of lading functions as the document entitling its holder to claim delivery of the goods. In other words, the holder of the bill of lading is entitled to demand delivery from the carrier. Against this background, the status of an electronic bill of lading as a document of title remains unclear under the current legal framework. The function of serving as a document of title is the prerequisite for negotiability. Traditional bills of lading may be transferred or pledged through endorsement, thereby playing a central role in trade settlement and secured financing. If blockchain electronic bills of lading cannot be legally recognized as having this essential function, their conventional core roles in trade settlement, financial pledge, and related commercial transactions will inevitably be constrained by legal obstacles (Balci & Surucu-Balci, 2021).

2.2. Heightened Privacy Risks under Data Transparency and Multi-Party Sharing Mechanisms

The inherent transparency of blockchain-based data is a double-edged sword. On the one hand, information sharing can reduce transaction costs, improve transaction efficiency, and accelerate the circulation of corporate funds (Pang et al., 2024). On the other hand, this very transparency may render transaction data visible to all nodes on the chain, making commercially sensitive information contained in bills of lading—such as cargo details and pricing—more vulnerable to unauthorized access. Although such data are shared transparently on-chain, firms are generally unwilling to expose their supply chain details or customer information to competitors (Dutta et al., 2020). For example, the disclosure of logistics routes may allow others to infer cost structures, while the leakage of banking transaction information may undermine a firm's business strategy. In addition, blockchain electronic bills of lading must often be connected to multiple external systems, which inevitably raises issues relating to interface access and data exchange. For instance, in the financial settlement stage of cross-border trade, banks from both countries, third-party payment institutions, customs authorities, and other relevant actors all need to share data. Because

blockchain systems may operate under different technical standards, forced interaction frequently requires the opening of API interfaces. Consequently, the question of which party should open its interface becomes a critical issue. If one party opens its system to another, the disclosing party may face a heightened risk of data leakage (Pang et al., 2025a), since customer information within the system may be accessed by multiple participants. This makes it difficult to ensure data privacy. At the same time, once multiple actors are connected to the system, the allocation of rights and responsibilities becomes blurred. This problem is particularly acute in cross-border settings, where differences in legal rules, regulatory policies, and jurisdictional arrangements across countries make it difficult to determine liability and pursue accountability in the event of a data breach.

2.3. Lagging Financial Regulation and Heightened Risks in Cross-Border Capital Flows

Although blockchain electronic bills of lading offer technological advantages in improving transaction efficiency and streamlining settlement procedures, their practical application in cross-border trade has not entirely eliminated reliance on third-party platforms (Yang, 2018; Pang et al., 2025b). These platforms may become focal points of fraud risk. Owing to opaque arrangements between third-party service providers and banks, merchants are often unaware of the specific terms governing their cooperation, which creates information asymmetry and may enable intermediaries to reap excessive profits. For example, a third-party platform may enter into a hidden revenue-sharing agreement with a bank while representing the fees charged to merchants as "mandatory bank charges," thereby creating new opportunities for rent-seeking and corruption. At the same time, if blockchain electronic bills of lading were to become fully decentralized, operational efficiency and financial security could not necessarily be ensured simultaneously (Zhang & Miao, 2025). This gives rise to a series of potential consequences, including the financial risks associated with near-instant cross-border settlement through blockchain networks. Under the SWIFT system, international remittances typically take three to five working days to reach the recipient, whereas once blockchain-based interfaces are opened, cross-border transfers may be completed within seconds. However, traditional state-centered financial regulatory mechanisms often struggle to keep pace with such speed (Nguyen et al., 2022), thereby creating a regulatory time gap that may facilitate illicit activities such as money laundering. In the context of cross-border trade, capital can move across borders with little friction, while regulation remains territorially bounded. At present, regulatory standards for cryptocurrencies and related digital financial activities vary considerably from one jurisdiction to another. In particular, some Southeast Asian jurisdictions have not yet established stringent regulatory frameworks in this area, thereby creating regulatory loopholes or "regulatory havens" for cross-border capital flows.

3. Governance Responses

3.1. Establishing a Legal Framework Compatible with Blockchain Electronic Bills of Lading

To address the core problems of legal uncertainty surrounding electronic bills of lading and the unclear status of their function as documents of title, it is necessary to establish a legal framework specifically adapted to blockchain electronic bills of lading. The first priority is to promote the revision of relevant domestic laws and regulations so as to clarify the meaning of blockchain electronic bills of lading, confirm their legal equivalence to paper bills of lading, and recognize that they perform the three essential functions of a bill of lading, namely, serving as evidence of the contract of carriage, as a receipt for the goods, and as a document of title. At the same time, international experience should be drawn upon to incorporate the principles of functional equivalence and technological neutrality (Li & Hu, 2025), thereby constructing a legal regime for electronic bills of lading that is both suited to China's national conditions and compatible with international rules. This would facilitate the smooth use

of blockchain electronic bills of lading in both domestic and international trade. In particular, reference may be made to the principles embodied in the UNCITRAL Model Law on Electronic Transferable Records (MLETR). The principle of functional equivalence means that an electronic record should be accorded the same legal effect as a paper document so long as it is capable of performing the same functions. The principle of technological neutrality means that the law should not prescribe any specific technology for the implementation of electronic bills of lading. In other words, legislation should focus on the legal effects of electronic bills of lading rather than on the technical form through which they are realized, thereby leaving sufficient room for future technological development.

3.2. Improving the Legal Framework for Data Security, Strengthening Technological Oversight, and Clarifying the Allocation of Responsibility

For blockchain electronic bills of lading to be widely applied in cross-border trade, it is essential to ensure that data operate within a secure and stable system environment. Accordingly, greater emphasis should be placed on the supervision of data security, the continuous improvement of the legal framework governing data protection, and the establishment of a clear framework for cross-border data sovereignty (Li et al., 2024). More specifically, regulations on the data security of blockchain electronic bills of lading should be formulated to clarify the classification standards for core data in the shipping industry. Information that does not involve the identity of relevant parties or the security of funds may be permitted to flow across borders, whereas sensitive data that may threaten commercial confidentiality or national security—such as the identity of cargo owners and transaction amounts—should be subject to mandatory local storage, and any cross-border transfer should require approval from the competent national cyberspace authority. At the same time, the legal responsibilities of third-party institutions should be strengthened. Payment institutions and logistics platforms should be required to disclose the logic governing data interface permissions, connect to regulatory blockchain nodes operated by the central bank, and report abnormal access activities in real time. Where data leakage causes significant losses, the responsible parties should be subject to penalties such as fines and business restrictions. In terms of technological oversight, a national-level data security protection network should be established, under which API callers are subjected to multiple layers of authentication and high-risk requests are intercepted in a timely manner. Through a combination of legal boundary-setting and technology-enabled regulatory penetration, the ultimate goal is to ensure that sensitive data remain stored domestically, controlled within the blockchain system, and used in a transparent and accountable manner.

3.3. Improving the Financial Regulatory System and Promoting Coordinated Cross-Border Regulatory Governance

The systemic financial risks associated with blockchain electronic bills of lading—such as fraud by third-party institutions, excessively rapid cross-border capital flows, and inconsistencies in financial regulatory standards across jurisdictions—essentially stem from a structural mismatch between technological efficiency and lagging regulatory systems. In other words, these risks reflect systemic vulnerabilities generated by the gap between rapidly evolving technology and comparatively slow institutional adaptation. Accordingly, the widespread adoption of blockchain electronic bills of lading must be supported by a sound financial regulatory framework and an effective mechanism for cross-border regulatory cooperation (Yao et al., 2026). To address opaque arrangements between third-party platforms and banks, a penetrating supervision mechanism should be established. All participating nodes, including carriers, third-party service providers, and banks, should be required to connect to a cross-border trade big data platform and upload key operational data in real time, thereby reducing the risk of third-party fraud. As for regulatory loopholes in the supervision of cross-border capital flows, these issues cannot be resolved by any single country or regulatory authority acting alone. Governments should therefore work toward global cooperation

and jointly establish a cross-border regulatory coordination system. Under such a system, the central banks of participating jurisdictions could deploy regulatory nodes on the blockchain to monitor abnormal transactions in real time and use smart contracts to automatically freeze suspicious accounts where necessary. In addition, with regard to cross-border capital transactions passing through jurisdictions that are not members of the Financial Action Task Force (FATF), a certain proportion of risk reserves could be mandatorily deposited with the Bank for International Settlements (BIS), thereby creating external compliance pressure and encouraging those jurisdictions to strengthen their regulatory frameworks.

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