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Incentive Mechanism in Port Logistics Service Supply Chain Based on Blockchain and Contract Optimization

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ABSTRACT

The research findings indicate that the blockchain-induced optimization coefficient of logistics costs is positively associated with the wholesale prices of logistics capabilities. Conversely, it is negatively correlated with the unit service cost of carrier enterprises, as well as the profit of the port logistics service supply chain (LSSC). Both revenue-sharing contracts and quantity-flexibility contracts are capable of achieving the coordination of the port LSSC. The coordination condition is that the wholesale price of logistics capacity equals the unit service cost of carrier enterprises after blockchain-based optimization. These contracts enable flexible profit distribution within the port LSSC, thereby enhancing its overall coordination.

KEYWORDS

Port LSSC, Blockchain, Supply Chain Coordination, Contract Theory

INTRODUCTION

With the advancement of information technology, the port logistics service supply chain (LSSC) has witnessed rapid evolution. The crucial role of maritime shipping and supply chain management is consistently emphasized in China's strategic planning for modern logistics systems. As the linchpin of global trade, the development of LSSC is essential for increasing the volume of seaborne trade and plays a vital role in China’s pursuit of becoming a maritime powerhouse. In this changing landscape, the LSSC consists of numerous stakeholders, which inherently raises the risk of operational misalignment and potential decreases in overall profitability. Each node within the LSSC is constantly adapting its development paradigm and actively forging cooperative relationships with other entities in the supply chain. Consequently, the challenges of supply chain coordination and the stability of cooperative alliances have become more prominent, highlighting the necessity of robust collaborative frameworks to ensure the efficient and harmonious operation of the LSSC.

Contract theory serves as a robust analytical framework for addressing coordination challenges in supply chain management(Nie, H. 2017). Various canonical contract models, such as the wholesale-price contract, repurchase contract, revenue-sharing contract (RSC), and option contract, are useful in this regard. In port LSSC, the strategic formulation of contracts is crucial for defining the responsibilities of each participant, optimizing resource allocation, reducing costs, and enhancing

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overall operational efficiency (Olesen et al., 2014). Guo et al. (2005) developed a decision-making model for each entity in the supply chain coordination process using an option mechanism. Their research revealed that both the supply chain and its constituents can achieve more favorable financial returns under this mechanism compared to the traditional vendor model. Xu et al. (2008) introduced two restrictive repurchase contracts to align supply chain interests by limiting the quantity of products subject to repurchase. In scenarios where demand is sensitive to price, Chen et al. (2019) employed a revenue sharing + repurchase + promotion cost sharing combined contract to effectively mitigate the double-marginalization effect prevalent in supply chains. Currently, the majority of domestic and international academic research on supply chain coordination is based on contract theory (Ala & Sammons, 2015; Khaled & Wook 2023; Seo et al., 2016; Talley, 2014). However, these studies often focus on conventional scenarios and have limited in-depth exploration of integrating blockchain technology as a parameter within contract theory.

In recent years, the emergence of blockchain technology has presented new opportunities for the coordination and management of the LSSC. This has led to a surge in research on the integration of blockchain with supply chain operations, which has become a prominent area of interest in both academic and industrial communities. Blockchain technology, characterized by its decentralization, high transparency, and strong traceability, has significant potential for enhancing supply chain transparency, fostering trust among participants, and streamlining contract enforcement. By implementing blockchain, the real-time sharing and verification of supply chain information can be facilitated, which in turn reduces information asymmetry, minimizes transaction costs, and improves the efficiency and reliability of contract execution. Several scholars have contributed to the understanding of blockchain's role in supply chain management. Peters et al. (2015) highlighted the broad application potential and value of blockchain across various sectors. Hou et al. (2019) emphasized the ability of blockchain technology to seamlessly integrate the different flows in a supply chain—physical, financial, and informational. This integration is crucial for reducing the time and cost associated with logistics chain certification. Hou et al. (2019) also explored the practical application value of blockchain in supply chain contexts, thoroughly discussing its security mechanisms and reliability. Zhao (2022) considered the technical attribute of blockchain's decentralization and its implications for the investment decisions of port and shipping supply chain members. Their research led to the construction of a port supply chain model for carriers and ports, exploring strategies for centralization and investment. Deng (2021) conducted a systematic study on the trust mechanism within the port supply chain, leveraging the capabilities of blockchain technology. Gao et al. (2022) designed and implemented a port supply chain system based on the Fabric blockchain, enhancing data trust and security by adding supervisory nodes to the Fabric–PS chain system. Zuo et al. (2019) investigated the impact of port LSSC coordination when considering big data elements, suggesting that the appropriate introduction of big data services can contribute to achieving port LSSC coordination. The insights from these studies highlight the transformative impact of blockchain technology on supply chain management, providing a foundation for further research and practical applications in this field (Centobelli et al., 2018).

The current body of research on the coordination of the port LSSC mainly focuses on scenarios without disruptions. However, the practical application of blockchain technology in port LSSC coordination has shown positive impacts that have not been fully incorporated into existing theoretical frameworks. There is a lack of comprehensive theoretical analysis on how to examine the factors influencing port LSSC coordination within the framework of contract theory. Additionally, the way to utilize blockchain technology to improve port LSSC coordination and enhance the overall performance of the supply chain remains largely unexplored. Blockchain's characteristics, such as its decentralized nature, transparency, and traceability, suggest its potential to address challenges involving trust and information asymmetry in the supply chain. The technology's ability to enable real-time information sharing and verification is recognized for its potential to reduce transaction costs and increase the effectiveness of contract execution. These aspects have become focal points of interest in both