

Research Article

The Safe Financial Processing Method for Realizing Supply Chain Integrated Business Intelligence Using Blockchain Application Scenarios

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In order to improve the financial processing effect of supply chain integrated business intelligence, this study applies blockchain technology to the financial processing of supply chain integrated business intelligence and conducts an evolutionary game analysis on the factors that affect the selection of information-sharing strategies for logistic service supply chain nodes. By establishing the evolutionary game model of logistic service integrators and logistic service providers under the strategy of information sharing and information nonsharing, the value of information sharing in the logistic service supply chain is discussed from a qualitative and quantitative perspective. In addition, this study constructs the expected profit mathematical model of a two-level logistic service supply chain composed of logistic service integrators and logistic service providers. The experimental research results show that the safe financial processing method for realizing supply chain integrated business intelligence using blockchain application scenarios has good results.

1. Introduction

Nowadays, with the development of science and technology and the continuous improvement of people's demand for a high-quality life, the entire social needs, production methods, and social division of labor are constantly changing. The production of commodities has changed from a model of complete production by a single company to a model of cooperative production by multiple companies. Moreover, market competition has evolved from simple customer competition to competition between the entire supply chain involving multiple links in commodity production [1]. Banks and other funding parties radiate financial products and services to the upstream and downstream and even the entire industry chain around relevant core companies to solve the financial problems of corporate procurement, sales, and inventory in the supply chain. This financial operation mode is called supply chain

finance. Supply chain finance mainly includes financing services such as goods mortgage, advance payment, and accounts receivable. The supply chain finance business is mainly participated by banks and other funders, large-scale core enterprises, small and medium-sized suppliers, and other enterprises. Due to the special requirements of the supply chain finance industry for information privacy and security, the current supply chain finance system has many problems [2].

The blockchain technology is an organic collection of many existing technologies, which mainly include cryptography, consensus algorithms, and distributed systems. The blockchain is simply a distributed ledger, which allows every distributed node in the blockchain network to participate in the blockchain, and each participant shares the same permanent and transparent transaction record ledger. Blockchain technology uses cryptography-related technologies to realize that every transaction in the blockchain can

be traced back, and it ensures that no one can change the transactions recorded in the blockchain shared ledger. At the same time, the distributed consensus algorithm protocol is used to allow each participant of the blockchain to reach a consensus on the transaction result and record it in the shared ledger. Blockchain smart contract technology can replace manual operations, set the trigger conditions of the smart contract in advance, and automatically execute the smart contract to complete the transfer of assets after the transaction is executed to a certain stage [3].

The blockchain system can be regarded as a distributed multinode shared database ledger. Each distributed node in the blockchain system communicates through a peer-to-peer protocol, that is, P2P technology; and each transaction in the system can use a one-way hash function, asymmetric encryption, and other related cryptography technologies to achieve high security. Since the blockchain is equivalent to a distributed system in which all participants share the ledger, any company participating in the same blockchain has a copy of the entire ledger as the upstream supplier of the financial participants of the blockchain supply chain. Downstream buyers, core companies, and financial institutions can share benefits from related financing businesses, while minimizing policy and operating risks without the need to build a financial system.

This study combines the blockchain technology to analyze the security financial management of the supply chain integrated business intelligence, builds an intelligent system, and verifies the performance of the system to improve the security financial management effect of the supply chain integrated business intelligence.

2. Related Work

The “ghost protocol” proposed in document [4] ensures the integrity of the blockchain, records the entire process of value transfer (transaction) immutably, and uses decentralization and trustless methods to collectively maintain the reliability of a databook sexual solution; this databook is completely public and not under the control of any organization. Literature [5] proposes that blockchain is a technology with breakthrough significance across the ages, and the core ideas behind this technology, such as decentralization, trustlessness, and national accounting, are its greatness. Therefore, blockchain technology will be the core technology that has the most potential to trigger the fourth industrial revolution after steam engine, electricity, information, and internet technology.

The core feature of blockchain technology is that the transaction information on the chain cannot be tampered with, and it is difficult to interfere, modify, or delete it under the existing technical conditions. Literature [6] proposes that immutability is also the most important difficulty in realizing landing applications. The immutability of blockchain may turn its advantages into disadvantages in the activities of reversing financial services. Literature [7] pointed out that for some time, blockchain technology wanted to replace legal currency in the form of blockchain tokens, and even wanted to replace government

agencies with decentralized functions, but it was difficult to achieve in actual operation. Yes, blockchain technology is just a technology, and it needs to find an application scenario suitable for this technology in order to play its own role. Literature [8] believes that the blockchain has an “impossible triangle” in the three aspects of “decentralization,” “high efficiency and low energy,” and “security.” It is difficult to achieve three goals at the same time. To achieve two of them, it is necessary to abandon another goal, which means that if two of the attributes are strengthened, the third attribute will be automatically weakened. The premise of the use of blockchain technology is that users should keep the private key they generated. Once the private key is lost, they cannot perform any operations on the assets in their account. Individual ordinary users or users without much technical experience may feel private. If the key is lost, it is enough to apply for a replacement like an ID card, but in fact, it is impossible. Literature [9] believes that with the development of society, a large number of mathematical algorithms have been developed, resulting in the blockchain algorithm that may be cracked by new algorithms, so it may be a blockchain formed by mathematical principles someday in the future. The algorithmic security of the technology will be threatened. Such risks may not exist in the short term but may exist in the long term. Therefore, the application of blockchain technology to the business process of the securitization of accounts receivable assets may bring risks.

The blockchain technology is an emerging field of research. Domestic and foreign scholars in various industries use the theory of blockchain technology to solve problems that arise. Most scholars analyze the application of this technology theoretically. Literature [10] believes that the development of blockchain technology can not only make the asset securitization of accounts receivable become a reality but can also become a boost to social development; taking the application of blockchain technology in various industries as the research direction, the new intermediary will be based on blockchain technology, which provides the possibility to build a trust mechanism that does not rely on third-party platforms. One argument for the popularity of blockchain in society is that blockchain technology can rebuild business models, so it will change the production relations of traditional society. In essence, it is a human cognitive revolution, and capital is profit-seeking. Yes, the financial industry takes the lead after the emergence of a new technology. The literature [11] surveyed more than 1,300 financial institutions around the world. It can be seen that the number of financial institutions that use the combination of blockchain technology and traditional business processes will account for 55%; in 2020, it will reach 77%. Literature [12] starts with the business process of asset securitization of accounts receivable. The problems encountered in the business process of the asset securitization of accounts receivable are reflected in the following aspects [13]: the authenticity of the relevant assets in the pool cannot be effectively determined; the lack of repayment rules after the financial institution itself has problems;

in accounts receivable, the characteristics of asset securitization products are that there are many trading entities, the transaction structure of securitization products is relatively complicated, and the data transmission chain is long. These difficulties also indirectly lead to deeper problems, that is, it is difficult to obtain low capital costs for issuing securitized products, and the cost limits its further development [14]. Literature [15] believes that the traditional problem of the securitization of accounts receivable assets is that the transaction structure is complicated, the transaction chain of the participants is very long, and there may be external uncertain factors, which further trigger the problem of information asymmetry. Literature [16] proposes to establish a negative list system. Starting from the top level, the regulatory authorities play an intermediate role to solve the relationship between blockchain service organizations and specific landing application scenarios, and better regulate the development of blockchain technology.

3. Blockchain-Based Supply Chain Business Intelligence Security Financial Processing Model

The final profit of the game subject is determined by the strategy chosen by itself and the strategy chosen by the other party in the game. It represents the expected return when the two parties in the game choose to share or not share information.

Game party 1 adopts the information-sharing strategy, and the expected benefits are [17] as follows:

$$U_{11} = y(R_1 + gK_1Q_2 + \alpha Q_1 - C_1 - \theta Q_1) + (1 - y)(R_1 - C_1 - \theta Q_1). \quad (1)$$

Game party 1 adopts the information nonsharing strategy, and the expected benefits are as follows:

$$U_{12} = y(R_1 + K_1Q_2) + (1 - y)R_1. \quad (2)$$

The average expected return of the game party 1 is as follows:

$$\bar{U}_1 = xU_{11} + (1 - x)U_{12}. \quad (3)$$

Game party 1 chooses the copy dynamic equation of the information-sharing strategy as [18] follows:

$$F(x) = \frac{dx}{dt} = x(U_{11} - \bar{U}_1). \quad (4)$$

Substituting formulas (1)–(3) into (4), we get the following:

$$\begin{aligned} \frac{dx}{dt} &= x(1 - x)(U_{11} - U_{12}) \\ &= x(1 - x)\{y[K_1Q_2(g - 1) + \alpha Q_1] - C_1 - \theta Q_1\}. \end{aligned} \quad (5)$$

According to formula (5), when $dx/dt = 0$, three possible equilibrium solutions can be obtained as follows: $x_1^* = 0$, $x_2^* = 1$, and $y^* = C_1 + \theta Q_1 / K_1 Q_2 (g - 1) + \alpha Q_1$.

However, these three solutions are not necessarily all evolutionary stable strategies. According to the stability theorem of differential equations, when $dx/dt = 0$ and $F'(x) < 0$ are satisfied, it is an evolutionary stable strategy in a stable state. Therefore, when we find the first derivative of formula (5), we get the following:

$$F'(x) = (1 - 2x)\{y[K_1Q_2(g - 1) + \alpha Q_1] - C_1 - \theta Q_1\}. \quad (6)$$

Through formulas (5) and (6), it can be analyzed that the evolutionary stable strategies of game party 1 are [19] as follows:

- (1) If $y = y^* = C_1 + \theta Q_1 / K_1 Q_2 (g - 1) + \alpha Q_1$, then $dx/dt \equiv 0$, which shows that the three solutions are all evolutionary stable strategies.
- (2) If $y \neq y^* = C_1 + \theta Q_1 / K_1 Q_2 (g - 1) + \alpha Q_1$, $x_1^* = 0$, $x_2^* = 1$ are all evolutionary stable equilibrium points of x . Therefore, the different situations of $C_1 + \theta Q_1 / K_1 Q_2 (g - 1) + \alpha Q_1$ are discussed and analyzed.
 - (i) When $C_1 + \theta Q_1 > K_1 Q_2 (g - 1) + \alpha Q_1$, for any $y (0 \leq y \leq 1)$, $F'(x^* = 0) < 0$, and $x_1^* = 0$ is the evolutionary stable strategy of game party 1.
 - (ii) When $C_1 + \theta Q_1 < K_1 Q_2 (g - 1) + \alpha Q_1$, we discuss in two situations.

When $y < y^* = C_1 + \theta Q_1 / K_1 Q_2 (g - 1) + \alpha Q_1$, $F'(x_1^* = 0) < 0$, $F'(x_2^* = 1) > 0$, so $x_1^* = 0$ is a stable equilibrium point. When $y > y^* = C_1 + \theta Q_1 / K_1 Q_2 (g - 1) + \alpha Q_1$, $F'(x_1^* = 0) > 0$, $F'(x_2^* = 1) < 0$, so $x_2^* = 1$ is a stable equilibrium point. It can be seen that in the case of $C_1 + \theta Q_1 < K_1 Q_2 (g - 1) + \alpha Q_1$, the steady state is affected by the value of y^* . The larger the y^* is, the smaller the probability that y will fall within the interval $[y^*, 1]$, and the probability that game party 1 chooses the information-sharing strategy will decrease accordingly.

Game party 2 chooses the expected benefits of the information-sharing strategy as [20] follows:

$$U_{21} = x(R_2 + gK_2Q_1 + \alpha Q_2 - C_2 - \theta Q_2) + (1 - x)(R_2 - C_2 - \theta Q_2). \quad (7)$$

The expected return of the game party 2 who chooses the information nonsharing strategy is as follows:

$$U_{22} = x(R_2 + K_2Q_1) + (1 - x)R_2. \quad (8)$$

The average expected return of the game party 2 is as follows:

$$\bar{U}_2 = yU_{21} + (1 - y)U_{22}. \quad (9)$$

The copy dynamic equation for the game party 2 to choose the information-sharing strategy is as follows:

$$F(y) = \frac{dy}{dt} = y(U_{21} - \bar{U}_2). \quad (10)$$

Substituting formulas (7)–(9) into (10), we get the following:

$$\begin{aligned} \frac{dy}{dt} &= y(1-y)(U_{21} - U_{22}) \\ &= y(1-y)\{x[K_2Q_1(g-1) + \alpha Q_2] - C_2 - \theta Q_2\}. \end{aligned} \quad (11)$$

According to formula (11), when $dy/dt = 0$, three possible stable solutions can be obtained as follows: $y_1^* = 0, y_2^* = 1, x^* = C_2 + \theta Q_2 / K_2 Q_1 (g-1) + \alpha Q_2$. However, these three solutions do not necessarily belong to evolutionary stable strategies. From the stability theorem of differential equations, we know that when $dy/dt = 0$ and $F'(y) < 0$, it is an evolutionary stable strategy in a stable state. Therefore, by taking the first-order derivative of equation (11), we obtain the following:

$$F'(y) = (1-2y)\{x[K_2Q_1(g-1) + \alpha Q_2] - C_2 - \theta Q_2\}. \quad (12)$$

Through formulas (11) and (12), it can be analyzed that the evolutionary stable strategies of game party 2 are as follows:

- (1) If $x = x^* = C_2 + \theta Q_2 / K_2 Q_1 (g-1) + \alpha Q_2$, then $dy/dt \equiv 0$, which means that the three solutions are all evolutionary stable strategies, and the results of the two strategies of information sharing and non-sharing for game party 2 are the same.
- (2) If $x \neq x^* = C_2 + \theta Q_2 / K_2 Q_1 (g-1) + \alpha Q_2, y_1^* = 0, y_2^* = 1$ are all evolutionary stable equilibrium points of y . Therefore, the different situations of $C_2 + (\theta - \alpha)Q_2 / K_2 Q_1 (g-1)$ are discussed and analyzed.
 - (i) When $C_2 + \theta Q_2 > K_2 Q_1 (g-1) + \alpha Q_2$, for any $x (0 \leq x \leq 1), F'(y^* = 0) < 0, y_1^* = 0$ is the evolutionary stable strategy of game party 2.
 - (ii) When $C_2 + \theta Q_2 < K_2 Q_1 (g-1) + \alpha Q_2$, we discuss in two situations [21].

If $x < x^* = C_2 + \theta Q_2 / K_2 Q_1 (g-1) + \alpha Q_2, F'(y_1^* = 0) < 0, F'(y_2^* = 1) > 0$, so $y_1^* = 0$ is a stable equilibrium point. If $x > x^* = C_2 + \theta Q_2 / K_2 Q_1 (g-1) + \alpha Q_2, F'(y_1^* = 0) > 0, F'(y_2^* = 1) < 0$, so $y_2^* = 1$ is a stable equilibrium point. It can be seen from the above that in the case of $C_2 + \theta Q_2 < K_2 Q_1 (g-1) + \alpha Q_2$, the steady state is affected by the value of x^* . The larger the x^* , the smaller the probability that x falls within the $[x^*, 1]$ interval, and the possibility of the player 2 choosing the information-sharing strategy will decrease.

The two parties of the game are independent of each other. However, it requires the cooperation of both parties to form a stable evolution strategy. This is not only to analyze the evolution process of information-sharing behavior among supply chain members but also to consider the situation of both parties. From formulas 5 and 11, it can be seen that the possible stable strategies are $(0, 0), (0, 1), (1, 0), (1, 1), (x^*, y^*)$, and the existing evolutionary situations are as follows:

- (1) When $C_1 + \theta Q_1 > K_1 Q_2 (g-1) + \alpha Q_1, C_2 + \theta Q_2 > K_2 Q_1 (g-1) + \alpha Q_2$, the additional benefits obtained by both parties of the game by taking

information-sharing behaviors are small, and they are not enough to make up for the cost and existing risks of information-sharing inputs. As shown in Figure 1(a), the evolution process converges to $x^* = 0, y^* = 0$, and the stable point is $(0, 0)$. The evolutionary stable strategy of integrators and providers is (not sharing and not sharing).

- (2) When $C_1 + \theta Q_1 > K_1 Q_2 (g-1) + \alpha Q_1, C_2 + \theta Q_2 < K_2 Q_1 (g-1) + \alpha Q_2$, the cost and risk borne by the integrator for information sharing are higher than the benefits that can be obtained by information sharing. However, the additional benefits obtained by the provider's choice of information-sharing strategy are greater than the costs and risks involved in information sharing. As shown in Figure 1(b), the evolution process converges to $x^* = 0, y^* = 1$, and the stable point is $(0, 1)$. The evolutionary and stable strategy of integrators and providers is (not sharing and sharing).
 - (a) Dynamic evolution phase diagram of case 1.
 - (b) Dynamic evolution phase diagram of case 2.
- (3) When $C_1 + \theta Q_1 < K_1 Q_2 (g-1) + \alpha Q_1, C_2 + \theta Q_2 > K_2 Q_1 (g-1) + \alpha Q_2$, when the integrator's information cost and risk are less than the shared benefits, information sharing is the best strategy for the integrator. However, the cost and risk of provider information sharing exceed the benefits obtained, and the best strategy is to not share information. Therefore, as shown in Figure 2(a), the evolution process ends at $x^* = 1, y^* = 0$, the stable point is $(1, 0)$, and the evolutionary stability strategy is (shared and not shared).

In the two situations shown in formulas (2) and (3), the game player unilaterally adopts an information-sharing strategy, with one party choosing information sharing and the other party choosing not to share. Entities that adopt information-sharing strategies can obtain greater additional benefits when they begin to share. However, as the game process is repeated, the information input cost and information-sharing risk of the information-sharing party will gradually rise. In the end, it will also evolve into unwillingness to share information. Therefore, in both cases, the final result of the information-sharing game between integrators and providers is that information is not shared, and the evolutionary stability point is $(0, 0)$, as shown in Figure 2(b).
- (4) When $C_1 + (\theta - \alpha)Q_1 < K_1 Q_2 (g-1), C_2 + \theta Q_2 < K_2 Q_1 (g-1) + \alpha Q_2$, the benefits obtained by the integrator and the provider by adopting the information-sharing strategy are greater than the cost and risk of the input. However, there are two evolutionary stable points $(0, 0)$ and $(1, 1)$ for both parties, which are (shared and shared) and (not shared and not shared), as shown in Figure 3.

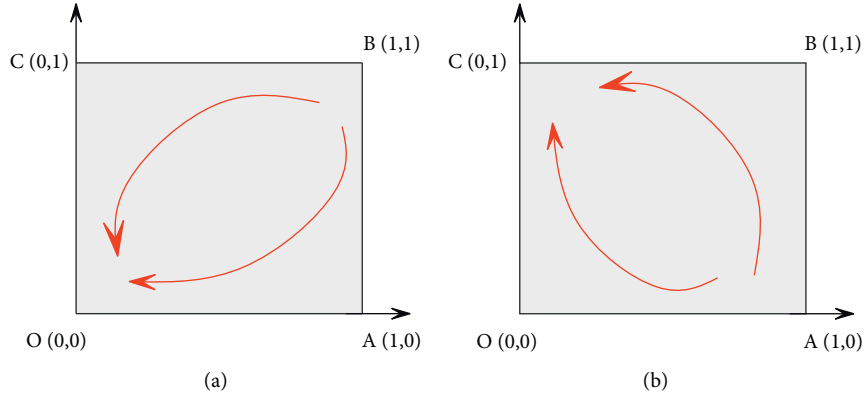


FIGURE 1: Dynamic evolution phase diagram 1. (a) Dynamic evolution phase diagram of case 1. (b) Dynamic evolution phase diagram of case 2.

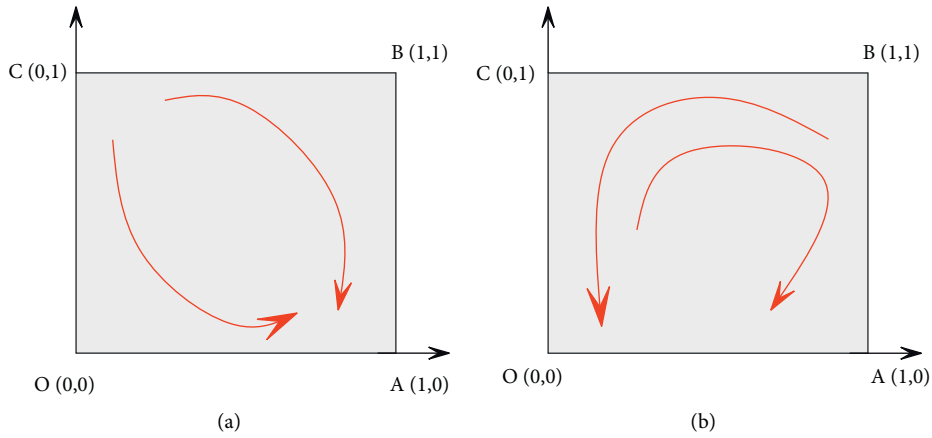


FIGURE 2: Dynamic evolution phase diagram 2. (a) Dynamic evolution phase diagram of case 3. (b) The dynamic evolution phase diagram of case 2 and case 3.

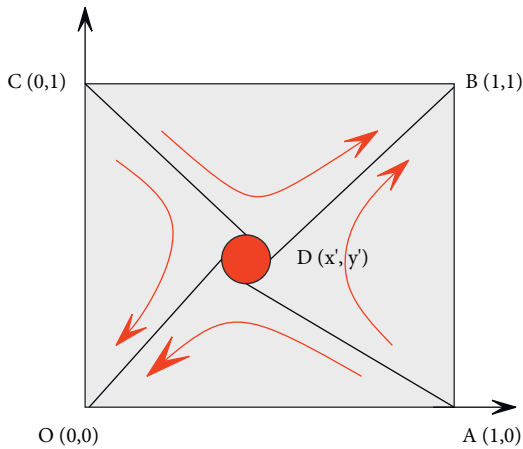


FIGURE 3: Dynamic evolution phase diagram of case 4.

The broken line ADC is the dividing line of the two evolutionary results (0,0) and (1,1). In the OADC region, the evolution process converges to $x^* = 0, y^* = 0$, and the stable point is (0,0). In the end, both parties of the game will choose the information nonsharing strategy. In the ABCD region, the evolution process gradually converges to $x^* = 1, y^* = 1$,

the final stable state is (1,1), and both players in the game choose to share information. The critical point $D(x^*, y^*)$ determines the final result of the evolutionary game, and the strategic choice of the game player will change with the change in the critical point. When the critical point $D(x^*, y^*)$ is close to the origin, the area OADC decreases and the area ABCD increases, and the game player is more likely to choose an information-sharing strategy. Conversely, if the value of the critical point $D(x^*, y^*)$ becomes larger, the area of OADC becomes larger, the area of ABCD decreases, and the two sides of the game are more likely to tend to nonsharing of information. The change in the critical point $D(x^*, y^*)$ is closely related to the parameters of both parties. Among them, the area of ABCD is as follows:

$$S_{ABCD} = 1 - \frac{1}{2} \left[\frac{C_1 + \theta Q_1}{K_1 Q_2 (g - 1) + \alpha Q_1} + \frac{C_2 + \theta Q_2}{K_2 Q_1 (g - 1) + \alpha Q_2} \right]. \quad (13)$$

From the above evolutionary game analysis process, it can be seen that whether a logistic service supply chain node enterprise will choose to share information depends on the enterprise's own capabilities, the payment matrix of the evolutionary game, and the initial values of various

parameters. With the passage of time and the repeated progress of the game process, the changes in the values of various parameters may cause the players of the game to choose different strategies. This study uses critical points $D(x^*, y^*)$ to analyze various parameters that may affect the outcome of the evolutionary game.

From $x^* = (C_2 + \theta Q_2) / [K_2 Q_1 (g - 1) + \alpha Q_2]$, $y^* = (C_1 + \theta Q_1) / [K_1 Q_2 (g - 1) + \alpha Q_1]$, it can be seen that the information-sharing cost, risk coefficient, incentive coefficient, synergy coefficient, information absorption and utilization capacity, and information-sharing degree of each node of the supply chain are important factors that affect the size of the critical point.

Under uncertain market conditions, customer demand is generally price-sensitive. Therefore, the market logistic service demand Q faced by integrators is uncertain. Here, the random variable Q has the characteristics of the probability distribution $F(Q)$, and the customer enterprise logistic service demand can be expressed by the following formula:

$$\begin{aligned} \text{Volume} &= \text{initial demand volume} \\ &+ \text{volume decrease rate} \times (\text{price}) \\ &+ \text{volume variation range} \\ &\times \sin\left(\frac{\text{price}}{\text{variation cycle}}\right). \end{aligned} \quad (14)$$

Among them, initial demand volume is the initial demand for logistic services, volume decrease rate is the slope of change in service demand, volume variation range is the range of change in service demand, and variation cycle is the price cycle of service demand changes.

The change in customer demand described by a sine curve is shown in Figure 4.

From Figure 4 above, we can see the impact of price changes on the anticipated demand for logistic services by

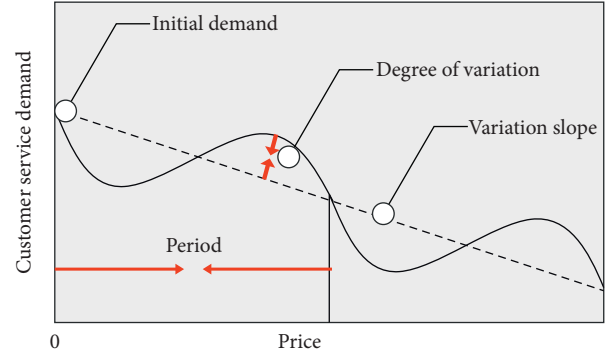


FIGURE 4: Price-sensitive customer service demand curve.

client companies. Demirkan (2008) uses a normal distribution function to describe the effect of random demand on price. In order to facilitate model analysis and calculation, this study uses a uniform distribution function to express the demand price sensitivity in the logistic service supply chain model, that is, we assume that the demand for logistic services of price-sensitive client companies in a period is uniformly distributed in the interval $[Q(p) - \theta, Q(p) + \theta]$ (θ is the demand fluctuation coefficient, $\theta > 0$), as shown in Figure 5 below as follows:

$$Q(p) = a - bp. \quad (15)$$

Among them, a is a known constant, such as the actual demand in the previous cycle. b is a constant, which is the price sensitivity coefficient of market demand, $a > 0$, and $b > 0$.

In order to simplify the model, this study does not consider the marginal cost of both the supply chain and the demand side, and directly uses revenue instead of profit for calculation. According to the uniform distribution probability density function $F(Q)$ in the above figure, the expected profit function of the integrator is as follows:

$$\begin{aligned} \prod \text{collection} &= \int_{Q(p)-\theta}^s [(P-V)Q(p)]F(Q)dQ + \int_s^{Q(p)+\theta} [(P-V)S]F(Q)dQ \\ &= \frac{-(P-V)S^2 + 2(P-V)[Q(p) + \theta]S - (P-V)[Q(p) - \theta]^2}{4\theta} \\ &= -\frac{P-V}{4\theta} \{S - [Q(p) + \theta]\}^2 + (P-V)Q(p) \\ &= -\frac{P-V}{4\theta} [S - (a - bP + \theta)]^2 + (P-V)(a - bP). \end{aligned} \quad (16)$$

The first term in formula (15) represents the income when the actual logistic service demand is less than the logistic service capacity S purchased by the integrator. The second term represents the income when the actual logistic

service demand is greater than the logistic service capacity S purchased by the integrator.

The income of the logistic service provider is equal to the product of the logistic service capability S purchased by the

integrator and the unit logistic service price V . The cost of the provider is mainly composed of two parts. One is the unit logistic service capacity cost m , such as fixed costs such as logistic elements, which reflect the normal economic scope of capacity. The other is the operation and management cost n , which is related to the management of the enterprise and mainly includes the cost of improving the management ability and the increase in the complexity of the business model. That is, the profit function of the logistic service provider is as follows:

$$\prod_{\text{Supply}} = VS - mS - nS^2. \quad (17)$$

Due to the randomness of customer demand, uncertain market demand will affect the logistic service costs of integrators and providers. When the logistic service capabilities cannot meet customer needs, integrators and provider groups will incur lost opportunity costs. When the logistic service capacity is higher than the customer's demand, this will produce waste.

The expected cost when the logistic service capacity purchased by the integrator is lower than the actual logistic demand is as follows:

$$\begin{aligned} L(Q) &= \int_S^{Q(p)+\theta} \alpha [Q(p) - S] F(Q) dQ \\ &= \frac{\alpha}{2\theta} \left\{ \frac{S^2}{2} - S[Q(p) + \theta] + \frac{[Q(p) + \theta]^2}{2} \right\} \\ &= \frac{\alpha}{4\theta} \{ S - [Q(p) + \theta] \}^2 = \frac{\alpha}{4\theta} \{ S - (a - bP + \theta) \}^2. \end{aligned} \quad (18)$$

The parameter α represents the opportunity cost of unit loss caused when the customer's needs cannot be met. Therefore, the expected cost when the logistic service capability purchased by the integrator is higher than the logistic demand is as follows:

$$\begin{aligned} M(Q) &= \int_{Q(p)-\theta}^S V [S - Q(p)] F(Q) dQ \\ &= \frac{V}{2\theta} \left\{ S^2 - S[Q(p) - \theta] - \frac{S^2}{2} + \frac{[Q(p) - \theta]^2}{2} \right\} \\ &= \frac{V}{4\theta} \{ S - [Q(p) - \theta] \}^2 = \frac{V}{4\theta} \{ S - (a - bP - \theta) \}^2. \end{aligned} \quad (19)$$

Unlike the product supply chain, logistic services are intangible and perishable. Therefore, excess service capacity neither generates inventory nor residual value.

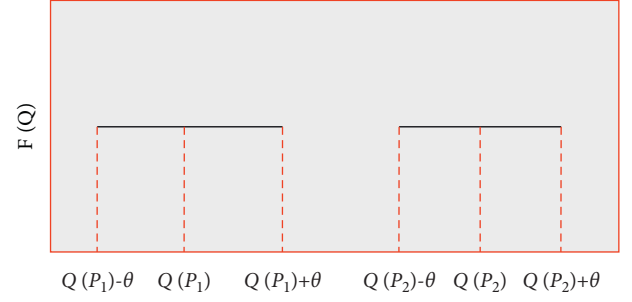


FIGURE 5: Price-sensitive customer service demand.

The single-loop information flow mode refers to the unidirectional flow of information on the chain. In this model, logistic service supply chain integrators and providers independently predict the logistic demand of the market, and there is no demand information sharing between the two. The integrator makes the logistic service integration planning decision based on the customer's demand information, and the provider makes the logistic service supply planning decision based on the integrator's order information, as shown in Figure 6.

Under the single-loop information-sharing model, integrators and providers reach a consensus on services through negotiation. In this mode, because the integrator directly contacts with the customer and grasps important customer information and market demand status, it belongs to the dominant party, and the provider belongs to the follower. Therefore, the logistic service integrator first maximizes its expected profit and determines the optimal purchase amount S . However, integrators will generate uncertain capacity risks and need to bear the uncertain cost of logistic service volume. Therefore, the expected profit function of the integrator is as follows:

$$\begin{aligned} \Psi_{\text{collection}} &= \Pi_{\text{collection}} - M(Q) - L(Q) \\ &= -\frac{P + \alpha}{4\theta} \{ S - (a - bP + \theta) \}^2 + P(a - bP) - VS. \end{aligned} \quad (20)$$

However, the provider's profit function is $\Psi_{\text{Supply}} = \Pi_{\text{Supply}}$, and the provider determines the optimal price V through the integrator's service purchase volume S . We assume that $d\Psi_{\text{Supply}}/dS = V - m - 2nS = 0$, and the relationship between the provider's optimal pricing and purchase volume can be obtained as follows:

$$V = m + 2nS. \quad (21)$$

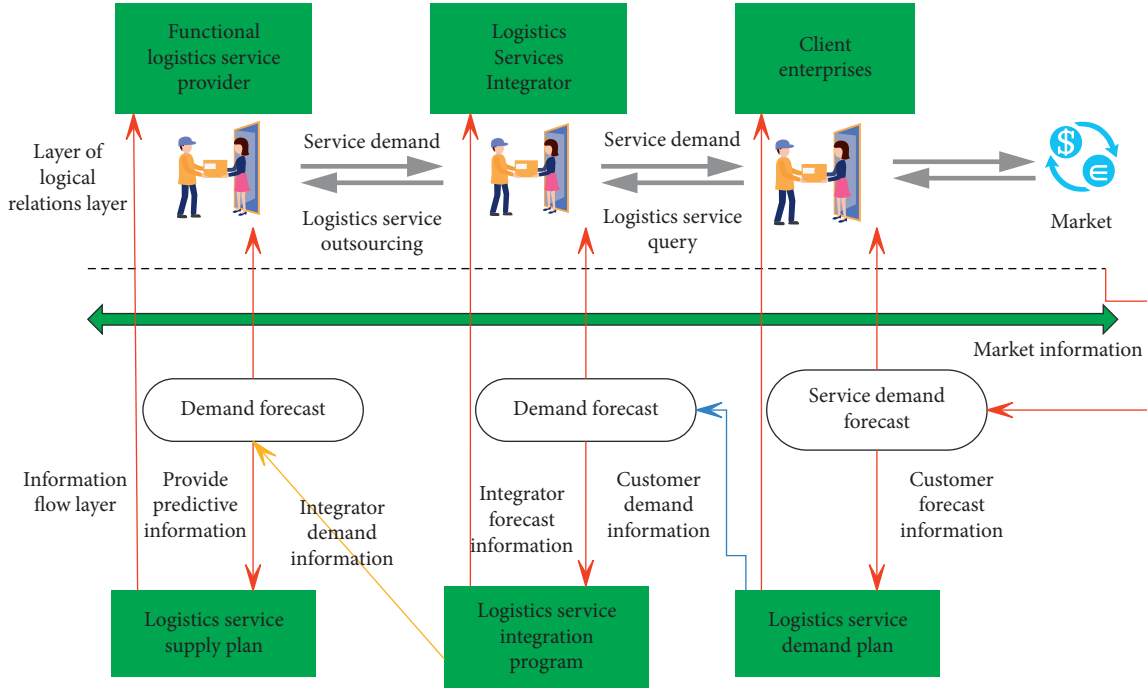


FIGURE 6: Single-loop information flow mode.

Incorporating formula (20) into the integrator's profit function equation (19), when the following two conditions

are met, the integrator's own expected profit is the largest as follows:

$$\begin{cases} \frac{\partial \Psi_{\text{collection}}}{\partial S} = -\left(\frac{P+\alpha}{2\theta} + 4n\right)S + \frac{(P+\alpha)(a-bP+\theta)}{2\theta} - m = 0 \\ \frac{\partial \Psi_{\text{collection}}}{\partial P} = -\frac{S^2}{4\theta} + \frac{(a-bP+\theta)}{2\theta}S - \frac{(a-bP+\theta)^2}{4\theta} + \frac{b(P+\alpha)(a-bP+\theta)}{2\theta} - \frac{b(P+\alpha)}{2\theta} + a - 2bP = 0 \end{cases} \quad (22)$$

According to equation (22), the optimal purchase quantity of the integrator can be obtained as follows:

$$S_1 = \frac{(P+\alpha)(a-bP+\theta) - 2m\theta}{P+\alpha + 8n\theta}. \quad (23)$$

It is the optimal logistic service volume of the logistic service supply chain, and the provider determines the optimal unit logistic service capacity price V through the optimal purchase volume S to maximize its own revenue.

Then, the total expected profit of the logistic service supply chain is as follows:

$$\begin{aligned} \Psi_1 &= \Psi_{\text{collection}} + \Psi_{\text{Supply}} = \Pi_{\text{collection}} - M(Q) - L(Q) + \Pi_{\text{Supply}} \\ &= -\left(\frac{P+\alpha}{4\theta} + n\right)S^2 + \left[\frac{(P+\alpha)(a-bP+\theta)}{2\theta} - m\right]S - \frac{(P+\alpha)}{4\theta}(a-bP+\theta)^2 + P(a-bP). \end{aligned} \quad (24)$$

We bring the optimal solution S_1 into formulas (16), (19), and (23) to obtain the expected profits of logistic service providers, integrators, and the entire supply chain, respectively.

The collaborative control information flow model is an information-sharing model led by logistic service integrators. The integrator takes the initiative to share the customer's logistic service demand information with the provider for collaboration. In this mode, the provider makes

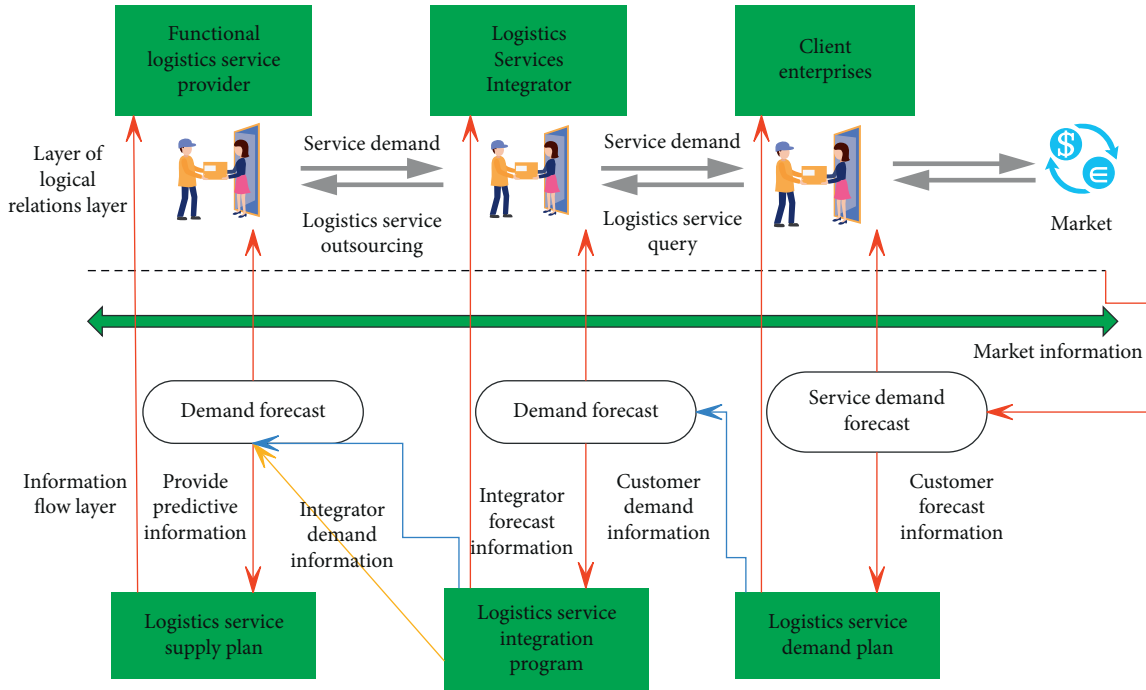


FIGURE 7: Cooperative control information flow mode.

logistic service supply planning decisions based on the integrator's order information and the customer's service demand information, as shown in Figure 7.

Under this information flow model, information asymmetry may occur between the integrator and the provider. That is, the order volume predicted by the integrator differs from the customer demand predicted by the provider. At this time, the provider coordinates the supply chain by adjusting the number S of logistic service capabilities. Therefore, the cost of uncertain capacity is borne by the provider. However, the integrator only needs to bear the

purchase cost of the logistic service capability, that is, the expected profit function of the integrator is as follows:

$$\begin{aligned} \Psi_{\text{collection}} &= \Pi_{\text{collection}} \\ &= -\frac{P-V}{4\theta} [S - (a - bP + \theta)]^2 + (P - V)(a - bP). \end{aligned} \quad (25)$$

When formula (15) satisfies the following two conditions, the integrator expects the profit to be maximized as follows:

$$\begin{cases} \frac{\partial \Psi_{\text{collection}}}{\partial S} = \frac{(P - V)(a - bP + \theta - S)}{2\theta} = 0 \\ \frac{\partial \Psi_{\text{collection}}}{\partial P} = -\frac{S^2}{4\theta} + \frac{(a - bP + \theta) - b(P - V)}{2\theta} S - \frac{(a - bP + \theta)^2}{4\theta} + \frac{b(P - V)(a - bP + \theta)}{2\theta} + a - 2bP + bV = 0 \end{cases} \quad (26)$$

From equation (26), the optimal purchase amount of the integrator can be obtained as follows:

$$S_{\text{collection}} = a - bP + \theta. \quad (27)$$

This shows that when integrators do not have to bear the cost of uncertain capabilities; in order to meet customer needs, integrators always tend to purchase the maximum amount of logistic services.

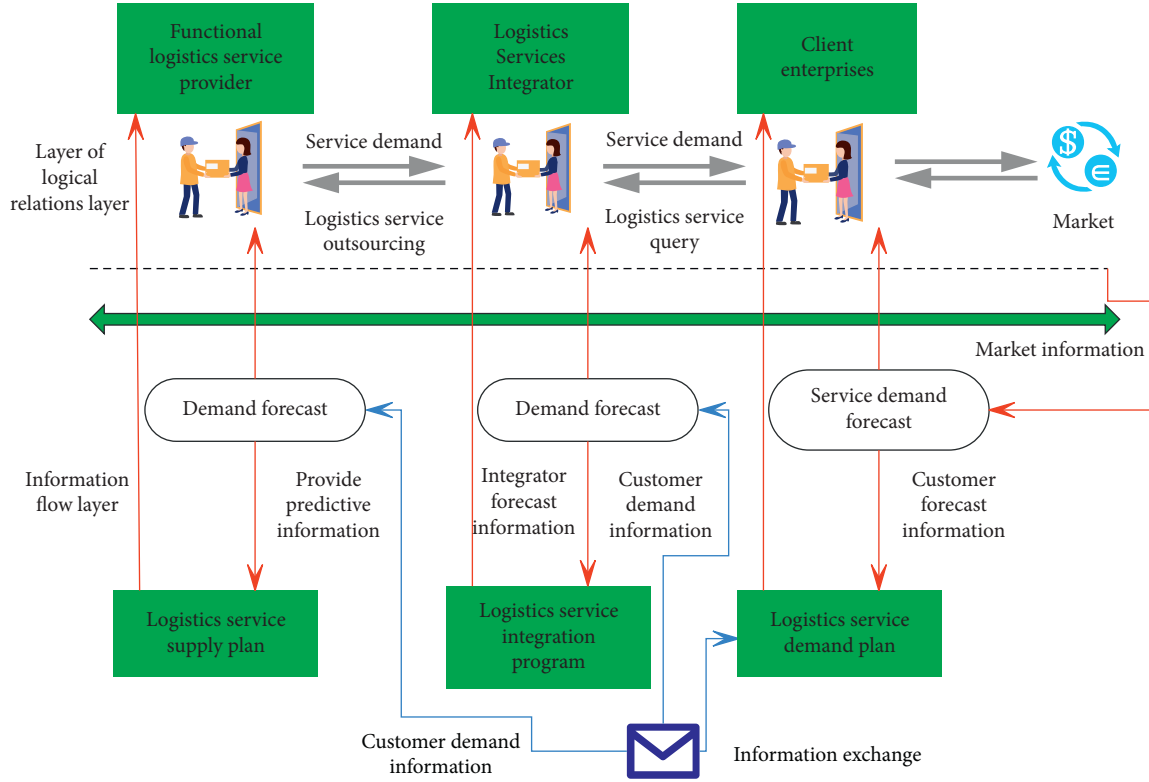


FIGURE 8: Centralized control information flow mode.

Substituting formula (26) into the expected profit function of the provider, we get the following:

$$\Psi_{\text{Supply}} = \Pi_{\text{Supply}} - M(Q) - L(Q) = -\left(\frac{V + \alpha}{4\theta} + n\right)S^2 + \left[\frac{\alpha}{2\theta}(a - bP + \theta) + \frac{V}{2\theta}(a - bP - \theta) + V - m\right]S - \frac{\alpha}{4\theta}(a - bP + \theta)^2 - \frac{V}{4\theta}(a - bP - \theta)^2 = -nS^2 + (V - m)S - m\theta. \quad (28)$$

We assume that $d\Psi_{\text{Supply}}/dS = -2nS + V - m = 0$, and the optimal service volume of the available provider is $S_{\text{Supply}} = V - m/2n$, that is, $V = m + 2nS$. It shows that no matter how the cost of the provider changes, the optimal pricing strategy is always only related to the volume of logistic services. In order to balance the capabilities of the entire supply chain, the integrator's purchase volume should be equal to the provider's supply volume. We assume $dS_{\text{collection}}/dP = -b < 0$, and $S_{\text{collection}}$ is a monotonically decreasing function of P . We assume $dS_{\text{Supply}}/dV = 1/2n > 0$, and S_{Supply} is a monotonically increasing function of V . It shows that there must be a unique equilibrium solution for $S_{\text{collection}} = S_{\text{Supply}}$ to maximize the profits of both, that is, $P = 2n(a + \theta) - V + m/2nb$. The provider decides the price V that maximizes its own interests based on the integrator's

maximum purchase volume, and the integrator decides the price P for the customer on the basis of the provider's price V . The total expected profit of the logistic service supply chain is as follows:

$$\Psi_2 = \Psi_{1/4^-} + \Psi_{1\oplus} = \Pi_{1/4^-} + \Pi_{1\oplus} - M(Q) - L(Q). \quad (29)$$

We bring the optimal solution of $S_2 = S_{\text{collection}} = S_{\text{Supply}}$ into formulas (15), (23), and (26) to obtain the expected profits of logistic service integrators, providers, and the entire supply chain.

The centralized control information flow model is a way to use information technology to share information in the supply chain network. In this model, a decentralized supply chain can achieve optimal organizational performance. Information sharing among supply chain members can produce

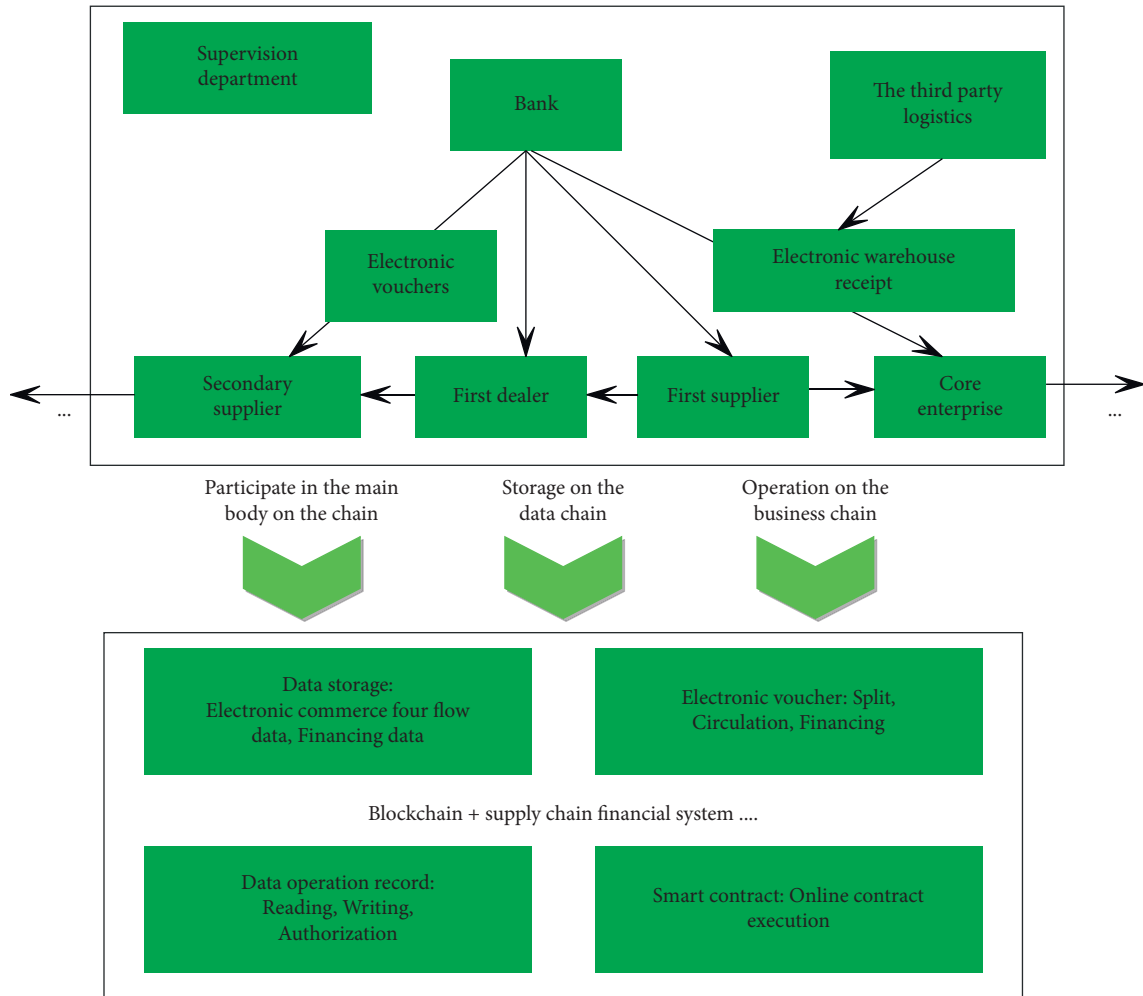


FIGURE 9: The operating mechanism of blockchain + supply chain finance.

deterministic changes, such as reducing or eliminating the “bullwhip effect.” The use of information transmission and interaction technology to increase vertical information sharing can improve the service performance of providers in the logistic service supply chain and the entire supply chain. Providers use information-sharing technology to shorten the distance with customers and can synchronize with integrators to obtain customer logistic demand information in the market, and providers can directly make service supply chain decisions based on customer demand information. In this way, the provider can take the initiative to adopt corresponding strategies to support the integrator’s decision-making, in order to

achieve the balance of capabilities of the entire logistic service supply chain, as shown in Figure 8.

Under this information-sharing model, in the logistic service supply chain of integrators, providers, and customer enterprises, each member shares market demand information and makes unified decisions, with the goal of maximizing the overall benefits of the logistic service supply chain. Therefore, the expected profit of the entire supply chain is the sum of the expected profit of the integrator and the provider. Subsequently, the uncertain capacity cost is eliminated, and the cost is ultimately borne by the integrator and the provider. To simplify the model and

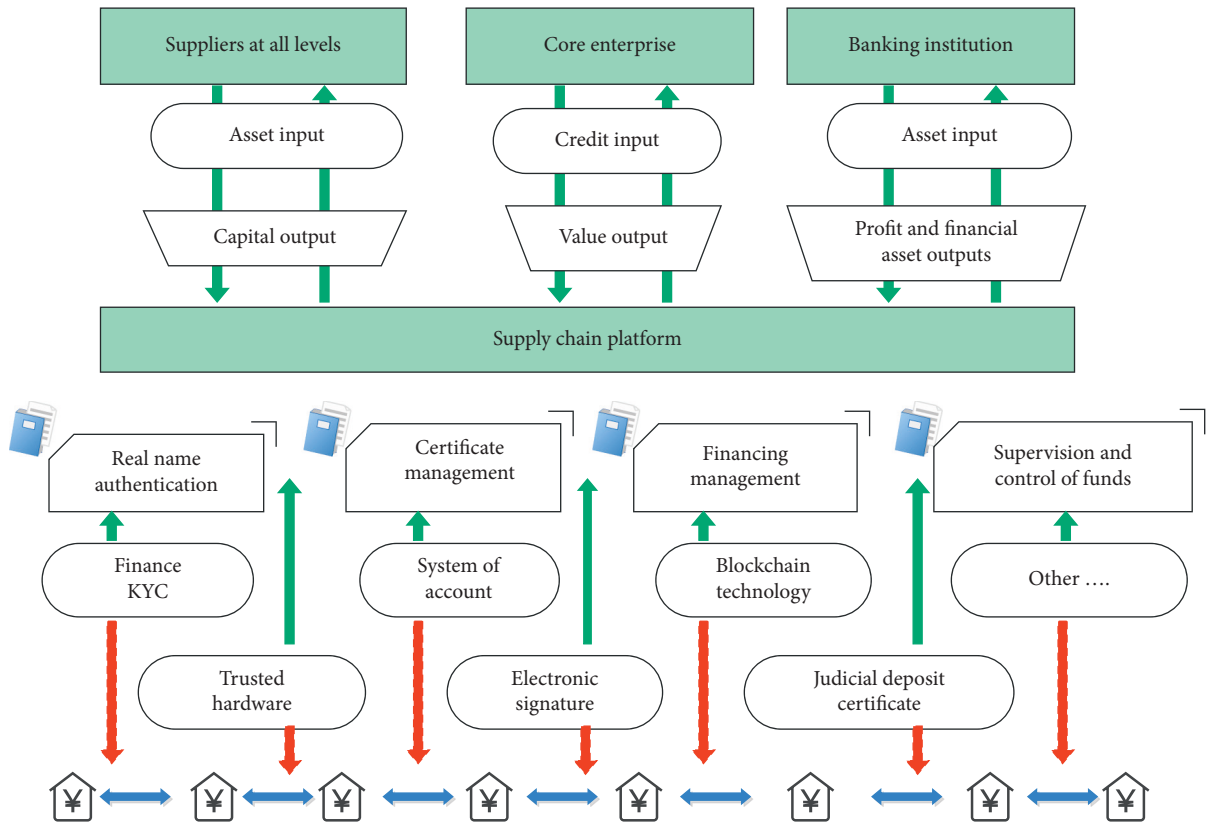


FIGURE 10: Schematic diagram of using blockchain application scenarios to realize the core functions of supply chain integrated business intelligence financial processing.

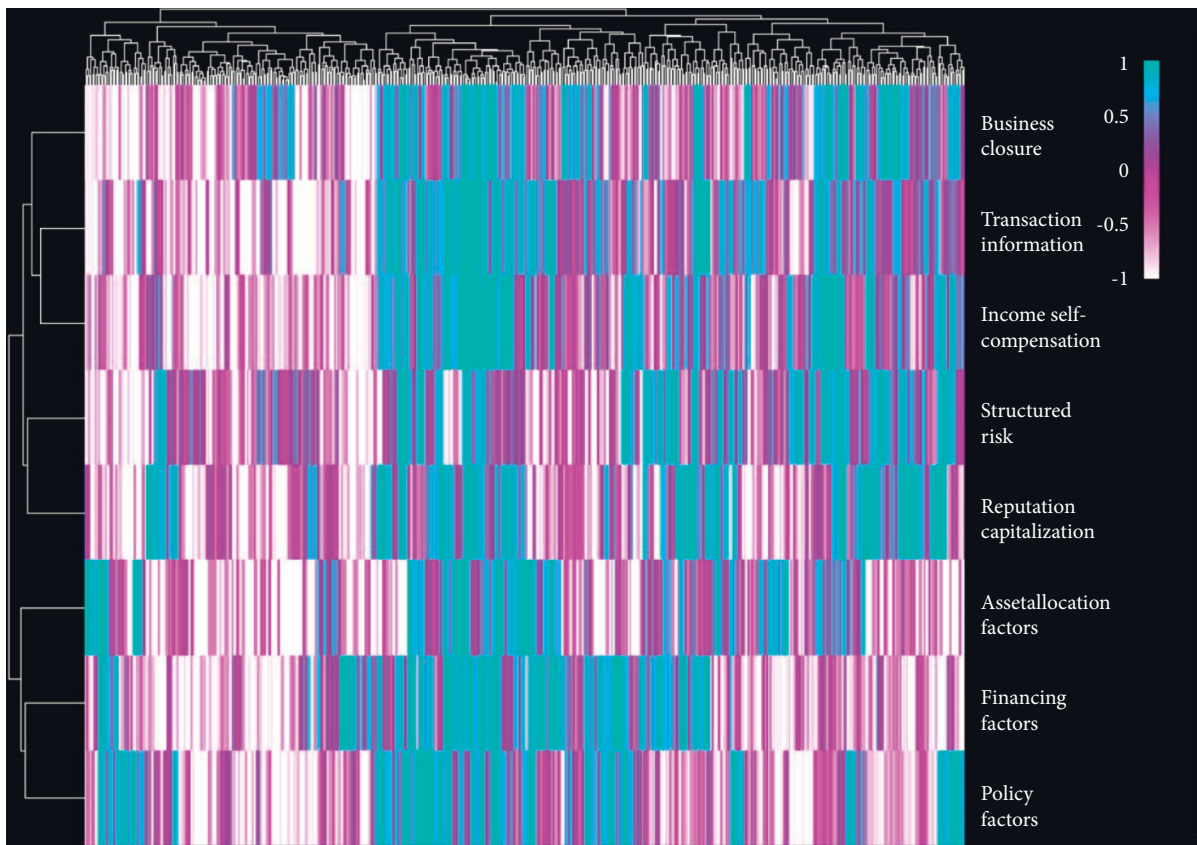


FIGURE 11: The processing effect of the safe financial processing method for realizing supply chain integrated business intelligence using blockchain application scenarios.

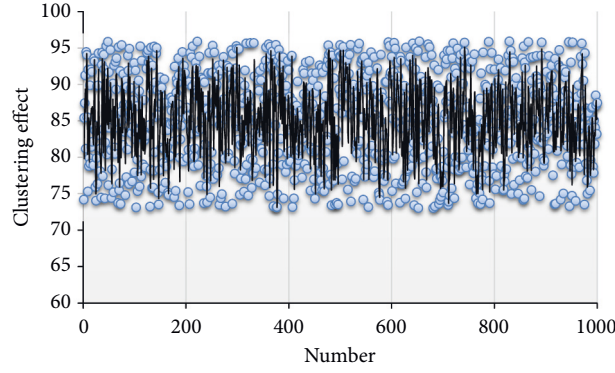


FIGURE 12: The clustering effect of the system.

calculations, we assume that the commitment ratio is 1 : 1, that is, $\Psi_{\text{collection}} = \Pi_{\text{collection}} - 1/2[M(Q) + L(Q)]$, $\Psi_{\text{Supply}} =$

$\Pi_{\text{Supply}} - 1/2[M(Q) + L(Q)]$. Therefore, the total revenue of the supply chain is simply calculated as follows:

$$\begin{aligned} \Psi_3 &= \Psi_{\text{collection}} + \Psi_{\text{Supply}} \\ &= -\left(\frac{P + \alpha}{4\theta} + n\right)S^2 + \left[\frac{(P + \alpha)(a - bP + \theta)}{2\theta} - m\right]S - \frac{(P + \alpha)}{4\theta}(a - bP + \theta)^2 + P(a - bP) \end{aligned} \quad (30)$$

In order to maximize the total revenue of the supply chain, the following two conditions must be met as follows:

$$\begin{cases} \frac{\partial \Psi}{\partial S} = -\left(\frac{P + \alpha}{2\theta} + 2n\right)S + \frac{(P + \alpha)(a - bP + \theta)}{2\theta} - m = 0 \\ \frac{\partial \Psi}{\partial P} = -\frac{S^2}{4\theta} + \frac{(a - bP + \theta)}{2\theta}S - \frac{(a - bP + \theta)^2}{4\theta} + \frac{b(P + \alpha)(a - bP + \theta)}{2\theta} - \frac{b(P + \alpha)}{2\theta} + a - 2bP = 0 \end{cases} \quad (31)$$

According to formula (29), the optimal logistic service volume of the supply chain is as follows:

$$S_3 = \frac{(P + \alpha)(a - bP + \theta) - 2m\theta}{P + \alpha + 4n\theta}. \quad (32)$$

We assume that $d\Psi_{\text{collection}}/dS = -2P - V + \alpha/4\theta S + 2P - V + \alpha/4\theta(a - bP + \theta) - V/2 = 0$, and the available service volume of the integrator is $S_{\text{collection}} = a - bP + \theta - 2V\theta/2P - V + \alpha$. We assume that $d\Psi_{\text{Supply}}/dS = -(V + \alpha/4\theta + 2n)S + V + \alpha/4\theta(a - bP + \theta) + V/2m = 0$, and the optimal service volume of the available provider is $S_{\text{Supply}} = (V + \alpha)(a - bP + \theta) + 2V\theta - 4m\theta/V + \alpha + 8n\theta$.

4. The Safe Financial Processing Method for Realizing Supply Chain Integrated Business Intelligence Using Blockchain Application Scenarios

On the basis of the above algorithm analysis, the blockchain application scenario is used to realize the secure financial processing of supply chain integrated business intelligence, and the model in this study is constructed and the

performance is analyzed. The behaviors and activities of multiple participating entities involved in the development of supply chain finance business, banks, core enterprises, upstream and downstream enterprises, and related service entities must comply with commercial rules and contract requirements. However, the complex structure and sophistication of business operations increase the difficulty of risk control for banks. The characteristics of blockchain technology can effectively meet the control of the causes of supply chain financial risks. The application of blockchain to the supply chain financial business can effectively reduce the difficulty of business risk management, thereby reducing the probability of risk occurrence. Figure 9 shows the operating mechanism of blockchain technology embedded in supply chain financial services.

As shown in Figure 10, the core functions of the supply chain platform mainly include four parts: real-name authentication, credential management, financing management, and capital management and control.

Based on the above model, the safe financial processing method for realizing supply chain integrated business intelligence using blockchain application scenarios was validated, and the results shown in Figure 11 below were obtained.

From the results shown in Figure 11 above, the safe financial processing method for realizing supply chain integrated business intelligence using blockchain application scenarios has good results. On this basis, this study clusters the effects of the model and obtains the results shown in Figure 12.

From the above analysis, it can be seen that the safe financial processing method for realizing supply chain integrated business intelligence using blockchain application scenarios has good results and can play an important role in the safe financial processing of supply chain integrated business intelligence.

5. Conclusions

The blockchain-based supply chain financial system mainly uses core companies and suppliers to record the information involved in transactions. When the core enterprise participates in the transaction in the supply chain financial system, it only needs to confirm the transaction order with the corresponding private key, which reduces the risk of banks and other financial institutions in the supply chain to a certain extent. Furthermore, the reduction in financing risks has further reduced the financing costs of participating companies in the supply chain and promoted the efficient operation of the supply chain financial system. In addition, the blockchain-based supply chain financial system uses smart contracts to replace manual operations. This study combines the blockchain technology to analyze the security financial management of the supply chain integrated business intelligence, builds an intelligent system, and verifies the performance of the system to improve the security financial management effect of the supply chain integrated business intelligence. The experimental research results show that the safe financial processing method for realizing supply chain integrated business intelligence using blockchain application scenarios has good results.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding this work.

Acknowledgments

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