Research on the Revenue of All Parties in the Supply Chain Based on Blockchain Prepayment Financing Platform

Haoxin Wang(✉)

Beijing Technology and Business University, Beijing, China
whx1127726825@163.com

Abstract. This study takes a prepayment financing system consisting of small and medium-sized retailers, core enterprise manufacturers and commercial banks as the research object, constructs a prepayment financing model that is closer to the actual operation of the relevant enterprises and a prepayment financing model under a blockchain platform, and compares and analyses the differences in benefits of each supply chain subject and the supply chain as a whole under the two models in the context of random market demand and retailers' financial constraints. The advantages of the blockchain financing platform in reducing the cost of the whole supply chain and increasing the revenue of each subject are discussed. The above research enriches the content of prepayment financing and can provide decision support for the operational management practice of supply chain finance.

Keywords: supply chain finance · blockchain · prepayment financing · SMEs · revenue sharing

1 Introduction

According to national industry and commerce statistics, SMEs currently registered for business in China account for more than 99% of the total number of enterprises in the country. SMEs contribute 58.5% of GDP, 68.3% of foreign exports, 52.2% of tax revenue and 80% of employment each year. At present, SMEs in China mainly obtain financing through loans from banks, while the fixed assets of SMEs account for a smaller proportion of total assets, have fewer collateral assets and lower credit ratings, and are classified by the banking sector as high-risk and high-cost types, making SMEs "deterred" from taking out loans and banks fearful of lending. This has led to a "fear of lending" mentality among banks. According to relevant studies, SMEs in China only obtain 12% of their active capital from banks, which is much lower than that of other countries. As a result, financing difficulties have been plaguing the development of SMEs. The prepayment-based supply chain finance business model refers to a financing business in which the purchaser applies for a pledge loan to the financial institution with an established warehouse position in the financial institution's designated warehouse on the premise that the upstream core enterprise (the seller) commits to repurchase, and the financial institution controls its right to take delivery.

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Supply chain financing based on prepayment can be specifically categorised into models such as first invoice, guaranteed delivery and letter of credit facilities. The prepayment mode allows manufacturers to generate prepayments at the procurement stage, prolonging their working capital turnover period and putting financial pressure on the enterprise. The prepayment financing model can alleviate the financing problems of manufacturing SMEs with stable production to a certain extent. Supply chain finance is supposed to be the best financing solution to solve the financing dilemma of SMEs, but the lack of control over the authenticity of the trade background of the bills, the high risk of default, the cumbersome loan process, and the high financing and transaction costs have made banks less willing to carry out accounts receivable financing, which has exacerbated the "difficult and expensive financing" situation for SMEs. This has exacerbated the current situation of "difficult and expensive financing" for SMEs, and even endangered the entire supply chain.

In order to break through the existing barriers faced by the development of supply chain finance and promote the further development of supply chain finance, it is imperative to innovate the existing technology and industry model. Blockchain technology, as a technical system that brings together various research results such as timestamps, encryption algorithms, smart contracts, and distributed data storage, is decentralised, tamper-proof and traceable, and can help supply chain finance solve many challenges, such as information asymmetry, high cost of bank credit, and ineffective resolution of transaction background authenticity. At present, scholars have conducted more mature research on accounts receivable financing and inventory financing, while less research has been conducted on prepayment financing. The research on prepayment financing is also limited to the qualitative analysis of business model, operation process and revenue risk, and there is less quantitative research on the combination of prepayment financing and blockchain technology.

The research on blockchain combined with supply chain finance is still in its initial stage, and scholars mostly explore the ways and possibilities of applying blockchain to supply chain finance from the perspective of blockchain technology features. For example, Kshetri (2018) [4] studied the impact of blockchain technology on the cost, quality, speed, dependency, risk management, continuity and variability of supply chain management, and illustrated through case studies how blockchain technology can serve all purposes of supply chain management. Tonnissen (2020) [5] constructed an explanatory model for the application of blockchain technology to supply chain operations by analysing several case studies, summarising the impact of blockchain technology on the logistics industry, the application and research issues of blockchain technology, and its impact on business models. Helo [3] and others have systematically reviewed the development of blockchain technology and analysed the possible ways in which it can be applied to supply chain operations and management. Choi [2] constructed a product information disclosure platform supported by blockchain technology and explored the value of the platform for supply chain decision-making from the perspective of information disclosure within the supply chain.

Based on a blockchain technology-based advance financing platform, this paper constructs a comparative model of the benefits of supply chain parties and the supply chain as a whole under the condition of random market demand and financial constraints of retailers, and verifies the facilitating effect of the advance financing platform in enhancing the benefits of supply chain finance parties and the supply chain finance as a whole by means of numerical analysis.

2 Materials and Methods

2.1 Prepayment Financing Model

Consider a supply chain consisting of a financially constrained retailer R and a core business supplier S. In this supply chain system, the market demand for the product is random, and the cost price, wholesale price, selling price and residual value all remain constant during the sales period, in line with the typical characteristics of the "paperboy" model. The financing options available for this supply chain are traditional prepayment financing and blockchain technology-based prepayment platform financing. Under the traditional supply chain prepayment financing model, the retailer first signs an order contract with the core manufacturer and orders a quantity Q according to its own capital level, financing interest rate and market demand, and when the market demand is insufficient, i.e. $x < Q$, the unsold products are recovered by the manufacturer at a recovery price g, and the buyback price is less than the purchase price $g < Pr$. The retailer applies to the bank for financing and pays a margin. The amount of margin is B and the retailer's own funds are $B + bPQr$, ($b \geq 0$ and the retailer's own funds are far from sufficient to deliver the goods). The bank needs to carry out a pre-loan assessment of both the core business and the retailer operating conditions, taking into account the creditworthiness and operating conditions of both the core manufacturer and the retailer, before providing the retailer with financing. After successful financing, the bank pays (1-b) PQr on behalf of the retailer and receives the rights to the goods. The retailer receives sales revenue at the end of the sales period and repays the bank (1-b) $rPQ(1 + rT)$, and the bank returns the margin (Fig. 1).

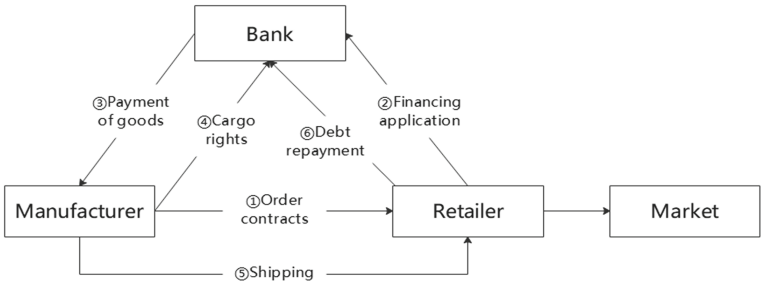

Fig. 1. Prepayment financing process

2.2 Prepayment Financing Model Under Blockchain Platform

Based on the decentralised, de-trusted and non-tamperable features of blockchain technology, all parties in the supply chain can upload their business information to the blockchain platform, and the information is transmitted interactively with the chain, so that both borrowers and lenders can intuitively understand each other's real business conditions. Under the blockchain prepayment platform financing model, the retailer entrusts the bank on the blockchain platform to purchase goods from the manufacturer of the core business and prepay a certain amount of deposit. The bank procures the goods from the core enterprise manufacturer to obtain the right of goods, and after the goods are warehoused, digital assets are formed on the blockchain platform (using blockchain technology to upload warehouse receipt status data in real time, forming "digital assets" mapped to the flow of physical storage assets), and the bank impounds the product certificate of conformity (products without certificate of conformity cannot be resold), and the retailer redeems the goods from the bank and obtains the certificate of conformity within the contract period. The bank charges a fee for the platform service. In this model, the retailer enters into a quantity $\mathbf{Q_B}^*$order with the core business manufacturer, the retailer applies to the bank for financing through the platform and posts a deposit, the platform issues the financing certificate and collects the deposit and fees $\theta(1-b)PrT\,\mathbf{Q_B}^*$ (Fig. 2).

2.3 Basic Assumptions

(1) Zero inventory is assumed at the beginning of the financing period as retailers order according to market demand.
(2) Repurchase risk (including credit risk) is borne by the supplier and the repurchase price is less than the supply and sale price.
(3) For the purposes of this study, only market risk and default risk are considered and other risk factors are ignored.
(4) Due to the prevailing climate of oversupply, it is assumed here that out-of-stock costs are not considered.
(5) SMEs are risk neutral while banks use a different approach to risk control, i.e. SMEs make sales behavior decisions based on maximizing expected returns, while banks not only maximize expected returns but also risk management and positive returns.

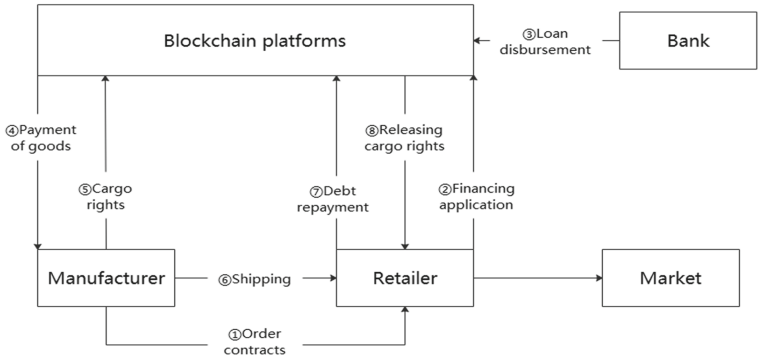

Fig. 2. The prepayment financing process under the blockchain platform

(6) To simplify the model for ease of study, logistics costs are not considered here, nor are storage costs, as the goods are always stored and controlled by the manufacturer.
(7) The buyback is the same in both models if the order volume is greater than the market demand (explained below).

2.4 Summary of Notation

B Amount of retailer's own funds
P Market price
$\mathbf{P_r}$ Purchase price
T Term of financing
$\mathbf{r_s}$ Bank funding cost rate
τ Product disposal price
g Commodity recovery price
x Demand
$\mathbf{x_b}$ Demand under blockchain platform
Q Order quantity in T
$\mathbf{Q}^*$ Optimal order size for retailers under prepayment financing models
$\mathbf{Q_B^*}$ Optimal order quantity for retailers under the blockchain prepayment platform financing model
r Financing rate
$\mathbf{F(x)}$ Demand probability distribution function
$\mathbf{f(x)}$ Demand density function
θ Platform usage rates
m Bank unit credit cost
v Blockchain platform unit maintenance costs

3 Results and Discussion

3.1 The Parties Expect to Benefit Analysis Upfront Financing Mode

3.1.1 Retailers Expect Revenue

The actual demand for the commodity is $\boldsymbol{x}$, the retailer's order quantity is Q. The expected demand is

$$\mathbf{Ex} = \int_0^{\infty} \mathbf{xf(x)dx} \tag{1}$$

Actual sales

$$\mathbf{S(x)} = \mathbf{Emin(x, Q)} = \mathbf{Ex} = \int_0^{\mathbf{Q}} \mathbf{xf(x)dx} + \int_{\mathbf{Q}}^{\infty} \mathbf{Qf(x)dx}$$

$$= \mathbf{Q} - \int_0^{\mathbf{Q}} \mathbf{F(x)dx} \tag{2}$$

If all the items on hold are bought back, the buyback volume is

$$\mathbf{G(x) = Emax(0, Q - x) = \int_0^{Q} (Q - x)f(x)dx + \int_{Q}^{\infty} 0f(x)dx}$$
$$\mathbf{= \int_0^{Q} (Q - x)f(x)dx} \tag{3}$$

When the optimal order quantity is reached, the buyback quantity is

$$\mathbf{G_P(x) = \int_0^{Q^*} (Q^* - x)f(x)dx} \tag{4}$$

If the retailer orders only with its own funds the order quantity $\mathbf{Q = (B + bP_rQ)/P_r}$.

Its revenue is $\pi^{\mathbf{r}} = \mathbf{(P - P_r)\,(B + bP_rQ)/P_r - B - bP_rQ}$ The optimal order quantity cannot be reached, and if the optimal order quantity is to be reached, bank financing is required. The revenue function of the retailer in the prepayment financing model is

$$\pi_{\mathbf{p}}^{\mathbf{r}}(\mathbf{Q}) = \begin{cases} \mathbf{(P - P_r)Q - (1 - b)P_rQTr} & \text{Q <x} \\ \mathbf{Px - P_rQ + g(Q - x) - (1 - b)P_rQTr} & \text{Q} \geq \text{x} \end{cases} \tag{5}$$

Retailers expect revenue of

$$\mathbf{E}\left[\mathbf{p}_{\mathbf{p}}^{\mathbf{r}}(\mathbf{Q})\right] = \mathbf{(P - P_r)Q - (1 - b)P_rQTr - (P - g)\int_0^{Q} (Q - x)f(x)dx} \tag{6}$$

The derivative of Q equals zero to find the retailer's optimal order quantity

$$\mathbf{Q^* = F^{-1}\left(\frac{P - P_r - (1 - b)P_rTr}{P - g}\right)} \tag{7}$$

3.1.2 Manufacturer Expect Revenue

Earnings function for core business manufacturers under prepayment financing

$$\pi_{\mathbf{p}}^{\mathbf{m}}(\mathbf{Q}) = \begin{cases} \mathbf{(P_r - c)Q} & \text{Q} < \text{x} \\ \mathbf{P_rx - cQ + \tau(Q - x) - g(Q - x)} & \text{Q} \geq \mathbf{x} \end{cases} \tag{8}$$

The core business expectation of profit is

$$\mathbf{E}\left[\pi_{\mathbf{p}}^{\mathbf{m}}(\mathbf{Q})\right] = \mathbf{(P_r - c)Q - (g - t)\int_0^{Q} (Q - x)f(x)dx} \tag{9}$$

(Note: Here the core firm manufacturer's recycling disposal cost per unit of goods $(\boldsymbol{g - \tau})$ should be no greater than the profit per unit of product $(\boldsymbol{P_r - c})$, i.e. $(\boldsymbol{P_r - c}) \geq (\boldsymbol{g - \tau})$ otherwise the firm will not buy back)

3.1.3 Bank Expected Return

Here it is assumed that the retailer's own funds come in part or in full to cover the margin and that all the funds needed to buy the goods are financed from the bank. As this is a closed-loop system, the retailer defaults when the sum of the retailer's sales revenue and the residual value of unsold inventory is insufficient to repay the bank's principal and interest. The threshold of default for the retailer is then

$$\mathbf{PA} + \mathbf{g}(\mathbf{Q} - \mathbf{A}) < (1 - \mathbf{b})\mathbf{P_r}\mathbf{Q}(1 + \mathbf{Tr})\,\mathbf{A} < \frac{(1 - \mathbf{b})\mathbf{P_r}\mathbf{Q}(1 + \mathbf{Tr}) - \mathbf{gQ}}{\mathbf{P} - \mathbf{g}} \tag{10}$$

When $(1 - \boldsymbol{b})\mathbf{P}_{\boldsymbol{r}}(1 + \mathbf{Tr}) < \boldsymbol{P}$ when A < Q, when $(1 - \boldsymbol{b})\mathbf{P}_{\boldsymbol{r}}(1 + \mathbf{Tr}) > \boldsymbol{P}$ when A > Q,

When A < Q, if the retailer defaults, the bank will receive the funds in the closed account and deal with the pledge of the remaining goods recovered

$$\pi_{\mathbf{b}}(\mathbf{Q}) = \begin{cases} (\mathbf{P} - \mathbf{P_r})\mathbf{Q} - (1 - b)\mathbf{P_r}\mathbf{Q}(1 + \mathbf{r_s}\mathbf{T}) \\ +\mathbf{bP_r}Q - \mathbf{mQ}\ \mathrm{Q} < \mathrm{x} \\ (\mathbf{P} - \mathbf{P_r})x - (1 - \mathbf{b})\mathbf{P_r}\mathbf{Q}(1 + \mathbf{r_s}\mathbf{T}) + \\ \mathbf{g}(\mathbf{Q} - x) - \mathbf{m}Q + \mathbf{bP_r}\mathbf{Q}\ \mathrm{Q} \geq \mathrm{x} \end{cases} \tag{11}$$

If the retailer does not default, the bank's return is

$$\pi_b = (1 - \mathbf{b})\mathbf{P_r}\mathbf{QT}(\mathbf{r} - \mathbf{r_s}) \tag{12}$$

The bank has to pay a certain credit cost m, then the expected return of the commercial bank is

$$\begin{aligned} \mathbf{E}[\pi_{\mathbf{p}}^{\mathbf{b}}(\mathbf{Q})] &= \mathbf{PQ} + (1 - \mathbf{b})\mathbf{P_r}\mathbf{QT}(\mathbf{r} - \mathbf{r_s}) - \mathbf{mQ} \\ &+\mathbf{bP_r}\mathbf{Q} + (\mathbf{p} - \mathbf{g})\int_0^{\mathbf{Q}} (\mathbf{Q} - \mathbf{x})\mathbf{f}(\mathbf{x})\mathbf{dx} \end{aligned} \tag{13}$$

3.2 Expected Benefits for All Parties in the Blockchain Prepayment Platform Financing Model

3.2.1 Retailers Expect Revenue

Same as Eq. (4) When the optimal order quantity is reached, the repurchase quantity is

$$\mathbf{Gb}(\mathbf{x}) = \int_0^{\mathbf{Q_b^*}} (\mathbf{Q_b^*} - \mathbf{x_b})\mathbf{f}(\mathbf{x_b})\mathbf{dx_b} \tag{14}$$

The impact of blockchain technology on market demand is analyzed qualitatively, taking into account the available literature and expert opinion. Typically, information about the quality of a product or service is asymmetrical between producers and consumers, and the transparency and traceability of information that blockchain platforms have can have an incentive effect on the demand for goods, so $x_b > x$. In addition, the essence of blockchain is a decentralized database, due to its decentralization, collective

maintenance and unchangeable of time-series data, it makes a large amount of real and reliable information stored in the blockchain database, and the real and reliable data information can help enterprises improve the accuracy of product demand prediction and reduce demand variability. So in the case that the order quantity is greater than the market demand, we can assume that when retailers use blockchain prepayment financing, the retailers' returns are similar or less compared to traditional prepayment financing, and for the convenience of calculation and illustration, we assume that Gb(x) = $G(x)$, i.e. the returns are the same.

Profit from the blockchain platform, capital turnover is accelerated, eliminating the cumbersome loan process under the traditional supply chain finance model, and only a certain rate θ of platform usage fee is payable. Revenue function for retailers under this model

$$\pi_{\mathbf{B}}^{\mathbf{r}}(\mathbf{Q}) = \begin{cases} (\mathbf{P}-\mathbf{P_r})\mathbf{Q} - \theta(1-\mathbf{b})\mathbf{P_r}\mathbf{QT}\ \mathrm{Q} < \mathrm{x_b} \\ \mathbf{P}\mathbf{x_b} - \mathbf{P_r}\mathbf{Q} + \mathbf{g}(\mathbf{Q}-\mathbf{x_b}) - \theta(1-\mathbf{b})\mathbf{P_r}\mathbf{QT}\ \mathrm{Q} \geq \mathrm{x_b} \end{cases} \tag{15}$$

Its expected return is

$$\begin{aligned} \mathbf{E}[\pi_{\mathbf{B}}^{\mathbf{r}}(\mathbf{Q})] &= (\mathbf{P}-\mathbf{P_r})\mathbf{Q} - \theta(1-\mathbf{b})\mathbf{P_r}\mathbf{QT} \\ &-(\mathbf{P}-\mathbf{g})\int_0^{\mathbf{Q}} (\mathbf{Q}-\mathbf{x_b})\mathbf{f}(\mathbf{x_b})\mathbf{dx_b} \end{aligned} \tag{16}$$

Optimum order quantity is

$$\mathbf{Q_B^*} = \mathbf{F}^{-1}\left(\frac{\mathbf{P}-\mathbf{P_r}-\theta(1-\mathbf{b})\mathbf{P_r}\mathbf{T}}{\mathbf{P}-\mathbf{g}}\right) \tag{17}$$

3.2.2 Manufacturer Expected Return

With the blockchain platform, core businesses can earn some revenue by saving management costs, improving capital turnover, reducing out-of-stock costs, and reducing inventory costs and recovery costs by forecasting demand through retailer's business conditions.

Corporate profit functions

$$\pi_{\mathbf{B}}^{\mathbf{m}}(\mathbf{Q}) = \begin{cases} (P_{\mathbf{r}}-\mathbf{c})\mathbf{Q}+\beta\ \mathrm{Q} < \mathrm{x}_b \\ \mathbf{P_r}\mathbf{x} - \mathbf{c}\mathbf{Q} + \tau(\mathbf{Q}-\mathbf{x}) - \mathbf{g}(\mathbf{Q}-\mathbf{x})+\beta\ \mathrm{Q} \geq \mathrm{x_b} \end{cases} \tag{18}$$

expected return

$$\mathbf{E}[\pi_{\mathbf{B}}^{\mathbf{r}}(\mathbf{Q})] = (\mathbf{P_r}-\mathbf{c})\mathbf{Q} + \beta - (\mathbf{g}-\tau)\int_0^{\mathbf{Q}} (\mathbf{Q}-\mathbf{x_b})\mathbf{f}(\mathbf{x_b})\mathbf{dx_b} \tag{19}$$

2) Bank expected return

Under the blockchain prepayment financing platform, banks do not need to pay for credit costs, but only for a certain amount of platform maintenance **v**, and $\mathbf{v} \ll \mathbf{m}$.

The retailer default threshold is

$$\mathbf{PA}^* + \mathbf{g}(\mathbf{Q} - \mathbf{A}*) < \theta(1 - \mathbf{b})\mathbf{P_r}\mathbf{QT} + (1 - \mathbf{b})\mathbf{P_r}\mathbf{Q} \tag{20}$$

$$\mathbf{A}^* < \frac{(1 - \mathbf{b})\mathbf{P_r}\mathbf{Q}(1 + \theta\mathbf{T}) - \mathbf{gQ}}{\mathbf{P} - \mathbf{g}} \tag{21}$$

When $(1 - b)(1 + \theta T)\mathrm{P}_r < P$ when A* < Q, when $(1 - b)(1 + \theta)\mathrm{P}_r > P$ A* > Q, when A* < Q, if the retailer defaults, the bank will receive the funds in the closed account and process the pledge of the remaining goods to recover the money

$$\pi_{\mathbf{B}}(\mathbf{Q}) = \begin{cases} (\mathbf{P} - \mathbf{P_r})\mathbf{Q} - (1 - \mathbf{b})\mathbf{P_r}\mathbf{Q}(\theta + \mathbf{r_s})\mathbf{T} \\ +\mathbf{bP_r}\mathbf{Q} - \mathbf{vQ}\ \mathrm{Q} < \mathrm{x_b} \\ (\mathbf{P} - \mathbf{P_r})\mathbf{x_b} - (1 - \mathbf{b})\mathbf{P_r}\mathbf{Q}(1 + \mathbf{r_s})\mathbf{T} \\ +\mathbf{g}(\mathbf{Q} - \mathbf{x_b}) - \mathbf{vQ} + \mathbf{bP_r}\mathbf{Q}\ \mathrm{Q} \geq \mathrm{x_b} \end{cases} \tag{22}$$

If there is no default, the bank's return is

$$\pi_{\mathbf{b}}^{\mathbf{B}} = (1 - \mathbf{b})\mathbf{P_r}\mathbf{QT}(\theta - \mathbf{r_s}) \tag{23}$$

Expected return

$$\begin{aligned} &\mathbf{E}[\pi_{\mathrm{p}}^{\mathrm{b}}] = \mathbf{Q} - \mathbf{vQ} - (1 - \mathbf{b})\mathbf{P_r}\mathbf{Q}(\theta - \mathbf{r_s})\mathbf{T} + \mathbf{bP_r}\mathbf{Q} - \\ &(\mathbf{P} - \mathbf{g})\int_0^{\mathrm{Q}} [(\mathbf{Q} - \mathbf{x_b})]\mathbf{f}(\mathbf{x_b})\mathbf{dx_b} \end{aligned} \tag{24}$$

3.3 Comparative Analysis

3.3.1 Retailer Comparison

$$\begin{aligned} &\Delta\pi_{\mathbf{B-p}}^{\mathbf{r}} = \mathbf{E}[\pi_{\mathbf{B}}^{\mathbf{r}}] - \mathbf{E}[\pi_{\mathbf{p}}^{\mathbf{r}}] \\ &= (\mathbf{P} - \mathbf{P_r})(\mathbf{Q_B^*} - \mathbf{Q}^*) - \theta(1 - \mathbf{b})\mathbf{P_r}\mathbf{TQ_B^*} \\ &+(1 - \mathbf{b})\mathbf{P_r}\mathbf{Q}^*\mathbf{Tr} - (\mathbf{P} - \mathbf{g})[\int_0^{\mathbf{Q_B^*}} (\mathbf{Q_B^*} - \mathbf{x_b})\mathbf{f}(\mathbf{x_b})\mathbf{dx_b} \\ &- \int_0^{\mathbf{Q}^*} (\mathbf{Q}^* - \mathbf{x})\mathbf{f}(\mathbf{x})\mathbf{dx}] \end{aligned} \tag{25}$$

provided the market is stable and the blockchain technology is mature $\theta < r$, F(x) monotonically increases and reduces the cost of financing, and its inverse function also monotonically increases, so $Q_B^* > Q^*$, based on numerous studies, blockchain technology can improve the efficiency of financing, so $\theta(1 - \mathrm{b})\mathrm{P}_r TQ_B^* < (1 - b)\mathrm{P}_r Q^*\mathrm{Tr}$, and because Gb(x) = Gp(x); In summary, **Proposition 1** is obtained: the difference in revenue between the chain platform prepayment financing model and the traditional prepayment financing model for retailers is constantly greater than zero.

It follows from that proposition that blockchain financing platforms can only charge rates if $\theta < r$ When the expected revenue of retailers under the financing mode of blockchain platform is constantly greater than the expected revenue under the traditional supply chain finance financing mode, retailers will choose the prepayment financing mode of blockchain platform, and in the actual business environment, the usage fee rate charged by the blockchain financing platform for the sake of customer source and capital θ are often cheaper, or even provide technical support to enterprises for free, so the proposition $\theta < r$, and $\theta(1 - \mathrm{b})\mathrm{P}_r TQ_B^* < (1 - b)\mathrm{P}_r Q^*\mathrm{Tr}$ are closer to the real situation.

3.3.2 Manufacturer Comparison

Differences in earnings of core businesses under the two models

$$\begin{aligned}
&\Delta\pi_{\mathbf{B-p}}^{\mathbf{m}} = \mathbf{E}[\pi_{\mathbf{B}}^{\mathbf{m}}] - \mathbf{E}[\pi_{\mathbf{p}}^{\mathbf{m}}] \\
&= (\mathbf{P_r} - \mathbf{c})(\mathbf{Q_B^*} - \mathbf{Q}^*) + \beta - (\mathbf{g} - \tau) \\
&[\int_0^{\mathbf{Q_B^*}} (\mathbf{Q_B^*} - \mathbf{x_b})\mathbf{f}(\mathbf{x_b})\mathbf{dx_b} - \int_0^{\mathbf{Q}^*} (\mathbf{Q}^* - \mathbf{x})\mathbf{f}(\mathbf{x})\mathbf{dx}]
\end{aligned} \tag{26}$$

Proposition 2: Under the premise that the market is cleared and the blockchain technology is mature, the revenue difference between the blockchain platform prepayment financing model and the traditional prepayment financing model for core business manufacturers is constantly greater than zero.

Proof: Because $Q_B^* > Q^*$, $(\mathrm{P}_r - c) \geq (g - \tau)$ and $\beta > 0$, Get the proof.

From the proposition, it is clear that the core business manufacturer saves management costs, improves capital turnover and reduces out-of-stock costs through the blockchain financing platform, and earns some revenue by reducing inventory costs and recovery costs by forecasting demand through the retailer's operating conditions, increasing its profits.

3.3.3 Comparative Analysis of Bank Returns

When A > Q, since the retailer would have defaulted regardless of the market demand and the bank would not have accepted the financing business due to risk considerations, only the case A < Q is considered.

$$\begin{aligned}
&\Delta\pi_{\mathbf{B-p}}^{\mathbf{b}} = \mathbf{E}[\pi_{\mathbf{B}}^{\mathbf{b}}] - \mathbf{E}[\pi_{\mathbf{p}}^{\mathbf{b}}] \\
&= (\mathbf{P} + \mathbf{bP_r})(\mathbf{Q_B^*} - \mathbf{Q}^*) - (1 - \mathbf{b})\mathbf{P_r}(\theta - \mathbf{r_s})\mathbf{Q_B^*}\mathbf{T} + \\
&(1 - \mathbf{b})\mathbf{P_r}\mathbf{Q}^*\mathbf{T}(\mathbf{r} - \mathbf{r_s}) - \mathbf{vQ_B^*} + \mathbf{mQ}^* - (\mathbf{P} - \mathbf{g}) \\
&[\int_0^{\mathbf{Q_B^*}} (\mathbf{Q_B^*} - \mathbf{x_b})\mathbf{f}(\mathbf{x_b})\mathbf{dx_b} - \int_0^{\mathbf{Q}^*} (\mathbf{Q}^* - \mathbf{x})\mathbf{f}(\mathbf{x})\mathbf{dx}]
\end{aligned} \tag{27}$$

Proposition 3: Out of the clear and with mature blockchain technology $\boldsymbol{\theta < r}$ when the difference in returns between the blockchain platform prepayment financing model and the traditional prepayment financing model for banks is constantly greater than zero.

Proof: Because $\theta < r$, therefore $(1 - b)r\mathrm{P}_r\mathrm{QT} > \theta\mathrm{TP}_r\mathrm{Q}$, and $Q_B^* > Q^*$, v ≪ m Get the proof.

Under the blockchain prepayment financing model, there is no need for banks to audit the real operations of retailers, which enhances financing efficiency, reduces financing difficulties and eliminates the financing costs of traditional supply chain finance. The bank's credit cost is reduced, the retailer's risk of default is reduced, and the time and management costs required throughout the financing period are reduced. At the same time, because of the lower financing interest rate and faster financing efficiency, more SMEs will be attracted to apply for financing and the bank's revenue will be significantly increased.

3.4 Numerical Simulation

The numerical simulation in this paper focuses on assigning values to the parameters in the mathematical model and then bringing them into the model results obtained in the previous chapter, changing one of the variables, controlling the rest of the remaining variables constant, and making relationship diagrams using MATLAB in order to discover the impact of the blockchain financing platform on the revenue of the supply chain parties.

Suppose a product is a best seller at a certain time and the market price is 300$ per unit, corresponding to a certain supply chain specializing in the manufacture and sale of such appliances, and the retailer buys from the manufacturer at a price of 200$ per unit. The retailer is familiar with the market and estimates the demand for this sales cycle to be 100 in the region of $ per 100 unit, fluctuating up and down. Assuming that this cycle is one month, the retailer has insufficient capital of its own and applies for financing from a partner bank with a cost of capital rate of 5% and an interest rate of 10%. The manufacturer promises to buy back.

the goods at a150 price of $ per piece during the commodity financing period, and the retailer disposes of the unsold goods on its own at a price of 100$ per piece. Assume that the density function of market demand during the financing period obeys U(0,200).

3.4.1 The Impact of the Retailer's Own Funds on Its Own Expected Return and the Bank's Expected Return

As can be seen from the previous equation, the amount of a retailer's own funds has a positive impact on its own returns and a negative impact on the bank's returns, controlling for other variables that are held constant, the retailer's own funds float between [0.1, 0.6], as shown in Fig. 3.

3.4.2 The Impact of Blockchain Platform Usage Rates on Retailer Returns Under Both Financing Models

Controlling other variables constant, the fixed merchant's own capital rate is 0.2 and the blockchain platform fee rate is taken between [0.01, 0.15], as shown in Fig. 4, the relationship between the retailer's expected return and the blockchain platform fee rate can be obtained, as the platform fee rate increases the retailer's expected return

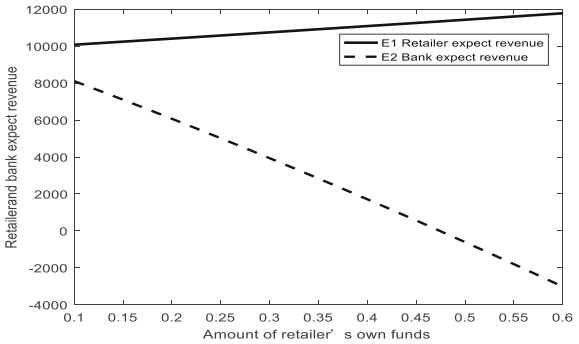

Fig. 3. Relationship between banks' and retailers' expected returns and retailers' own funds volume

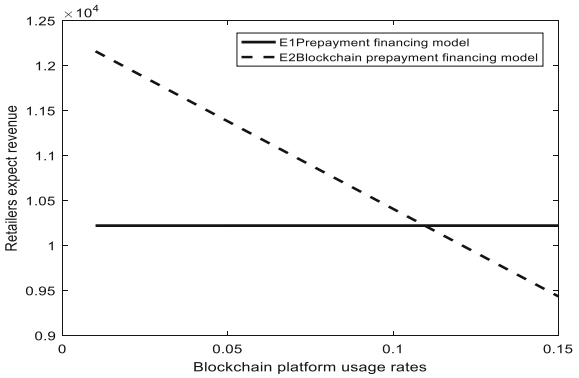

Fig. 4. Expected revenue for retailers at different platform usage rates

decreases, but even if the platform fee rate is the same as the bank financing rate of the traditional prepaid account financing model, the blockchain platform financing model under the However, even if the platform fee rate is the same as the bank financing rate of the traditional prepaid financing model, the expected revenue of retailers under the blockchain platform financing model is still higher than the traditional prepaid financing model.

3.4.3 Analysis of Banks' Returns Under Different Blockchain Platform Usage Rates

Controlling other variables constant, the fixed merchant's own funds rate is 0.2 and the blockchain platform fee rate takes values between [0.01–0.15], one can see the relationship between the bank's expected return and the blockchain platform fee rate, as shown in Fig. 5. Because a low fee rate retailer will have more funds for stocking, the number of loans increases, while the bank's expected return increases significantly with a low blockchain platform usage fee rate due to reduced credit costs, reduced loan process and reduced loan approval time.

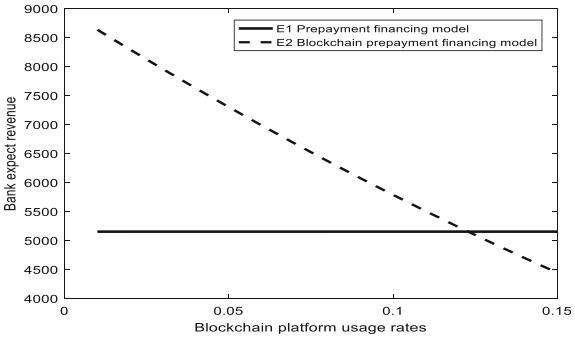

Fig. 5. Expected revenue for bank at different platform usage rates

4 Conclusion and Outlook

This study takes the prepayment financing system composed of small and medium-sized retailers, core enterprise manufacturers and commercial banks as the research object, constructs a prepayment financing model that is closer to the actual operation of the relevant enterprises and a prepayment financing model under the blockchain platform, compares and analyses the differences in benefits of each main body of the supply chain and the supply chain as a whole under the two models in the context of random market demand and financial constraints of retailers, and discusses the advantages of the blockchain financing platform in reducing the cost of the whole supply chain and increasing the benefits of each subject, and the following conclusions were obtained.

Under the premise of a stable market and mature blockchain technology, (1) the expected revenue of retailers under the blockchain platform financing model is constantly greater than the expected revenue under the traditional supply chain finance financing model. (2) The core enterprise manufacturer saves management costs, improves capital turnover and reduces out-of-stock costs through the blockchain financing platform, and earns a certain amount of revenue by reducing inventory costs and recovery costs by forecasting demand through the retailer's operating conditions, thus increasing its profits. (3) Under the blockchain platform prepayment financing model, there is no need for banks to audit the real operation of retailers, which enhances financing efficiency, reduces financing difficulty and eliminates the financing cost of traditional supply chain finance. On the other hand, the blockchain platform can prompt core enterprises to save management costs, improve capital turnover, reduce out-of-stock costs, and increase their revenue in many ways such as reducing inventory costs and recovery costs by forecasting demand through retailers' operating conditions, which will be applied to the entire supply chain to enhance overall revenue.

In summary, this paper takes supply chain finance as the research background, takes prepayment financing system and members as the research object, establishes the mathematical model of prepayment financing and prepayment financing under blockchain platform, studies the operation mechanism of the system and the decision making and revenue distribution of members, and obtains some research conclusions with theoretical and practical significance, which can provide decision support for the operation and

management practice of supply chain finance. However, due to the limitation of time and resources, and also due to my limited academic level, this paper is bound to have some flaws and shortcomings, and many of the assumptions in this paper are based on the ideal state. If some of the assumptions are relaxed, such as considering the handling fee of bank financing, considering the risks other than default risk; when studying the optimal financing rate of prepayment financing, it is no longer assumed that the margin paid by SMEs to banks is equal to their own capital; considering the costs of various transactions, then the research on prepayment financing may yield different conclusions and may provide a different perspective for the research on supply chain finance.

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