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SUPPLY CHAIN FINANCING MODEL UNDER A NEW MECHANISM OF BANKRUPTCY GUARANTEE

Abstract. *This paper proposes a new mechanism of bankruptcy guarantee for the capital constrained retailer. We study the optimal decision-making of supplier and retailer under the two financing modes of trade credit and bank credit, and to further analyze the double marginalization under different financing modes. Firstly, the optimal wholesale price and order quantity of the supplier and the retailer under two financing modes are given respectively. Then, the relationship between wholesale price and insurance weight coefficient under supply chain coordination is obtained. Finally, a numerical example is given to verify the effectiveness of the proposed mechanism. The results show that the trade credit model is superior to the bank credit model in improving both supplier and retailer's profit and the efficiency of the supply chain. The interest rate of bank loans is an important indicator that affects the profits of the supplier and the retailer, and the increase of interest rate aggravates double marginalization. The effect of residual value of product on supply chain efficiency is not significant, while the increase of shortage cost greatly aggravates double marginalization.*

Keywords: *insurance agreement; trade credit; bank credit; double marginalization.*

JEL Classification: G22, G31, G32

1. Introduction

Small and medium-sized enterprises (SMEs), dominated by private enterprises, have become important contributors to boost economic growth in the social and economic systems due to its small scale, large number, strong ability to create jobs

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and flexible operations. However, it is much more difficult for SMEs to obtain financial services than large-sized enterprises, especially in lending from banks and other formal financial institutions. With the rapid development of SMEs, one of the main problems is the difficulty in financing. In the entire supply chain, the difficulty of member enterprises in financing reduces the performance of both the enterprises themselves and their supply chain, which has become one of the key bottlenecks affecting the efficiency improvement and coordinated development of the supply chain.

Supply chain finance is one of the effective ways to solve the difficulty and high cost of financing and no warranty for micro-, small- and medium-sized enterprises, and it is also the optimal solution to financing management among enterprises, which is to effectively increase the profits of all participants in the supply chain by integrating the financing processes of suppliers, retailers and consumers (Pfohl and Gomm (2009)). In case of financial pressure, enterprises usually finance in two channels. One is through bank credit (external financing), but there are relatively high thresholds of borrowing from banks. Moreover, the enterprises are vulnerable to financial exclusion, and they often need collateral or credit guarantee. The other is through trade credit (internal financing), which means that the supplier allows the retailer to take delivery of the goods first, until the retailer pays the supplier after selling the goods. A large number of literatures studied these two financing methods. Petersen and Raghuram (1997) conducted a comparative study and found that trade credit was widely applied for financing in both developed and developing countries. Smith (1987)proposed that the screening mechanism of trade credit is more effective than that of bank credit. Babich et al. (2012) analyzed the impact of trade credit and bank credit on the supplier selection and supply chain performance under capital constraints in a single-period model. Buzacott and Zhang (2004) studied a deterministic multi-period production and inventory control model and incorporated asset-based financing into production decisions. Dada and Hu (2008) studied the strategy for financing inventory management with capital constraints under given financing interest rates in the classical newsboy model. Kouvelis and Zhao (2012)studied the pricing of suppliers when retail enterprises pay all the money to suppliers in advance after borrowing from banks, and compared the preferences of retail enterprises for such financing strategy and their financing strategies from suppliers. Cai et al. (2014) proved that trade credit and bank credit can be replaced but if retailers have very low internal

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capital but it grows, and then empirically validated this prediction based on a panel of 674 firms in China over the period 2001-2007.

Although some literatures have studied the effects of different financing modes in the supply chain system to a certain extent, they have not taken into account the improvement of risk distribution in supply chain, and assumed that the enterprises subject to capital constraints have limited liability, which means that the borrowing enterprises that are declared bankruptcy do not need to repay the loans that can not be repaid, which is not in line with the actual situation. Kouvelis and Zhao (2011) found that there were differences between the optimal decision of bankruptcy risk model and that of traditional newsboy model. In the wholesale price contract of supply chain with supplier as the core, retailers should not only undertake the risk of market demand fluctuation alone, but also encounter the problem of order decision-making caused by capital constraints. Order amount is an important decision variable for retailers. When the retailer orders an insufficient amount, it will lead to a loss of customers, damage to goodwill and a decline in revenue, which is also known as shortage loss. When the retailer has excessive inventory, he not only needs to bear higher interest on borrowing, but there is also residual value loss of surplus products. Insurance, as an important risk management tool, has been widely used in real life. In recent years, scholars have also combined insurance with supply chain for in-depth studies. Jr and Taskin (2008) designed an insurance policy framework for government agencies, not-for-profit organizations, and private corporations to quantify the risks and benefits of inventory decisions that are related to preparations for disaster relief or supply chain interruption, and compared the optimal inventory levels under supply chain disturbance with the classical newsboy solution, while the difference was interpreted as insurance premium. In the light of risk transfer between subjects of supply chain, Lin et al. (2010) proposed an insurance contract and compared the insurance contract with the revenue-sharing contract, while the results showed that the insurance contract could coordinate the supply chain. With the rapid growth of trade credit, default risk increases accordingly. Wang et al. (2018) considered three common mechanisms to solve the problem of credit default, screening, checking or insurance, and found that retailers would prefer the insurance mechanism in case of poor credit of retailers. On the basis of the existing literature, this paper assumes that bankruptcy insurance is provided by the core enterprise in the supply chain for the changes in demand. It is assumed that, when the retailer goes bankrupt because

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of shortage loss and residual value loss, the bankruptcy loss is provided by the supplier, but the retailer needs to pay a certain guarantee fee to the supplier at the beginning. The insurance has not only improved the risk distribution within the supply chain, but also enables the guaranteed retailer to obtain bank financing so as to make reasonable decisions on ordering.

In addition, when the two subjects of the supplier and retailer are taken into account, it is likely that each member of the supply chain merely considers their own marginal benefits in decision-making, while neglecting the marginal benefits of other members in the supply chain, which may lead to the unilateral decision-making that may affect the market demand when the benefits of supply chain are distributed among different members. In this regard, each party will gain lower profits, thus resulting in the phenomenon of double marginalization. Li et al. (2013)explored a generalized supply chain model effected by supply uncertainty after the supplier had chosen the production input level. After investigating the decentralized systems under wholesale price contracts, results showed that double marginalization effects would lead to supply insufficiencies, in the cases of both deterministic and random demands. Jing et al. (2012)studied the case where both the retailer and the manufacturer were capital constrained. Results demonstrated that, for the sake of a higher efficiency of the overall supply chain, the bank should finance the manufacturer if production cost was low, otherwise, finance the retailer. Jing and Seidmann (2014)investigated the relative advantages and disadvantages of trade credit and bank credit in the supply chain composed of suppliers and retailers with constrained capital, and found that trade credit can more effectively alleviate double marginalization in case that the production is low. Hua et al. (2019) came to a different conclusion in the study on a two-echelon supply chain consisting of a capital-constrained retailer ordering via the option contract to satisfy uncertain demand from a single supplier, and believed that under trade credit, the supply chain will become more efficient in case of a high production cost and it will become less efficient in case of a low production cost. Based on the existing literature, this paper will also conduct a comparative study on the double marginalization of supply chain under two modes of trade credit and bank credit.

Furthermore, scholars also studied the coordinated management under the mode of supply chain finance, which is to coordinate the business collaboration of the supply chain through financing services so as to improve the overall efficiency of the supply chain, and achieve a win-win result. Cachon and Lariviere

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(2005)compared the revenue-sharing contract with other supply chain contracts and analyzed the issue concerning supply chain coordination in the classical newsboy model. Lee and Rhee (2011)investigated trade credit from the perspective of suppliers and regarded it as a tool of supply chain coordination. Assuming that retailers are subject to capital constraints and the cost of inventory financing is positive, they took into account four coordination mechanisms of supply chain contracts, namely, all-unit quantity discount, repurchase, double dipping and revenue sharing, concluding from the perspective of supplier-retailer cooperation in the construction of supply chain that the supply chain cannot be fully coordinated only based on the supplier's discount subsidies if the retailer adopts direct financing, and that if additional credit sales are used for the contract, the supplier can fully coordinate the supply chain to maximize the common profits.Kouvelis and Zhao (2016) studied the coordination of supply chain financing with capital constraints in the presence of bankruptcy costs and found that the necessary condition for supply chain coordination was to redistribute the debt in the channel in proportion, leading to the failure of the quantity discount contract to coordinate the supply chain. Peng et al. (2018) considered that the quantity discount contract can efficiently coordinate the low-carbon supply chain, but the revenue-sharing contract cannot. Hu et al. (2018) considered the supply chain coordination under the constraints of the retailer’s profit margin. In this paper, supply chain coordination will be achieved through design parameters, and the corresponding relationship between relevant parameters and supplier’s decision variable will be given.

2. Model description and basic hypothesis

Considering that the supplier has plenty of operating funds in the two-stage supply chain consisting of a single supplier and a single retailer but the retailer has no funds, the retailer can obtain funds by means of bank credit or trade credit. It is assumed that both the supplier and the retailer are risk-neutral and decentralized decision-makers, each pursuing the maximization of their own profits. The decision-making sequence of the supply chain can be summarized as follows: before the selling season, the supplier supplies the goods at a unit cost c, and sells it to the retailer at a wholesale price w, among which $w \leq w_0$(w_0 refers to the the highest price acceptable to the retailer). Then, the retailer determines the order quantity q according to the wholesale price, and sells the goods at the retail market

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at a price p. The market demand of the product $\widetilde{D}$ is random (the probability density function of $\widetilde{D}$ is f(x) and its cumulative distribution function is F(x)). At the end of the selling season, the residual value of the retailer's products not sold is v, and a unit shortage cost s is incurred when the order quantity q is less than the market demand $\widetilde{D}$.[1]

The residual value loss and the shortage loss arising from the fluctuations of market demand are as follows:

$$Y = \begin{cases} (p-v)\left(q-\widetilde{D}\right)\widetilde{D} \le q \\ s\left(\widetilde{D}-q\right)\widetilde{D} > q \end{cases}$$

(1)

In order to guarantee that the supplier's distribution channels are unimpeded, the supplier provides bankruptcy insurance for the trusted retailer and charges the insurance premium from the retailer. The retailer who purchases insurance can choose two financing modes of trade credit and bank credit, with an interest rate of bank credit r.

3. Research on supply chain coordination mechanism

In this section, we study the optimal decision-making of suppliers and retailers in two modes of trade credit and bank credit under the centralized and decentralized mechanisms, and then analyze the impact of model parameters on decision variables and profits of suppliers and retailers.

3.1. Research on supply chain coordination mechanism under the trade credit mode

Trade credit, an important source of financing for SMEs, is issued by suppliers to retailers, in which retailers can pay for finished products or services after receipt of goods. It is assumed that retailers with limited capital obtain funds through the mode of trade credit.

3.1.1 Centralized decision-making mechanism

Under the centralized decision-making mechanism, the overall profit function of the supply chain is as follows:

$$\Pi_1 = (p-c)q -$$

Y

(2)

Its expected profit function is as follows:

[1] Note: p>w>c>v>0, w>s>0.

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$$E[\Pi_1] = (p-c)q - \int_0^q (q-x)(p-v)f(x)dx - \int_q^{+\infty} s(x-q)f(x)dx \quad (3)$$

The first-order partial derivative of the expected profit of the whole supply chain to the output is as follows:

$$\frac{\partial E[\Pi_1]}{\partial q} = p - c + s - (p - v + s)F(q) \quad (4)$$

The second-order partial derivative of the expected profit of the whole supply chain to the output is as follows:

$$\frac{\partial^2 E[\Pi_1]}{\partial q^2} = -(p - v + s)f(q) \quad (5)$$

As shown in the Eq. (5), $\frac{\partial^2 E[\Pi_1]}{\partial q^2} < 0$, which means that there is an optimal production q_{cd}^* that maximizes the expected profit of the whole supply chain.

$$q_{cd}^* = F^{-1}\left(\frac{p-c+s}{p-v+s}\right) \quad (6)$$

Corollary1. Assuming that the market demand $\widetilde{D}$ obeys uniform distribution $\widetilde{D}$~[0,D], the optimal production under the centralized decision-making mechanism of trade credit is as follows:

$$q_{cd}^* = \frac{p-c+s}{p-v+s}D \quad (7)$$

The overall profit of the supply chain is as follows:

$$\Pi_1^* = \frac{D}{2}\left[\frac{(p+s-c)^2}{p+s-v} - s\right] \quad (8)$$

Corollary2. The relationship between the optimal production q_{cd}^*, the overall

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profit of the supply chain Π_1^* and parameters under the centralized decision-making mechanism of trade credit is shown in Table 1 as follows:

Table 1. The relationship between the optimal production, the overall profit of the supply chain and parameters under the centralized decision-making mechanism of trade credit

	p	c	v	s	D
q_{cd}^*	↑	↓	↑	↑	↑
Π_1^*	↑	↓	↑	↑	↑

As shown in Table 1, under the centralized decision-making mechanism of trade credit, it is equivalent to suppliers producing products and selling them directly in the retail market. The optimal production is positively correlated with p, v, s, D and negatively correlated with c. The higher the retail price and the market demand are, the larger the optimal production determined by the supplier will be. The higher the production cost is, the smaller the optimal production will be. When the residual value of the product is even close to the cost, the supplier will produce the products infinitely. When the shortage cost is higher, the supplier will increase the optimal production so as to lower the loss caused by the shortage. The change in the overall profit of the supply chain is consistent with that of the optimal production to parameters.

3.1.2. Decentralized decision-making mechanism

The profit function of the retailer under the general wholesale price contract is as follows:

$$\Pi_r = (p-w)q - Y =$$

$$\begin{cases} (p-w)q - (p-v)\left(q-\widetilde{D}\right)\widetilde{D} \le q \\ (p-w)q - s\left(\widetilde{D}-q\right)\widetilde{D} > q \end{cases} \quad (9)$$

Unlike the sales mode on trade credit in the existing literature, it is assumed that the premium paid by the retailer to the supplier is as follows in accordance with the theory of insurance:

$$I_1 = \lambda E[max(-\Pi_r, 0)]$$

$$= \lambda\left[(p-v)\int_0^{\mu_1 q}(\mu_1 q - x)f(x)\,dx + s\int_{\mu_2 q}^{+\infty}(x - \mu_2 q)f(x)\,dx\right] \quad (10)$$

If the retailer loses money, the retailer can get compensation from the supplier

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as follows:

$$Z_1 = max(-\Pi_r, 0) =$$

$$\begin{cases} -(p-v)\widetilde{D} + (w-v)q\widetilde{D} \le \frac{w-v}{p-v}q \\ s\widetilde{D} - (p-w+s)q\widetilde{D} \ge \frac{p-w+s}{s}q \\ 0 \qquad \text{Otherwise} \end{cases}$$

(11)

Setting $\mu_1 = \frac{w-v}{p-v}$, $\mu_2 = \frac{p-w+s}{s}$, obviously,$\mu_1 < 1, \mu_2 > 1$, which means that there will be compensation incurred when the deviation between market demand $\widetilde{D}$ and the order quantity q reaches a certain extent.

After the introduction of the insurance contract, the retailer's profit function can be expressed as follows:

$$\Pi_{r1} = (p-w)q - Y - I_1 + Z_1$$

(12)

The expected profit function of the retailer is as follows:

$$E[\Pi_{r1}] = (p-v)\int_{\mu_1 q}^{q}(x-\mu_1 q)f(x)\,dx + s\int_{q}^{\mu_2 q}(\mu_2 q - x)f(x)dx - \lambda(p-v)\int_{0}^{\mu_1 q}(\mu_1 q - x)f(x)dx + \lambda s\int_{\mu_2 q}^{+\infty}(x - \mu_2 q)f(x)\,dx \quad (13)$$

The first-order partial derivative of the retailer's expected profit to order quantity q can be expressed as follows:

$$\frac{\partial E[\Pi_{r1}]}{\partial q} = (1-\lambda)(w-v)F(\mu_1 q) + (1-\lambda)(p-w+s)F(\mu_2 q) - (p-v+s)F(q) + \lambda(p-w+s)$$

(14)

The second-order partial derivative of the retailer's expected profit to order quantity q can be expressed as follows:

$$\frac{\partial^2 E[\Pi_{r1}]}{\partial q^2} = (1-\lambda)(w-v)\mu_1 f(\mu_1 q) + (1-\lambda)(p-w+s)\mu_2 f(\mu_2 q) - (p-v+s)f(q)$$

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(15)

Setting $\lambda > max(1 - \frac{(p+s-v)f(q)}{(w-v)\mu_1 f(\mu_1 q)+(p-w+s)\mu_2 f(\mu_2 q)}, 0)$, then $\frac{\partial^2 \mathrm{E}[\Pi_{r1}]}{\partial q^2} < 0$.

When the above condition is satisfied, there is an optimal order quantity q_1^* to maximize the expected profit of retailers. Thus, the optimal order price q_1^* can be obtained by setting the Eq. (14) equal to zero.

Assuming that the supplier can foresee the retailer's optimal response function q_1^* when deciding the wholesale price w, the profit function of the supplier is as follows:

$$\Pi_{m1} = (w - c)q_1^* + I_1 - Z_1 \quad (16)$$

Its expected profit function is as follows:

$$E[\Pi_{m1}] = (w - c)q_1^* + (\lambda - 1)(p - v)\int_0^{\mu_1 q_1^*}(\mu_1 q_1^* - x)f(x)\,dx +$$

$$(\lambda - 1)s\int_{\mu_2 q}^{+\infty}(x -$$

$$\mu_2 q_1^*)f(x)dx$$

(17)

Taking was the independent variable, the partial derivative of $E[\Pi_{m1}]$ is obtained. According to the first-order and second-order conditions of profit maximization, the wholesale price can be obtained as follows in case of the maximization of suppliers' expected profit when the first-order partial derivative is set equal to 0:

$$\frac{\partial E[\Pi_{m1}]}{\partial w} = q_1^* + (w - c)\frac{\partial q_1^*}{\partial w} + (\lambda - 1)(\int_0^{\mu_1 q_1^*}\frac{\partial q_1^*}{\partial w}f(x)\,dx +$$

$$\int_{\mu_2 q_1^*}^{+\infty}\frac{\partial q_1^*}{\partial w}f(x)\,dx) \quad (18)$$

Setting $\frac{\partial E[\Pi_{m1}]}{\partial w} = 0$, the optimal order price w_1^* can be obtained.

Proposition 1. Under the decentralized decision-making mechanism of trade credit, the optimal decisions made by retailers and suppliers from the perspective of maximizing individual interests are as follows:

$$\begin{cases} (1-\lambda)(w-v)F(\mu_1 q_1^*) + (1-\lambda)(p-w+s)F(\mu_2 q_1^*) \\ -(p-v+s)F(q_1^*) + \lambda(p-w+s) = 0 \\ q_1^* + (w-c)\frac{\partial q_1^*}{\partial w} + (\lambda-1)(\int_0^{\mu_1 q_1^*}\frac{\partial q_1^*}{\partial w}f(x)\,dx + \int_{\mu_2 q_1^*}^{+\infty}\frac{\partial q_1^*}{\partial w}f(x)\,dx) = 0 \end{cases} \quad (19)$$

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Corollary3. When the supplier insurance market is a perfect insurance market, i.e. $\lambda = 1$, the optimal order quantity is as follows:

$$q_1^* = F^{-1}\left(\frac{p-w+s}{p-v+s}\right)$$ [2]

(20)

Assuming the market demand $\widetilde{D}$ obeys the uniform distribution $\widetilde{D}$~[0,D], the optimal decision is as follows under the decentralized decision-making mechanism of trade credit in a perfectly competitive insurance market:

$$\begin{cases} q_1^* = \frac{p-w+s}{p-v+s}D \\ w_1^* = \frac{p+s+c}{2} \end{cases}$$

(21)

Corollary4. The condition of supply chain coordination under the decentralized decision-making mechanism is to induce the retailer to purchase the optimal order quantity of goods equivalent to the optimal production under the centralized decision-making mechanism. By adjusting the insurance weight coefficient λ, $q_1^* = q_{cd}^*$.It is set that $\# = \frac{s(w_1^*-v)^2(p-c+s)+(p-v)(p-c+s)(p-w_1^*+s)^2}{s(p-v)(p-v+s)}$. Assuming that the market demand $\widetilde{D}$ obeys the uniform distribution $\widetilde{D}$~[0,D], the optimal insurance weight coefficient λ_1^* can be obtained as follows when the supply chain is coordinated:

$$\lambda_1^* = \frac{p-c+s-\#}{p-w_1^*+s-\#}$$

(22)

3.2. Research on the supply chain coordination mechanism under the mode of bank credit.

The development of SMEs is inseparable plenty of circulating funds, but it is difficult for a number of enterprises to avoid difficulties in capital turnover. At this time, a great many SMEs choose to apply for bank loans. The following will analyze how retailers that are subject to capital restraints solve the shortage of funds for goods purchase by means of bank credit. It is less likely for SMEs to provide collateral and pledge needed by banks because of their small number of

[2]At this time, the insurance market is perfectly competitive.

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funds and small scale of operation. At this moment, it becomes an approach to overcome the difficulty in lending by obtaining the credit guarantee from a third party. It is assumed in this paper that the supplier acts as the guarantor of the retailer's bank credit and that the supplier repays the bankrupt part of the bank credit for the retailer when the latter goes bankrupt. In order to obtain this insurance right, the retailer pays a premium to the supplier.

3.2.1. Centralized decision-making mechanism

Under the centralized decision-making mechanism, the overall profit function of the supply chain is as follows:

$$\Pi_2 = (p - c(1+r))q - Y \tag{23}$$

Its expected profit function is as follows:

$$E[\Pi_2] = (p - c(1+r))q - (p-v)\int_0^q (q-x)f(x)dx - s\int_q^{+\infty}(x-q)f(x)dx \tag{24}$$

Its optimal production q_{cd}^{**} is as follows:

$$q_{cd}^{**} = F^{-1}\left(\frac{p-c(1+r)+s}{p-v+s}\right) \tag{25}$$

Corollary5. Under the centralized mechanism, the optimal production of trade credit is larger than that of bank credit.

In fact, it can be inferred that $F^{-1}\left(\frac{p-c+s}{p-v+s}\right) > F^{-1}(\frac{p-c(1+r)+s}{p-v+s})$ from $c < c(1+r)$, which means $q_{cd}^{*} > q_{cd}^{**}$.

3.2.2. Decentralized decision-making mechanism

The retailer's profit function under the general wholesale price contract is as follows:

$$\Pi_r = \big(p - w(1+r)\big)q - Y$$

$$= \begin{cases} (p - w(1+r))q - (p-v)\big(q - \widetilde{D}\big)\widetilde{D} \le q \\ (p - w(1+r))q - s\big(\widetilde{D} - q\big)\widetilde{D} > q \end{cases} \tag{26}$$

The amount of compensation paid by the supplier for the retailer is as follows:

$$Z_2 =$$

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$$\begin{cases} -(p-v)\widetilde{D} + (w(1+r)-v)q\widetilde{D} \le \frac{w(1+r)-v}{p-v}q \\ s\widetilde{D} - (p-w(1+r)+s)q\widetilde{D} \ge \frac{p-w(1+r)+s}{s}q \\ 0 \qquad \text{other} \end{cases} \quad (27)$$

Corollary6. Setting $\mu_3 = \frac{w(1+r)-v}{p-v}$,$\mu_4 = \frac{p-w(1+r)+s}{s}$, it can be obtained that $0 < \mu_1 < \mu_3 < 1 < \mu_4 < \mu_2$ since the bank interest rate $r > 0$. Then, when the retailer chooses bank credit, the probability that there is a loss due to the demand fluctuations will increase.

Due to the premium:

$$I_2 = \lambda E[max(-\Pi_r, 0)]$$

$$= \lambda[(p-v)\int_0^{\mu_3 q}(\mu_3 q - x)f(x)\,dx + s\int_{\mu_4 q}^{+\infty}(x - \mu_4 q)f(x)\,dx] \quad (28)$$

After the introduction of insurance contract, the retailer's profit function under the decentralized decision-making mechanism is as follows:

$$\Pi_{r2} = (p - w(1+r))q - Y - I_2 + Z_2 \quad (29)$$

It can prove that there is an optimal order quantity q_2^* to maximize the retailer's expected profit.In fact, it is set as follows:

$$(1-\lambda)(w(1+r)-v)F(\mu_3 q_2^*) + (1-\lambda)(p-w(1+r)+s)F(\mu_4 q_2^*) - (p-v+s)F(q_2^*) + \lambda(p-w(1+r)+s) = 0 \quad (30)$$

As the supplier can foresee the retailer's optimal response function q_2^* when deciding the wholesale price w, the supplier's profit function is as follows:

$$\Pi_{m2} = (w-c)q + I_2 - Z_2 \quad (31)$$

According to the first-order and second-order conditions of profit maximization, the optimal wholesale price w_2^* satisfies the following condition when the supplier's expected profit is maximized:

$$q_2^* + (w-c)\frac{\partial q_2^*}{\partial w} + (\lambda - 1)(\int_0^{\mu_3 q_2^*}\frac{\partial q_2^*}{\partial w}f(x)\,dx + \int_{\mu_4 q_2^*}^{+\infty}\frac{\partial q_2^*}{\partial w}f(x)\,dx) = 0 \quad (32)$$

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Proposition 2. Under the decentralized decision-making mechanism of bank credit, the optimal decisions made by the retailer and the supplier in order to maximize their interests satisfy the following conditions:

$$\begin{cases} (1-\lambda)(w(1+r)-v)F(\mu_3 q_2^*) + (1-\lambda)(p-w(1+r)+s)F(\mu_4 q_2^*) \\ \qquad -(p-v+s)F(q_2^*) + \lambda(p-w(1+r)+s) = 0 \\ q_2^* + (w-c)\frac{\partial q_2^*}{\partial w} + (\lambda-1)(\int_0^{\mu_3 q_2^*} \frac{\partial q_2^*}{\partial w} f(x)\,dx + \int_{\mu_4 q_2^*}^{+\infty} \frac{\partial q_2^*}{\partial w} f(x)\,dx) = 0 \end{cases}$$

(33)

Corollary 7. It is set as $\#_1 = \frac{(w_2^*(1+r)-v)^2(p-c(1+r)+s)}{(p-v)(p-v+s)}$,$\#_2 = \frac{(p-c(1+r)+s)(p-w_2^*(1+r)+s)^2}{s(p-v+s)}$. Assuming that the market demand $\widetilde{D}$ obeys the uniform distribution $\widetilde{D}$~[0,D], the optimal insurance weight coefficient λ_2^* is as follows to make the supply chain coordinated under the bank credit mode:

$$\lambda_2^* = \frac{p-c(1+r)+s-\#_1-\#_2}{p-w_2^*(1+r)+s-\#_1-\#_2}$$

(34)

4. Numerical analysis

Numerical analysis was conducted on the impact of model parameters on the ordering strategies and expected profits of members in the supply chain. First of all, it is assumed that the retail price p=40, the production cost c=10, the residual value of surplus products v=3, the shortage loss s=6, the insurance weight coefficientλ=0.70, the bank interest rate r=0.05 and the maximum market demand D=1,000. The following will study the effect of introducing insurance and the profit of the decision-makers under the two financing modes.

Insurance agreement is an important concept introduced in this model. Among them, the parameter λ is the insurance intensity coefficient required by the supplier. The larger λ is, the higher the premium paid by the retailer to the supplier will be. On the contrary, the lower the bankruptcy compensation the supplier pays for the retailer will be. The influence of insurance weight coefficient is shown in Figure 1-4 as follows:

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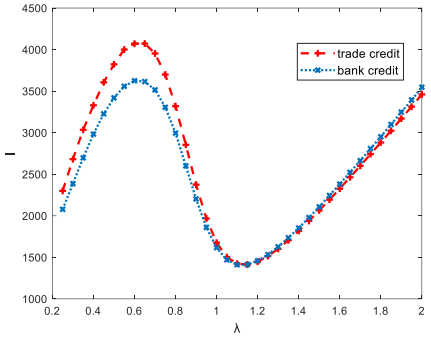

Figure 1. Relationship between premiumI and λ

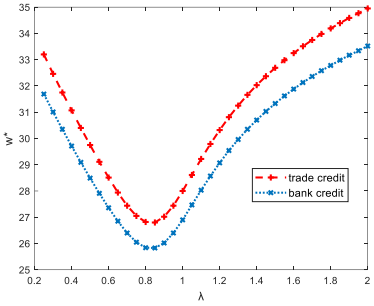

Figure 2. Relationship between w* and λ

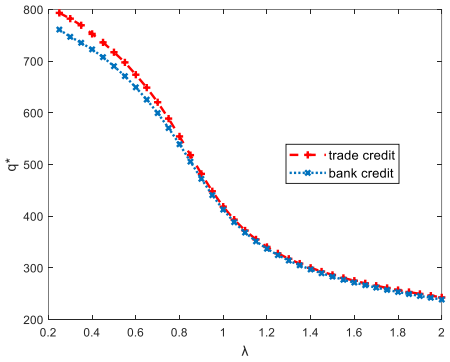

Figure 3. Relationship between q* and λ

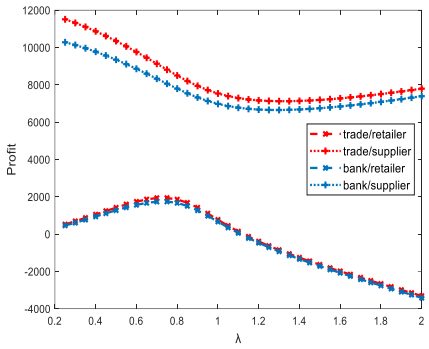

Figure 4.Relationship between profit and λ

Generally speaking, the premium should increase with the increase of insurance weight coefficient. However, as can be seen from Figure 1, the premium first increases progressively and then decreases progressively and finally increases with the weight coefficient λ, which is because the bankruptcy insurance is an agreement within the supply chain and a transfer payment within the supply chain system. The change in the weight coefficient λaffects the optimal decision-making of the retailer and the supplier. As shown in Figure 3, the order quantity of retailers decreases with the increase of insurance weight coefficient. When the insurance weight coefficient increases, the retailer should bear more insurance premium, so that the retailer chooses to lower the optimal order quantity. According to Figure 1-3, in case of $0.6 \leq \lambda \leq 1.1$, the premium decreases with the increase of the weight coefficient because the wholesale price does not change significantly during this period, while the retailer dramatically lowers the order quantity because of the

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increase in the insurance weight coefficient, thus changing the distribution of the retailer's profit and ultimately leading to the decline in the premium. As shown in Figure 4, when the weight of insurance coefficient is greater than 1.1, the retailer will not accept the insurance.

The supply chain can be coordinated by changing the value of λ, the relationship between the optimal wholesale price determined and the corresponding value of λto coordinate the supply chain is shown in Figure 5 as follows:

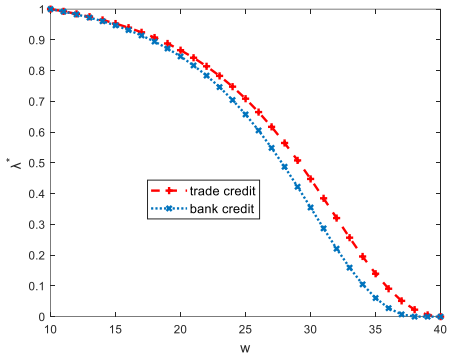

Figure 5.Relationship between λ^* and w

When the supply chain is coordinated, the insurance weight coefficient λ is smaller than 1, and thus suppliers, as core enterprises, do not make profits through the insurance contract but choose a lower insurance weight coefficient to motivate retailers to choose higher order quantity. The following will analyze the decisions and profit of each decision-maker under the two financing modes. The results of the comparative analysis are shown in Table 2:

Table 2. Parameter analysis of optimal decision and profit of the supplier and the retailer under two financing modes[3]

parameter	w*	q*(centralized mechanism)	Π_m	Π_r	q*(decentralized mechanism)	Supply chain efficiency
p=35	24.33	588.15	7328.60	1331.55	815.79	89.79%
	23.43	568.83	6654.78	1164.80	802.63	84.62%
p=40	27.44	620.64	9129.69	1931.68	837.21	91.64%
	26.40	599.70	8328.45	1736.87	825.58	86.37%
c=5	26.16	732.12	12509.08	2983.82	953.49	93.63%
	25.12	711.22	11606.36	2784.96	947.67	88.24%

[3] The first line of each parameter represents the case of the trade credit mode, and the second line represents the case of the bank credit mode.

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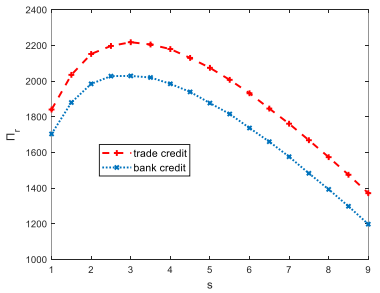
c=12	28.05	576.32	7933.05	1520.75	790.70	90.53%
	27.00	556.20	7172.79	1335.90	776.74	85.32%
v=0	27.24	575.01	8420.20	1675.50	782.61	91.06%
	26.21	556.49	7682.41	1499.28	771.74	85.82%
v=4	27.52	636.78	9390.14	2018.72	857.14	91.80%
	26.47	615.43	8565.43	1821.68	845.24	86.54%
s=1	32.32	721.01	10133.63	1840.43	815.79	98.60%
	30.86	682.48	9050.46	1703.54	802.63	91.60%
s=5	27.72	632.32	9160.54	2074.30	833.33	92.98%
	26.65	608.89	8337.50	1876.64	821.43	87.52%
r=0.03	27.44	620.64	9129.69	1931.68	837.21	91.65%
	26.81	607.48	8637.36	1809.13	830.23	88.38%
r=0.08	27.44	620.64	9129.69	1931.68	837.21	91.65%
	25.81	588.56	7891.53	1633.75	818.60	83.50%

From Table 2, we can see that the trade credit mode is superior to the bank credit mode in terms of both supplier and retailer's profit and supply chain efficiency, which further verifies the conclusion of Corollary 5. With the rise of bank interest rate, both sides' profit under the bank credit mode decreases and the efficiency of the supply chain decreases significantly, which aggravates double marginalization. For parameters p and c, increasing retail prices and reducing production costs can naturally increase the profits of both sides and alleviate double marginalization. The higher the residual value of the product is, the higher the profits of both sides will be. However, the change of residual value of products has no significant impact on supply chain efficiency. For the shortage cost s, it can be seen from the table that there is no monotonous relationship between the profits of both parties and the shortage cost. Figure 6-9 further analyses the impact of the shortage cost s.



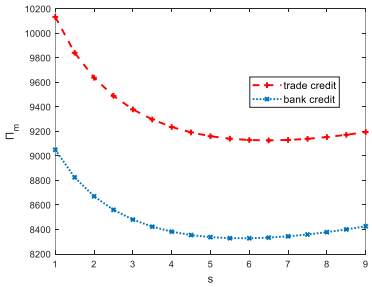


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Figure 6.Relationship between Π_r and s

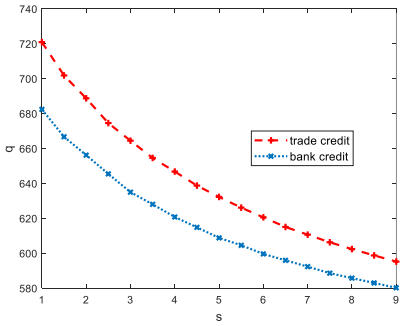

Figure 7.Relationship between Π_m and s

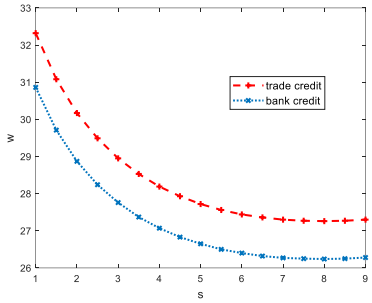

Figure 8.Relationship between q* and s

Figure 9.Relationship between w* and s

As shown in Figure 6-9, it can be seen that, when $\lambda < 1$, insurance, as a tool of income distribution within the supply chain, sacrifices the supplier's income and promotes the retailer to maintain a higher order quantity, thus improving the efficiency of the supply chain. With regard to the increase of the shortage cost, the retailer chooses to reduce the order quantity in order to reduce his own risk while the supplier anticipates a reduction in order quantity to lower the wholesale price, and the wholesale price drops faster than before, so the retailer's profit increases first and then decreases, and the supplier's profit decreases quickly and then tends to be flat. Furthermore, under the centralized decision-making mechanism, when the cost of goods shortage increases, the risk of goods shortage will be dealt with by increasing the output, and thus the change in the optimal order quantity is inversely related to that of the cost of goods shortage under the centralized and decentralized decision-making mechanisms. Therefore, under the insurance contract model, the increase of the cost of goods shortage greatly aggravates double marginalization.

5. Conclusion

For SMEs, capital turnover is one of the links that affect the development of enterprises. Most of the SMEs have undergone financial shortage. Coupled with the regulations of banks on tightening loans, it is likely for SMEs to fall into the dilemma of poor capital turnover. In this paper, the bankruptcy insurance of retailers is introduced into the supply chain coordination mechanism and the optimal decision-making of suppliers and retailers under two modes of trade credit and bank credit is studied in view of the fact that retailers are subject to capital constraints, and the influence of parameters on the overall profits of supply chain

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and the double marginalization is discussed, while the insurance weight coefficient is further designed to achieve the supply chain coordination. The results show that the increase of insurance weight coefficient will lead to a sharp decline in order quantity of retailers, and that retailers will not accept the bankruptcy insurance provided by suppliers in case of excessive the weight of insurance coefficient. As the guarantor of bankruptcy for core enterprises and retailers, suppliers will choose lower insurance weight coefficients to encourage retailers to choose a higher order quantity instead of making profits through an insurance contract. The trade credit mode is superior to the bank credit mode in terms of the profit of suppliers and retailers and the efficiency of the supply chain. Moreover, the rise in the bank interest rate or in the shortage cost has greatly aggravated the double marginalization. In the future studies, we will further explore the supply chain coordination mechanism and double marginalization in case that the suppliers are subject to capital constraints.

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