

## A Study of Port LSSC Coordination Considering Blockchain Factors Under Contract Theory

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**Abstract:** For a port logistics service supply chain (LSSC) composed of a port enterprise and a carrier enterprise, Stackelberg game theory is used to study the blockchain factors and construct coordination decisions for port LSSC under revenue sharing contracts and quantity flexibility contracts, in order to solve the problem of difficult coordination between port enterprises and carrier enterprises in decentralized decision-making due to double marginal effects and imperfect trust mechanisms. Research has shown that the optimization coefficient of logistics costs by blockchain is positively correlated with wholesale prices of logistics capabilities, negatively correlated with the unit service cost of carrier enterprises, and negatively correlated with the profit of port LSSC and the optimization coefficient of blockchain logistics costs. Both revenue sharing contracts and quantity flexibility contracts can achieve port service supply chain coordination, with the coordination condition that the wholesale price of logistics capacity is equal to the unit service cost of carrier enterprises after blockchain optimization. The contract makes the profit distribution of port LSSC flexible, enhancing the coordination of port LSSC.

**Keywords-** Port LSSC, Blockchain, Supply Chain Coordination, Contract Theory

### 1. Introduction

With the development of information technology, the rapid development of port logistics service supply chain is promoted. China's modern logistics system planning has repeatedly mentioned that we should attach great importance to shipping and supply chain. As the artery of global trade, the development of port logistics service supply chain (LSSC) will promote the growth of seaborne trade volume and play an important role in building a maritime power. With the development of this idea, there are many partners in the port logistics service supply chain (LSSC), which is easy to cause incoordination and overall revenue reduction, etc. Each node enterprise is constantly changing its own development concept and actively establishing cooperative relations with other enterprises in the supply chain. The issue of supply chain coordination and cooperation stability has attracted more and more attention.

Contract theory provides a powerful theoretical tool to solve the coordination problem in supply chain. Typical supply chain contract models include wholesale price contract, repurchase contract, revenue sharing contract, option contract and so on. In the supply chain of port logistics services, reasonable contracts can be formulated to clarify the responsibilities of each member of the supply chain, optimize resource allocation, reduce costs, and improve overall operational efficiency[1]. Guo Qiong[2] established the decision-making model of each decision-making body in the process of supply chain coordination through the option mechanism, and found that the returns of the supply chain and its members under the option mechanism were better than those under the Newsvendor model. Xu J [3] proposed two restrictive repurchase contracts to coordinate the supply chain by limiting the quantity of repurchased products. Under the condition that demand is price sensitive, Xu Guangye constructs the value range of contract parameters when the revenue sharing contract model can realize the coordination of dual-channel supply chain. The research on combination contract is also quite mature. For example, Xu Guangshu designed the combination contract of "quantity discount + cost sharing + income sharing" in the fresh supply chain. When the parameters meet certain conditions, the combination contract can realize the optimal profit of the

system and the Pareto improvement of the profits of both parties. Chen Xiaochun adopted the combination contract of "revenue sharing + repurchase + promotion cost sharing" to effectively eliminate the existing problem of double marginal effect [4]. At present, domestic and foreign scholars mainly study supply chain coordination from contract theory [5-9], but they are often limited to normal scenarios, and the integration of blockchain into contract theory as a parameter is rarely studied in depth.

In recent years, the emergence of blockchain technology has introduced novel opportunities for the coordination and management of logistics service supply chain. This has led to a surge in research focusing on the integration of blockchain with supply chain operations, which has become a prominent area of interest within the academic and industrial communities. Blockchain technology, characterized by its decentralization, high transparency, and robust traceability, holds 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 bolsters the efficiency and reliability of contract execution. Several scholars have contributed to the understanding of blockchain's role in supply chain management. Peters G W [10] pointed out that it has a wide range of application potential and value in many fields. Hou Jiankun [11] pointed out that blockchain technology can better integrate the supply chain flow (physical flow, financial flow and information flow), reduce the certification time and certification cost of the logistics chain, and analyzed the potential application scenarios of blockchain in smart ports. Vecchione Anthony [12] analyzed in detail the practical application value of blockchain in the supply chain, and conducted an in-depth discussion on its security mechanism and reliability. Zhao Huida [13] considered the technical characteristics of blockchain decentralization and the investment choices of members of the port and shipping supply chain, built the port supply chain of carriers and ports, and discussed the combination strategy of whether to centralize and whether to invest. Deng Xinjiao [14] systematically studied the trust mechanism of port supply chain by means of blockchain. Gao Na [15] designed and implemented a port supply chain system based on the Fabric blockchain. Add supervisory nodes to the Fabric-PS chain system to enhance data trust and security. Zuo Yonggang [16] studied the impact of port LSSC coordination considering big data factors, and the appropriate introduction of big data services is conducive to the realization of port LSSC coordination.

At present, the study of port LSSC coordination usually only focuses on the supply chain coordination under normal circumstances. In actual production, blockchain technology has played a positive role in port LSSC coordination. How to analyze the factors affecting port LSSC coordination under the framework of contract theory, how to use blockchain technology to improve port LSSC coordination and promote the overall effectiveness of the supply chain has not been fully answered theoretically, which has become the focus of increasing attention in academia and industry.

In view of this situation, this paper takes the port logistics service supply chain as the research object, uses Stackelberg game to build a model under the benefit-sharing contract and quantitative flexible contract considering blockchain factors, and analyzes the conditions that the model parameters of the benefit-sharing contract and quantitative flexible contract need to meet. And discuss the impact of blockchain on supply chain members' decisions, expected profits, and coordinated contracts. The integration point of contract theory and blockchain technology is deeply analyzed, and the coordination strategy of port LSSC based on blockchain is proposed, in order to provide useful reference for related enterprises and researchers.

## **2. A blockchain-based port LSSC coordination model under contract theory**

### **2.1A Coordination Model for Port LSSC Based on Blockchain under Revenue Sharing Contracts**

This section aims to address the challenge of integrating blockchain services within the port Logistics and Supply Chain Services (LSSC) framework. We propose to utilize a revenue-sharing contract to establish a coordination mechanism that ensures carrier enterprises consistently employ blockchain services, thereby enhancing logistics service quality and maximizing the benefits for the entire port LSSC, with the primary goal of achieving the optimal outcomes for port enterprises. We also examine how port enterprises can adjust incentive transfer

payments to carrier enterprises in response to changes in logistics demand, which in turn affects the profit distribution and the overall coordination mechanism of the port LSSC.

Although the port LSSC has blockchain services, it is still difficult to clarify the actual logistics needs in advance due to the uncertainty of logistics market risks. In this case, port enterprises and carrier enterprises can coordinate through the revenue sharing contract, which can attract more logistics capacity of the port to order. Under the revenue-sharing contract, port enterprises and carrier enterprises choose the right combination of wholesale price and retained income ratio to realize flexible distribution of port LSSC profits, which ensures the practical application ability of revenue-sharing contract. At the same time, the carrier enterprise must introduce new contract parameters to safeguard its own reasonable interests. From the standpoint of the carrier enterprise, whether to accept the contract depends on whether the carrier enterprise can get more expected profits. If the port enterprise chooses the appropriate proportion of retained profit to coordinate the port LSSC and gives the minimum expected profit required by the carrier enterprise, then the expected profit of the port enterprise is the best.

**Table 1 . Symbol Definition**

Symbol	Definition
$D$	Logistics demand ceiling
$\alpha$	Blockchain optimization factor for logistics costs
$f_0(x)$	There is no blockchain service when the flow demand density function
$f_1(x)$	Blockchain service logistics demand density function
$F_0(x)$	Logistics demand distribution function without blockchain service
$F_1(x)$	Blockchain service logistics demand distribution function
$w$	Logistics capacity wholesale price
$\Pi$	port LSSC profit
$\Pi_s$	Profit of carrier enterprise
$g(x)$	$f_1(x) - f_0(x)$
$m_p$	Unit service cost of port enterprise
$x$	Actual logistics demand
$T$	Expected transfer payment
$s$	Blockchain service level
$n_p$	Blockchain service unit input cost
$\eta$	Total cost of using blockchain services for carrier enterprises
$I(x)$	Based on $x$ , give carrier enterprise incentive transfer payment
$K^*$	Port enterprise profit maximum order quantity
$\Pi_p$	Port enterprise profit
$S(K)$	Expected sales volume of logistics capability of port enterprises
$K^0$	Port LSSC profit maximizes when ordering volume
$\zeta$	The proportion of revenue retained by port enterprises
$\theta$	Return ceiling, $\theta \in (0,1)$
$m_s$	Unit service cost of carrier enterprise
$p$	The unit price of logistics capacity sold by port enterprises
$\lambda$	Blockchain service cost factor

### 2.1.1 Problem Description And Technical Hypothesis

This section seeks to solve the problem of port LSSC under the blockchain service, how to use the revenue sharing contract to design a coordination mechanism to ensure that carrier enterprises strictly use blockchain services, improve the quality of logistics services, and maximize the benefits of the entire port LSSC under the premise of meeting the maximum benefits of port enterprises. Based on the change of logistics demand, port enterprises give carrier enterprises a certain incentive transfer payment, which changes the profit distribution of port LSSC and affects the coordination mechanism of port LSSC.

The port LSSC under the block chain service, port enterprises use blockchain and other technologies to unify the logistics resources and logistics capabilities of dispersed carrier enterprises, virtualize and integrate the logistics resources and logistics capabilities of existing carrier enterprises through blockchain services, and dynamically combine them according to the personalized and diversified needs of the demanders of logistics services. Carrier enterprises choose whether to accept logistics business through blockchain analysis of logistics capacity and demand matching. In the process, Port companies introduce blockchain services at a unit cost  $n_p$ , Port enterprises book logistics capacity  $K$  at price  $w$  to carrier enterprises based on blockchain service prediction, and port enterprises face logistics demand  $x$  with unit price  $p$ . The value range of logistics demand  $x \in [0, D]$ , If the logistics capacity  $K$  ordered by the port enterprise according to the supply and demand relationship predicted by the blockchain service is greater than the logistics demand  $x$ , the logistics demand is met; On the contrary, part of the excess logistics demand  $K$  cannot be met. Port enterprises pay a certain incentive transfer payment to carrier enterprises based on logistics needs to ensure the quality of logistics services of carrier enterprises. Port enterprises reach a consensus with carrier enterprises. Port enterprises first order logistics capacity from carrier enterprises at wholesale price, and share a certain percentage of income to carrier enterprises as return after the completion of logistics cycle. Assume that the port enterprise shares all the profits to the carrier enterprise according to the proportion of  $1 - \zeta$  and the proportion of retained profits of the port enterprise is  $\zeta$ .

By adopting technologies such as blockchain, Internet of Things and cloud computing, port enterprises will unify the logistics resources and logistics capabilities of dispersed carrier enterprises, virtualize and integrate the logistics resources and logistics capabilities of existing carrier enterprises through blockchain services, and dynamically combine them according to the personalized and diversified needs of the demanders of logistics services. Port enterprises directly face the end customers, logistics needs to send their own cargo information to port enterprises, including location, transport volume, vehicle information and other related information, but the specific logistics services are provided by the carrier enterprises. Assume that the cost of using blockchain services for carrier enterprises is  $\eta = \lambda s^2$

### 2.1.2 Model Construction And Model Solving

Under the revenue sharing contract, in the blockchain-based port LSSC coordination model,  $px$  is the sales volume of port enterprises. Due to the blockchain service, the logistics demand density function follows the distribution  $f_1(x)$ , then the expected profit of port enterprises is as follows:

$$\Pi p = \int_0^K (px - n_p K - m_p K - wK - I(x) - px + \zeta px) f_1(x) dx \quad (1)$$

$$\text{Extract } \int_0^K (n_p K - (m_p + w)K) f_1(x) dx \quad (2)$$

In the port LSSC under the blockchain service, the net profit of the carrier enterprise blockchain service is not less than 0, so there are constraints 1:

$$\int_0^K (px + I(x) - \zeta px + wK - am_s K - \eta) f_1(x) dx \geq 0 \quad (3)$$

In the port LSSC, the port enterprise introduces the blockchain service, and the profit of the carrier enterprise when the blockchain service is not less than the profit when the blockchain service is not used. Simplification is bound by constraint 2:

$$\int_0^K [(px + I(x) - \zeta px - \eta - am_s K) f_1(x) - (px + I(x) - \zeta px - m_s K) f_0(x)] dx \geq 0 \quad (4)$$

Defined  $h_1, h_2$  is a constraint multiplier, and all are greater than zero, can obtain Lagrange integrand function.

$$L = \zeta p x f_1(x) - I(x) f_1(x) + h_1 [(px + I(x) - \zeta px - \eta - am_s K) f_1(x) - (px + I(x) - \zeta px - m_s K) f_0(x)] + h_2 [(px + I(x) - \zeta px + wK - am_s K - \eta) f_1(x)] \quad (5)$$

Use Euler-Lagrange equation, obtain:

$$L'(I) = h_2 f_1(x) - f_1(x) + h_1 g(x)$$

$$h_1 L'(h_1) = h_1 \{ (px + I(x) - \zeta px) [f_1(x) - f_0(x)] - \eta f_1(x) - am_s K f_1(x) + m_s K f_0(x) \}$$

$$h_2 L'(h_2) = h_2 ((px + I(x) - \zeta px + wK - am_s K - \eta) f_1(x)) \quad (6)$$

令  $L'(I) = 0$ ,  $h_1 L'(h_1) = 0$ ,  $h_2 L'(h_2) = 0$ , Necessary conditions for obtaining an optimal solution.

$$I(x) = \frac{f_1(x)\eta + f_1(x)am_s K - f_0(x)m_s K}{g(x)} + (\zeta - 1)px \quad 0 \leq x \leq K \quad (7)$$

Easy to know  $g(x)$  can't be zero, otherwise  $I(x)$  it's meaningless. In order to achieve the optimal profit of port enterprises under the blockchain service, in the blockchain-based port LSSC coordination model, port enterprises make the decision on the optimal logistics capacity of port enterprises to the carrier enterprises for the purpose of maximizing their own profits, then the order volume of the optimal port enterprises must also reach the optimal profit of the entire port LSSC. Assume that the loss is zero when the logistics capacity is insufficient.

The profit function of port LSSC is described below:

$$\Pi(K) = pS(K) - \eta - am_s K - m_p K - n_p K \quad (8)$$

The profit function of port enterprises is described as follows:

$$\Pi_p = pS(K) - T - m_p K - n_p K \quad (9)$$

The carrier enterprise profit function can be expressed as:

$$\Pi_s = T - am_s K - \eta \quad (10)$$

Expected incentive transfer payments under the benefit sharing contract, let

$$\Lambda = f_1(x)\eta + f_1(x)am_s K - f_0(x)m_s K$$

$$I(K) = \int_0^K \frac{\Lambda}{g(x)} f_1(x) dx + (\zeta - 1)pS(K) \quad (11)$$

Transfer of port LSSC under the Revenue sharing contract:

$$T = I(K) - \zeta pS(K) + wK + pS(K) \quad (12)$$

Assume the order quantity  $K^0$  when the port LSSC profit is maximum, because  $F(x)$  is strictly increasing function, and the port LSSC profit function is strictly concave, so there is

$$\frac{\partial S(K)}{\partial K} = \frac{\partial (K - \int_0^K F_1(x) dx)}{\partial K} = 1 - F_1(K^0) = \frac{am_s + m_p + n_p}{p} \quad (13)$$

The assumption  $K^*$  is the optimal logistics capacity of the port enterprise

$$\frac{\partial \Pi_p(K)}{\partial K} = pS'(K^*) - (m_p + n_p + w) = 0 \quad (14)$$

The profit of port enterprises is satisfied when it is optimal:

$$\frac{\partial S(K)}{\partial K} = \frac{\partial(K - \int_0^K F_1(x)dx)}{\partial K} = 1 - F_1(K^*) = \frac{w + m_p + n_p}{p} \quad (15)$$

General (13) and (15), Blockchain-based port LSSC revenue sharing contract coordination needs to meet:

$$a = w/m_s \quad a \in [0, \frac{p \int_0^K [F_0(x) - F_1(x)]dx - n_p K - \eta}{m_s K} + 1] \quad (16)$$

### 2.1.3 Analysis Of Profit

When the port LSSC under the blockchain service realizes the coordination under the revenue sharing contract, there is also the flexibility of profit distribution between the port enterprises and the carrier enterprises in the supply chain. There are various forms of revenue sharing contract, but the main purpose is to attract port enterprises to order more logistics capacity from carrier enterprises more optimistic, and realize the Pareto improvement of port LSSC. The revenue sharing contract can flexibly distribute the total profit of port LSSC among members by adjusting the retention ratio while keeping the port LSSC in a coordinated state. Port LSSC coordination under blockchain services needs to meet:

$$\int_0^K \frac{\Lambda}{g(x)} f_1(x)dx \leq pS(K) - am_s K - m_p K - n_p K \quad (17)$$

The upper limit of port enterprises' share in port LSSC profits is:

$$\Pi(K) - \Pi_s(K) = pS(K) - am_s K - m_p K - n_p K - \int_0^K \frac{\Lambda}{g(x)} f_1(x)dx \quad (18)$$

Carrier enterprises negotiate with port enterprises to share port LSSC profits and reduce the profit share of port enterprises. Its lower limit is that the profit function of port enterprises is zero, so the profit range of port enterprises is as follows:

$$0 \leq \Pi_p(K) = pS(K) - am_s K - m_p K - n_p K - \int_0^K \frac{\Lambda}{g(x)} f_1(x)dx \quad (19)$$

Similarly, the profit range of the carrier enterprise can be obtained:

$$\int_0^K \frac{\Lambda}{g(x)} f_1(x)dx - \eta \leq \Pi_s(K) \leq pS(K) - am_s K - m_p K - n_p K - \eta \quad (20)$$

In the above analysis, port LSSC can realize the free distribution of profits under the revenue sharing contract. Port enterprises introduce blockchain services to optimize logistics service costs through blockchain services, thus affecting port LSSC profits, but certain conditions can still be met to increase the profits of port LSSC and port enterprises.

## 2.2 Blockchain-Based Port LSSC Coordination Model Under Quantitative Flexible Contract

What this section seeks to solve is how to design a blockchain-based port LSSC coordination mechanism by means of quantitative flexible contract. On the premise of maximizing the benefits of port enterprises, port enterprises give certain incentive transfer payments to carrier enterprises based on changes in logistics needs, so that carrier enterprises can strictly use blockchain services and optimize the quality of information sharing. Improve the quality of logistics services to maximize the benefits of the entire port LSSC. Under the quantitative flexible contract, the port enterprises hope that the logistics capacity can be flexible under the premise of ensuring the supply, so that the carrier enterprises can share the uncertain market risks together, while the carrier enterprises require the port enterprises to commit to a minimum logistics capacity order quantity to ensure that the uncertain market risks shared by the carrier enterprises are within a certain range. The portion of the logistics capacity ordered by the port enterprise from the carrier enterprise shall be refunded by the carrier enterprise to the port enterprise (there is a ceiling  $\theta K$ ).

In the port LSSC under the blockchain service, the port enterprises introduce blockchain service at the unit cost

$n_p$ , which reduces the cost and efficiency of the blockchain service and reduces the logistics cost of the carrier enterprise, which can reduce the unit logistics service cost  $m_s$  of the carrier enterprise. Port companies predict supply and demand based on blockchain services, order logistics capacity  $K$  at wholesale prices  $W$ , and port companies face logistics needs  $x$  with unit prices  $w$ . If the logistics demand is less than the logistics capacity order quantity, then the logistics demand is met, if the logistics demand is greater than the logistics capacity of the order, then only the transaction can be completed. for the part where the multi-order logistics capacity is less than that  $\theta K$  ( $\theta \in [0,1]$ ), the port enterprise requires a refund to the carrier enterprise at the price  $(w + m_p + n_p)$ .

### 2.2.1 Model Construction And Model Solving

The expected profit function of port enterprises under quantitative flexible contract can be obtained by constructing a model based on the assumptions.

$$\begin{aligned} \Pi_p = & \int_0^{(1-\theta)K} (px - (m_p + n_p + w)(1-\theta)K - I(x))f_1(x)dx \\ & \int_{(1-\theta)K}^K (px - (m_p + n_p + w)K + (m_p + n_p + w)(K - x) - I(x))f_1(x)dx \end{aligned} \quad (21)$$

Analyze (21) and extract from it

$$-\int_0^{(1-\theta)K} (m_p + n_p + w)Kf_1(x)dx + \int_0^{(1-\theta)K} (m_p + n_p + w)\theta Kf_1(x)dx \quad (22)$$

Since (21) is a fixed value, after simplification we can get:

$$\int_0^{(1-\theta)K} (px - I(x))f_1(x)dx + \int_{(1-\theta)K}^K (px - (m_p + n_p + w)x - I(x))f_1(x)dx \quad (23)$$

In the port LSSC, the port enterprises introduce blockchain services, but the carrier enterprises provide specific logistics services, and the carrier enterprises need to meet the blockchain services when the net profit is not less than the blockchain services without the use of the net profit, the simplification is constrained 1:

$$\begin{aligned} & \int_0^{(1-\theta)K} (I(x) - (w + m_p + n_p)\theta K)[f_1(x) - f_0(x)]dx + \\ & \int_{(1-\theta)K}^K (I(x) - (w + m_p + n_p)(K - x))[f_1(x) - f_0(x)]dx - \\ & \int_0^K (\eta + am_s K)f_1(x)dx + \int_0^K m_s Kf_0(x)dx > 0 \end{aligned} \quad (24)$$

In the blockchain-based port LSSC coordination model, the net profit of carrier enterprises when using blockchain services is not less than zero, so there are constraints in simplification 2:

$$\begin{aligned} & \int_0^{(1-\theta)K} (wK + I(x) - (w + m_p + n_p)\theta K - am_s K - \eta)f_1(x)dx + \\ & \int_{(1-\theta)K}^K (wK + I(x) - (w + m_p + n_p)(K - x) - am_s K - \eta)f_1(x)dx > 0 \end{aligned} \quad (25)$$

Defined  $h_1, h_2$  as constraint multipliers, all of which are greater than zero, Lagrange integrand functions can be obtained, and the necessary conditions for optimal solutions can be obtained by using Euler-Lagrange equations. For the specific process, refer to the above section for calculation

$$\begin{cases} I(x) = \frac{\Lambda}{g(x)} + (w + m_p + n_p)\theta K & 0 \leq x \leq (1-\theta)K \\ I(x) = \frac{\Lambda}{g(x)} + (w + m_p + n_p)K - (w + m_p + n_p)x & (1-\theta)K \leq x \leq K \end{cases} \quad (26)$$

Through the analysis, it is found that the blockchain-based port LSSC coordination model under the quantitative flexible contract can determine the selection of different payment rules according to the interval of actual logistics

demand. When  $x = (1 - \theta)K$ , the incentive transfer payments under the two forms of blockchain services are equal. When  $0 \leq x \leq (1 - \theta)K$ , it's subtracted from the incentive transfer function  $(w + m_p + n_p)x - (w + m_p + n_p)(1 - \theta)K$  to maximize the benefits of port enterprises.

In the blockchain-based port LSSC coordination model, it is concluded that the expected incentive transfer payment under the quantitative flexible contract is:

$$I(K) = \int_0^D \frac{\Lambda}{g(x)} f_1(x) dx + (w + m_p + n_p) \int_{(1-\theta)K}^K F_1(x) dx \quad (27)$$

Further solving, transfer payments under quantitative flexible contracts can be obtained:

$$T = wK + I(K) - (w + m_p + n_p) \int_{(1-\theta)K}^K F_1(x) dx \quad (28)$$

Under the quantitative flexible contract, the port enterprise makes the decision on the optimal logistics capacity of the port enterprise to the carrier enterprise for the purpose of maximizing its own profit, then the optimal logistics capacity of the port enterprise must also make the port LSSC achieve the optimal profit. Salvage values are not taken into account here, and out-of-stock losses are assumed to be zero. Based on technical assumptions and parameter Settings,  $pS(K)$  is Logistics sales for port LSSC,  $(am_s + m_p + n_p)K$  is Logistics costs of supply chain services for port logistics.

Assuming that the order quantity  $K_0$  when the port LSSC profit is maximum, because  $F(x)$  it is an increasing function, the profit function of the port supply chain is strictly concave, and the port LSSC coordination based on blockchain services under the quantitative flexible contract needs to meet the following requirements:

$$a = w/m_s \quad a \in [0, \frac{p \int_0^K [F_0(x) - F_1(x)] dx - n_p K - \eta}{m_s K} + 1] \quad (29)$$

Generally speaking, quantitative flexible contracts exist  $\int_{(1-\theta)K}^K F_1(x) dx$  in the transaction rules, and the logistics distribution function of blockchain services  $F_1(x)$  is difficult to predict, making the profit function difficult to determine and difficult to obtain the coordination conditions of quantitative flexible contracts. The port LSSC under the blockchain service will just offset this due to its own functional characteristics. Due to the modification of blockchain service and port LSSC, the expression of coordination condition function of quantity flexibility contract and revenue sharing contract converges.

### 2.2.2 Analysis Of Profit

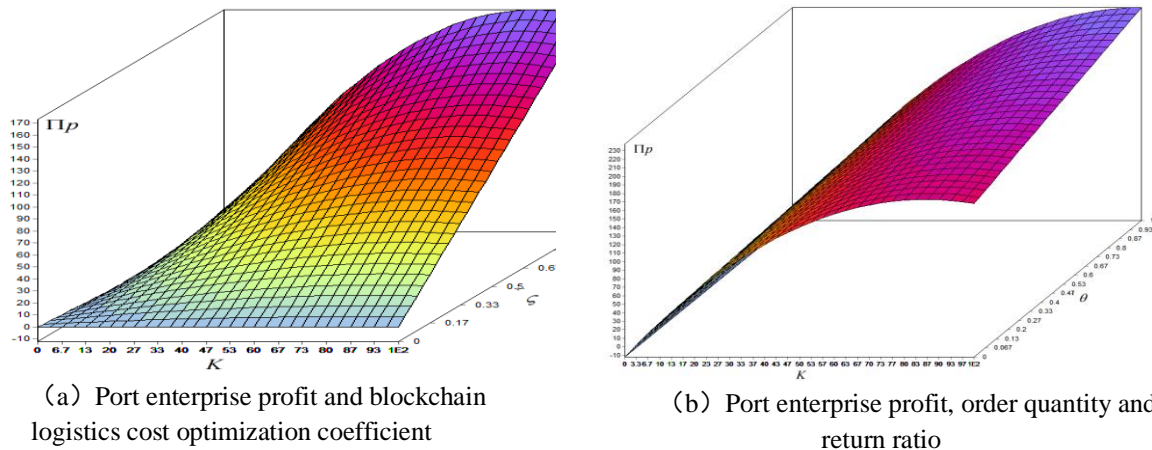
According to the blockchain-based port LSSC coordination model under the quantitative flexible contract, the port LSSC coordination model (29) is obtained in the previous section, and can be obtained:

(1) When  $pS(K) - am_s K - m_p K - n_p K - \eta < 0$ , Port LSSC profit is negative, so port enterprises and carrier enterprises must have at least one loss, so whether or not to raise the port enterprise profit ceiling point, port LSSC can not be coordinated.

(2) When  $pS(K) - am_s K - m_p K - n_p K - \eta > 0$ , Assume that the total cost of using blockchain services for the carrier enterprise  $\eta$  is a fixed value. If Carrier enterprise profit  $\Pi_s(K) < 0$ , satisfy  $\int_0^K \frac{\Lambda}{\eta g(x)} f_1(x) dx \leq 1$ , If port LSSC profit is positive and carrier enterprise profit is negative, port LSSC coordination cannot be realized. If Carrier enterprise profit  $\Pi_s(K) > 0$ , satisfy  $\int_0^K \frac{\Lambda}{\eta g(x)} f_1(x) dx > 1$ , Then port LSSC profit is positive, carrier profit enterprise is positive, can achieve port LSSC coordination.

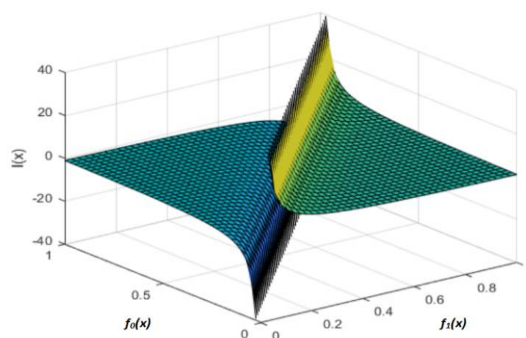
### 3. Numerical Simulation

After repeated research, the theoretical model is selected to test the simulation data as follows: the unit price of logistics capacity sold by port enterprises  $p=5$ ,  $mp=0.5$ , the block chain unit input cost of port enterprises  $np=0.1$ , the unit service cost of carrier enterprises  $ms=1$ , the ordered quantity of port enterprises  $K \in [0,100]$ , the price of logistics capacity  $w=1$ ,  $\eta = 12$ , and the value  $a$  in  $[0,1]$ . Assume that the logistics demand is uniformly distributed  $U-(0,100)$ , and the chart below is generated.



**Figure.1 Simulation diagram of port logistics service supply chain under contract theory**

Under the revenue-sharing contract, in the blockchain-based port LSSC coordination model, port LSSC coordination can be achieved only when  $a = w/m_s$  is met. The port will share all the profits of port LSSC to the carrier enterprise in accordance with the proportion of  $(1 - \zeta)$ , and the port enterprise will retain the profit proportion of  $\zeta$ . It can be easily seen from Figure 1 that when  $\zeta=1$ , the quantity of logistics capacity ordered  $K=86.7$ , the port enterprise obtains the maximum profit  $\Pi p=172.89$ ; when  $\zeta=0$ , the port enterprise obtains the minimum profit; when  $\zeta=1$ , the carrier enterprise obtains the minimum profit; when  $\zeta=0$ , the carrier enterprise obtains the maximum profit; the profit sharing contract makes the profit distribution of port LSSC flexible. Port enterprises and carrier enterprises can freely distribute the profits of port LSSC through the determined value, which makes port enterprises more optimistic about ordering logistics capacity, increases the cooperation enthusiasm between port enterprises and carrier enterprises, and enhances the coordination of port LSSC. The port enterprise obtains the maximum profit  $\Pi p=238$  under the quantity flexible contract.



**Figure 2 Function diagram of  $I(x)$**

By observing Figure 2, the function graphs for setting different parameters are consistent,  $I(x)$  there is no extreme value, and there is a discontinuity point, With or without blockchain services, the logistics demand density function  $f_0(x)=f_1(x)$ , to the right of the discontinuity point,  $I(x)$  is negative, the carrier enterprise needs to be punished; On discontinuity point left, give carrier enterprise to obtain positive  $I(x)$ ,  $f_1(x)$  from left to right,  $I(x)$  jump from positive infinity to negative infinity is due to the fact that the blockchain service does



not have any impact on logistics demand at this point.

#### 4. CONCLUSION

This paper builds a blockchain-based port LSSC coordination model under the contract theory. The model considers blockchain services and other factors, and realizes the optimal benefit of port LSSC under the premise of meeting the optimal order quantity of port enterprises to maximize their interests. Due to the double marginal effect of the port supply chain and the imperfect trust mechanism, it is difficult for port enterprises and carrier enterprises to achieve port LSSC coordination in decentralized decision-making. Therefore, the contract mechanism coordination is introduced, and the port LSSC coordination can be achieved under the quantity flexible contract and the revenue sharing contract, and the coordination conditions are both. As the structure of port logistics service supply chain constructed by port enterprises becomes more and more complex, the integrated logistics resources and capabilities become more and more, and the organization expands, its "centralization" problem will become more and more serious, and the carrier enterprises will be reduced to accessories. As carriers cannot directly face the logistics needs and lack the bargaining power over logistics capabilities, no matter how strong the optimization role of blockchain services, for carriers, the role is only to assist in improving the quality of logistics services, thus affecting the logistics demand, and the increase in logistics demand can increase the profits of carriers. And blockchain services only bring about an increase in logistics demand is an increase in probability, with uncertainty). Therefore, the "centralized" port logistics service supply chain still needs to be upgraded. The suggestion of this paper is "decentralization", transforming the "centralized" port logistics service supply chain into "logistics service ecological platform" and creating logistics ecological environment, instead of integrating and controlling carrier enterprises, forming an equal, sharing and win-win "logistics service ecological platform".

**Author Contributions:** Methodology, Z.YG. (Zuo Yonggang); Software, H.J. (Hu Jing) and R. F.(Rui Fei); Validation, Z.YG.; Writing—original draft, Z.YG. and H.J.; Writing—review & editing, Z.YG. H.J.; Visualization, Z.YG.; Funding acquisition, H.J. . All authors have read and agreed to the published version of the manuscript.

#### ACKNOWLEDGMENT

This work was supported by Anhui Province University Philosophy and Social Science Research Project(GrantNumber:SK2021A1031); Anhui Industry Polytechnic Quality Engineering Project(Grant Number: 2023jpkc07);the Anhui Province Quality Engineering Project(Grant Number :2022jyxm 212);Anhui Province University Philosophy and Social Science Research Project(Grant Number:2024AH040293);Anhui Province University Philosophy and Social Science Research Project(Grant Number:2023AH053131);Anhui Province University Philosophy and Social Science Research Project(Grant Number:2024AH052913).

**Institutional Review Board Statement:** Not applicable.

**Informed Consent Statement:** Not applicable.

**Data Availability Statement:** The data presented in this study are available on request from the corresponding author.

**Conflicts of Interest:** The authors declare no conflict of interest.

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