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Financing the overconfident newsvendor under the information asymmetry

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Abstract: Overconfident newsvendors perceive the expected outcome of an uncertain event as more certain than actuality. Built upon the classic newsvendor model, a system with a profit-maximizing bank and an overconfident retailer is studied, where the retailer is capital-constrained and might borrow bank loans. Based on retailers' initial capital, we clarify them as severely poor, medium poor and rich, respectively. We obtain the equilibrium order quantity and bank interest rate under the information symmetry and asymmetry. Under the information symmetry, when the retailer is severely poor or medium poor, he always accesses bank loans. Under the information asymmetry, when the retailer is severely poor, he borrows from the bank. However, when the retailer is medium poor, he uses up all his initial capital without borrowing bank loans. The retailer with limited funds is willing to disclose his cognition of the market demand to the bank. The information asymmetry might reduce the loss of the system's profit, which is caused by double marginalization effect.

Keywords: Stackelberg game; bank financing; overconfident newsvendor; information asymmetry
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1 Introduction

In the process of the enterprise operation, managers always make decisions to maximize the profit of their own companies. From the perspective of the whole system, these are not always the optimal decisions. This phenomenon is called double marginalization. Spengler, an American economist, researched the behavior of industrial organization that when there is a single upstream seller (such as a manufacturer) and a single downstream buyer (such as a distributor) in the industry chain. In the market, in order to maximize their respective interests, upstream and downstream enterprises have caused the entire industry chain to experience two price increases (marginalization). However, the downstream buyer whose purpose is to maximize his own profits tends to purchase products in quantities that are not optimal for the upstream.

Double marginalization involves the firm's ordering decisions. In fact, the decision-making behavior between upstream and downstream regarding product price, quality, promotion, technology, etc., which only considers self-interest, is a form of double marginalization. Double marginalization is the essential source of channel conflicts.

When facing uncertain marketing demand, managers of companies always need to decide the quantity of purchased goods. To make better decisions, managers consider several factors, such as risks of demand variety, inventory costs, financing costs and available liquid capital. Limited capital is the constraint for a large number of companies when making purchase decisions, especially for small- and medium-sized enterprises. In the case that liquid capital is limited, companies need to enhance the purchasing power by means of short-term financing. Bank financing is one of the important short-term financing. Now a lot of researchers consider banks to be completely competitive. However, for small- and medium-sized enterprises and start-ups, it is often difficult to dominate the process of financing from banks due to the lack of collateral, credit history and business reliability.

Enterprises use short-term financing when their capital is limited. There are two kinds of common short-term financing sources: external short-term financing and internal short-term financing. The external short-term financing may come from bank loans or loans from third-part investment institutions. The interest rate of

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external short-term financing may be determined by markets (in the case of complete competition) or by banks and third-part investment institutions (in the case of monopoly by banks or third-party investment institutions). Internal financing often refers to the financing from the internal supply chain, generally seeking financing from the upstream or downstream of its own supply chain. For example, if the retailer seeks financing from upstream companies, the wholesale price paid before the start of the selling season will be lower than that paid by the retailer after the start of the selling season. When the capital is not enough to support the optimal operation and the company has short-term financing sources, the enterprise will not necessarily use short-term financing, which depends on the initial capital and the interest rate of short-term financing. When enterprises choose short-term financing, there are advantages and disadvantages between different kinds of short-term financing methods.

A large number of articles have considered the problem of limited funds that enterprises may face before. Limited capital is a problem that many enterprises often face, especially small- and medium-sized enterprises. Earlier operational research papers default that enterprises will not face the problem of limited funds, and study the optimal decision of enterprises without considering the limited funds. In fact, the funds or resources of enterprises are almost impossible to be unlimited, and they might not be able to support the enterprises to make the optimal decisions. At this time, they need to use short-term financing to make up for their own financial defects. Therefore, many subsequent papers began to study the optimal decision making of enterprises in the case of limited funds. The majority of these papers typically rely on a key assumption—that is, decision-makers are rational.

Nowadays, more and more behavioral researches have emerged, and have identified a wide range of biases. These biases might have influence on the decision-making in the operation management. Within these biases, overconfidence is a kind of cognitive bias that decision-makers think the outcome of an uncertain event is more certain than it really is. It's one of the most consistent, powerful, and widespread cognitive biases[1]. Ren[2] built the model of overconfident retailer's decision in the supply chain and obtains the linear relationship between the retailer's optimal order quantity and the degree of overconfidence and the extra expenses caused by the retailer's overconfidence.

In the process of enterprise operation, managers tend to be more optimistic about the situation of the enterprise, such as the market size and stability. Psychological researches have shown that most people are overconfident in their relative abilities and over-optimistic about their future[3,4]. People are often overconfident in the estimation of random results, and they always believe that the expected results of uncertain events are more accurate than the actual situation. For the operation management, overconfidence is one of the most common and influential cognitive biases. Overconfidence also occurs in trained decision-makers. Croson et al.[5] conducted a survey among undergraduate and graduate students: A uniform distribution with a lower limit of 1 and an upper limit of 300 was considered. This means that any number between 1 and 300 may be drawn. Two questions are asked to the students participating in the survey: What are your estimates of the 25% percentile of this distribution? What is the estimate of 75% quantile of this distribution? They found that the difference between the two answers was 126.24, while the theoretical difference between the two answers should be 150.

Overconfidence is widespread. Overconfidence refers to the arbitrariness of people. Overconfident decision-makers are often independent of their own decisions and do not change for the development law of objective things and changes in the objective environment. Overconfidence has been observed in almost all professions. Overconfidence can also be understood as a kind of cognitive bias. People believe that their grasp of some information is more accurate, so overconfidence is often more likely to appear in their specialty or field of expertise.

Overconfidence might lead to serious consequences. Previous studies have used overconfidence to explain some past wars, corporate failures and stock market bubbles[6-12].

Overconfidence is classified in previous literature[13]. The first type is called overestimation. People always overestimate their abilities and the possibility of success. For example, a student did a test with 20 questions and thought he had answered 15 questions correctly, but in fact, the number of questions he might have answered correctly was only 12. In fact, about 64% of empirical researches are aimed at this type of overconfidence. The second one is that people often think they are better than others. In fact, most people think they are above average. About 5% of empirical researches are aimed at this type of overconfidence. The third type is called overconfidence. This kind of overconfidence refers to people's overconfidence in the accuracy of their cognition. About 31% of empirical researches are about this kind of overconfidence. In this paper, we study the third kind of overconfidence.

Information economics believes that information asymmetry has caused an imbalance in the interests of both parties in market transactions, affecting the principles of social fairness and justice, and the efficiency of market allocation of resources. For example, buyers are always inferior to sellers of the information about purchased goods. Therefore, the sellers can always get rewards beyond the value of the goods by virtue of their information advantages. Because of the information asymmetry, the transaction relationship has become a principal and agency relationship. Among them, the member with the information advantage in the transaction is the agent, and the member without the information advantage is the principal. The two members in the transaction are actually playing an information game. The person who possesses the information gains an advantage in the transaction. This is actually a kind of information rent value. In fact, the information rent is the link between each transaction link.

Most of the current literature on supply chain financing does not consider information asymmetry and overconfidence. The existing information asymmetry literature often considers the asymmetry of cost information, but in fact the asymmetry of information involves many aspects. The asymmetry of demand information is common in reality, and the accuracy of the supply chain members' cognition of the market is different. The supply chain members may not share their cognition of demand with other members. Overconfidence has been mainly studied in the literature of supply chain management in the past. The literature generally does not consider the limited funding of supply chain members, which does not correspond to reality.

We set up a single-stage Stackelberg game model with information symmetry and asymmetry. There are two players in the game, namely the bank which is the leader in the game and the retailer which is the follower. First of all, the bank sets the interest rate of bank loans. According to the interest rate of bank loans, his own initial funds and his cognitive marketing demand, the retailer determines the ordering quantity of goods, whether to get loans from the bank and the amount of bank loans. After the selling season, if the income of the retailer is not enough to repay the principal and interest of the bank loans, the retailer will go bankrupt and the bank will only receive part of the loans.

The information in the system might be symmetric, that is, the bank knows that the retailer is overconfident, or asymmetric, that is, the bank does not know that the retailer is overconfident. We consider a system consisting of a monopoly bank and a capital-constrained retailer. The bank determines the loan interest rate and the retailer decides the order quantity of products in response to the uncertain demand in the marketing stage. Retailers are overconfident and have a biased perception of the market demand. The market demand perceived by retailers is less volatile than the actual market demand.

Finally, we obtain the equilibrium ordering quantity and bank loan interest rate under information symmetry and asymmetry. Under information symmetry and information asymmetry, the retailer's decisions of short-financing are different. The retailer with limited funds is willing to disclose his cognition of market demand to the bank to get more profits. Information asymmetry might reduce the loss of the system's profit, which is caused by double marginalization effect.

We divide the paper into six parts. After Introduction, we review the existing literature from perspectives of short-term financing, information asymmetry and overconfidence. Then, we present the model with three situations: without short-term financing, when the retailer is overconfident under information asymmetry, or overconfident under information symmetry. After that, we use numerical experiments to compare the retailer's profit, the bank's profit, the retailer's order quantity and the system's profit under information symmetry and asymmetry, respectively. In the end, we present the conclusions of this paper.

2 Literature review

Our research is closely related to two aspects of literature: Overconfident newsvendors and short-term financing in operations and management-finance (OM-finance) interface.

We would review the existing literature from perspectives of short-term financing, information asymmetry and overconfidence.

2.1 Short-term financing in OM-finance interface

The researches related to supply chain financing are aimed to solve the financial difficulty faced by small- and medium-sized enterprises. Most of literature on operation management believed that the company had enough funds to support the production and purchase of the optimal number of goods. In fact, many companies do not have enough initial capital to support operations. Buzacott and Zhang[14] firstly considered the situation that the company might be overconfident. In the absence of short-term financing, they might have to give up the optimal decision-making, which shows the importance of short-term financing. Pfohl and Gomm[15] reviewed the researches regarding financial flows in supply chains, and proposed a conceptual framework for mathematical model of supply chain financing.

The two common forms of short-term financing are bank financing and trade credit financing.

Bank financing is a common way of short-term financing. Generally, we will divide banks into two situations in the model, perfect competition and monopoly. Buzacott and Zhang[14] modeled the available funds in each period as a function of assets, and could be updated according to the dynamics of the production activities. Dada[16] considered a game model with a monopolistic leader bank and a retailer with insufficient funds. Zhou and Groenevelt[17] focused on a supply chain with a supplier and a retailer with limited funds. The supplier would help the capital-constrained retailer to repay the interest expense of bank loans. Zhang[18] studied a multi-product newsboy problem with supplier quantity discounts and budget constraint. Zhang et al.[19] studied a supply chain with a manufacturer and multiple capital-constrained retailers, where the retailers had accesses to bank loans. They considered a game-theoretic model consisting of a large seller and multiple capital-constrained newsvendors, who obtain financing from banks subject to capital regulation. The seller sets the wholesale price and decides whether to orchestrate a joint finance program for its dealers by collaborating with a bank, and the dealers choose their inventory level and the financing source. Bi et al.[20] provided theoretical guidelines for employing an innovative bank financing scheme in a push supply chain, where the supplier shares partial of the retailer's bank loan repayment. Kouvelis and Xu[21] developed a supply chain theory of (recourse/ non-recourse) factoring and reverse factoring showing when these post-shipment financing schemes should be adopted and who really benefits from the adoption.

Another common short-term financing source is trade credit financing. Zhao and Huchzermerier[22] studied a supply chain with suppliers and retailers with limited funds. They solved the problem of limited funds in two ways: choosing the earlier payment with a lower unit price and the later payment with a higher price, or buyer backed purchase order financing.

Besides these, if retailer orders rely on the entire working capital, we refer to it as self-financing. Moreover, a lot of literature has studied multiple short-term financing sources. Chen et al.[23] studied a model with a completely competitive bank, a supplier and a capital-constraint retailer, and examined the retailer's choice between these two sources. Kouvelis and Zhao[24] studied a system consisting of a completely competitive bank, a supplier and a retailer facing capital constraints. Kouvelis and Zhao[25] studied a supplier and a retailer with limited capital and a bank with bank interest rate determined by credit rating. The supplier can use the bank loans, the retailer's advance payment and his own initial funds for production, and the retailer can use the bank loans and trade credit when necessary. Deng et al.[26] compared buyer finance with bank finance in a supply chain with an assembly and multiple heterogeneous capital-constrained component suppliers.

2.2 Information asymmetry

Information asymmetry might involve various types, such as demand data, inventory data, cost information. Cachon et al.[27] researched the value of sharing demand and inventory data among one supplier, multiple identical retailers in the model.

Most literature about information asymmetry considers that only part of the supply chain members get the full information about cost. Cakanyildirim et al.[28] analyzed a supply chain composed of a supplier and a retailer, where the supplier's unit production cost is only known to himself, and discussed the retailer's preference for supplier types under different market conditions, and evaluated the influence of the reserve profit of the supplier, retail price and demand uncertainty on the best contract. Cao et al.[29] studied the wholesale price contract design in a dual-channel supply chain under asymmetric cost information, and analyzed the impact of asymmetric cost information on the equilibrium strategy, profit of supply chain members, and the value of cost information in the perspective of the entire system and system members. Zissis et al.[30] considered a supply chain consisting of a manufacturer and a retailer, where the manufacturer provides a quantity discount contract and the retailer has private information about the inventory costs. Ma et al.[31] considered a supply chain that includes a supplier and a retailer, where the supplier can invest in corporate social responsibility activities to improve customers' perceptions of the company and increase demand, while the retailer can apply marketing efforts to improve the demand. The retailer lacks complete information on the cost of corporate social responsibility activities. Kerkkamp et al.[32] analyzed the principal-agent contract model with asymmetric information between a supplier and a retailer. Both the supplier and the retailer have a classic nonlinear economic ordering cost function, including ordering and holding costs.

2.3 Overconfident newsvendor

Overconfidence is a common kind of human property. There have been quantities of papers in consideration of this consumers' property. Odean[12] studied the market with overconfident price makers, strategic insiders and risk averse market makers. Camerer and Lovallo[6] published an empirical study, which showed that the failure rate of business is very high. This paper created an experimental introductory game to explore whether overconfidence in one's own ability is part of the reason for the high failure rate. Hilary and Menzly[33] pointed out that the analysts with more accurate revenue forecasts in the first four quarters are often far from the consensus in subsequent revenue forecasts. Ishikawa and Takahashi[34] tested the relationship between managerial overconfidence and corporate financing decision-making based on the previous records of earnings forecasts of listed companies in Japan, and found that compared with the actual situation, managers have a stable forecasting trend of rise , and the probability of stock issuance in the open market decreased by about 4.7%. Kamoto[35] studied the interaction between managers' decision-making. These managers are optimistic and overconfident about the development and risk of the company caused by internal financing. Zhou et al.[36] presented a model of an overconfident newsvendor who has both biased belief on mean and variance of demand and investigates the deviation on orders and profits between the overconfident newsvendor and the rational one, then calculated the loss of these deviations caused by overconfidence. Ren et al.[2] obtained the linear relationship between the retailer's optimal order quantity and the degree of overconfidence and the extra expenses caused by the retailer's overconfidence. Li et al.[37] studied overconfident retailers with competitive relationships. In this case, overconfidence might have a positive effect on competitive retailers, and retailers with higher overconfidence degree may not get fewer profits.

3 Model description

We consider two roles in the system: A monopoly bank that decides the loan interest rate and the overconfident retailer that decides the ordering quantity. Table 1 lists the variables and parameters considered in the model.

The retailer may be overconfident. When he decides the ordering quantity, he refers to the market demand distribution he thinks, rather than the actual demand distribution[37].

$$D = \alpha \cdot \mu + (1 - \alpha) \cdot \xi \qquad (1)$$

where D is the perceived market demand of retailer, and ξ is the actual market demand. Their mean and variance are

$$E(\xi) = \mu, \ \mathrm{Var}(\xi) = \sigma^2, E(D) = \mu,$$

and $\mathrm{Var}(D) = (1-\alpha)^2 \cdot \sigma^2$. Since $0 \leqslant \alpha \leqslant 1$, we have $\mathrm{Var}(D) \leqslant \mathrm{Var}(\xi)$. When $\alpha = 0$, there is no bias in the retailer's cognition; when $0 < \alpha < 1$, the retailer is overconfident; when $\alpha = 1$, the retailer thinks that the demand is constant and equal to the mean value.

Table. 1. The variables and parameters.

Decision variables	q^{1*}, q^{2*}	Retailer's ordering quantity under information asymmetry and information symmetry
	r^{1*}, r^{2*}	Bank's lending rate under asymmetric and symmetric information
Parameters	k	Retailer's initial capital
	p	Retailer's unit retail price of goods (we normalize $p = 1$)
	w	Retailer's unit wholesale price
	α	Retailer's overconfidence degree
	π_r^n	Retailer's expected profit without capital-constraint
	π_r^i	Retailer's expected profit under information asymmetry ($i = 1$) and under information symmetry ($i = 2$)
	π_b^i	Bank's expected profit under information asymmetry ($i = 1$) and under information asymmetry ($i = 2$)
	$f(D), g(\xi)$	The density function of perceived market demand and actual market demand of overconfident retailers
	$F(D), G(\xi)$	The distribution function of perceived market demand and actual market demand of overconfident retailers

If the retailer is overconfident, the actual demand is more volatile than the retailer's cognition, $\xi \geqslant_v D$.

In the Stackelbleg game, the bank is the leader and decides the bank loan interest rate at the beginning of the events. Then, the follower retailer decides the ordering quantity according to the bank loan interest rate. At the end of selling season, the retailer gets the selling revenue and repay the bank loans or gets bankruptcy. See Figure 1.

In the following, we would calculate the optimal solution of the retailer's order quantity and the bank loan interest rate in four cases. The four cases are: ① self-financing, ② the retailer can accept bank financing without considering information asymmetry, ③ the retailer can accept bank financing under the information asymmetry, ④ the retailer can accept bank financing

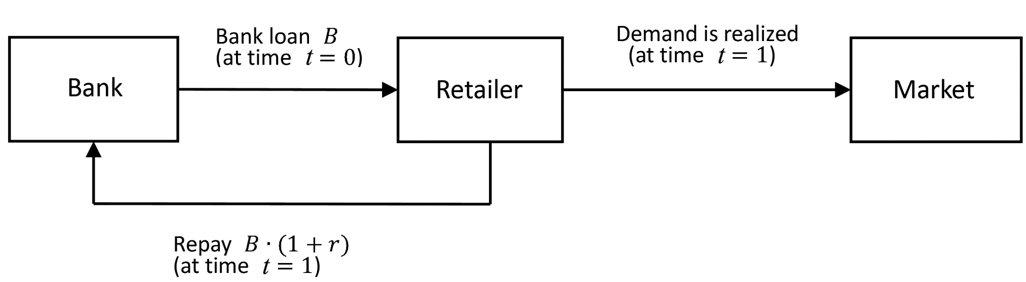

Figure 1. The consequence of events.

under the information symmetry.

4 The newsvendor-like retailer and the bank

In this section, we study the optimal decisions of the retailer and the bank in these cases: Unbiased or overconfident retailer with self-financing, unbiased retailer with bank financing, overconfident retailer with bank financing under information asymmetry or symmetry.

4.1 Self-financing

In this case, the retailer (hereinafter referred to as he) has no short-term financing sources and can only use his own initial funds to order goods.

Firstly, we assume that the retailer has sufficient funds and has no bias to the market demand, the retailer's expected profit is

$$\pi_r^n(\xi) = E[\min(\xi,q)] - w\cdot q = \int_0^q \overline{G}(\xi)\mathrm{d}\xi - w\cdot q \tag{2}$$

Proposition 4.1[5] When the retailer's capital is sufficient,

① if the retailer is unbiased, $q^{n*} = \overline{G}^{-1}(w)$;

② if the retailer is overconfident, $\widehat{q}^{n*} = \overline{F}^{-1}(w)$;

③ the relationship between q^{n*} and $\widehat{q}^{n*}$ is

$$\widehat{q}^{n*} = \alpha\cdot\mu + (1-\alpha)\cdot q^{n*};$$

④ for all α, $\pi_r^n(\widehat{q}^{n*})$ decreases with α increasing.

When the retailer is rich, his order quantity is related to his cognition of demand and the wholesale price. Proposition 4.1 indicates that an overconfident retailer's order quantity is a linear function of his overconfidence level α.

4.2 Unbiased retailer

4.2.1 The unbiased retailer's optimal decision

According to the retailer's order quantity q and the retailer's initial capital k, he needs to borrow $(w\cdot q-k)^+$ from the bank. At the end of the selling season, his expected revenue is $E[\min(\xi,q)]$. If his revenue is not high enough to repay bank loans, he could only return all his income to the bank and declare bankruptcy. Therefore, the expected loan which the retailer could repay to the bank is

$$E\{\min[E[\min(\xi,q)],(w\cdot q-k)\cdot(1+r_b)]\}.$$

When the retailer's capital is not enough for optimal ordering quantity, $k\leqslant w\cdot\overline{G}^{-1}(w\cdot(1+\widetilde{r}(k)))$, he might borrow from the bank. The bank loan interest rate is within the range of $[0,\widetilde{r_b}(k)]$, where $\widetilde{r_b}(k)=\dfrac{\overline{G}(\frac{k}{w})-w}{w}$. The expected profit of retailer is

$$\pi_r^0 = E\{E[\min(\xi,q)] - (w\cdot q-k)\cdot(1+r_b)\}^+ - k \tag{3}$$

The retailer's loan obligation is $y_b(q,r_b)$, where

$$y_b(q,r_b) = (w\cdot q-k)\cdot(1+r_b).$$

At the end of the selling season, the retailer collects the revenue $\min(\xi,q)$, which is used to repay his debt $y_b(q,r_b)$. If the realized demand is too low to repay the bank loans, the retailer has to face bankruptcy risk. The retailer's expected profit at the end of the period could be expressed as

$$\pi_r^0 = E\{[\min(\xi,q)] - [\min(\xi,y_b(q,r_b))]\}^+ - k = \int_{y_b}^q \overline{G}(\xi)\mathrm{d}\xi - k \tag{4}$$

When the retailer is unbiased, he will go bankrupt if the market demand is below the bankruptcy threshold y_b. Then the bank could only get the retailer's revenue. We can simplify the retailer's expected profit as

$$\pi_r^0 = \int_{y_b}^q \xi\mathrm{d}G(\xi) + q\cdot\overline{G}(q) - (w\cdot q-k)\cdot(1+r_b)\cdot\overline{G}(y_b) - k = \int_{y_b}^q \overline{G}(\xi)\mathrm{d}\xi - k.$$

Differentiating π_r^0 with respect to q, we have

$$\frac{\partial\pi_r^0}{\partial q} = \overline{G}(q) - \overline{G}(y_b)\cdot\frac{\partial y_b}{\partial q} = \overline{G}(q) - w\cdot(1+r_b)\cdot\overline{G}(y_b).$$

The retailer's optimal ordering quantity must satisfy the first-order condition:

$$\overline{G}(q) = w\cdot(1+r_b)\cdot\overline{G}(y_b).$$

We further have

$$\frac{\partial^2\pi_r}{\partial q^2} = -g(q) + w^2\cdot(1+r_b)^2\cdot g(y_b) = -\overline{F}_\xi(q)\cdot[h_\xi(q) - w\cdot(1+r_b)\cdot h_\xi(y_b)].$$

Since $h(x)$ is an increasing function, we can get

$$h_\xi(q) > h_\xi(y_b) > w\cdot(1+r_b)\cdot h_\xi(y_b).$$

Therefore, $\dfrac{\partial^2\pi_r}{\partial q^2}<0$.

Proposition 4.2 Given the bank loan interest rate r_b, when the retailer is unbiased, the optimal order quantity is

$$Q_0 = \begin{cases} q_r^{0*}, 0\leqslant k < w\cdot\overline{F}_\xi^{-1}(w\cdot(1+r_b)); \\ \dfrac{k}{w}, w\cdot\overline{F}_\xi^{-1}(w\cdot(1+r_b)) \leqslant k < w\cdot\overline{F}_\xi^{-1}(w); \\ \overline{F}_\xi^{-1}(w), k\geqslant w\cdot\overline{F}_\xi^{-1}(w) \end{cases} \tag{5}$$

where $\overline{G}(q_r^{0*}) = w\cdot(1+r_b)\cdot\overline{G}(y_b(q_r^{0*}))$, $y_b(q_r^{0*}) = (w\cdot q_r^{0*}-k)\cdot(1+r_b)$. q_r^{0*} represents the retailer's optimal order quantity when he is capital-constrained and borrows from the bank. $y_b(q_r^{0*})$ represents the bankruptcy threshold.

In the first region, the retailer, severely poor, borrows from the bank; in the second region, the retailer is medium poor, but will not borrow from the bank because of the high interest rate of the bank; in the third region, the retailer is rich enough to support the optimal ordering decision, so there is no need to borrow from the bank.

The condition of q_r^{0*} can be simplified as

$$(q_r^{0*}-\frac{k}{w})\cdot\overline{G}(q_r^{0*})=y_b(q_r^{0*})\cdot\overline{G}(y_b(q_r^{0*})).$$

By taking derivative of k, we have

$$[\overline{G}(y_b)-y_b\cdot g(y_b)]\cdot\frac{\partial y_b}{\partial k}=[\overline{G}(q_r^{0*})-(q_r^{0*}-\frac{k}{w})\cdot g(q_r^{0*})]\cdot\frac{\partial q_r^{0*}}{\partial k}-\frac{1}{w}\cdot\overline{G}(q_r^{0*}),$$

$$\frac{\partial y_b}{\partial k}=\frac{\overline{G}(q_r^{0*})\cdot\left\{[1-(q_r^{0*}-\frac{k}{w})\cdot h_\xi(q_r^{0*})]\cdot\frac{\partial q_r^{0*}}{\partial k}-\frac{1}{w}\right\}}{\overline{G}(y_b)-y_b\cdot g(y_b)}.$$

By taking derivative of w, we have

$$[\overline{G}(y_b(q_r^{0*}))-y_b(q_r^{0*})\cdot g(y_b(q_r^{0*}))]\cdot\frac{\partial y_b(q_r^{0*})}{\partial w}=\frac{k}{w^2}\cdot\overline{G}(q_r^{0*})+\overline{G}(q_r^{0*})\cdot[1-(q_r^{0*}-\frac{k}{w})\cdot h_\xi(q_r^{0*})]\cdot\frac{\partial q_r^{0*}}{\partial w},$$

$$\frac{\partial y_b(q_r^{0*})}{\partial w}=\frac{\overline{G}(q_r^{0*})\cdot\left\{[1-(q_r^{0*}-\frac{k}{w})\cdot h_\xi(q_r^{0*})]\cdot\frac{\partial q_r^{0*}}{\partial w}+\frac{k}{w^2}\right\}}{\overline{G}(y_b(q_r^{0*}))-y_b(q_r^{0*})\cdot g(y_b(q_r^{0*}))}=$$

$$\frac{\overline{G}(q_r^{0*})}{\overline{G}(y_b(q_r^{0*}))}\cdot\frac{[1-(q_r^{0*}-\frac{k}{w})\cdot h_\xi(q_r^{0*})]\cdot\frac{\partial q_r^{0*}}{\partial w}+\frac{k}{w^2}}{1-y_b(q_r^{0*})\cdot h_\xi(y_b(q_r^{0*}))}.$$

By taking derivative of r_b, we have

$$\frac{\partial q_r^{0*}}{\partial r_b}\cdot[\overline{G}(q_r^{0*})-(q_r^{0*}-\frac{k}{w})\cdot g(q_r^{0*})]=\frac{\partial y_b(q_r^{0*})}{\partial r_b}\cdot[\overline{G}(y_b(q_r^{0*}))-y_b(q_r^{0*})\cdot g(y_b(q_r^{0*}))],$$

$$\frac{\partial y_b(q_r^{0*})}{\partial r_b}=\frac{\overline{G}(q_r^{0*})}{\overline{G}(y_b(q_r^{0*}))}\cdot\frac{1-(q_r^{0*}-\frac{k}{w})\cdot h_\xi(q_r^{0*})}{1-y_b(q_r^{0*})\cdot h_\xi(y_b(q_r^{0*}))}\cdot\frac{\partial q_r^{0*}}{\partial r_b}.$$

Differentiating

$$\overline{F}_\xi(q_r^{0*})=w\cdot(1+r_b)\cdot\overline{F}_\xi(y_b(q_r^{0*}))$$

with respect to r_b, we have

$$\frac{\partial q_r^{0*}}{\partial r_b}\cdot[\frac{w^2\cdot(1+r_b)^2}{p}\cdot g(y_b(q_r^{0*}))-p\cdot g(q_r^{0*})]=w\cdot\overline{G}(y_b(q_r^{0*}))-w\cdot y_b(q_r^{0*})\cdot g(y_b(q_r^{0*})),$$

$$\frac{\partial q_r^{0*}}{\partial r_b}=\frac{1-y_b(q_r^{0*})\cdot h_\xi(y_b(q_r^{0*}))}{(1+r_b)\cdot[w\cdot(1+r_b)\cdot h_\xi(y_b(q_r^{0*}))-h_\xi(q_r^{0*})]}.$$

Since $w\cdot(1+r_b)\leqslant 1$ and $h_\xi(y_b(q_r^{0*}))\leqslant h_\xi(q_r^{0*})$, we have

$$w\cdot(1+r_b)\cdot h_\xi(y_b(q_r^{0*}))-h_\xi(q_r^{0*})\leqslant 0.$$

Assuming that $m(x)=x\cdot\overline{F}(x)$, we have

$$\frac{\mathrm{d}m(x)}{\mathrm{d}x}=\overline{F}(x)-x\cdot f(x)=\overline{F}(x)\cdot[1-x\cdot h(x)].$$

When $0\leqslant x\cdot h(x)<1$, $m(x)$ would increase with x increasing. When $x\cdot h(x)\geqslant 1$, $m(x)$ decreases with the increase of x. Also, $x\cdot h(x)$ is a monotone increasing function of x. Therefore, $m(x)$ takes the maximum value at the point when $x\cdot h(x)=1$. If $y_b\cdot h(y_b)>1$, $y_b\cdot\overline{F}(y_b)\geqslant q_r^{0*}\cdot\overline{F}(q_r^{0*})>(q_r^{0*}-\frac{k}{w})\cdot\overline{F}(q_r^{0*})$, which is opposite with

$$(q_r^{0*}-\frac{k}{w})\cdot\overline{F}(q_r^{0*})=y_b\cdot\overline{F}(y_b).$$

In conclusion, we have $y_b\cdot h(y_b)\leqslant 1$.

By differentiating $y_b\cdot h(y_b)+\overline{F}(y_b)$, we have

$$\frac{\partial[y_b\cdot h(y_b)+\overline{F}(y_b)]}{\partial y_b}=h(y_b)+y_b\cdot h'(y_b)-f(y_b)=h(y_b)\cdot[1-\overline{F}(y_b)]+y_b\cdot h'(y_b)>0.$$

And $[y_b\cdot h(y_b)+\overline{F}(y_b)]_{(y_b=0)}=1$. Therefore,

$$y_b\cdot h(y_b)+\overline{F}(y_b)\geqslant 1.$$

In summary, we get the conclusion that

$$1-\overline{F}(y_b)\leqslant y_b\cdot h(y_b)\leqslant 1.$$

Then, we could get a series of partial derivatives:

$$\frac{\partial q_r^{0*}}{\partial r_b}=\frac{1-y_b(q_r^{0*})\cdot h_\xi(y_b(q_r^{0*}))}{(1+r_b)\cdot[w\cdot(1+r_b)\cdot h_\xi(y_b(q_r^{0*}))-h_\xi(q_r^{0*})]}\leqslant 0,$$

$$\frac{\partial y_b(q_r^{0*})}{\partial r_b}=\frac{\overline{G}(q_r^{0*})}{\overline{G}(y_b(q_r^{0*}))}\cdot\frac{1-(q_r^{0*}-\frac{k}{w})\cdot h_\xi(q_r^{0*})}{1-y_b(q_r^{0*})\cdot h_\xi(y_b(q_r^{0*}))}\cdot\frac{\partial q_r^{0*}}{\partial r_b}\leqslant 0,$$

$$\frac{\partial\pi_r(q_r^{0*})}{\partial r_b}=\overline{G}(q_r^{0*})\cdot\frac{\partial q_r^{0*}}{\partial r_b}-\overline{G}(y_b(q_r^{0*}))\cdot\frac{\partial y_b(q_r^{0*})}{\partial r_b}=\frac{\partial q_r^{0*}}{\partial r_b}\cdot\overline{G}(q_r^{0*})\cdot$$

$$\frac{(q_r^{0*}-\frac{k}{w})\cdot h_\xi(q_r^{0*})-y_b(q_r^{0*})\cdot h_\xi(y_b(q_r^{0*}))}{1-y_b(q_r^{0*})\cdot h_\xi(y_b(q_r^{0*}))}\leqslant 0.$$

Since

$$(q_r^{0*}-\frac{k}{w})\cdot\overline{G}(q_r^{0*})=y_b(q_r^{0*})\cdot\overline{G}(y_b(q_r^{0*}))$$

and

$$\overline{G}(q_r^{0*})\leqslant\overline{G}(y_b(q_r^{0*})),$$

we can get $q_r^{0*}-\frac{k}{w}\geqslant y_b(q_r^{0*})$. Therefore,

$$(q_r^{0*}-\frac{k}{w})\cdot h_\xi(q_r^{0*})-y_b(q_r^{0*})\cdot h_\xi(y_b(q_r^{0*}))\geqslant 0.$$

Differentiating

$$\overline{G}(q_r^{0*})=w\cdot(1+r_b)\cdot\overline{G}(y_b(q_r^{0*}))$$

with respect to$k$, we have

$$\frac{\partial q_r^{0*}}{\partial k}=\frac{(1+r_b)\cdot h_\xi(y_b(q_r^{0*}))}{w\cdot(1+r_b)\cdot h_\xi(y_b)\cdot[1-(q_r^{0*}-\frac{k}{w})\cdot h_\xi(q_r^{0*})]-h_\xi(q_r^{0*})\cdot[1-y_b\cdot h(y_b)]}<0.$$

Lemma 4.1 Given the retailer's initial capital k and the distribution function of demand,

① q_r^{0*} is decreasing in r_b;

② $y_b(q_r^{0*})$ is decreasing in r_b.

Given the retailer's initial capital k and the distribution function of the demand, when the interest rate increases, the retailer faces a larger bankruptcy risk. When the unit profit of goods cannot balance the cost of bank financing, the retailer stops to use bank loans. As for the bankruptcy threshold, it is related to both the retailer's order quantity and the bank loan interest rate. With the increasing of the interest rate, the retailer's order quantity decreases and the bankruptcy threshold decreases.

4.2.2 The profit-maximizing bank's optimal decision

The bank, as a Stackelberg leader, anticipates the retailer's optimal order quantity Q_0. When the retailer uses bank loans and the collected revenue is not enough to repay the bank loans, the bank could get $\min(\xi,q)$; when the retailer uses bank loans and the collected revenue is enough to repay the bank loans, the bank could get $(w\cdot q-k)\cdot(1+r_b)$. Then, we get the bank's expected profit

$$\pi_b^0=E\{\min[E[\min(\xi,q)],(w\cdot q-k)\cdot(1+r_b)]\}-(w\cdot q-k)=\int_0^{y_b}\overline{G}(\xi)\mathrm{d}\xi-(w\cdot q-k)\quad(6)$$

The optimal bank loan interest rate is achieved by solving

$$r_b^{0*}=\operatorname{argmax}[\int_0^{y_b(q^{0*}(r_b),r_b)}\overline{G}(\xi)\mathrm{d}\xi-(w\cdot q^{0*}(r_b)-k)]\quad(7)$$

When the retailer is unbiased and capital-constrained, he will go bankrupt if the market demand is below the bankruptcy threshold y_b. Then the bank could only get the retailer's revenue. When the market demand is higher than y_b, the retailer could pay back all the loans to the bank. We can simplify the expected profit of the bank as

$$\pi_b^0=E\{\min[E[\min(\xi,q)],(w\cdot q-k)\cdot(1+r_b)]\}-(w\cdot q-k)=\int_0^{y_b}\xi\mathrm{d}G(\xi)+(w\cdot q-k)\cdot(1+r_b)\cdot\overline{G}(y_b)-(w\cdot q-k)=\int_0^{y_b}\overline{G}(x)\mathrm{d}x-(w\cdot q-k).$$

Differentiating

$$(q^{0*}-\frac{k}{w})\cdot\overline{G}(q^{0*})=y_b(q^{0*})\cdot\overline{G}(y_b(q^{0*}))$$

with respect to q^{0*}, we have

$$\overline{G}(q^{0*})-(q^{0*}-\frac{k}{w})\cdot g(q^{0*})=\frac{\partial y_b}{\partial q^{0*}}\cdot[\overline{G}(y_b(q^{0*}))-y_b(q^{0*})\cdot g(y_b(q^{0*}))].$$

That is

$$\frac{\partial y_b(q^{0*})}{\partial q^{0*}}=\frac{\overline{G}(q^{0*})}{\overline{G}(y_b(q^{0*}))}\cdot\frac{1-(q^{0*}-\frac{k}{w})\cdot h_\xi(q^{0*})}{1-y_b(q^{0*})\cdot h_\xi(y_b(q^{0*}))}.$$

Similarly, we have

$$\frac{\partial\pi_b^0}{\partial q^{0*}}=\overline{G}(q^{0*})\cdot\frac{1-(q^{0*}-\frac{k}{w})\cdot h_\xi(q^{0*})}{1-y_b(q^{0*})\cdot h_\xi(y_b(q^{0*}))}-w.$$

We assume $\epsilon_\xi(r_b)$ as $\frac{\overline{G}(q^{0*}(r_b))\cdot[1-(q^{0*}(r_b)-\frac{k}{w})\cdot h_\xi(q^{0*}(r_b))]}{w\cdot[1-y_b\cdot h_\xi(y_b(q^{0*}(r_b)))]}$, $M_\xi(q^{0*})$ as $\frac{1-(q^{0*}-\frac{k}{w})\cdot h_\xi(q^{0*})}{1-y_b(q^{0*})\cdot h_\xi(y_b(q^{0*}))}$.

$$(M_\xi(q^{0*}))'_{q^{0*}}=\frac{1}{[1-y_b\cdot h_\xi(y_b(q^{0*}))]^2}\cdot\{-(h_\xi(q^{0*})+(q^{0*}-\frac{k}{w})\cdot h'_\xi(q^{0*}))\cdot(1-y_b\cdot h_\xi(y_b(q^{0*})))+$$

$$(h_\xi(y_b(q^{0*}))+y_b\cdot h'_\xi(y_b(q^{0*})))\cdot(1-(q^{0*}-\frac{k}{w})\cdot h_\xi(q^{0*}))\cdot\frac{\overline{G}(q^{0*})\cdot[1-(q^{0*}-\frac{k}{w})\cdot h_\xi(q^{0*})]}{\overline{G}(y_b(q^{0*}))\cdot[1-y_b\cdot h_\xi(y_b(q^{0*}))]}\}=$$

$$-\frac{h_\xi(q^{0*})+(q^{0*}-\frac{k}{w})\cdot h'_\xi(q^{0*})}{1-y_b\cdot h_\xi(y_b(q^{0*}))}+w\cdot(1+r_b)\cdot\frac{h_\xi(y_b(q^{0*}))+y_b\cdot h'_\xi(y_b(q^{0*}))}{1-y_b\cdot h_\xi(y_b(q^{0*}))}\cdot[M_\xi(q^{0*})]^2.$$

$(q^{0*}-\frac{k}{w})\cdot\overline{G}(q^{0*})=y_b(q^{0*})\cdot\overline{G}(y_b(q^{0*}))$ and $\overline{G}(q^{0*})\leqslant\overline{G}(y_b(q^{0*}))$, so

$$q^{0*}\geqslant q^{0*}-\frac{k}{w}\geqslant y_b(q^{0*}),1-(q^{0*}-\frac{k}{w})\cdot h_\xi(q^{0*})\leqslant 1-y_b\cdot h_\xi(y_b(q^{0*})).$$

Therefore, $0\leqslant[M_\xi(q^{0*})]^2\leqslant 1$. Since $0<\frac{w\cdot(1+r_b)}{p}\leqslant 1, h_\xi(q^{0*})\geqslant h_\xi(y_b(q^{0*})), (M_\xi(q^{0*}))'_{q^{0*}}\leqslant 0$.

$$\frac{\partial\pi_b^0}{\partial q^{0*}}=\overline{G}(q^{0*})\cdot\frac{1-(q^{0*}-\frac{k}{w})\cdot h_\xi(q^{0*})}{1-y_b(q^{0*})\cdot h_\xi(y_b(q^{0*}))}-w,$$

$$\frac{\partial^2\pi_b^0}{\partial(q^{0*})^2}=-f_\xi(q^{0*})\cdot M_\xi(q^{0*})+\overline{G}(q^{0*})\cdot(M_\xi(q^{0*}))'_{q^{0*}}<0.$$

Since $(M_\xi(q^{0*}))'_{q^{0*}}\leqslant 0$ and $\frac{\partial q^{0*}}{\partial r_b}\leqslant 0$, we have $(M_\xi(q^{0*}(r_b)))'_{r_b}\geqslant 0$. Since $\frac{\overline{G}(q^{0*}(r_b))}{w}$ increases with r_b increasing, $\epsilon_\xi(r_b)=\frac{\overline{G}(q^{0*}(r_b))}{w}\cdot M_\xi(q^{0*})$ increases with r_b increasing. Therefore, for a given initial capital k, $\epsilon_\xi(r_b)=1$ exists a unique solution. In the following, we uses $\widehat{r_b}(k)$ to express this solution.

① If $\epsilon_\xi(\widetilde{r_b})\leqslant 1$, then $\epsilon_\xi(0)\leqslant\epsilon_\xi(r_b(k))\leqslant\epsilon_\xi(\widetilde{r_b}(k))\leqslant 1$, $\frac{d\pi_b^0}{dr_b}\geqslant 0$. We can get the optimal bank loan interest rate $\widetilde{r_b}(k)$.

② If $\epsilon_\xi(0)\geqslant 1$, then $1\leqslant\epsilon_\xi(0)\leqslant\epsilon_\xi(r_b(k))\leqslant\epsilon_\xi(\widetilde{r_b}(k))$, $\frac{d\pi_b^0}{dr_b}\leqslant 0$. We can get the optimal bank loan interest rate 0.

③ If $\epsilon_\xi(0)<1$ and $\epsilon_\xi(\widetilde{r_b})>1$, then $\epsilon_\xi(0)\leqslant\epsilon_\xi(r_b(k))\leqslant\epsilon_\xi(\widetilde{r_b}(k))$, $\frac{d\pi_b^0}{dr_b}(r_b=\widetilde{r_b}(k))\leqslant 0$, $\frac{d\pi_b^0}{dr_b}(r_b=0)\geqslant 0$. We can get the optimal bank loan interest rate r_b^{0*}.

Proposition 4.3 When the retailer unbiased, the optimal bank loan interest rate R_b^0 is given by

$$R_b^0=\begin{cases}0,\epsilon_\xi(0)\geqslant 1;\\ \widetilde{r_b}(k),\epsilon_\xi(\widetilde{r_b})\leqslant 1;\\ r_b^{0*},\epsilon_\xi(0)<1\text{ 且 }\epsilon_\xi(\widetilde{r_b})>1\end{cases}\tag{8}$$

where $\epsilon_\xi(r_b)=\frac{\overline{G}(q(r_b))\cdot[1-(q(r_b)-\frac{k}{w})\cdot h_\xi(q(r_b))]}{w\cdot[1-y_b\cdot h_\xi(y_b(q(r_b)))]}$ and r_b^{0*} is given by

$$\begin{cases}\overline{G}(q(r_b^{0*}))\cdot\frac{1-(q(r_b^{0*})-\frac{k}{w})\cdot h_\xi(q(r_b^{0*}))}{1-y_b(q(r_b^{0*}))\cdot h_\xi(y_b(q(r_b^{0*})))}=w,\\ \overline{G}(q(r_b^{0*}))=w\cdot(1+r_b^{0*})\cdot\overline{G}(y_b(q(r_b^{0*})))\end{cases}\tag{9}$$

There are three situations of the optimal bank loan interest rate. In the first situation, the retailer would not borrow from the bank. In the second situation, the optimal interest rate is the upper limit of the bank loan interest rate. If the interest rate exceeds this threshold, the retailer would not use the bank loans.

4.3 Overconfident retailer under information asymmetry

4.3.1 The overconfident retailer's optimal decision

According to the retailer's order quantity q and the retailer's initial capital k, he needs to borrow $(w\cdot q-k)^+$ from the bank. At the end of the selling season, his expected revenue is $E[\min(\xi,q)]$. If his revenue is not high enough to repay bank loans, he could only return all his income to the bank and declare bankruptcy. Therefore, the expected loan which retailer could repay to the bank is

$$E\{\min[E[\min(\xi,q)],(w\cdot q-k)\cdot(1+r_b)]\}.$$

In this case, the bank does not know that the retailer is overconfident and thinks that the retailer's perception of demand is correct.

Proposition 4.4 Given the bank loan interest rate r_b, when the retailer is overconfident, the optimal ordering quantity Q_1 is given by

$$Q_1=\begin{cases} q_r^{1*},0\leqslant k<w\cdot\overline{F}^{-1}(w\cdot(1+r_b)); \\ \dfrac{k}{w},w\cdot\overline{F}^{-1}(w\cdot(1+r_b))\leqslant k<w\cdot\overline{F}^{-1}(w); \\ \overline{F}^{-1}(w),k\geqslant w\cdot\overline{F}^{-1}(w)\end{cases} \tag{10}$$

where q_r^{1*} is given by

$$\overline{F}(q_r^{1*})=w\cdot(1+r_b)\cdot\overline{F}(y_b(q_r^{1*})).$$

In the first region, when the retailer is severely poor, he would borrow from the bank; in the second region, when the retailer is medium poor, he will use up all his initial capital, but will not borrow from the bank because of the high interest rate of the bank; in the third region, the retailer is rich enough to support the optimal ordering decision, so there is no need to borrow from the bank.

4.3.2 The profit-maximizing bank's optimal decision under the information asymmetry

However, from the perspective of the bank, the relationship between the retailer's optimal order quantity q_b^1 and the bank loan interest rate r_b satisfies $p\cdot\overline{G}(q_b^1)=w\cdot(1+r_b)\cdot\overline{G}(y_b(q_b^1))$. That is, she would decides the interest rate based on q_b^1 rather than q_r^{1*}.

When the retailer's capital is in the first region, he might borrow from the bank. In the perception of the bank, his expected profit is given by

$$\pi_b^1=E\{\min[\min(\xi,q_b^1),y_b(q_b^1,r_b)]\}-(w\cdot q_b^1-k)=\int_0^{y_b(q_b^1)}\overline{G}(\xi)\mathrm{d}\xi-(w\cdot q_b^1-k) \tag{11}$$

We use q_b^1 to represent the optimal ordering quantity in the bank's perception under information asymmetry. In the bank's perception, the retailer's optimal ordering quantity satisfies

$$(q_b^1-\frac{k}{w})\cdot\overline{G}(q_b^1)=y_b(q_b^1)\cdot\overline{G}(y_b(q_b^1)).$$

Taking derivative on the both side with q_b^1, we have

$$\frac{\partial y_b(q_b^1)}{\partial q_b^1}=\frac{\overline{G}(q_b^1)\cdot[1-(q_b^1-\frac{k}{w})\cdot h_\xi(q_b^1)]}{\overline{G}(y_b(q_b^1))\cdot[1-y_b(q_b^1)\cdot h_\xi(y_b(q_b^1))]},$$

$$\frac{\partial\pi_b^1}{\partial q_b^1}=\overline{G}(q_b^1)\cdot\frac{1-(q_b^1-\frac{k}{w})\cdot h_\xi(q_b^1)}{1-y_b\cdot h_\xi(y_b(q_b^1))}-w,$$

$$\frac{\mathrm{d}\pi_b^1}{\mathrm{d}r_b}=\frac{\partial\pi_b^1}{\partial q_b^1}\cdot\frac{\mathrm{d}q_b^1}{\mathrm{d}r_b}+\frac{\partial\pi_b^1}{\partial r_b}=$$

$$w\cdot\frac{\mathrm{d}q_b^1}{\mathrm{d}r_b}\cdot[\frac{\overline{G}(q_b^1)\cdot[1-(q_b^1-\frac{k}{w})\cdot h_\xi(q_b^1)]}{w\cdot[1-y_b\cdot h_\xi(y_b)]}-1].$$

Assuming that

$$\epsilon_\xi(r_b)=\frac{\overline{G}(q_b^1(r_b))\cdot[1-(q_b^1(r_b)-\frac{k}{w})\cdot h_\xi(q_b^1(r_b))]}{w\cdot[1-y_b\cdot h_\xi(y_b)]},$$

$$M_\xi(q_b^1)=\frac{1-(q_b^1-\frac{k}{w})\cdot h_\xi(q_b^1)}{1-y_b\cdot h_\xi(y_b(q_b^1))}.$$

Similarly, we can prove that $(M_\xi(q_b^1))'_{q_b^1}\leqslant0$. Thus, $\frac{\partial^2\pi_b^1}{\partial(q_b^1)^2}<0$. Because $(M_\xi(q_b^1))'_{q_b^1}\leqslant0$ and $\frac{\mathrm{d}q_b^1}{\mathrm{d}r_b}\leqslant0$, we have $(M_\xi(q_b^1(r_b)))'_{r_b}\geqslant0$. $\frac{\overline{G}(q_b^1(r_b))}{w}$ increases with the increase of r_b, so

$$\epsilon_\xi(r_b)=\frac{\overline{G}(q_b^1(r_b))}{w}\cdot M_\xi(q_b^1(r_b))$$

increases with the increase of r_b. Therefore, for a given initial capital k, there exists a unique solution for $\epsilon_\xi(r_b)=1$. We use $\widehat{r_b^1}(k)$ to represent this solution.

① If $\epsilon_\xi(\widetilde{r_b})\leqslant1$, then $\epsilon_\xi(0)\leqslant\epsilon_\xi(r_b(k))\leqslant\epsilon_\xi(\widetilde{r_b}(k))\leqslant1=\epsilon_\xi(\widehat{r_b^1}(k))$, $\frac{\mathrm{d}\pi_b^1}{\mathrm{d}r_b}\geqslant0$. We can get the optimal bank loan interest rate $\widetilde{r_b}(k)$.

② If $\epsilon_\xi(0)\geqslant1$, then $\epsilon_\xi(\widehat{r_b^1}(k))=1\leqslant\epsilon_\xi(0)\leqslant\epsilon_\xi(r_b(k))\leqslant\epsilon_\xi(\widetilde{r_b}(k))$, $\frac{\mathrm{d}\pi_b^1}{\mathrm{d}r_b}\leqslant0$. We can get the optimal bank loan interest rate 0.

③ If $\epsilon_\xi(0)<1$ and $\epsilon_\xi(\widetilde{r_b})>1$, then

$$\epsilon_\xi(0)<1=\epsilon_\xi(\widehat{r_b^1}(k))<\epsilon_\xi(\widetilde{r_b}(k)),$$

$$\frac{\mathrm{d}\pi_b^1}{\mathrm{d}r_b}(r_b=\widetilde{r_b}(k))<0,\frac{\mathrm{d}\pi_b^1}{\mathrm{d}r_b}(r_b=0)>0.$$

We can get the optimal bank loan interest rate $\widehat{r_b^1}(k)$.

Proposition 4.5 When the retailer is overconfident and information between the bank and the retailer is asymmetric, the optimal bank loan interest rate R_b^1 is given by

$$R_b^1 = \begin{cases} 0, \epsilon_\xi(0) \geqslant 1; \\ \widetilde{r_b}(k), \epsilon_\xi(\widetilde{r_b}) \leqslant 1; \\ r_b^{1*}, \epsilon_\xi(0) < 1 \text{ 且 } \epsilon_\xi(\widetilde{r_b}) > 1 \end{cases} \quad (12)$$

where

$$\epsilon_\xi(r_b) = \frac{\overline{G}(q_b^1(r_b)) \cdot [1 - (q_b^1(r_b) - \frac{k}{w}) \cdot h_\xi(q_b^1(r_b))]}{w \cdot [1 - y_b \cdot h_\xi(y_b(q_b^1(r_b)))]}$$

and r_b^{1*} satisfies

$$\begin{cases} \overline{G}(q_b^1(r_b^{1*})) \cdot \dfrac{1 - (q_b^1(r_b^{1*}) - \frac{k}{w}) \cdot h_\xi(q_b^1(r_b^{1*}))}{1 - y_b(q_b^1(r_b^{1*})) \cdot h_\xi(y_b(q_b^1(r_b^{1*})))} = w, \\ \overline{G}(q_b^1(r_b^{1*})) = w \cdot (1 + r_b^{1*}) \cdot \overline{G}(y_b(q_b^1(r_b^{1*}))) \end{cases} \quad (13)$$

However, the actual ordering quantity of the retailer satisfies

$$\begin{cases} \overline{F}(q_r^{1*}) = w \cdot (1 + r_b) \cdot \overline{F}(y_b(q_r^{1*})), \\ D = \alpha \cdot \mu + (1 - \alpha) \cdot \xi \end{cases} \quad (14)$$

There are three situations of the optimal bank loan interest rate. In the first situation, the retailer would not borrow from the bank. In the second situation, the optimal interest rate is the upper limit of the bank loan interest rate. If the interest rate exceeds this threshold, the retailer would not use the bank loans.

4.4 Overconfident retailer and bank under information symmetry

4.4.1 The overconfident retailer's optimal decision

In this case, the bank knows that the retailer is overconfident and is aware of the retailer's perception of demand. Similarly, we can get the retailer's optimal order quantity Q_2.

$$Q_2 = \begin{cases} q_r^{2*}, 0 \leqslant k < w \cdot \overline{F}^{-1}(w \cdot (1 + r_b)); \\ \dfrac{k}{w}, w \cdot \overline{F}^{-1}(w \cdot (1 + r_b)) \leqslant k < w \cdot \overline{F}^{-1}(w); \\ \overline{F}^{-1}(w), k \geqslant w \cdot \overline{F}^{-1}(w) \end{cases} \quad (15)$$

where q_r^{2*} solves $\overline{F}(q_r^{2*}) = w \cdot (1+r_b) \cdot \overline{F}(y_b(q_r^{2*}))$.

In the first region, when the retailer is severely poor, he would borrow from the bank; in the second region, when the retailer is medium poor, he will use up all his initial capital, but will not borrow from the bank because of the high interest rate decided by the bank; in the third region, the retailer is rich enough to support the optimal ordering decision, so there is no need to borrow from the bank.

4.4.2 The profit-maximizing bank's optimal decision under the information symmetry

The expected profit of the bank is given by

$$\pi_b^2 = E\{\min[\min(\xi, q_r^{2*}), y_b(q_r^{2*}, r_b)]\} - (w \cdot q_r^{2*} - k) = \int_0^{y_b(q_r^{2*})} \overline{G}(\xi)\mathrm{d}\xi - (w \cdot q_r^{2*} - k) \quad (16)$$

In this case, the bank is aware of the retailer's perception of the market demand. That is, the bank knows the retailer's optimal ordering quantity when borrowing from the bank is given by

$$(q_r^2 - \frac{k}{w}) \cdot \overline{F}(q_r^2) = y_b(q_r^2) \cdot \overline{F}(y_b(q_r^2)).$$

Taking derivative with q_r^2 on both sides, we have

$$\frac{\partial y_b(q_r^2)}{\partial q_r^2} = \frac{\overline{F}(q_r^2) \cdot [1 - (q_r^2 - \frac{k}{w}) \cdot h_D(q_r^2)]}{\overline{F}(y_b(q_r^2)) \cdot [1 - y_b(q_r^2) \cdot h_D(y_b(q_r^2))]}.$$

Taking derivative with r_b on both sides of $\overline{F}(q_r^2) = w \cdot (1+r_b) \cdot \overline{F}(y_b(q_r^2))$, we have

$$\frac{\partial q_r^2}{\partial r_b} \cdot [w^2 \cdot (1 + r_b)^2 \cdot f(y_b(q_r^2)) - f(q_r^2)] = w \cdot \overline{F}(y_b(q_r^2)) - w \cdot y_b(q_r^2) \cdot f(y_b(q_r^2)),$$

$$\frac{\partial q_r^2}{\partial r_b} = \frac{1 - y_b(q_r^2) \cdot h_D(y_b(q_r^2))}{(1 + r_b) \cdot [w \cdot (1 + r_b) \cdot h_D(y_b(q_r^2)) - h_D(q_r^2)]} \leqslant 0.$$

The bank's expected profit is

$$\pi_b^2 = E\{\min[p \cdot E[\min(\xi, q_r^2)], (w \cdot q_r^2 - k) \cdot (1 + r_b)]\} - (w \cdot q_r^2 - k) =$$

$$p\int_0^{y_b} \xi \mathrm{d}G(\xi) + (w \cdot q - k) \cdot (1 + r_b) \cdot \overline{F}_\xi(y_b) - (w \cdot q_r^2 - k) = p \cdot \int_0^{y_b} \overline{G}(\xi)\mathrm{d}\xi - (w \cdot q_r^2 - k).$$

Differentiating π_b^2 with respect to q_r^2, we have

$$\frac{\partial \pi_b^2}{\partial q_r^2} = p \cdot \overline{G}(y_b) \cdot \frac{\partial y_b}{\partial q_r^2} - w = p \cdot \overline{G}(y_b) \cdot \frac{\overline{F}(q_r^2) \cdot [1 - (q_r^2 - \frac{k}{w}) \cdot h_D(q_r^2)]}{\overline{F}(y_b(q_r^2)) \cdot [1 - y_b(q_r^2) \cdot h_D(y_b(q_r^2))]} - w = p \cdot \overline{G}(y_b) \cdot$$

$$\frac{y_b(q_r^2)\cdot[1-(q_r^2-\frac{k}{w})\cdot h_D(q_r^2)]}{(q_r^2-\frac{k}{w})\cdot[1-y_b(q_r^2)\cdot h_D(y_b(q_r^2))]}-w=w\cdot[p\cdot(1+r_b)\cdot\overline{G}(y_b)\cdot\frac{1-(q_r^2-\frac{k}{w})\cdot h_D(q_r^2)}{1-y_b(q_r^2)\cdot h_D(y_b(q_r^2))}-1].$$

Differentiating π_b^2 with respect to r_b, we have

$$\frac{d\pi_b^2}{dr_b}=\frac{\partial\pi_b^2}{\partial q_r^2}\cdot\frac{dq_r^2}{dr_b}+\frac{\partial\pi_b^2}{\partial r_b}=[\overline{G}(y_b)\cdot\frac{\partial y_b}{\partial q_r^2}-w]\cdot\frac{dq_r^2}{dr_b}=$$

$$\left\{\overline{G}(y_b)\cdot\frac{\overline{F}(q_r^2)\cdot[1-(q_r^2-\frac{k}{w})\cdot h_D(q_r^2)]}{\overline{F}(y_b(q_r^2))\cdot[1-y_b(q_r^2)\cdot h_D(y_b(q_r^2))]}-w\right\}\cdot\frac{dq_r^2}{dr_b}=$$

$$w\cdot\frac{dq_r^2}{dr_b}\cdot\left\{\overline{G}(y_b)\cdot(1+r_b)\cdot\frac{1-(q_r^2-\frac{k}{w})\cdot h_D(q_r^2)}{1-y_b(q_r^2)\cdot h_D(y_b(q_r^2))}-1\right\}.$$

We use $M_D(q_r^2)$ to represent $\frac{1-(q_r^2-\frac{k}{w})\cdot h_D(q_r^2)}{1-y_b\cdot h_D(y_b(q_r^2))}$. Differentiating $M_D(q_r^2)$ with respect to q_r^2, we have

$$(M_D(q_r^2))'_{q_r^2}=-\frac{h_D(q_r^2)+(q_r^2-\frac{k}{w})\cdot h'_D(q_r^2)}{1-y_b\cdot h_D(y_b(q_r^2))}+\frac{w\cdot(1+r_b)}{p}\cdot\frac{h_D(y_b(q_r^2))+y_b\cdot h'_D(y_b(q_r^2))}{1-y_b\cdot h_D(y_b(q_r^2))}\cdot[M_D(q_r^2)]^2.$$

Because $(q_r^2-\frac{k}{w})\cdot\overline{F}(q_r^2)=y_b(q_r^2)\cdot\overline{F}(y_b(q_r^2))$ and $\overline{F}(q_r^2)\leqslant\overline{F}(y_b(q_r^2))$, we can get $q_r^2\geqslant q_r^2-\frac{k}{w}\geqslant y_b(q_r^2)$. Thus,

$$1-(q_r^2-\frac{k}{w})\cdot h_D(q_r^2)\leqslant 1-y_b\cdot h_D(y_b(q_r^2)).$$

We can get the conclusion that $0\leqslant[M_D(q_r^2)]^2<1$, $(M_D(q_r^2))'_{q_r^2}\leqslant 0$ and $\frac{\partial^2\pi_b^2}{\partial(q_r^2)^2}<0$.

Because $(M_D(q_r^2))'_{q_r^2}\leqslant 0$ and $\frac{\partial q_r^2}{\partial r_b}\leqslant 0$, we have $(M_\xi(q_r^2(r_b)))'_{r_b}\geqslant 0$. Moreover,

$$\epsilon_\xi(r_b)=\overline{G}(y_b)\cdot(1+r_b)\cdot M_\xi(q_r^2(r_b))=\frac{\overline{F}(q_r^2)}{w}\cdot M_\xi(q_r^2(r_b)).$$

$\frac{\overline{F}(q_r^2)}{w}$ increases with the increase of r_b, so $\epsilon_\xi(r_b)$ increases with the increase of r_b. Therefore, for a given initial capital k, there exists a unique solution for $\epsilon_\xi(r_b)=1$. We use $\widehat{r_b^2}(k)$ to represent this solution.

① If $\epsilon_\xi(\widetilde{r_b})\leqslant 1$, then we have

$$\epsilon_\xi(0)\leqslant\epsilon_\xi(r_b(k))\leqslant\epsilon_\xi(\widetilde{r_b}(k))\leqslant 1=\epsilon_\xi(\widehat{r_b^2}(k))$$

and $\frac{d\pi_b^2}{dr_b}\geqslant 0$. We can get the optimal bank loan interest rate $\widetilde{r_b}(k)$;

② If $\epsilon_\xi(0)\geqslant 1$, then we have

$$\epsilon_\xi(0)\leqslant\epsilon_\xi(r_b(k))\leqslant\epsilon_\xi(\widetilde{r_b}(k))\leqslant 1=\epsilon_\xi(\widehat{r_b^2}(k))$$

and $\frac{d\pi_b^2}{dr_b}\geqslant 0$. We can get the optimal bank loan interest rate 0;

③ If $\epsilon_\xi(0)<1$ and $\epsilon_\xi(\widetilde{r_b})>1$, then we have

$$\epsilon_\xi(0)<1=\epsilon_\xi(\widehat{r_b^2}(k))<\epsilon_\xi(\widetilde{r_b}(k))$$

and $\frac{d\pi_b^2}{dr_b}(r_b=\widetilde{r_b}(k))<0$, $\frac{d\pi_b^2}{dr_b}(r_b=0)>0$. We can get the optimal bank loan interest rate $\widehat{r_b^2}(k)$.

Proposition 4.6 When the retailer is overconfident and information between the bank and the retailer is symmetric, the optimal bank loan interest rate R_b^2 is given by

$$R_b^2=\begin{cases}0,\epsilon_D(0)\geqslant 1;\\ \widetilde{r_b}(k),\epsilon_D(\widetilde{r_b})\leqslant 1;\\ r_b^{2*},\epsilon_D(0)<1\text{ 且 }\epsilon_D(\widetilde{r_b})>1\end{cases}\tag{17}$$

where

$$\epsilon_D(r_b)=\frac{\overline{F}(q_r^{2*}(r_b))\cdot[1-(q_r^{2*}(r_b)-\frac{k}{w})\cdot h_D(q_r^{2*}(r_b))]}{w\cdot[1-y_b\cdot h_D(y_b(q_r^{2*}(r_b)))]},$$

and r_b^{2*} satisfies the following equations:

$$\begin{cases}(1+r_b^{2*})\cdot\overline{G}(y_b(q(r_b^{2*})))\cdot\\ \quad\frac{1-(q(r_b^{2*})-\frac{k}{w})\cdot h_D(q(r_b^{2*}))}{1-y_b(q(r_b^{2*}))\cdot h_D(y_b(q(r_b^{2*})))}=1,\\ \overline{F}(q(r_b^{2*}))=w\cdot(1+r_b^{2*})\cdot\overline{F}(y_b(q(r_b^{2*})))\end{cases}\tag{18}$$

There are three situations of the optimal bank loan interest rate. In the first situation, the retailer would not borrow from the bank. In the second situation, the optimal interest rate is the upper limit of the bank loan interest rate. If the interest rate exceeds this threshold, the retailer would not use the bank loans.

5 Numerical experiments

We now numerically compare the retailer's profit, the bank's profit, the retailer's order quantity and the system's profit under the information symmetry and asymmetry, respectively. We assume that the random demand satisfies an exponential distribution with coincidence coefficient of 15[20]. When the retailer is overconfident, his realized market demand satisfies an exponential distribution with the coincidence coefficient of 10. We assume the wholesale price is 0.6.

5.1 The unbiased retailer and bank

Observation 5.1 When the retailer's initial capital is not enough to order the optimal quantity of goods, he always borrows from the bank. When the retailer is unbiased, the optimal ordering quantity is

$$Q_0 = \begin{cases} q_r^{0*}, 0 \leqslant k < w \cdot \overline{G}^{-1}(w); \\ \overline{G}^{-1}(w), k \geqslant w \cdot \overline{G}^{-1}(w). \end{cases}$$

In Figure 2, when the retailer is unbiased, the retailer's financing decision can be divided into two stages: when the initial capital is insufficient to support the optimal ordering decision, the retailer will borrow from the bank; when the initial capital of the retailer is sufficient to support the optimal ordering decision, the retailer does not need to borrow from the bank.

We get the following conclusions from Figure 3. With the increase of initial capital of the retailer, the bank loan interest rate decreases. The bank needs to set a higher interest rate to neutralize the risk that the retailer's revenue might be unable to recover the loans. This can also reduce the retailer's order quantity and reduce the bankruptcy risk of the retailer. When the retailer's initial capital can support the ordering goods of the optimal quantity, the retailer does not need bank loans. Then, the interest rate of the bank loans will be reduced to 0.

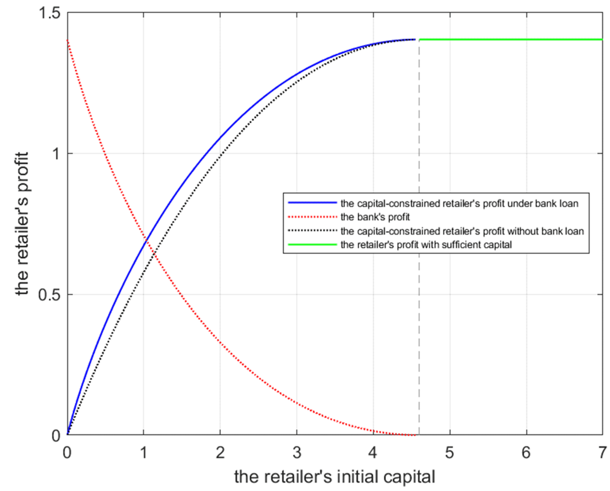

Figure 2. Profits of no biased retailer and bank position.

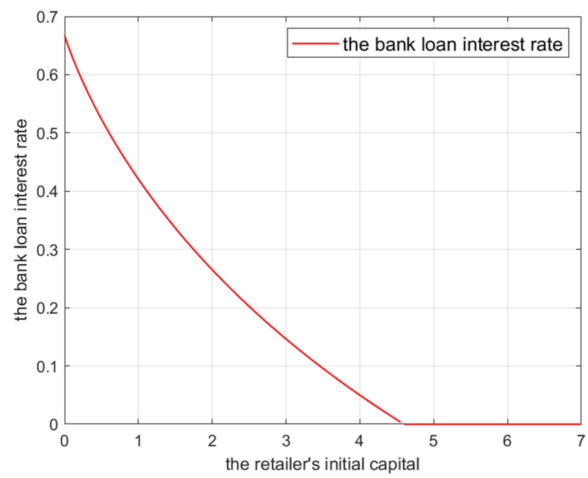

Figure 3. The bank loan interest rate with unbiased retailer.

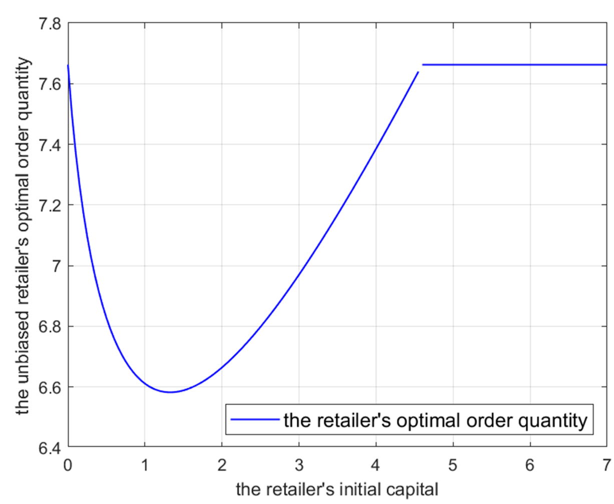

Figure 4. The unbiased retailer's optimal order quantity.

With the increase of initial capital, the retailer's ordering quantity first decreases and then increases (see Figure 4). When the initial capital of the retailer is low, the bank loan interest rate is very high. The amount of bank loans that the retailer needs to repay is very large, which makes it possible for the retailer to go bankrupt. Therefore, in order to get more income to repay the bank loans and to avoid bankruptcy, the retailer would choose to meet the market demand as much as possible. When the initial capital of the retailer exceeds a certain value, the retailer's order quantity will increase with the initial capital.

5. 2 Overconfident retailer and bank under information asymmetry

Observation 5.2 Under information asymmetry, when the retailer is overconfident, with the increase of initial capital k, his financing decision can be divided into three stages or two stages according to the retailer's overconfidence degree. When the overconfidence degree is not very high,

$$Q_1=\begin{cases} q_r^{1*}, 0\leqslant k<w\cdot \bar{F}^{-1}(w\cdot(1+r_b)); \\ \dfrac{k}{w}, w\cdot \bar{F}^{-1}(w\cdot(1+r_b))\leqslant k<w\cdot \bar{F}^{-1}(w); \\ \bar{F}^{-1}(w), k\geqslant w\cdot \bar{F}^{-1}(w). \end{cases}$$

When the overconfidence degree is extremely high,

$$Q_1=\begin{cases} q_r^{1*}, & 0\leqslant k<w\cdot \bar{F}^{-1}(w); \\ \bar{F}^{-1}(w), & k\geqslant w\cdot \bar{F}^{-1}(w). \end{cases}$$

When the retailer's overconfidence degree is not very high and the information between the bank and the retailer is asymmetric, with the increase of the retailer's initial capital, there are two turning points in the retailer's financing decision (see Figure 5): When the retailer's initial capital is lower than the first turning point, the retailer gets loans from the bank; when the retailer's initial capital is between the first and the second turning point, the retailer's initial capital is insufficient to support the optimal ordering decision. However, because of the high cost of borrowing from the bank, the retailer will only use his initial capital for ordering goods. When the retailer's initial capital exceeds the third turning point, his initial capital is enough to support the optimal ordering decision, so the retailer does not need to borrow from the bank.

When the retailer's overconfidence degree is extremely high and the information between the bank and the retailer is asymmetric, with the increase of the retailer's initial capital, there is only one turning point in the retailer's financing decision (see Figure 6): When the retailer's initial capital is lower than the turning point, the retailer gets loans from the bank; when the retailer's initial capital exceeds the turning point, his initial capital is enough to support the optimal ordering decision, so the retailer does not need to borrow from the bank.

Under different financing decisions, the retailer's decision of ordering quantity can be divided into several stages (see Figure 7): Under the background that the retailer is short of funds and borrows from the bank, if his initial capital is low, the bank loan interest rate would be very high, and the retailer is more likely to go bankrupt. The retailer will order more goods to meet the uncertain market demand, in order to obtain more sales revenue to repay the bank loans. When the retailer's

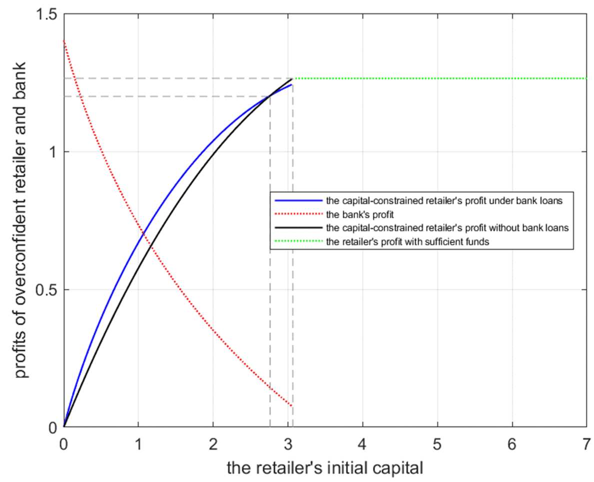

Figure 5. Profits of overconfident retailer and bank under information asymmetry.

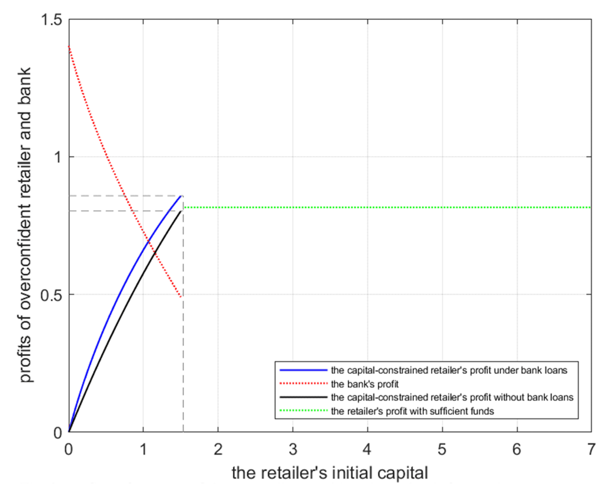

Figure 6. Profits of overconfident retailer and bank under information asymmetry.

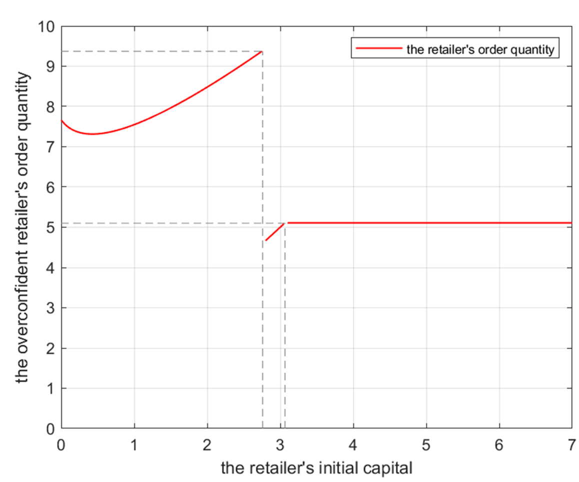

Figure 7. The overconfident retaler's order quantity under information asymmetry.

capital is insufficient but does not borrow from the bank, the retailer's order quantity is proportional to his

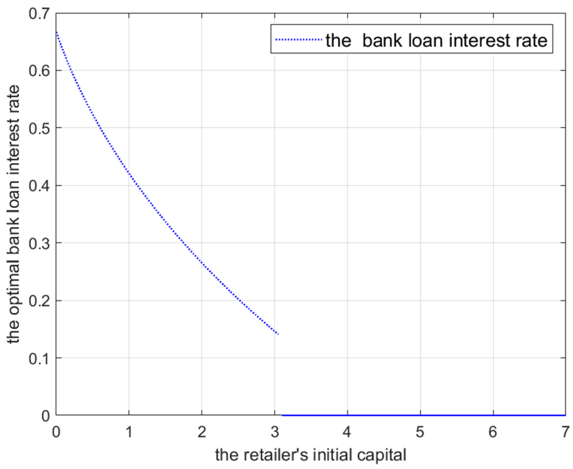

Figure 8. The bank loan interest rate under information asymmetry.

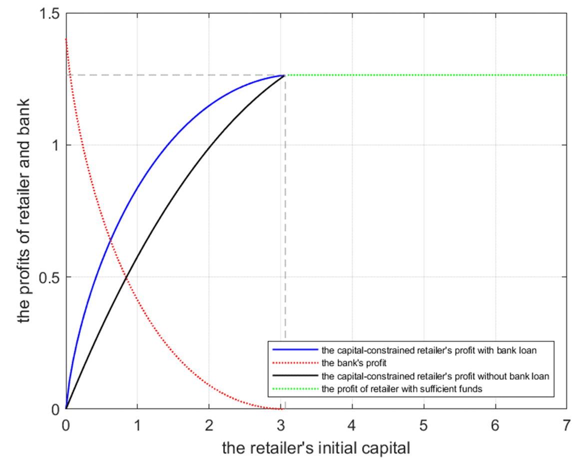

Figure 9. The profits of overconfident retailer and bank under informaton symmetry.

initial capital. When the retailer's initial capital is sufficient to support the optimal ordering decision, the retailer's order quantity remains constant.

When the retailer is capital-constrained and borrows from the bank, the bank loan interest rate decreases with the increase of the retailer's initial capital (see in Figure 8).

5.3 Overconfident retailer and bank under information symmetry

Observation 5.3 Under information symmetry, when the retailer is overconfident, with the increase of initial capital k, his financing decision can be divided into two stages:

$$Q_2=\begin{cases} q_r^{2*}, & 0\leqslant k<w\cdot \bar{F}^{-1}(w); \\ \bar{F}^{-1}(w), & k\geqslant w\cdot \bar{F}^{-1}(w). \end{cases}$$

When the retailer is overconfident and the information between the bank and the retailer is symmetric, the retailer's financing decision can be divided into two stages (see Figure 9): When the initial capital is insufficient to support the optimal ordering decision, the retailer will certainly borrow from the bank; when the initial capital of the retailer is sufficient to support the optimal ordering decision, the retailer does not need to borrow money from the bank. With the increase of retailer's initial capital, the bank loan interest rate decreases. When the retailer's initial capital is enough to support the optimal ordering decision, the bank loan interest rate becomes zero.

When the retailer is capital-constrained and borrows from the bank, the bank loan interest rate decreases with the increase of the retailer's initial capital (see in Figure 10).

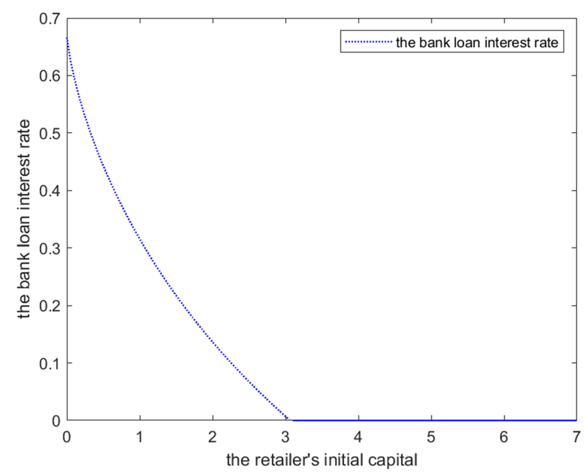

Figure 10. The bank loan interest rate under information symmetry.

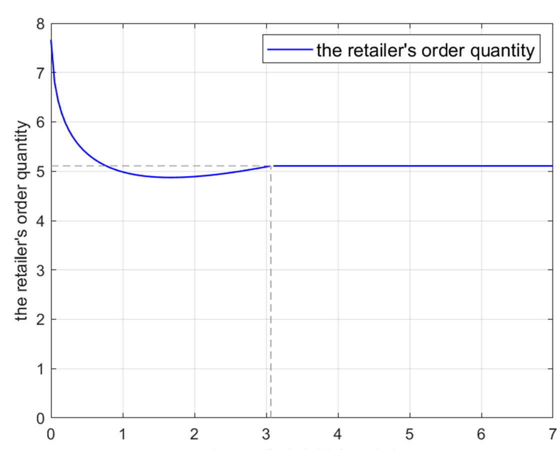

Figure 11. The overconfident retailer's order quantity under information symmetry.

Under different financing decisions, the retailer's decision of ordering quantity can be divided into several stages (see in Figure 11): Under the background that the retailer is capital-constrained and borrows from the bank, if he is severely poor, the bank loan interest rate would be very high, and the retailer is more likely to go bankrupt. The retailer orders more goods to meet the uncertain demand, in order to obtain more sales revenue

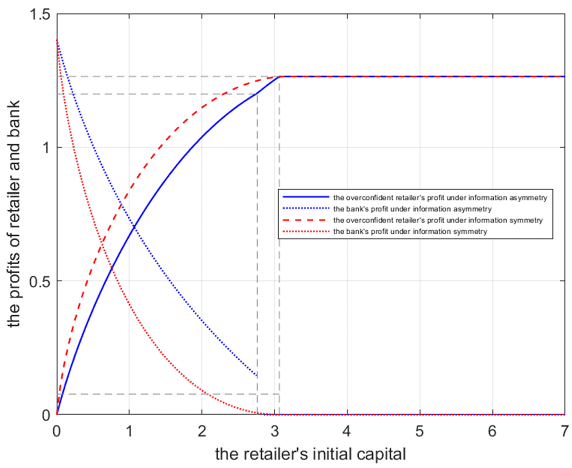

Figure 12. The influence of information asymmetry and symmetry to the profits of retailer and bank.

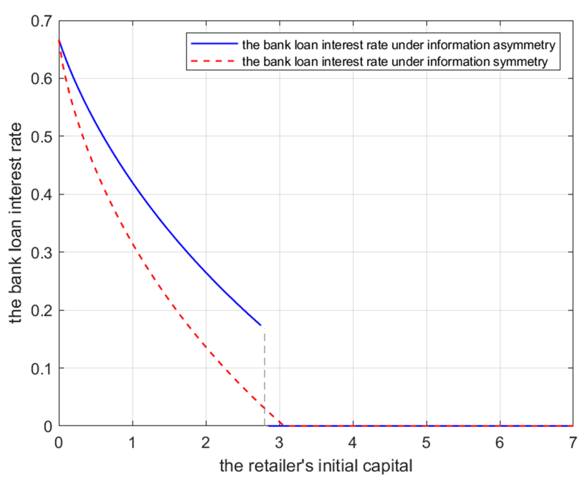

Figure 13. The influence of information asymmetry and symmetry to the bank loan interest rate.

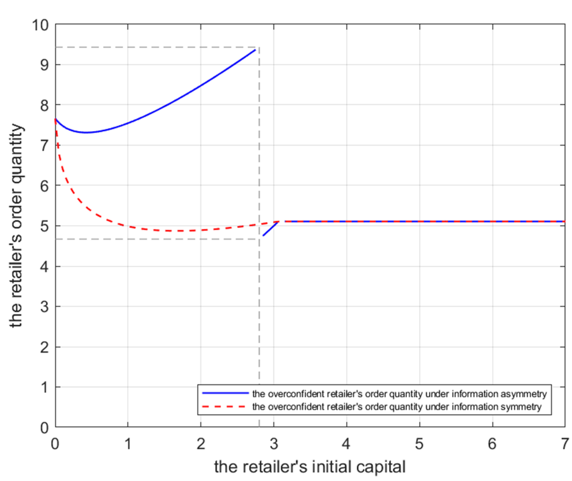

Figure 14. The influence of information asymmetry and symmetry to the retailer's order quantities.

to repay the bank loans. When the retailer is medium poor, the retailer borrows from the bank. When the

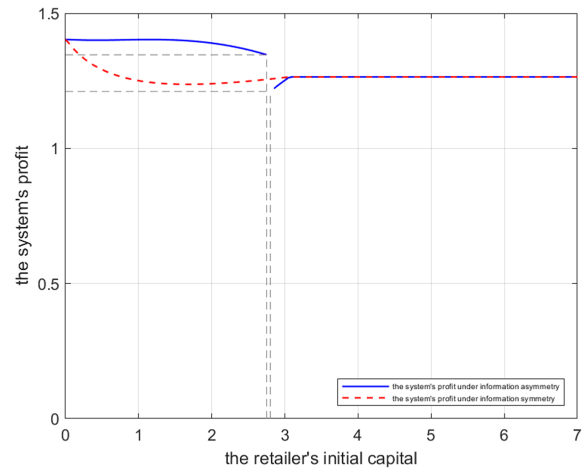

Figure 15. The influence of information asymmetry and symmetry to sysytem's profit.

retailer's initial capital is sufficient to support the optimal ordering decision, the retailer's order quantity remains constant.

5.4 The comparison under information asymmetry and symmetry

We get the retailer's and the bank's profit, bank loan interest rate and the retailer's ordering quantity with the changes of retailer's initial capital in the case of information symmetry and asymmetry, as shown in Figures 12−15.

When the retailer is overconfident, the expected profit of the retailer under information symmetry is higher than that under information asymmetry. But the expected profit of the bank under information symmetry is lower than that when the information is asymmetric (see Figure 12). The retailer is willing to disclose his demand cognition to the bank. This can bring more profit to him. The impact of information symmetry on the total profit of the system composed of the bank and the retailer is not monotonous. In some cases, information asymmetry can make the total profit of the system greater than that under information symmetry.

When the retailer's initial capital is lower than the first turning point, the bank loan interest rate under the information asymmetry is high than that under the information symmetry (see Figure 13). This phenomenon can be explained as follows. To maximize her own profits, the bank has a unique value rate about the ordering quantity related to the bank loan interest which the retailer is hoped to execute. The retailer's ordering quantity in the bank's perception under the information asymmetry is larger than that under the information symmetry, which is also the retailer's real ordering quantity under the information symmetry. When the information between them is asymmetric, to adjust the ordering quantity to the same point which can maximize the bank's profits, the bank increases the bank loan interest rate compared with the interest rate under the information symmetry (see Figure 14).

When the information among the retailer and the bank is asymmetric, the total profit of the system can be divided into three stages (see Figure 15). When the retailer's initial capital is very low and gets loans from the bank, the total profit of the system is composed of profits of the bank and the retailer. When the retailer has low initial capital but does not borrow from the bank, the total profit of the bank and the retailer is the same as that of the retailer. And the total profit increases with the increase of the retailer's initial capital. When the retailer's initial capital is enough to support the optimal ordering decision, the retailer will not borrow from the bank, and the total profit of the bank and the retailer is consistent with that of the retailer. When the information among the bank and the retailer is symmetric, the total profit of the system can be divided into two stages. When the initial capital of the retailer cannot support the optimal ordering decision, the total profit of the system decreases first and then increases. When the initial capital of the retailer is enough to support the optimal ordering decision, the total profit of the system remains unchanged.

6 Conclusions

Based on the newsvendor model, we analyze a system with a leader bank and a follower retailer under the information asymmetry and information symmetry. The bank sets the loan interest rate, and the retailer decides the order quantity and financing choices. We obtain the equilibrium when the retailer is in different initial capital endowments.

We find that the information symmetry impacts the decision-making of the monopoly bank and the overconfident retailer. Under information asymmetry, the retailer's financing decision can be divided into three stages. When the retailer is severely poor, he gets loans from the bank. When the retailer is medium poor, he does not borrow from the bank and use up his initial funds to order goods. When the retailer is rich, he chooses the optimal order quantity. Under the information symmetry, the retailer's financing decision can be divided into two stages. When the capital is insufficient, the retailer borrows bank loans. With sufficient funds, the retailer uses his own initial capital and order a constant number of goods.

This phenomenon can be explained as: When the information among the bank and the retailer is asymmetric, the retailer's order quantity estimated by the bank is smaller than the actual order quantity, so the bank cannot estimate the bank loan interest rate corresponding to the order quantity accurately. Therefore, when the retailer is medium poor, the unit profit of the goods is not enough to make up for the interest rate of bank loans. As a result, retailers will not borrow from the bank in this region. When the information between the bank and the retailer is symmetric, the bank can accurately adjust the bank loan interest rate according to the retailer's order quantity, so there does not exist the case that the retailer's capital is not enough to support the optimal order decision, but he does not borrow from the bank. The information symmetry can make the retailer get more income, so the retailer tends to disclose his demand cognition to the bank.

The following result is surprising. Indeed, the information asymmetry is so common and its impact is so great that it affects the efficiency of the marketing mechanism in allocating resources, causing the members with the information advantage to obtain too much surplus in the transaction, due to the gap of information power. The excessive disparity leads to a serious imbalance in the benefit distribution structure. However, we get some conclusions which are opposite of our expectation before. According to the retailer's different initial capital, information asymmetry might reduce the loss of the system's total profit, which is caused by double marginalization effect conditionally. When the retailer's initial capital is insufficient but does not borrow from the bank, information asymmetry will cause a further loss to the total profit of the system. The reasons for this phenomenon is that when the retailer is short of funds and borrows from the bank, since the retailer is more optimistic about the demand, his order quantity is more likely to meet more market demand, which can reduce the loss of the system's profit caused by the double marginalization effect to a certain extent. When the retailer is short of funds but does not borrow from the bank, to meet more demand, he uses his own initial funds to order goods. In this case, the order quantity is less than that with the bank loans, so it meets less demand, and causes a further loss to the system's profit.

In reality, banks can deal with the information asymmetry through several ways. Firstly, banks can use the credit investigation system to understand the credit status of the enterprise. Also, banks should collect the public information and understand the situation of the company. Banks need to collect information from industry and commerce, taxation, customs, courts, statistics bureaus and so on to analyze the situation of the company. Besides these, the bank could exchange information with other banks and share information channels.

Considering the risk factors, the amount of bank loans cannot be unlimited in reality. In our model, we don't assume an upper limit of the amount of bank loans. In the subsequent research, we might assume that the upper limit of bank loans is related to some factors of the retailer, such as the credit status. Then, we can try to discuss this assumption's influence on avoiding the disadvantages of overconfidence.

Although our model is representative of some actual supply chains, we recognize that our conclusions are limited to the setting. We use exponential distributions to describe the random demand in the numerical simulation, while there are other influencing factors in the random demand in reality. Also, we don't pay much attention to the magnitude of the retailer's overconfidence degree. We don't consider the supplier's decision on the wholesale price as well.

As an attempt at linking the overconfident newsvendor problem with bank financing under the information asymmetry, we have several research directions to explore. First, we will study the overconfident retailer's decision under the information symmetry and asymmetry with other short-term financing sources. Second, credit rating of newsvendors is an emerging research issue, so we will consider credit rating in bank loans in the following researches. Third, we will expand the problem into supply chains.

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Conflict of interest

The authors declare no conflict of interest.

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信息不对称背景下过度自信的零售商融资策略

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摘要：过度自信的零售商对于随机事件的结果的认知比实际情况更确定. 我们研究了包含一个利润最大化的银行和一个过度自信的零售商的系统. 其中，零售商受到资金约束，可能需要使用银行贷款. 基于零售商的初始资金，我们将零售商分为严重贫困、中等贫困和富裕三类. 在信息对称和信息不对称的情况下，得到了零售商的均衡订货量和银行利率. 在信息对称的情况下，资金受限的零售商总是使用银行贷款. 在信息不对称的情况下，当零售商严重贫困时，他会向银行贷款. 然而，当零售商中等贫困时，他会使用全部的初始资金，但不使用银行贷款. 资金受限的零售商愿意向银行披露其对市场需求的认知. 在某些情况下，信息不对称会减少双边界化效应造成的系统利润损失.

关键词：斯塔克伯格博弈；银行融资；过度自信的零售商；信息不对称