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Who should finance the supply chain? Impact of accounts receivable mortgage on supply chain decision

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ABSTRACT

We attempt to understand the role of accounts receivable mortgage in a capital-constrained supply chain and to capture the interaction of firms' operations decisions within non-cooperation or cooperation conditions based on different bank credit policies. We consider a short-term loan directly to the retailer as a supplement to accounts receivable financing. Given different bank credit policies based on the retailer's and manufacturer's original operational capacity, we identify optimal decisions in different situations, finding that supply chain efficiency is better attained using bank short-term loans. Generally, firms with high solvency order more compared to low solvency firms. Specifically, we find that the optimal sourcing choices depend on the ratio of the share of the manufacturer with the share of the retailer (RMR). When RMR is low, trade credit would be better for sourcing. Conversely, bank credit would be the better choice for a capital-constrained supply chain. Finally, we present empirical evidence to demonstrate the results of our study.

1. Introduction

Accounts receivables are a key part of a company's financial management practices, especially for firms that do not have sufficient working capital. They can increase supply chain efficiency, resulting in shorter production cycles. For manufacturers, accounts receivable is mainly due to trade credit offered to retailers, which may increase manufacturer default risk. The global factoring industry has been growing at a relatively fast pace since 1996, increasing nearly 9% per annum on average, with total volume amounts of EUR 2376 billion in 2016 (). Factoring could formally separate manufacturer accounts receivables from retailers' assets in the event of bankruptcy, thus transferring debt from the manufacturer to factors (Kouvelis and Xu, 2018). However, under accounts receivable mortgaging, the credit assets of the manufacturer do not belong to banks, differing from factoring. Banks offer short-term loans based on orders and manufacturer credit conditions. There is a risk-sharing mechanism for banks to participate in transaction activity.

Recently, more and more banks offer financing services to manufacturers with good credit conditions. According to World Bank statistics, Chinese current movable assets amount to 50 trillion to 70 trillion yuan. Only receivables mortgages can be conveniently used to obtain movable property guaranteed to finance. Accounts receivable mortgage means that supply chain enterprises use their accounts receivable (one type of trade credit) as collateral for commercial bank loans. If the borrower defaults on its repayment obligations, the lender will use the secured receivables to repay the loan. Data shows that the average annual rate of accounts receivable mortgage has increased by 23% (Wang, 2019). Further, TAB Bank has announced that it has provided a \$2 million asset-based revolving credit facility for a transportation company based in Utah (Morris, 2019).

Recently China's second-largest e-commerce company, Jingdong, conducted accounts receivable financing. Table 1 shows 's primary financing products, including Jing Bao Bei, Jing Cai, and Jing small loans. Each product charges different interest rates for different types of SMEs (Small and Medium Enterprises) by offering short-term loans. Accounts receivable financing plays an important role in Jingdong's growth. has provided payment and financial services to 8 million online and offline merchants and 400 million individual users.

Accounts receivable mortgage contracts are complex, depending on many factors such as the firms' original operational capacity, solvency, order decision, market risk, bank's credit policy, and so forth. Moreover,

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Table 1
's business model.

Product name	Applicable scene	Features	Interest characteristics
Jing Bao Bei	Accounts receivable financing	No warranty mortgage	Interest on a daily basis; with a financing period of fewer than 15 days, there will be a repayment fee
Jing Cai	Buyer's financing	Purchase first, post payment	The weekly settlement, repayment on time within 14 days of the repayment period, no commission; The monthly settlement, repayment period of 50 days, installment repayment rate of 0.5%/period, and non-installment rate of 0.6%/ period.
Jing small loan	Financing without receivables	No mortgage, fast loan	Daily interest rate: 0.033%–0.05%; repayment period: 2–12 months

retailers and manufacturers are not isolated in the markets (Xu et al., 2022). They may choose to cooperate with each other, which can significantly moderate the double marginal effect (Yang et al., 2015) and can improve supply chain efficiency (Wu et al., 2019). The effect mechanism to supply chains when sourced from accounts receivable mortgages is still unclear. We are interested in the differences between retailer financing directly from commercial banks in capital-constrained supply chains compared to sourcing from trade credit based on accounts receivable mortgages. These observations motivated us to examine the following questions in this paper. What is the impact on supply chain decisions when bank credit policies differ in interest rates based on different orders for manufacturer accounts receivable mortgage contracts? How does operations strategy differ between credit policies directly offered to retailers rather than to the manufacturer?

To answer the above question, we establish a Stackelberg game that involves three parties: a capital-constrained retailer, a capital-constrained manufacturer, and a bank. The bank evaluates the manufacturer's or retailer's original operational capacity and solvency and gives interest rates compensating for default risk when market demand is stochastic. For trade credit with accounts receivable mortgage, banks consider lending thresholds based on the assessment of risk and give risk-free rates when orders fall below this threshold, making them appear safe. Banks also consider the manufacturer's initial capital and original operational capacity and set interest rate compensation by setting general rates for SMEs and compensatory rates for riskier cases. When retailers source directly from the bank, bank interest rates are based on credit policy. We find that retailer sourcing from the bank would lead to better supply chain efficiency and lead greater profits. With high solvency, order quantities are greater. We examine empirical evidence from China and find that trade credit is a supplement source of capital for firms. Furthermore, we find that initial capital's effect on the manufacturer is more significant than the retailer's initial capital on supply chain decisions.

Our work has three-fold contributions compared to prior studies (Alan and Gaur, 2018): In the capital-constrained supply chain, banks' risk preferences and various interest rates are taken into account (Barrot, 2016); Theoretical mechanisms and the effects of account receivable mortgage on the choices of capital-constrained manufacturers and retailers are identified (Birge, 2014). The panel regression used in this paper examines the effects of accounts receivable mortgages using realistic data.

Our research reveals two important managerial implications. First, higher solvency retailers or manufacturers order more even when facing market risks no matter what their accounts receivable mortgage or bank credit conditions, and sourcing from bank loans benefits firms the most based on empirical evidence. Second, we empirically identify the effects of capital constraint retailers' decisions under different situations based on Chinese data.

The rest of this paper is structured as follows. Relevant work is reviewed in Section 2. Section 3 proposes the basic model and assumptions. Stackelberg equilibrium with accounts receivable mortgage and bank financing are derived in Sections 4 and 5 respectively. Section 6 presents the empirical examination. Section 7 shows conclusions. Proofs and related notation are collected in the Appendix.

2. Literature review

There is a great deal of published work about operations management considering the intersection of finance and operations in recent years, see e.g., Kouvelis and Zhao (2011), Gupta and Dutta (2011), Birge (2014), Jacobson and von Schedvin (2015), Tsao (2019). We see three closely related streams of literature: those addressing the operations-finance interface faced with stochastic demand, inventory management by trade credit, and factoring and accounts receivable financing in supply chains.

There is increasing interest in the operations-finance interface literature on firms' operational decisions with random market demand. Xu and Birge (2004), Tunca and Zhu (2018), Luo and Shang (2014), and Alan and Gaur (2018) analyzed the decision of capital-constrained buyers based on game theory, showing that supply chain efficiency would be increased with financing. Kouvelis and Zhao (2011) considered the trade credit effect on decisions with existing bankruptcy costs, finding that the retailer's wealth and supplier's wholesale price would increase. Jing et al. (2012) found that retailers prefer to trade credit when competing banks offer interest rates of zero compared to bank financing. However, when banks have the market power to set interest rates, the choices depend on the bank's credit policy. Chod (2016) established multi-item sourcing for capital-constrained retailers from trade credit, using the linear demand model and newsvendor model respectively, finding that the inventory decision is distorted by debt financing. Kouvelis and Zhao (2017) studied the impact of credit ratings on supply chain decisions, finding optimal short-term financing choices with different rates. Yang and Birge (2018) modeled conditions for retailers' optimal sourcing, considering bank credit, trade credit, or portfolio credit methods. They additionally empirically examined results in light of their theory. Our work is related to Kouvelis and Zhao (2017), and Yang and Birge (2018), using the framework of "selling to newsvendor" (see Lariviere and Porteus, 2001). Johari and Hosseini-Motlagh (2022) consider the evolutionary game theory to analyze the credit strategy in the supply chain. The findings show that the credit time option is the evolutionarily stable approach for pharma distributors in the long run, taking into account the uncertain default risk. However, the above work considers the bank as risk-natural to the retailers and manufacturers, which leads to a fixed risk–free interest rate. They do not consider the impact of banks' risk preference on the interest rate when the player's source is from the bank. Wu et al. (2019) consider the capital-constraint supply chain's financing and investment behavior in a stochastic green product market with a risk-natural bank. Our paper considers the banks' risk preference for the supply chain players. Bi et al. (2021) consider a two-echelon supply chain with one supplier and one retailer to investigate the retailer's trade credit strategy and ordering policy. But they do not consider the different interest rates charged by banks in their risk evaluation. In our work, manufacturers and retailers are both capital-constraint. We add consideration of the effect of a capital-constrained manufacturer sourcing from the mortgage of accounts receivable based on banks' risk preference. Besides, most above works are based on commercial banks offering zero rates. We set the banks would provide different types of interest rates (risk-free rate, general rate, and risk compensation interest rate) based on their risk evaluation on the qualification of the players. A primary contribution of our work is an analysis of the impact of diverse bank interest rates with accounts receivable mortgage contracts on supply chain decisions. This complements existing operations-finance interface literature.

The second stream focuses on inventory policy in the presence of trade credit. Most of the work considers capital-constant retailers in inventory management. Haley and Higgins (1973) developed a lot-size model based on inventory policy and trade credit, the earliest work combining trade credit and inventory management. Jamal et al. (1997) considered trade credit in an EOQ model with deterministic demand. Buzacott and Zhang (2004) modeled EOQ to optimize inventory by incorporating asset-based financing in production decisions based on a deterministic as well as a stochastic model. Rui and Lai (2015) studied a buyer firm's procurement strategy in the presence of the risk of supplier product adulteration with moral hazard. Iancu et al. (2017) modeled inefficiencies stemming from a firm's operating flexibility under debt, finding that inventory-heavy firms can reap the full benefits of additional operating flexibility. Other works on inventory management include Moses and Seshadri (2000), Gupta and Wang (2008), and Luo and Shang (2014). The above works do not consider the existence of capital-constraint on manufacturers. They just consider the retailer's need source from trade credit. Our work proposes the capital-constraint manufacturer can finance from the bank with an account receivable mortgage. The interest rate charged by the bank is divided into different banks' risk preferences and inventory conditions, which are also captured by our work. We give a new insight into the existing literature on inventory policy.

The third stream of literature concerning constrained buyer sourcing focuses on factoring or accounts receivable financing. From the perspective of factoring under conditions of trade credit, Smith and Schnucker (1994) conducted an empirical study finding that factors are more likely to be used when information and monitoring costs are high. Soufani (2002) used data from the UK, concluding that factoring increases firm liquidity, and is widely used in industries. Klapper (2006) demonstrated that reverse factoring mitigates the problem of borrowers' informational opacity if only receivables from high-quality buyers are factored in. This literature primarily studied factoring based on empirical research. van der Vliet et al. (2015) developed a supply chain stock model with reverse factoring. They concluded that payment term extension depends on demand uncertainty and the supplier cost structure. Kouvelis and Xu (2018) presented a newsvendor model to analyze factoring and reverse factoring and identified situations where recourse factoring or non-recourse factoring performs better in terms of supply chain efficiency. For accounts receivable financing, Cerqueiro et al. (2016) analyzed data from a large bank that included timely assessments of collateral values, concluding that it was important for collateralization to reduce debt risk. Tang et al. (2017) modeled capital-constrained manufacturer sourcing from account-receivable mortgages (purchasing order financing) and buyer-direct financing. Their work identified operational and financial environments in which manufacturers may benefit from financing their suppliers directly. Fu et al. (2021) consider equity financing for manufacturers. They find that chain efficiency depends on the cost allocation among chain members. Hosseini-Motlagh et al. (2021) aim at the evolutionary tendencies of a group of financially troubled producers in Iran who receive financial assistance from a dominating distributor in exchange for long-term sustainability investments. However, the above article only utilizes the theoretical analysis of buyer sourcing (Xu et al., 2022), and they do not consider the realistic data to examine the impact of factoring and account receivable mortgages. The banks' risk preference is also ignored. In this paper, we collect the account receivable mortgage data from the Wind database in China and conduct panel regression to examine the detailed impact of buyer sourcing by account receivable mortgage on supply chain decisions.

The contribution of our work could be summarized as follows (Alan and Gaur, 2018). banks' risk preferences and different interest rates are considered in the capital-constraint supply chain (Barrot, 2016); the theoretical mechanism and impact of account receivable mortgages on the decision of capital-constraint manufacturers and retailers are identified (Birge, 2014). the work conducts a panel regression based on realistic data to examine the impact of an accounts receivable mortgage.

3. Model and notation

We consider a supply chain consisting of a capital-constrained retailer (he), a capital-constrained manufacturer (she), and a bank (it). The capital-constrained retailer can source from the manufacturer through trade credit or from the bank by bank loan to realize an optimal order decision. The manufacturer can only obtain cash from the bank based on an accounts receivable mortgage contract. An accounts receivable mortgage contract is that the bank would give different loan amounts and interest rates according to the order amount of accounts receivable and the qualifications of manufacturers and retailers. In our work, the qualifications of manufacturers and retailers would be evaluated by their initial capital. The accounts receivable mortgage contract includes a multi-discount interest rate (risk-free interest rate, general loan interest rate for SMEs, and risk compensation interest rate) according to the retailer's order quantity contract, retailer's initial capital (B_R), and manufacturer's initial capital (B_M).

The retailer faces stochastic market demand (D). Assume that the random demand distribution $F(D)$ is continuously differentiable and that the probability density function is $f(D)$. Stochastic demand has an increasing failure rate (IFR). In other words, the hazard rate $h(D) = \frac{f(D)}{\overline{F}(D)}$ and the general failure rate $H(D) = D\frac{f(D)}{\overline{F}(D)}$ both increase D (Jing et al., 2012; Kouvelis and Zhao, 2015).

In our context, the capital-constrained retailer considers his order quantity (q) and sale price p. The capital-constrained manufacturer decides wholesale price (w) and has unit cost of production c. Assume the relationship of price satisfies $p > w > c$. Because the retailer's initial capital is insufficient to realize order amount (wq), he needs to source ($wq - B_R$) from the manufacturer or the bank. We consider the following two situations: trade credit or bank loan.

When the retailer considers trade credit, there is an accounts receivable mortgage contract for the capital-constrained manufacturer

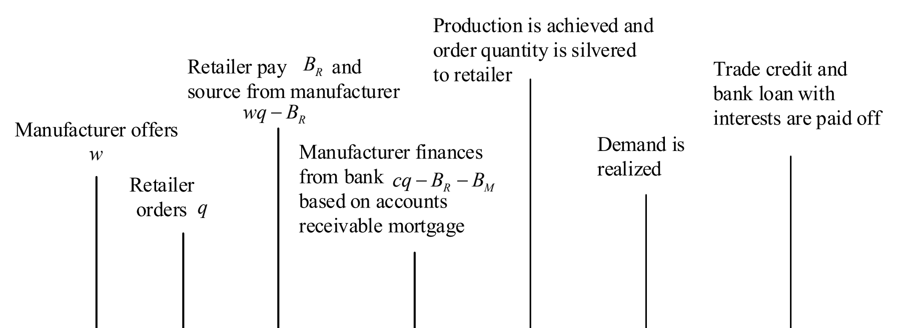


Fig. 1. The sequence of events with accounts receivable mortgage.

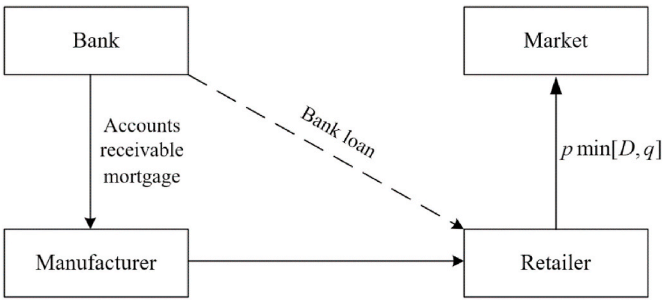


Fig. 2. The relationships among players.

from the bank. The retailer sources from trade credit to meet ordering gaps at the amount $(wq - B_R)$. Next, the capital-constrained manufacturer receives accounts receivable from the retailer, which will be paid off at the end of the retailer's transaction activity or else suffer default. Because the manufacturer's working capital is insufficient, even unable to pay production costs, the manufacturer considers an accounts receivable mortgage loan from the bank. When the retailer cannot defray the trade credit, he suffers bankruptcy. Subsequently, the manufacturer also cannot repay the bank and she bankrupt. In our context, we do not consider the bankruptcy costs of either retailer or manufacturer. This has twofold benefits for the manufacturer. On the one hand, the manufacturer receives a loan to cover production costs. On the other hand, the retailer's bankruptcy risk and bankruptcy loss to the manufacturer can be shifted to the bank. Fig. 1 shows the sequence of events.

Bank would give different interest rate for different account receivable mortgage and manufacturers' qualification (its initial capital). In this situation, the bank sets an accounts receivable mortgage contract to consider the bankruptcy risk of both retailer and manufacturer. A risk compensation mechanism can be established with this account receivable mortgage contract. The manufacturer's financing demand is $L_M = cq - B_R - B_M$.The commercial bank views that part of the manufacturer's accounts receivable as safety which can be charged at a risk free interest (r_f) and the ratio is θ. In other words, we have loan amount $L_{M,i} = \theta(wq - B_R)$ for interest rate r_f. The risk assessment coefficient θ $(0 < \theta \leq 1)$depends on many factors such as the degree of risk preference of commercial banks, inter-bank loan competition, state support policies for SMEs, and the ratio of central bank deposit reserve, etc. We have two scenarios (I and II) based on different demands of the manufacturer for a loan. For scenario I, when $L_M \leq L_{M,i}$, the bank's interest rate equals to r_f. For scenario II, when $L_M > L_{M,i}$, the excess loan, $L_{M,ii} = cq - B_R - B_M - \theta(wq - B_R)$ will be charged at interest rate r_M in order to compensate for default loss. r_M can be decided by the manufacturer's and retailer's working capital, bankruptcy events, general loan interest rate, and risk compensation mechanism, which can be discussed in detail.

Considering stochastic market demand, the retailer may suffer from overstocking. When demand D is lower than $q_{R,T}$, sales revenue pD will not pay for trade credit, which is $pD < wq - B_R$. The retailer will bankrupt and default on trade credit. The revenue totally transfers to the manufacturer as a result of no bankruptcy costs. Next, the manufacturer pays back the principal and interest to the bank. We have the retailer's bankruptcy threshold $q_{R,T} = \frac{wq - B_R}{p}$. The bankruptcy threshold reflects the order quantity when the firm just goes bankrupt.

If the random demand is specifically low, after the retailer's bankruptcy the transferred assets to the manufacturer cannot pay off the bank loan and interest, and the manufacturer suffers bankruptcy. The bank gains all the retailer's revenue. We have the manufacturer's bankruptcy threshold q_M, which is denoted by I and II according to different scenarios, yielding: $q_{M,I} = \frac{(1+r_f)(cq - B_R - B_M)}{p}$ for scenario I and $q_{M,II} = \frac{(1+r_f)L_{M,i} + (1+r_M)L_{M,ii}}{p}$ for scenario II.

As proposed above, the excess loan interest rate of the accounts receivable mortgage contract decided by the bank can be affected by many factors. We illustrate the interest rate for the contract as follows. Considering default risk, the bank sets r_M based on manufacturer's payment potential which depends on her bankruptcy threshold and order amount. Moreover, manufacturer and retailer initial capital proportions are also considered, representing the manufacturer's original initial operating condition. We obtain r_M satisfying Equation (Alan and Gaur, 2018). Especially, r represents the general loan interest rate for SMEs (Small and Medium Enterprises) and capital evaluation coefficient $\lambda > 0$.

$$r_M = \begin{cases} r & \dfrac{B_M}{B_M + B_R} \geq \dfrac{q_M}{q} \\ \left(1 + \lambda \dfrac{B_R}{B_M}\right) r & \dfrac{B_M}{B_M + B_R} < \dfrac{q_M}{q} \end{cases} \tag{1}$$

This paper uses the order quantity as the basis for evaluating the bankruptcy risk rate. The order quantity is belong to $[0, q]$. When the order quantity is less than the bankruptcy threshold for manufacturer (q_M), the manufacturer would go bankrupt. However, when the order quantity is higher than q_M, the manufacturer would not go bankrupt. Thus, we consider $\frac{q_M}{q}$ as the bankruptcy risk rate.

The bank compares initial capital proportion $\frac{B_M}{B_M+B_R}$ with the manufacturer's bankruptcy risk rate $\frac{q_M}{q}$. When the manufacturer's initial capital proportion is higher than its bankruptcy risk rate, $\frac{B_M}{B_M+B_R} > \frac{q_M}{q}$, the bank deduces that manufacturer's management capacity is well. Thus, it charges a general loan interest rate to the manufacturer for an excess loan. Nevertheless, when $\frac{B_M}{B_M+B_R} \leq \frac{q_M}{q}$, the bank considers that the manufacturer has high default probability and requires higher interest rate compared to the general loan interest rate for SMEs (r), which can be written as $\left(1 + \lambda \frac{B_R}{B_M}\right) r$, which is called the risk compensation interest rate. As can be seen, in our model, the risk compensation interest rate charged by bank is endogenous depending on retailer's and manufacturer's initial capital.

To extend our model, we study the situation where the retailer considers a bank loan for sourcing. Here the manufacturer's financing demand is eliminated and the manufacturer does not need to source from a commercial bank. When the retailer finances from a bank, he can pay wq to the manufacturer at the beginning. Then the manufacturer receives wq and starts to produce because wq is higher than production cost cq.Thus, in this context, the bank only lends money to the retailer and will suffer default risk directly from retailer. The bank then considers charging risk compensated interest rate $r_R = \left(1 + \lambda \frac{B_M}{B_R}\right) r$ in response to potential retailer bankruptcy. At the end of the transaction, the retailer needs to pay principle and interest $\left[1 + \left(1 + \lambda \frac{B_M}{B_R}\right) r\right](wq - B_R)$ to the bank. The retailer's bankruptcy threshold is $q_{R,B} = \frac{\left[1 + \left(1 + \lambda \frac{B_M}{B_R}\right) r\right](wq - B_R)}{p}$.

Fig. 2 shows the relationship of different players in our model. Due to the capital constraint for both retailers and manufacturers, the supply chain need to finance from bank. The first financial channel is accounts receivable mortgage to manufacturer and the second financial channel is the bank direct loan to the retailer. Then, the retailer sales the product to the stochastic demand's market. These two financial channels would be discussed in Section 4 and Section 5. Fig. 3 summarizes the sequence of different players' behavior with bank loan.

Based on the above analysis, the key notation is summarized in Table 3.

3.1. Assumptions

(i) $B_R + B_M > p > (1 + r_M)w > (1 + r_f)w > c \geq 1$ and $B_R + B_M > p > (1 + r_R)w > (1 + r_f)w > c \geq 1$ (Yang and Birge, 2018);

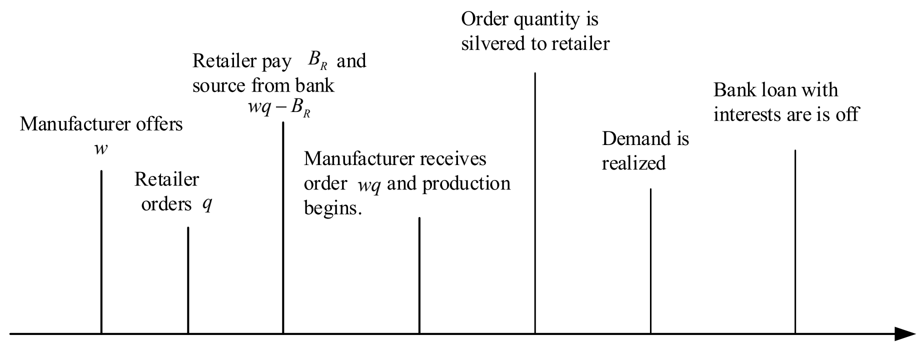


Fig. 3. Sequence of events with bank loan.

Table 3
Key notation.

Notation	Definition
q	Order quantity
q_R	Retailer's bankruptcy threshold
q_M	Manufacturer's bankruptcy threshold
w	Wholesale price
c	Unit production cost
D	Stochastic demand; CDF is $F(D)$, PDF is $f(D)$
B_R	Retailer's initial capital
B_M	Manufacturer's initial capital
θ	Risk assessment coefficient
λ	Capital evaluation coefficient
π_R	Profit of retailer
π_M	Profit of manufacturer
π_B	Profit of bank
L_M	Manufacturer's financing demand
r_f	Risk free interest rate
r	General loan interest rate for SMEs
r_M	The excess loan interest rate for manufacturer
r_R	The loan interest rate for retailer
Ω	Area of order quantity and risk assessment coefficient

Our main assumptions is as follow.

(*ii*) The capital market is perfect, i.e., there are no bankruptcy costs, taxes, or transaction costs; retailer and manufacturer are risk-neutral and pursue the maximization of their profit; The information in the market is perfect. There is no extra private information (Wu et al., 2019);
(*iii*) Retailer and manufacturer are both capital-constrained, we have $wq - B_R > 0$ and $cq - B_R - B_M > 0$;the bankruptcy threshold satisfies $q_M < q_{R,T}$ (Wu et al., 2019).
(*iv*) The demand distribution $F(D)$ has an increasing generalized failure rate (An et al., 2021).

Assumption *i* is based on the reality that the retailers' sale price is higher than unit production price and cost price. In this way, the players can obtain positive profit and avoids trivial cases. Also, there is a certain amount of initial capital to ensure that the bank can give accounts receivable collateral loans to the players. Assumption *ii* reveals the market is perfect, which is follows by many works (Wu et al., 2019; An et al., 2021). Assumption *iii* shows that the manufacturers and retailers are both capital-constraint and they need to finance to keep normal business. Finally, the most popular demand distributions, such as uniform and normal distributions, satisfy assumption *iv* (Kouvelis and Xu, 2018; Kouvelis and Zhao, 2011).

Following the model and assumptions, we consider a Stackelberg game theoretical model to study the equilibrium of a capital-constrained retailer and a capital-constrained manufacturer yielding an optimal operational decision based on the retailer's trade credit and manufacturer's accounts receivable mortgage contract or retailer financing from bank credit. in the next section, we illustrate the equilibrium based on trade credit with an accounts receivable mortgage.

4. Trade credit with accounts receivable mortgage

In this subsection, we study the optimal management decision of a capital-constrained retailer and a capital-constrained manufacturer under trade credit and accounts receivable mortgage contract covering such items as order quantity, wholesale price, retailer's optimal profit and manufacturer's optimal profit. Many factors can affect these operational strategies such as initial capital and interest rate. We also study the impacts of accounts receivable mortgage contracts on supply chain management based on two scenarios.

4.1. Retailer's problem

Initially, the retailer's initial capital is lower than wq and he sources $wq - B_R$ under trade credit. At the end of the transaction, the retailer obtains sales revenue $\min[pD, pq]$ and pays $\min[p\min[D,q],(wq - B_R)]$ to the manufacturer in trade credit payment. When stochastic demand is below the retailer's bankruptcy threshold, the retailer suffers bankruptcy. All the revenue transfers to the manufacturer and retailer profit in this condition equals initial capital loss. The following equation defines the retailer's profit function:

$$\pi_{R,T} = \begin{cases} -B_R & 0 \quad < D \le q_M \\ -B_R & q_M \quad < D \le q_{R,T} \\ -B_R + pD - (wq - B_R) & q_{R,T} < D \le q \\ -B_R + pq - (wq - B_R) & q \quad < D \end{cases}. \tag{2}$$

It can be simplified as follows:

$$E(\pi_{R,T}) = p\left[q - \int_{q_{R,T}}^{q} F(D)dD\right] - wq, \tag{3}$$

where $q_{R,T} = \frac{wq - B_R}{p}$.

To maximize the retailer's profit and obtain optimal order quantity, we have the following equation as:

$$\max : E(\pi_{R,T}) = p\left[q - \int_{q_{R,T}}^{q} F(D)dD\right] - wq. \tag{4}$$

Proposition 1. *In a decentralized supply chain where a capital-constrained retailer sources using trade credit, the optimal order quantity q_T^* satisfies the first-order optimality condition of its expected profit function, which is uniquely given as follows:*

$$p\overline{F}(q_T^*) = w\overline{F}(q_{R,T}), \tag{5}$$

where $q_{R,T} = \frac{wq - B_R}{p}$.

Proposition 1 *reflects that the optimal order quantity can be affected by initial capital and the manufacturer's wholesale price, similar to* Wu et al.

(2019). *We model the influence mechanism of initial capital and wholesale price.*

Lemma 1. *(i) retailer's optimal order quantity decreases with his initial capital,* $\frac{\partial q_T^*}{\partial B_R} < 0$ *;(ii) when wholesale price increases, order quantity decreases,* $\frac{\partial q_T^*}{\partial w} < 0$.

The implication of Lemma 1 *is that when initial capital is at a low level, the retailer orders more quantity to cover the possibility of default risk. Additionally, the manufacturer reduces wholesale price leading to the retailer ordering more in response to unit purchase cost decreasing.*

We now consider the capital-constrained manufacturer's equilibrium decision based on an accounts receivable mortgage contract.

4.2. Manufacturer's problem

The manufacturer offers retailer trade credit and receives accounts receivable $wq - B_R$. Given initial manufacturer capital (B_M) and cash B_R received from the retailer is below production costs. The manufacturer considers sourcing from the bank based on an accounts receivable mortgage contract. When the retailer suffers bankruptcy and the sales revenue transferring to manufacturer is lower than the manufacturer's bankruptcy threshold, the manufacturer bankrupts. In this context, the bank will suffer loss and it cannot recover original principle and interest. Assuming that there are no bankruptcy costs, the retailer's revenue eventually transfers to the bank. The manufacturer's profit is now $-B_M$. When demand faced by the retailer is higher than the manufacturer's bankruptcy threshold, after paying back the principle and interest to the bank, manufacturer profit is $\min[p\min[D,q],(wq-B_R)] - B_M - pq_M$. Thus, we have the manufacturer's profit as follows:

$$\pi_{M,T} = \begin{cases} -B_M & 0 < D \le q_M \\ pD - B_M - pq_M & q_M < D \le q_{R,T} \\ wq - B_R - B_M - pq_M & q_{R,T} < D \le q \\ wq - B_R - B_M - pq_M & q < D \end{cases}. \tag{6}$$

This can be expressed as follows:

$$E(\pi_{M,T}) = -B_M + p(q_{R,T} - q_M) - p\int_{q_M}^{q_{R,T}} F(D)dD\ , \tag{7}$$

where $q_{R,T} = \frac{wq - B_R}{p}$.

For manufacturer's bankruptcy threshold q_M,as seen above, there are two scenarios:

Scenario I: When a risk free loan offered by the bank exceeds manufacturer's financing demand, we have $L_{M,i} \ge cq - B_M - B_R$,where $L_{M,i} = \theta(wq - B_R)$; the interest rate in this situation is r_f; we denote q_M as $q_{M,I}$, which satisfies $q_{M,I} = \frac{(cq - B_M - B_R)(1+r_f)}{p}$.

Scenario II: when $L_{M,i} < cq - B_M - B_R$, we have $L_{M,ii} = cq - B_R - B_M - \theta(wq - B_R) > 0$; the bank charges risk compensation interest rate r_M for the manufacturer, and we denote q_M as $q_{M,II}$, which satisfies $pq_{M,II} = (1 + r_f)L_{M,i} + (1 + r_M)L_{M,ii}$; then the manufacturer's bankruptcy threshold is $q_{M,II} = \frac{[cq - B_M - B_R](1+r_M) - \theta(wq - B_R)(r_M - r_f)}{p}$.

Lemma 2. *In a decentralized supply chain, when a capital-constrained retailer uses trade credit and a capital-constrained manufacturer sources from an accounts receivable mortgage contract, the manufacturer's bankruptcy threshold decreases with both the retailer and manufacturer's initial capital and bank's risk assessment coefficient; this increases in order quantity.*

The implication behind Lemma 2 *is that manufacturer's bankruptcy risk can be affected by many factors. When retailers and manufacturers initially owe more working capital, the demand for trade credit and bank loans will decrease, leading to a decrease in retailer's and manufacturer's pay-off-pressure. Thus, bankruptcy probability decreases. With more order quantity, a larger loan is needed for the retailer and manufacturer, which increases both retailer and manufacturer's bankruptcy probability. For an increasing bank's risk assessment coefficient, the bank assumes that the manufacturer has a high payment potential. The bank offers a higher loan based on a risk-free interest rate to the manufacturer. The costs of financing decrease, and the manufacturer's bankruptcy risk decreases.*

Next, according to different bank risk assessment coefficients and retailer's order quantity, we obtain the bankruptcy threshold and interest rate of accounts receivable mortgage contracts, which can be seen in Fig. 4. *We define* $r_M^o = \left(1 + \lambda\frac{B_R}{B_M}\right)r$.Fig. 4 (*a*) *shows that the bank's compensation interest rate to be charged* r *and* r_M^o *both for* (θ, q) *in region* Ω_k. *For convenience, we assume that the interest rate is* r *for region* Ω_k. *Thus,* Ω_k *can be included in region* Ω_2^o. *We obtain* $\Omega_2 = \Omega_2^o + \Omega_k$ *as can be seen in* Fig. 4 (*b*).

Lemma 3. Define $(q_M, r_i)|(\theta, q) = (\theta, q) \rightarrow (q_M, r_i)$; in a decentralized supply chain, when a capital-constrained retailer uses trade credit and a capital-constrained manufacturer sources from an accounts receivable mortgage contract, the manufacturer's bankruptcy threshold and interest rate can be expressed: $(q_M, r_i)|(\theta, q) \in \left\{\{(q_{M,I}, r_f)\middle|\Omega_1\}, \{(q_{M,II}, r)\middle|\Omega_2\}, \left\{\left(q_{M,II}, \left(1 + \lambda\frac{B_R}{B_M}\right)r\right)\middle|\Omega_3\right\}\right\}$, where $(\theta, q) \in \{\{\Omega_1\}, \{\Omega_2\}, \{\Omega_3\}\}$.

The basis of Proposition 3 is that when a capital-constrained retailer considers trade credit and a capital-constrained manufacturer finances from an accounts receivable mortgage contract, the manufacturer's bankruptcy threshold and interest rate based on different order quantity q and bank's risk assessment coefficient θ satisfy: (i) when $(\theta, q) \in \Omega_1$, the risk free loan on an accounts receivable mortgage offered by the bank exceeds the manufacturer financing demand; the manufacturer's bankruptcy threshold is $q_{M,I}$, and bank loan interest rate is r_f; (ii) when $(\theta, q) \in \Omega_2$, risk free bank loan is below the manufacturer's sourcing demand; the manufacturer's bankruptcy threshold is defined as $q_{M,II}$, where $r_M = r$;(iii) when $(\theta, q) \in \Omega_3$, the risk free bank loan is below manufacturer's sourcing demand; and the manufacturer's bankruptcy threshold is $q_{M,II}$, where $r_M = \left(1 + \lambda\frac{B_R}{B_M}\right)r$.

We obtain the bankruptcy threshold and interest rate considering different combinations of order quantity and bank risk assessment coefficients. Moreover, we study the probability change in different regions influenced by retailers' and manufacturers' initial capital.

Corollary 1. With both capital-constrained retailers and manufacturers in a decentralized supply chain, the probability of (q_M, r_M) , ξ_i in region $\{\{\Omega_1\}, \{\Omega_2\}, \{\Omega_3\}\}$ can be affected by retailer's and manufacturer's initial capital as follows: (i) for retailer's initial capital effect, we have $\frac{\partial \xi_1}{\partial B_R} > 0$, $\frac{\partial \xi_2}{\partial B_R} > 0$ and $\frac{\partial \xi_3}{\partial B_R} < 0$; (ii) for manufacturer's initial capital effect, we have $\frac{\partial \xi_1}{\partial B_M} > 0$, $\frac{\partial \xi_2}{\partial B_M} > 0$ and $\frac{\partial \xi_3}{\partial B_M} < 0$; (iii) the effect of manufacturer's initial capital on probability change performs better than retailer's initial capital, which is $\left|\frac{\partial \xi_i}{\partial B_M}\right| > \left|\frac{\partial \xi_i}{\partial B_R}\right|$, $i = 1, 2, 3$; where $\xi_i = \frac{S(\Omega_i)}{S(\Omega_1) + S(\Omega_2) + S(\Omega_3)}$, and $S(\Omega_i)$ is the area of region Ω_i.

Corollary 1 *reflects two perspectives: manufacturer and bank. From the manufacturer's perspective,* ξ_i *is the probability of bankruptcy. The variable* ξ_i *is the bank's risk compensation interest rate (TCR), reflecting interest rate risk. Probability of different* (q_M, r_i) *can be affected by retailer's and manufacturer's initial capital which can both increase the probability of* $(q_{M,I}, r_f)$ *and* $(q_{M,II}, r)$, *as can be seen in* Fig. 5. *This also decreases the possibility that the bank charges a high compensation interest rate and reduces bankruptcy risk for manufacturers and retailers. We conclude that the manufacturer's initial capital effect on bankruptcy is more significant compared to that of the retailer. The manufacturer's initial management capacity is more important than the retailer's initial operation level. Thus, the bank should give more attention to evaluating the manufacturer's initial operational ability and payoff potential.*

From the perspective of the bank, a higher TCR means a smaller interest risk for the manufacturer's order decision. A moral hazard appears when the manufacturer faces high TCR, leading to ordering more quantity and increased bankruptcy risk. Given an increase of B_R *and* B_M, *the probability of*

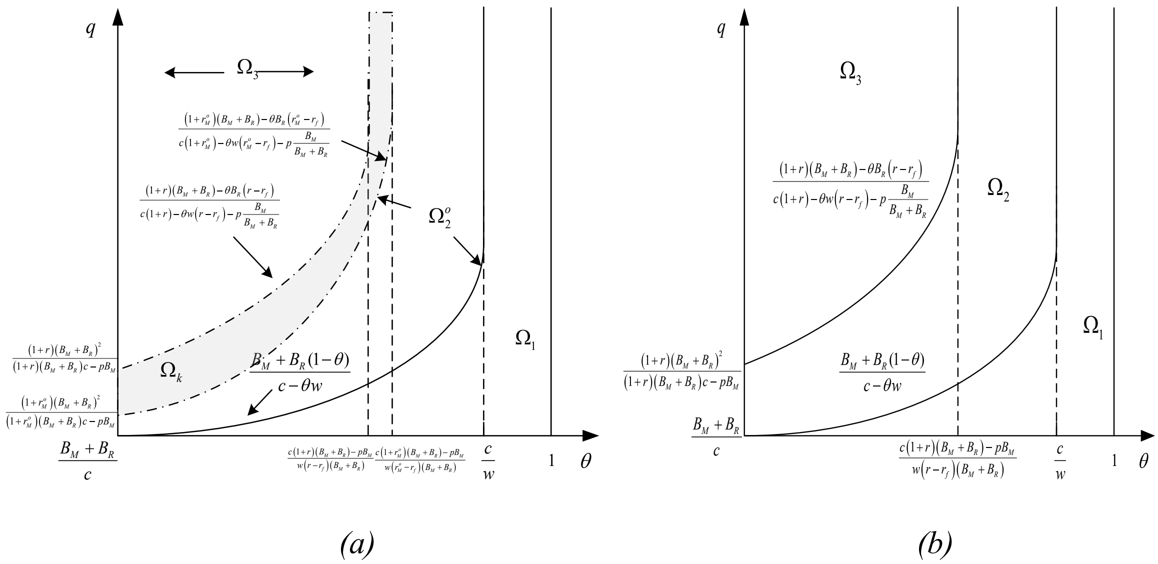


Fig. 4. Bankruptcy threshold and interest rate region for θ and q.

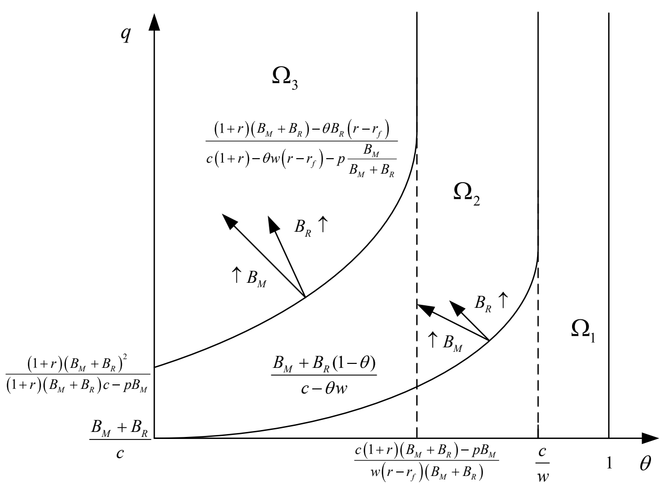


Fig. 5. *Dynamic effect of initial capital to bankruptcy threshold and interest rate region.*

$(q_{M,I}, r_f)$ and $(q_{M,II}, r)$ increases. In other words, the probability of condition that bank charges general interest rate for SMEs and the risk-free rate increases. The probability of condition of charging risk compensation interest rate $(q_{M,II}, r_M)$ decreases with B_R and B_M increasing.

Based on the above discussion, we identify the relationship between different manufacturers' bankruptcy thresholds with their interest rates. Now we consider the equilibrium of the supply chain and manufacturer to determine the optimal wholesale price. For the purpose to maximize the manufacturer's profit, we have:

$$\max : E(\pi_{M,T}) = -B_M + p(q_{R,T} - q_M) - p\int_{q_M}^{q_{R,T}} F(D)dD. \tag{8}$$

Proposition 2. In a decentralized supply chain, when a capital-constrained retailer uses trade credit and a capital-constrained manufacturer sources from an accounts receivable mortgage contract, the manufacturer's optimal wholesale price satisfies: (i) Under scenario I, the risk-free interest rate for the bank loan exceeds the manufacturer's sourcing demand; the optimal wholesale price w_T^* can be expressed as follows:

$$\frac{q_T^*\overline{F}(q_{R,T})}{w_T^*\overline{F}(q_{R,T}) - c(1+r_f)\overline{F}(q_{M,I})} = \frac{\frac{p}{w_T^*}\left[1 - q_T^* h(q_{R,T})\frac{w_T^*}{p}\right]}{ph(q_T^*) - w_T^* h(q_{R,T})}, \tag{9}$$

(ii) for scenario II, the manufacturer's financing demand is higher than the risk-free loan; the manufacturer's wholesale price decision follows:

$$\frac{\theta q_T^*(r_M - r_f)\overline{F}(q_{M,II}) + q_T^*\overline{F}(q_{R,T})}{w_T^*\overline{F}(q_{R,T}) - \left[(1+r_M)c - \theta w_T^*(r_M - r_f)\right]\overline{F}(q_{M,II})} = \frac{\frac{p}{w_T^*}\left[1 - q_T^* h(q_{R,T})\frac{w_T^*}{p}\right]}{ph(q_T^*) - w_T^* h(q_{R,T})}, \tag{10}$$

when $(\theta, q_T^*) \in \Omega_2$, we have $r_M = r$; when $(\theta, q_T^*) \in \Omega_3$, we have $r_M = \left(1 + \lambda\frac{B_R}{B_M}\right)r$; where $p\overline{F}(q_T^*) = w_T^*\overline{F}(q_{R,T})$, $q_{R,T} = \frac{w_T^* q_T^* - B_R}{p}$, $q_{M,I} = \frac{(cq_T^* - B_M - B_R)(1+r_f)}{p}$ and $q_{M,II} = \frac{[cq_T^* - B_M - B_R](1+r_M) - \theta(w_T^* q^* - B_R)(r_M - r_f)}{p}$.

From Equation (Chod, 2016), we know that under scenario I, the optimal wholesale price w_T^* can be impacted by many factors, such as the retailer's and manufacturer's initial operational ability (initial capital), risk-free rate and so on. In this situation, the risk assessment coefficients and the bank's general loan interest rate for SMEs, and the bank's capital evaluation coefficient cannot impact on the optimal wholesale price. Besides, the bankruptcy thread of retailers and manufacturers can also impact the optimal wholesale price.

According to Equation (Fisman and Love, 2003), we can obtain the optimal wholesale price w_T^* when the manufacturer's financing demand is higher than the risk-free loan. It is more complex than the scenario I. With different optimal order quantities and risk assessment coefficients, the bank will charge multi-level interest rates. We also identify the portfolio of different bank interest rate and optimal order quantity according to Ω_i. The optimal wholesale pricing may also be affected by the bankruptcy thread of manufacturers and retailers. Due to the complexity of Equation (Chod, 2016) and (Fisman and Love, 2003), it is unclear to give the detail impact of different factors on optimal wholesale price. We would utilize the numerical analysis to discuss Equation (Chod, 2016) and (Fisman and Love, 2003).

4.3. Bank's problem

Considering a capital-constrained retailer and a manufacturer in a supply chain using an accounts receivable mortgage contract from a bank, the optimal decision (q_T^*, w_T^*), involves many factors. We analyze bank profit under the supply chain's optimal strategy.

When the retailer's demand is below the manufacturer's bankruptcy threshold, the bank will suffer a loss. If the retailer's demand exceeds the manufacturer's bankruptcy threshold, the payment can be completely paid. Thus, the bank's payment received from the manufacturer is $p\min[D, q_M]$. We identify the bank's profit under the optimal decision as:

$$E(\pi_{B,T}) = pq_M - (cq_T^* - B_R - B_M) - p\int_0^{q_M} F(D)dD. \tag{11}$$

For different (q_M, r_i) in Equation (Frank and Goyal, 2003), it can be defined as follows:

$$(q_M, r_i)\big|(\theta, q_T^*) \in \left\{\{(q_{M,I}, r_f)|\Omega_1\}, \{(q_{M,II}, r)|\Omega_2\}, \left\{\left(q_{M,II}, \left(1+\lambda\frac{B_R}{B_M}\right)r\right)\Big|\Omega_3\right\}\right\}$$

According to Equation (Frank and Goyal, 2003), it shows that the interest and principle can be expressed by $pq_M - p\int_0^{q_M} F(D)dD$. The principle of the bank giving to manufacturer equals to $cq_T^* - B_R - B_M$. We also capture the different portfolio of manufacturers' bankruptcy thread and banks' interest rate, (q_M, r_i). The implication of Equation (Frank and Goyal, 2003) is that based on the optimal decision of the retailer and manufacturer both under capital constraint, we could calculate the effect of their initial operational capacity and accounts receivable mortgage contract on profit in three different conditions. We would utilize the numerical analysis to show the detail relationship of retailers and manufacturers' initial capital with bank' profit.

5. Bank financing

We study bank financing for the retailer in this subsection. With bank financing, the retailer can pay for an order completely before the transaction. In this context, the manufacturer does not need to finance production. We identify the capital-constrained supply chain model under bank finance for this situation.

5.1. Retailer's problem

The retailer is capital-constrained in this supply chain and sources from a commercial bank for $wq - B_R$. The bank charges a risk compensation interest rate as $r_R = \left(1+\lambda\frac{B_M}{B_R}\right)r$ based on the retailer's initial operating ability. At the end of the transaction, the retailer gains revenue pD and repays the bank's loan and interest. Considering the bankruptcy threshold, if $D < q_{R,B}$, the retailer goes bankrupt. The bankruptcy threshold of the retailer is $q_{R,B} = \frac{[1+r_R](wq-B_R)}{p}$. When $D \geq q_{R,B}$, after retailer repaying bank the retailer gains profit. We obtain the retailer's profit under bank credit as follows:

$$\pi_{R,B} = \begin{cases} -B_R & 0 < D \leq q_{R,B} \\ -B_R + pD - (wq - B_R)(1+r_R) & q_{R,B} < D \leq q \\ -B_R + pq - (wq - B_R)(1+r_R) & q < D \end{cases}. \tag{12}$$

It can be expressed as:

$$E(\pi_{R,B}) = p\left[q - \int_{q_{R,B}}^{q} F(D)dD\right] - B_R - (wq - B_R)(1+r_R), \tag{13}$$

where $q_{R,B} = \frac{[1+r_R](wq-B_R)}{p}$ and $r_R = \left(1+\lambda\frac{B_M}{B_R}\right)r$.

From Equation (Gupta and Wang, 2008), we obtain the profit of retailers when he considers finance from the bank. The expected revenue of the retailer in the stochastic demand market is $p[q - \int_{q_{R,B}}^{q} F(D)dD]$.The financial demand for retailer is $wq - B_R$. The interest rate charged by bank is r_R. After transaction ending, the retailer need to pay back the principle and interest, $(wq - B_R)(1+r_R)$, to the bank. We also find that the profit of retailer can be affected by sale price, initial capital of manufacturers and retailers, banks' capital evaluation coefficient, order quantity and wholesale price.

To maximize the retailer's profit and identify the optimal order quantity, we have the following equation:

$$\max : E(\pi_{R,B}) = p\left[q - \int_{q_{R,B}}^{q} F(D)dD\right] - B_R - (wq - B_R)(1+r_R). \tag{14}$$

Proposition 3. *In a decentralized supply chain, when a capital-constrained retailer uses a bank loan for sourcing, the optimal order quantity q_B^* satisfies the first-order optimality condition of its expected profit function, which is uniquely given as follows:*

$$p\overline{F}(q_B^*) = w\overline{F}(q_{R,B})\left[1 + \left(1+\lambda\frac{B_M}{B_R}\right)r\right], \tag{15}$$

where we have $q_{R,B} = \frac{\left[1+\left(1+\lambda\frac{B_M}{B_R}\right)r\right](wq_B^*-B_R)}{p}$.

The implication behind Proposition 3 *is that optimal order quantity of a capital-constrained retailer under bank credit can be affected by wholesale price, his initial capital and the bank's credit policy (manufacturer's initial operating capacity, interest rate for SMEs, and capital evaluation coefficient). We study the influences of some factors.*

Lemma 4. *In a decentralized supply chain, when a capital-constrained retailer uses a bank loan for sourcings: (i) wholesale price, manufacturer's initial capital, general interest rate for SMEs, and capital evaluation coefficient have a negative effect on optimal order quantity; (ii) there exists an initial capital ratio of $\widehat{\frac{B_M}{B_R}} = \frac{(1+r_R)^2 B_R h(q_{R,B})}{\lambda r[p-(1+r_R)h(q_{R,B})(wq_B^*-B_R)]}$; when $\frac{B_M}{B_R} \in \left(0, \widehat{\frac{B_M}{B_R}}\right)$, we have $\frac{\partial q_B^*}{\partial B_R} < 0$; when $\frac{B_M}{B_R} \in \left(\widehat{\frac{B_M}{B_R}}, \frac{cq_B^*-B_R}{B_R}\right)$, optimal order quantity increases with retailer's initial capital.*

Lemma 4 (i) shows that with the increase of the manufacturer's wholesale price, the costs for retailer increases. Thus, the retailer would order less; and bank loan costs are affected by the manufacturer's initial capital, general interest rate for SMEs, and capital evaluation coefficient. Compared to a high capital-constrained manufacturer's initial capital, the retailer will be rated as having a poorer operating capacity by the bank, financing costs increase, and the retailer will order less. Similarly, when the general interest rate for SMEs and capital evaluation coefficient increases, the retailer's debt pressure increases, leading to a decrease in order quantity.

For condition (ii) there is a two-fold influence mechanism for the retailer's order decision reflecting his initial capital or operating condition.

(a). When the initial capital ratio is at a low level, indicating that the retailer's initial operating conditions compared to the manufacturer are not so bad, the retailer avoids some market risks mainly consisting of overstocking risk, demand volatility, supply risk, and so on. In this context, the retailer does not need to order more to pursue high-risk returns and incur a higher probability of bankruptcy risk. The debt pressure is comparatively small with the bank's decreasing interest rate.

However, the retailer in this condition is not so sensitive to financing costs. The risk is more important. For a given market stochastic demand scale, if retailer sales are a higher proportion of his order quantity under stochastic demand, which can be achieved with less order quantity, he can make more profit with unit orders. Thus, the retailer chooses to order less avoiding an uncertain market, and gains profit with less possibility of overstocking.

(*b*). *In the situation of a high initial capital ratio, the retailer's initial operating condition is not so good. The retailer considers that high risk means high return as the main ordering strategy. The risk-return is specifically significant compared with the market risk for the retailer. With a retailer's initial capital increase or a higher operating condition, bank loan costs decrease, leading to expanding order quantity.*

After discussing the bank's credit policy to a capital-constrained retailer, we study the manufacturer's equilibrium decision.

5.2. Manufacturer's problem

The manufacturer receives wq at the beginning and starts to produce. The profit can be easily described as follows:

$$E(\pi_{M,B}) = wq - cq. \tag{16}$$

We consider the optimal operational decision for the manufacturer under the retailer's bank finance giving the following proposition.

Proposition 4. *In a decentralized supply chain, when a capital-constrained retailer uses a bank loan for sourcing, the optimal wholesale price w_B^* satisfies the following equation:*

$$w_B^* = \frac{c}{[1 - q_B^* h(q_B^*)] + q_B^* h(q_{R,B}) \frac{c}{p}\left[1 + \left(1 + \lambda \frac{B_M}{B_R}\right) r\right]}, \tag{17}$$

where $q_{R,B} = \dfrac{\left[1 + \left(1 + \lambda \frac{B_M}{B_R}\right) r\right]\left(w_B^* q_B^* - B_R\right)}{p}$.

The implication of Proposition 4 is that the manufacturer's optimal wholesale price will be affected by his initial capital when the bank offers retailer credit considering the retailer's initial operating condition with his business partner. It can also be influenced by the general interest rate of SMEs, production cost, and sale price. Considering Equations (Haley and Higgins, 1973) and (Iancu et al., 2017), we obtain the Stackelberg game equilibrium of the supply chain.

5.3. Bank's problem

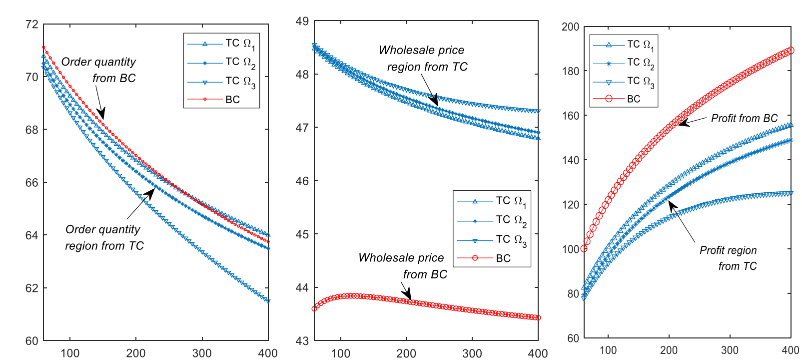
In this context, the bank's profit can be written as follows based on the optimal decision of the supply chain (q_B^*, w_B^*):

$$E(\pi_{B,B}) = \left(1 + \lambda \frac{B_M}{B_R}\right) r\left(w_B^* q_B^* - B_R\right) - p \int_0^{q_{R,B}} F(D)dD. \tag{18}$$

The bank's profit could be identified based on different initial capital and bank credit policies. In order to identify the effect of the retailer's and manufacturer's initial capital on operational decisions and compare the situations under an accounts receivable mortgage and bank credit, we conduct the following numerical experiments.

We consider the demand distribution $D \sim N(100, 30^2)$, unit production cost $c = 30$, sale price $p = 50$, risk assessment coefficient $\theta = 0.3$, capital evaluation coefficient $\lambda = 0.4$, risk-free interest rate $r_f = 3.25\%$, general interest rate for SMEs $r = 7\%$. Note that the risk-free

(a) Order quantity. (b) Wholesale price. (c) Retailer's profit.



(d) Manufacturer's profit. (e) Bank's profit. (f) supply chain/system's profit.

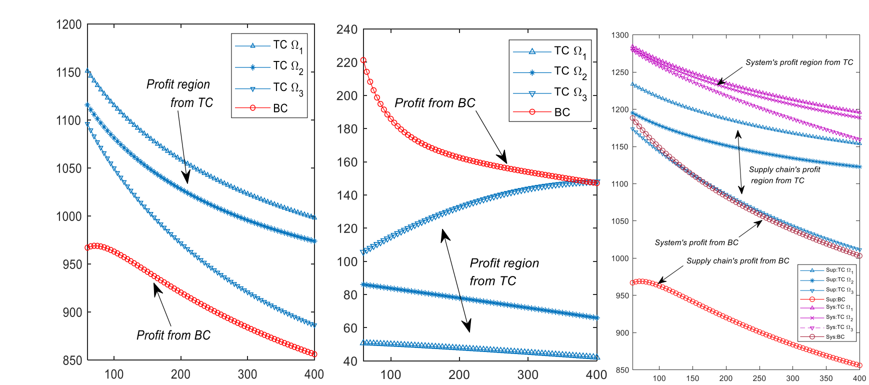
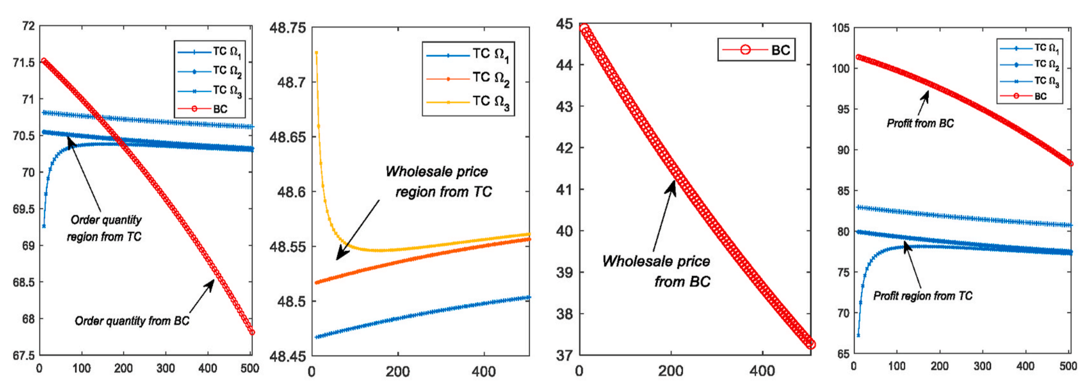


Fig. 6. impacts of retailer's initial capital.

interest rate is based on the one-year Shibor interest rate in January 2019 in China. And general interest rate for SMEs is defined as a 60% improvement of the Chinese one-year bank loan benchmark interest rate (4.35%) in January 2019, which is commonly adopted for Chinese bank lending to SMEs. Based on the parameters we have defined, we study the effects of retailer's and manufacturer's initial capital on order quantity, wholesale price, and institutes' profits respectively.

The retailer's initial capital impacts can be seen in Fig. 6. In this context, we set the manufacturer's initial capital as $B_M = 80$. From Fig. 6 (a), order quantity decreases in the retailer's initial capital no matter how the retailer sources. We consider three situations of Ω_1, Ω_2, Ω_3, defining as high solvency (H), moderate solvency (M), and low solvency (L) firms due to our model analysis that a higher interest rate is for lower solvency firms as risk compensation no matter the retailer or manufacturer. Different types of firms' order decisions sourced from trade credit can be divided by order region. Firms of type H that source using trade credit order the most. Fig. 6 (b) shows that the wholesale price from trade credit financing decreases with the initial capital of the retailer and is higher than that of BC. However, wholesale price in BC initially increases and then decreases. Remembering Lemma 4, the retailer's order quantity from BC initially increases and then decreases when surpassing the initial capital ratio threshold with an increasing of initial capital. When the retailer's initial capital is not large, he orders more leading to increased risk. Lower solvency firms experience higher wholesale prices named risk-shifting in the supply chain. This can be reflected in the wholesale price as shown in Fig. 6. Fig. 6 (c) shows that retailer's profit increases in initial capital both under BC or TC conditions. Profit in BC is higher than that in TC. A high-solvency retailer earns the most under conditions of trade credit. Fig. 6 (d) and (e) show the profit of the manufacturer and bank. The manufacturer's profit decreases with initial capital when the retailer sources from TC and the manufacturer sources from accounts receivable mortgage. Nevertheless, in the context of BC, the manufacturer's profit initially increases and then decreases due to wholesale price increases and then decreases. Supply chain profit and system's profit in Fig. 6 (f) both decrease with initial capital. High solvency firms make more profit.

Considering the manufacturer's initial capital, we give Fig. 7 by setting the retailer's initial capital as $B_R = 60$. We find that order quantity decreases with the manufacturer's initial capital in the end regardless of BC or TC whereas it increases when the manufacturer's initial capital is at a low level for low solvency firms. This shows that with financing costs decreasing for low solvency firms, they prefer ordering more in order to earn profit. However, when a manufacturer's initial capital increases continuously, the main concern for these firms is paying off the principle. Owing to market uncertainty, the risk is more important than profit in this context, leading to their order less with financing costs decreasing, called adverse selection. Fig. 7 (b) and (c) shows the same result of the wholesale price for L type firms. With trade credit, wholesale price increases finally in the manufacturer's initial capital. However, when retailer sources from a bank, wholesale price decreases with initial capital. Moreover, the wholesale price under TC is higher than that under BC. Fig. 7 (d) gives the relationship of retailer's profit showing that retailer sources from a bank can obtain more profit than from TC. In this context, the retailer will choose bank financing rather than trade credit. Besides, the retailer's profit decreases in the manufacturer's initial capital in all situations. Fig. 7 (e) shows the manufacturer's profit increases in her initial capital for trade credit and decreases for bank credit. Manufacturers' profit under TC is higher than that under BC. Fig. 7 (f) shows that when retailer finances from a bank, bank profit is higher than that when retailer finances from a manufacturer. Fig. 7 (g) and (h) show the supply chain profit and system's profit with changing manufacturer's initial capital. With the manufacturer's



(e) manufacturer's profit. (f) bank's profit. (g) supply chain's profit. (h) system's profit.

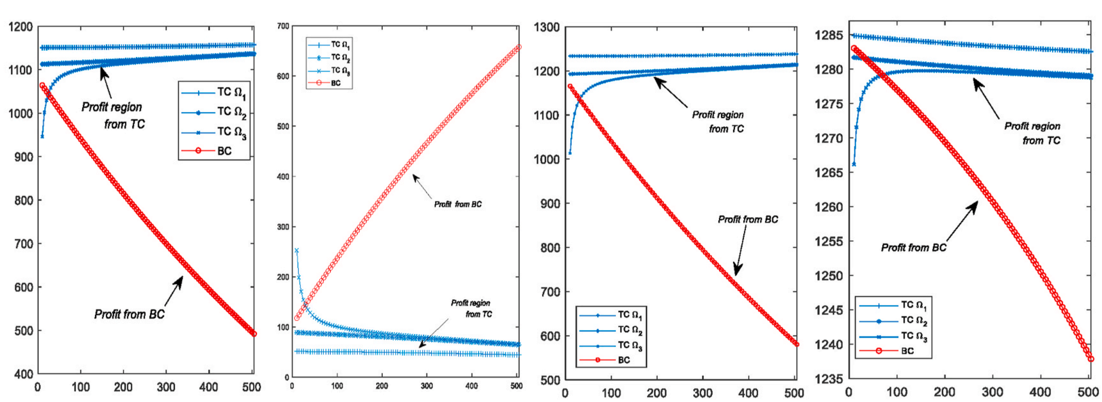


Fig. 7. The effect of the manufacturer's initial capital.

initial capital increases, it leads to both supply chain profit and system profit decreasing when the retailer sources from the bank. The Figure also shows that when the retailer sources using trade credit, this leads to higher supply chain (system) profit than that in BC. In this context, it is significant to improve system profit by using trade credit for sourcing.

As shown in numerical experiments, we find that (*i*) with an increase of solvency, the retailer orders more; (*ii*) it is better for a capital-constrained retailer to source from a bank if it is available. In this paper, we also examined the above results based on empirical evidence. Based on 17 industries of Chinese firms' data, we consider the panel regression to confirm the results of (*i*) and (*ii*). The detailed process is in the next section.

6. Empirical evidence

In order to examine our findings (*i*) with the increase of solvency, the retailer orders more; (*ii*) it is better for a capital-constrained retailer to source from the bank if it is available supported by numerical experiments. The empirical study is provided in this subsection. We use the Chinese firms' data which is from the Wind database from 2008 to 2017. These firms include many industries, such as electrical equipment, household appliances, light manufacturing, and so on, which are nearly 17 industries in China. There are many observation samples in our empirical study. We model panel regression to confirm our hypothesis.

6.1. Data description

The empirical test for trade credit effect in recent literature mainly uses supply and demand for trade credit from financial-statement data (accounts receivable and payable), see e.g., Smith and Schnucker (1994), Fisman and Love (2003), Barrot (2016), and Breza and Liberman (2017). We collected 6330 observation samples of Chinese firms from 2008 to 2017. The index includes the retailer's inventory level, cash level, accounts receivable, accounts payable, and short loans from banks. Because many trade credit cases use a short financing method, nearly 90 days, we use the change of these quotas between Q3 and Q4 to describe the retailer decision during this quarter. The method is similar to the works of Shyam-Sunder and Myers (1999), Frank and Goyal (2003), and Klapper et al. (2011), all of whom examine the pecking order theory by regressing changes in debt on an aggregate measure of financial deficit. Annual profits of retailers are also collected. All indexes are the ratio of total assets based on the corresponding year. The descriptive statistics of all samples are shown in Table 4. We obtain the mean, standard deviation, minimum, and maximum of samples. For example, the mean of the retailer's inventory change is −0.251%, the standard deviation is 3.668 and the maximum inventory change is 31.672% in all samples between 2008 and 2017.

We use the cash ratio to describe firm solvency, such as low solvency, moderate solvency and high solvency. We sort firms in order of average cash ratio of ten years by low to high. The first tripartite firms are marked as low solvency retailers, which includes 2110 samples. The second tripartite firms are marked as moderate solvency retailers. The last firms are defined as high solvency retailers. These firms' descriptive statistics can be described as Tables 5–7. We can find that low solvency retailer's mean profit is lower than high solvency firms. For accounts receivable change, high solvency firms are higher than M and L type retailers.

6.2. Regression model and hypotheses

Combining the above classifications with results in Proposition (Barrot, 2016) (Bi et al., 2021) and results of numerical experiments, we obtain the regression model regarding changes in accounts payable to examine effect of different solvency retailers' order decision, which can be written as follows:

$$\Delta AP^t = \alpha^t_{AP} + \beta^t_{AP}\Delta Inventory^t + control\ variables + \varepsilon, \tag{19}$$

where $t \in \{L, M, H\}$ represents the low solvency, moderate solvency and high solvency retailers, and the control variables include changes in cash, changes in short loan, changes in account receivable and year effect.

The results in above analysis show that high solvency firms order more than those with low solvency in accounts receivable mortgage contracts. Thus, the accounts payable by trade credit for high solvency retailers are higher for those with low solvency. Relating this to the above regression model, our hypothesis can be formally written as follows.

Hypothesis 1. $\beta^H_{AP} > \beta^M_{AP} > \beta^L_{AP} > 0$.

Similarly, we study the profit relationship for retailers sourcing using trade credit or bank credit and obtain the related hypothesis. According to the above results, high solvency firms prefer to source from banks and thus, bank loan effect to profit is more important than trade credit changes, which could be defined as changes in accounts payable. However, low solvency firms have difficulty sourcing from banks. Thus, the effect of accounts payable on profit is more significant than bank short loans. And for firms, a larger liability leads to a smaller profit. Thus, changes in short loan and account payable have negative impacts on profit.

The regression model can be written as follows:

$$Profit^t = \alpha^t_{profit} + \beta^t_{profit}\Delta AP^t + \tau^t_{profit}\Delta SL^t + control\ variables + \varepsilon, \tag{20}$$

where $t \in \{L, M, H\}$ represents the low solvency, moderate solvency and high solvency retailers, and the control variables include changes in cash, changes in account receivable and year effect.

Our hypothesis can be easily expressed as follows.

Hypothesis 2. $\tau^H_{profit} < \beta^H_{profit} < 0,\ \tau^M_{profit} < \beta^M_{profit} < 0\ and\ \beta^L_{profit} < \tau^L_{profit} < 0.$

6.3. Regression results

In order to choose a fixed effect model or a random effect model to estimate panel data, we first apply the Hausmann test to all samples, as can be seen in Table 8. P-value is smaller than 0.01 and so we reject the original hypothesis. The test result shows that the fixed effect model is better. Then we consider the fixed effect model to empirical observation of different solvency retailer effects.

Table 4
Descriptive statistics of all samples.

Variables (%)	Obs	Mean	Std.Dev.	Min	Max	p1	p99	Skew.	Kurt.
ΔInventory	6330	−0.251	3.668	−58.848	31.672	−11.344	10.126	−0.486	25.262
ΔCash	6330	0.924	4.974	−28.764	81.047	−10.823	17.348	1.883	23.276
ΔAP	6330	0.134	2.785	−41.703	26.777	−8.166	7.372	−0.822	21.315
ΔAR	6330	−1.138	3.203	−29.618	25.105	−11.759	7.295	−0.599	12.824
profit	6330	3.58	6.369	−116.351	49.697	−16.501	18.956	−1.815	34.119
ΔSL	6330	−0.407	4.411	−64.78	35.459	−14.615	11.693	−1.021	18.735

Table 5
Descriptive statistics for low solvency retailers (L).

Variables (%)	Obs	Mean	Std.Dev.	Min	Max	p1	p99	Skew.	Kurt.
ΔInventory	2110	−0.321	4.304	−58.848	31.096	−13.571	11.451	−1.252	28.458
ΔCash	2110	0.463	4.295	−18.422	81.047	−10.505	12.73	3.424	64.347
ΔAP	2110	0.368	3.268	−41.703	21.694	−8.797	8.307	−1.566	26.025
ΔAR	2110	−0.553	3.134	−29.618	21.514	−10.349	8.205	−0.069	16.827
profit	2110	1.743	6.476	−116.351	30.214	−23.328	14.637	−4.945	69.196
ΔSL	2110	−0.364	4.747	−28.516	27.203	−16.774	12.715	−0.499	8.478

Table 6
Descriptive statistics for moderate solvency retailers (M).

Variables (%)	Obs	Mean	Std.Dev.	Min	Max	p1	p99	Skew.	Kurt.
ΔInventory	2110	−0.174	3.711	−28.286	31.672	−10.224	11.535	0.841	17.114
ΔCash	2110	1.055	4.661	−24.468	35.437	−9.678	16.656	0.89	8.81
ΔAP	2110	0.072	2.607	−12.168	26.777	−7.789	6.387	0.286	10.528
ΔAR	2110	−1.271	3.337	−20.489	20.864	−13.282	7.337	−0.666	9.995
profit	2110	3.721	5.63	−58.654	39.748	−14.095	17.787	−0.961	16.029
ΔSL	2110	−0.448	4.278	−49.816	21.016	−14.041	10.653	−1.208	15.37

Table 7
Descriptive statistics for high solvency retailers (H).

Variables (%)	Obs	Mean	Std.Dev.	Min	Max	p1	p99	Skew.	Kurt.
ΔInventory	2110	−0.257	2.842	−22.14	19.891	−10.241	7.026	−0.624	10.353
ΔCash	2110	1.254	5.807	−28.764	54.376	−12.734	20.722	1.622	14.67
ΔAP	2110	−0.038	2.391	−22.453	18.752	−7.643	5.904	−0.516	13.434
ΔAR	2110	−1.591	3.045	−25.139	25.105	−10.992	5.027	−1.152	12.69
profit	2110	5.277	6.465	−38.018	49.697	−12.393	22.973	0.422	10.599
ΔSL	2110	−0.407	4.189	−64.78	35.459	−13.219	11.631	−1.572	38.416

Table 8
Hausman specification test.

	Coef.		Difference	S.E.
	Fixed effects	Random effects		
ΔInventory	0.1675447	0.1628622	0.0046825	0.0031119
ΔAR	0.1659834	0.1837237	−0.0177402	0.0048979
Chi-square test value	14.4			
P-value	0.0007			

The results for the above regressions are summarized in Table 9. Panel A shows that, after controlling for various factors, the correlations between changes in accounts payable and changes in inventory are highly significant, which is similarly to Yang and Birge (2018). Moreover, with increase of firms' solvency, effects of changes in inventory on account payable are greater, which is consistent with Hypothesis 1. Loosely speaking, changes in inventory can be described as the proportion of marginal inventory financed through trade credit. Thus, retailers with low solvency normally use trade credit to finance around 15% of their marginal inventory, depending on model specifications. Retailers with moderate solvency order 17.8% inventory with marginal trade credit using. For high solvency retailers, they use trade credit to source nearly 20% of marginal inventory. When we consider control variables, the effect can be softened. Furthermore, short loan's effect on account payable is negative, illustrating that it is an alternative financing channel for retailers. The result shows that a higher solvency retailer would like to order more inventory, which is beneficial to them.

Similarly, the effects of changes in accounts receivable and changes in short loans on profit are summarized in Panel B. The results show that it is significant for low solvency retailers sourcing from both trade credit and bank loan. Furthermore, trade credit impacts on marginal profit is more important than bank loan's effect. Around 25%–30% of marginal profit is made by trade credit financing and only 20% marginal profit is obtained with bank short loan. In this situation, trade credit is more beneficial to a capital-constrained retailer as a sourcing method. On the other hand, retailers with moderate and high solvency source from short loan is significant, affecting around 18.5% and 15.2% of marginal profit respectively. However, it is not significant for retailer finances from trade credit from perspective of earning profit. In this context, bank loans would be a better choice for retailers if it is available from a bank. Moreover, we find that moderate solvency firms sourcing from bank credit will impact marginal profit more significant compared to high solvency firms. Based on above analysis, the Hypothesis 2 can be examined.

6.4. Robustness test

From the last subsection, firm solvency is described by cash ratio. Intuitively, quick ratio is also an index to elaborate solvency. Now, we examine results. After re-dividing different level of solvency retailers based on quick ratio, the empirical results can be summarized in Table 10.

From panel A, change in inventory is more significant with increasing firms' solvency when consider in other control variables, similar to the discussion above. When we exclude changes in short-loan and changes in cash, the results show that marginal inventory financed through trade credit of moderate solvency retailers (15%) is a little lower than that of low solvency retailers (15.3%), which could be accepted with minor error. Thus, Hypothesis 1 can still be examined with quick ratio condition.

Given panel B, low solvency retailers sourcing from manufacturer impact 23.4% marginal profit compared to financing from the bank directly which is only around 22.6%. However, firm solvency increases, the firm would like to source from banks due to the effect of marginal profit increase irrespective of control variable values. Nearly 17% marginal profit of moderate solvency firms was obtained by short-loan

Table 9
Regressions Results for Changes in Accounts Payable and Profit from Q3 to Q4 with cash ratio.

	L	M	H	L	M	H
	Alan and Gaur (2018)	Barrot (2016)	Birge (2014)	Bi et al. (2021)	Breza and Liberman (2017)	Buzacott and Zhang (2004)
Panel A: $\Delta AP^t = \alpha_{AP}^t + \beta_{AP}^t \Delta Inventory^t + control\ variables + \varepsilon$						
ΔInventory	0.147***	0.178***	0.198***	0.117***	0.169***	0.180***
	(0.0164)	(0.0161)	(0.0191)	(0.0168)	(0.0169)	(0.0197)
ΔAR	0.150***	0.202***	0.149***	0.118***	0.193***	0.139***
	(0.0234)	(0.0191)	(0.0197)	(0.0237)	(0.0199)	(0.0204)
ΔSL				−0.0869***	−0.0641***	−0.0696***
				(0.0142)	(0.0118)	(0.0116)
ΔCash				−0.0925***	−0.0279**	−0.0259***
				(0.0170)	(0.0122)	(0.00956)
Constant	0.498***	0.359***	0.250***	0.482***	0.347***	0.234***
	(0.0651)	(0.0538)	(0.0571)	(0.0644)	(0.0537)	(0.0566)
Year fixed effects	Included	Included	Included	Included	Included	Included
Observations	2110	2110	2110	2110	2110	2110
R-squared	0.055	0.107	0.071	0.086	0.123	0.092
Panel B: $Profit^t = \alpha_{profit}^t + \beta_{profit}^t \Delta AP^t + \tau_{profit}^t \Delta SL^t + control\ variables + \varepsilon$						
ΔAP	−0.269***	−0.0700	−0.0319	−0.302***	−0.0521	−0.0450
	(0.0438)	(0.0457)	(0.0540)	(0.0446)	(0.0474)	(0.0550)
ΔSL	−0.194***	−0.185***	−0.152***	−0.199***	−0.182***	−0.152***
	(0.0282)	(0.0251)	(0.0285)	(0.0281)	(0.0252)	(0.0286)
ΔCash				−0.0581*	0.00619	−0.0246
				(0.0326)	(0.0246)	(0.0226)
ΔAR				0.151***	−0.0600	0.0224
				(0.0463)	(0.0426)	(0.0489)
Constant	1.771***	3.643***	5.214***	1.893***	3.560***	5.279***
	(0.125)	(0.101)	(0.114)	(0.128)	(0.115)	(0.137)
Year fixed effects	Included	Included	Included	Included	Included	Included
Observations	2110	2110	2110	2110	2110	2110
R-squared	0.038	0.028	0.015	0.046	0.029	0.016

Note: ***, ** and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Table 10
Regressions Results for Changes in Accounts Payable and Profit from Q3 to Q4 with quick ratio.

	L	M	H	L	M	H
	Alan and Gaur (2018)	Barrot (2016)	Birge (2014)	Bi et al. (2021)	Breza and Liberman (2017)	Buzacott and Zhang (2004)
Panel A: $\Delta AP^t = \alpha_{AP}^t + \beta_{AP}^t \Delta Inventory^t + control\ variables + \varepsilon$						
ΔInventory	0.153***	0.150***	0.234***	0.125***	0.135***	0.223***
	(0.0169)	(0.0163)	(0.0184)	(0.0177)	(0.0161)	(0.0195)
ΔAR	0.233***	0.152***	0.151***	0.208***	0.131***	0.144***
	(0.0299)	(0.0197)	(0.0161)	(0.0302)	(0.0199)	(0.0172)
ΔSL				−0.0696***	−0.115***	−0.0227**
				(0.0137)	(0.0128)	(0.0112)
ΔCash				−0.0643***	−0.0552***	−0.0164*
				(0.0155)	(0.0134)	(0.00940)
Constant	0.494***	0.375***	0.270***	0.481***	0.326***	0.269***
	(0.0633)	(0.0602)	(0.0521)	(0.0627)	(0.0595)	(0.0522)
Year fixed effects	Included	Included	Included	Included	Included	Included
Observations	2110	2110	2110	2110	2110	2110
R-squared	0.069	0.064	0.105	0.088	0.113	0.109
Panel B: $Profit^t = \alpha_{profit}^t + \beta_{profit}^t \Delta AP^t + \tau_{profit}^t \Delta SL^t + control\ variables + \varepsilon$						
ΔAP	−0.234***	−0.101**	−0.102*	−0.271***	−0.103**	−0.113**
	(0.0490)	(0.0411)	(0.0530)	(0.0502)	(0.0419)	(0.0541)
ΔSL	−0.226***	−0.176***	−0.121***	−0.231***	−0.179***	−0.119***
	(0.0305)	(0.0242)	(0.0272)	(0.0305)	(0.0242)	(0.0273)
ΔCash				−0.0409	0.0517**	−0.0718***
				(0.0327)	(0.0246)	(0.0217)
ΔAR				0.205***	0.0890**	−0.0874**
				(0.0672)	(0.0368)	(0.0411)
Constant	1.981***	3.453***	5.192***	2.168***	3.493***	5.167***
	(0.129)	(0.104)	(0.106)	(0.141)	(0.111)	(0.125)
Year fixed effects	Included	Included	Included	Included	Included	Included
Observations	2110	2110	2110	2110	2110	2110
R-squared	0.036	0.028	0.012	0.042	0.032	0.019

Note: ***, ** and * indicate significance at the 1%, 5%, and 10% levels, respectively.

and only 10% of the marginal profit was affected by trade credit. For high solvency firms, 12% marginal profit is obtained by short-loan which is higher than that by trade credit when we do not consider control variables. We thus accept Hypothesis 2.

Hypotheses 1 and 2 are both verified by the robustness test. Thus, we conclude that retailers order more with higher solvency. And bank short loan has a more significant impact on marginal profit for high solvency firms, leading to retailers sourcing from banks if it is available.

7. Conclusions

In this paper, we study both capital-constrained retailers and manufacturers under accounts receivable mortgage contracts. There are three situations of an interest rate for a manufacturer according to her solvency (initial capital ratio), order amount, and bank's credit policy. Different interest rates can be described such as risk-free interest rates, general interest rates for SMEs, and compensation interest rates. We obtain optimal order and pricing decisions for retailers and manufacturers with different bank credit policies and firms' original operational capacity. High-solvency manufacturers and retailers benefit more than low-solvency firms, which can be reflected in order quantity, respective profit, and system profit. We also consider bank credit as a supplement to study operational decisions under different bank credit policies, such as different capital evaluation coefficients and retailer's solvency which can be determined by initial capital in our model, reflecting firms' original operational capacity.

We find that retailers prefer to source from bank credit if available rather than trade credit, due to the fact that the profit and order quantity of the retailer is higher than that with trade credit for both capital-constrained supply chain conditions. In order to examine our findings, we examined Chinese firm data as empirical evidence. The empirical results are consistent with our finding that (*i*) with an increase of solvency, retailer orders more; (*ii*) it is better for a capital-constrained retailer to source from a bank if it is available. We conclude that trade credit is supplemental sourcing for capital-constrained firms sourcing from the bank in China.

There are some interesting further research opportunities including (*i*) dual-channel supply chain situations with asymmetric manufacturers; (*ii*) account receivable mortgage from multi-commercial-bank with interest rate competition.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The data that has been used is confidential.

Appendix

Proof.

Proof of Proposition 1. Taking the first derivative of Equation (Birge, 2014) with respect to order quantity, we have.

$\frac{\partial \pi_{R,T}}{\partial q} = p[1 - F(q)] - w + wF(q_{R,T}) = p\overline{F}(q) - w\overline{F}(q_{R,T})$. Let $\frac{\partial \pi_{R,T}}{\partial q} = 0$, we obtain the following: $p\overline{F}(q) = w\overline{F}(q_{R,T})$.

The second-order optimality condition of the retailer's expected profit function can be expressed by the following:

$\left.\frac{\partial^2 \pi_{R,T}}{\partial q^2}\right|_{p\overline{F}(q)=w\overline{F}(q_{R,T})} = -pf(q) + \frac{w^2}{p} f(q_{R,T}) = -w\overline{F}(q_{R,T})[ph(q) - wh(q_{R,T})]$. Remind that the IFR property and $q > q_{R,T}$, we obtain $h(q) > h(q_{R,T})$. Due to the assumption $p > w$ and $0 < \overline{F}(q_{R,T}) < 1$, it is easy to verify $\frac{\partial^2 \pi_{R,T}}{\partial q^2} < 0$, meaning that it is convex for $E(\pi_{R,T})$. The optimal order quantity exists when $\frac{\partial \pi_{R,T}}{\partial q} = 0$. Thus, we obtain Proposition 1.

Proof of Lemma 1. *(i)* According to Proposition 1, the first-order derivation of order quantity with respect to retailer's initial capital is given as: $\frac{\partial q_T^*}{\partial B_R} = -\frac{h(q_{R,T})}{p\left(h(q_T^*) - \frac{w}{p} h(q_{R,T})\right)}$. Due to the IPR property of the demand distribution, we have $h(q^*) > h(q_{R,T}) > 0$. According to $p > w$, we obtain $\frac{\partial q_T^*}{\partial B_R} < 0$.

(ii) The first-order derivation of retailer's bankruptcy threshold with respect to wholesale price is given as:

$\frac{\partial q_{R,T}}{\partial w} = \frac{\partial q_{R,T}}{\partial q} \frac{\partial q}{\partial w} + \frac{\partial q_{R,T}}{\partial w} = \frac{1}{p}\left(w \frac{\partial q}{\partial w} + q\right)$. From Equation (Breza and Liberman, 2017), taking the first-order derivation with respect to wholesale price, we obtain $\frac{\partial q_T^*}{\partial w} = \frac{\frac{p}{w}\left[1 - q_T^* h(q_{R,T}) \frac{w}{p}\right]}{wh(q_{R,T}) - ph(q_T^*)}$. Remind that the IFR property and we have $1 - q_T^* h(q_{R,T}) \frac{w}{p} > 1 - q_T^* h(q_{R,T}) > 1 - q_T^* h(q^*) > 1 - H(q_T^*) > 0$. According to $wh(q_{R,T}) - ph(q^*) < 0$,which has been proved before, we get $\frac{\partial q_T^*}{\partial w} < 0$.

Proof of Lemma 2. Taking the first derivative of manufacturer's bankruptcy threshold $q_{M,I}$ in scenario I with respect to B_R, B_M , θ and q separately. We obtain $\frac{\partial q_{M,I}}{\partial B_R} = -\frac{(1+r_f)}{p} < 0$, $\frac{\partial q_{M,I}}{\partial B_M} = -\frac{(1+r_f)}{p} < 0$, and $\frac{\partial q_{M,I}}{\partial q} = \frac{c(1+r_f)}{p} > 0$. The first-order derivation of bankruptcy threshold $q_{M,II}$ in scenario II w.r.t B_R, B_M , θ and q separately are given as follows:

$\frac{\partial q_{M,II}}{\partial B_R} = -\frac{1+\theta r_f + (1-\theta) r_M}{p}$, $\frac{\partial q_{M,II}}{\partial B_M} = -\frac{1+r_M}{p}$, $\frac{\partial q_{M,II}}{\partial \theta} = -\frac{(wq - B_R)(r_M - r_f)}{p}$ and $\frac{\partial q_{M,II}}{\partial q} = \frac{(c-\theta w) r_M + c + \theta w r_f}{p}$.

It is easy to verify $\frac{\partial q_{M,II}}{\partial B_R} < 0$, $\frac{\partial q_{M,II}}{\partial B_M} < 0$ and $\frac{\partial q_{M,II}}{\partial \theta} < 0$.

Remind that in scenario II, we have $\theta(wq - B_R) < cq - B_M - B_R$. We obtain $c - \theta w > 0$. Then we have $\frac{\partial q_{M,II}}{\partial q} > 0$. Thus, we gain Lemma 2.

Proof of Lemma 3. Considering in different region of (θ, q), we divide manufacturer's bankruptcy threshold into three conditions. Due to the assumption that manufacturer and retailer are capital-constrained and $\theta \in [0, 1]$. We have $L = cq - B_M - B_R \geq 0$. Then it is $q \geq \frac{B_M + B_R}{c}$, which we define $q^a = \frac{B_M + B_R}{c}$. In region Ω_1, manufacturer's bankruptcy and bank's interest rate satisfy $(q_{M,I}, r_f)$, which represents $\theta(wq - B_R) \geq cq - B_M - B_R$. We have $(c - \theta w)q \leq B_M + B_R(1 - \theta)$, reminding that the right of inequality is positive. When $c - \theta w < 0$, revealing that $\theta \in \left(\frac{c}{w}, 1\right]$, all of the order quantity satisfies this context. When $(c - \theta w) > 0$, we have $\theta \in \left(0\ ,\ \frac{c}{w}\right]$. The order quantity satisfies, $q \leq \frac{B_M + B_R(1-\theta)}{c - \theta w}$. We define $q^b = \frac{B_M + B_R(1-\theta)}{c - \theta w}$.

In region of Ω_2, bank charges interest rate $r_M = r$ and manufacturer's bankruptcy is $q_{M,II}$ if $\frac{B_M}{B_M + B_R} \geq \frac{q_M}{q}$. Thus, we have $q\left[(1 + r)c - \theta w(r - r_f) - p\frac{B_M}{B_R + B_M}\right] \leq (1 + r)(B_R + B_M) - \theta B_R(r - r_f)$, reminding that the right of inequality is positive. When $(1 + r)c - \theta w(r - r_f) - p\frac{B_M}{B_R + B_M} \leq 0$, all order quantity satisfies this situation. Next, we have $\theta > \frac{c(1+r)(B_R + B_M) - pB_M}{w(r - r_f)(B_R + B_M)}$. And we define $\theta^a = \frac{c(1+r)(B_R + B_M) - pB_M}{w(r - r_f)(B_R + B_M)}$. For $(1 + r)c - \theta w(r - r_f) - p\frac{B_M}{B_R + B_M} > 0$, we obtain the region of order quantity is $q \leq \frac{(1+r)(B_R + B_M) - \theta B_R(r - r_f)}{(1+r)c - \theta w(r - r_f) - p\frac{B_M}{B_R + B_M}}$ in this context. We set $q^c = \frac{(1+r)(B_R + B_M) - \theta B_R(r - r_f)}{(1+r)c - \theta w(r - r_f) - p\frac{B_M}{B_R + B_M}}$. We gain the region of (θ, q) for region Ω_2.

if $\frac{B_M}{B_M+B_R} < \frac{q_M}{q}$, we can obtain the region of Ω_3. The interest rate is $r_M = \left(1+\lambda\frac{B_R}{B_M}\right)r$. Similar to region of Ω_2, we set $\theta^b = \frac{c\left(1+\left(1+\lambda\frac{B_R}{B_M}\right)r\right)\left(B_R+B_M\right)-pB_M}{w\left(\left(1+\lambda\frac{B_R}{B_M}\right)r-r_f\right)\left(B_R+B_M\right)}$.

When $\theta\in(0,\ \theta^b)$, region Ω_3 is established. And we have $q > \frac{\left(1+\left(1+\lambda\frac{B_R}{B_M}\right)r\right)\left(B_R+B_M\right)-\theta B_R\left(\left(1+\lambda\frac{B_R}{B_M}\right)r-r_f\right)}{\left(1+\left(1+\lambda\frac{B_R}{B_M}\right)r\right)c-\theta w\left(\left(1+\lambda\frac{B_R}{B_M}\right)r-r_f\right)-p\frac{B_M}{B_R+B_M}}$. We denote $q^d = \frac{\left(1+\left(1+\lambda\frac{B_R}{B_M}\right)r\right)\left(B_R+B_M\right)-\theta B_R\left(\left(1+\lambda\frac{B_R}{B_M}\right)r-r_f\right)}{\left(1+\left(1+\lambda\frac{B_R}{B_M}\right)r\right)c-\theta w\left(\left(1+\lambda\frac{B_R}{B_M}\right)r-r_f\right)-p\frac{B_M}{B_R+B_M}}$. Due to $q^d < q^c$ and $\theta^b > \theta^a$, there exists the possibility that bank can charges interest rate of general SMEs rate and risk compensation rate both for overlapping part of Ω_2 and Ω_3. We assume this overlapping part charged by general rate of SMEs in this context for the convenience. Thus, we have the region of Ω_1, Ω_2, and Ω_3 satisfies follows:

$$\Omega_1 = \left\{\left\{(\theta,q)|\theta\in\left(\frac{c}{w},1\right]\right\}\cap\left\{(\theta,q)|\theta\in\left(\frac{c(1+r)(B_R+B_M)-pB_M}{w\left(r-r_f\right)(B_R+B_M)},\frac{c}{w}\right],q\in\left[\frac{B_M+B_R}{c},\frac{B_M+B_R(1-\theta)}{c-\theta w}\right]\right\}\right\};$$

$$\Omega_2 = \left\{\left\{(\theta,q)|\theta\in\left(\frac{c(1+r)(B_R+B_M)-pB_M}{w\left(r-r_f\right)(B_R+B_M)},\frac{c}{w}\right]\right\}\cap\left\{(\theta,q)|\theta\in\left(0\ ,\ \frac{c(1+r)(B_R+B_M)-pB_M}{w\left(r-r_f\right)(B_R+B_M)}\right],q\in\left(\frac{B_M+B_R(1-\theta)}{c-\theta w},\frac{(1+r)(B_R+B_M)-\theta B_R\left(r-r_f\right)}{(1+r)c-\theta w\left(r-r_f\right)-p\frac{B_M}{B_R+B_M}}\right]\right\}\right\};$$

$$\Omega_3 = \left\{(\theta,q)|\theta\in\left(0\ ,\ \frac{c(1+r)(B_R+B_M)-pB_M}{w\left(r-r_f\right)(B_R+B_M)}\right],q\in\left(\frac{(1+r)(B_R+B_M)-\theta B_R\left(r-r_f\right)}{(1+r)c-\theta w\left(r-r_f\right)-p\frac{B_M}{B_R+B_M}},+\infty\right)\right\}$$

We can describe of different manufacturer's bankruptcy threshold and bank's interest rate according to (θ,q) in Fig. 3.

Proof of Corollary 1. Remind that $\xi_i = \frac{S(\Omega_i)}{S(\Omega_1)+S(\Omega_2)+S(\Omega_3)}$, and $S(\Omega_i)$ is the area of region Ω_i. We define the max order quantity is $q^{\max}$. ξ_1 can be expressed as

$\xi_1 = \int_0^{\frac{c}{w}} q^b d\theta + q^{\max}\left(1-\frac{c}{w}\right)$. Similarly, we obtain $\xi_2 = \int_0^{\theta^a}(q^c-q^b)d\theta + \int_{\theta^a}^{\frac{c}{w}}(q^{\max}-q^c)d\theta$, and $\xi_3 = \int_0^{\theta^a}(q^{\max}-q^c)d\theta$.

Taking the first-order of derivation of ξ_i with respect to retailer's initial capital and manufacturer's initial capital respectively. It is easy to confirm Corollary 1. Consider that ξ_i represents the manufacture's bankruptcy risk with different region and tolerance of bank's risk compensation interest rate (TCR). With arising of retailer's and manufacturer's initial capital, retailer and manufacturer do not need to loan so much and the payment pressure of returning principle and interest to bank is small. We can propose that for manufacturer' and retailer's initial increase, the risk will decrease and bank's tolerance increase. In this context, the probability for bank charging low interest rate like risk-free rate and general rate for SMEs will increase. In other words, $\frac{\partial\xi_1}{\partial B_R} > 0$, $\frac{\partial\xi_2}{\partial B_R} > 0$, $\frac{\partial\xi_1}{\partial B_M} > 0$ and $\frac{\partial\xi_2}{\partial B_M} > 0$.

Take first condition of ξ_3 w.r.t, B_R and B_M separately and we obtain $\frac{\partial\xi_3}{\partial B_R} = -\left[q^c(\theta^a)\frac{\partial\theta^a}{\partial B_R} + \int_0^{\theta^a}\frac{\partial q^c}{\partial B_R}d\theta\right]$, and $\frac{\partial\xi_3}{\partial B_M} = -\left[q^c(\theta^a)\frac{\partial\theta^a}{\partial B_M} + \int_0^{\theta^a}\frac{\partial q^c}{\partial B_M}d\theta\right]$. According to derivative definition, we have

$\frac{\partial\theta^a}{\partial B_R} = \frac{c(1+r)(B_R+B_M)[w(r-r_f)-1]+pB_M}{[w(r-r_f)(B_R+B_M)]^2}$. Due to $\frac{c(1+r)(B_R+B_M)-pB_M}{w(r-r_f)(B_R+B_M)} < \frac{c}{w}$, we obtain $p\frac{B_M}{B_R+B_M} > c(1+r)-c(r-r_f)$. By simplifying $\frac{\partial\theta^a}{\partial B_R}$, we have $\frac{\partial\theta^a}{\partial B_R} = \frac{c(1+r)[w(r-r_f)-1]+p\frac{B_M}{B_R+B_M}}{[w(r-r_f)(B_R+B_M)]^2} > \frac{c(r-r_f)[w(1+r)-1]}{[w(r-r_f)(B_R+B_M)]^2}$. According to $w > c \geq 1$, It is easy to verify $\frac{c(r-r_f)[w(1+r)-1]}{[w(r-r_f)(B_R+B_M)]^2} > 0$ and therefore we obtain $\frac{\partial\theta^a}{\partial B_R} > 0$. Similarly, we have $\frac{\partial\theta^a}{\partial B_M} = -\frac{pwB_R(r-r_f)}{[w(r-r_f)(B_R+B_M)]^2}$. It is easy to obtain $\frac{\partial\theta^a}{\partial B_M} < 0$. Comparing $\frac{\partial\theta^a}{\partial B_M}$ with $\frac{\partial\theta^a}{\partial B_R}$, we have $\left|\frac{\partial\theta^a}{\partial B_R}\right| < \left|\frac{\partial\theta^a}{\partial B_M}\right|$. Now, we consider about q^c. we define $q_1^c = (1+r)c-\theta w(r-r_f)-p\frac{B_M}{B_R+B_M}$ and $q_2^c = (1+r)(B_R+B_M)-\theta B_R(r-r_f)$. Hence, q^c can be expressed as $q^c = \frac{q_2^c}{q_1^c}$. We obtain by taking the first-order condition with respect to B_M. We have $\frac{\partial q_1^c}{\partial B_M} = -\frac{pB_R}{(B_M+B_R)^2} < 0$ and $\frac{\partial q_2^c}{\partial B_M} = 1+r > 0$. It can be easily verified that $\frac{\partial q^c}{\partial B_M} > 0$. Take the first derivative of q_1^c and q_2^c with respect to B_R. We obtain $\frac{\partial q_1^c}{\partial B_R} = \frac{pB_M}{(B_M+B_R)^2} > 0$ and $\frac{\partial q_2^c}{\partial B_R} = 1+r-\theta(r-r_f) > 0$ separately.

If $\frac{pB_M}{B_M+B_R} < [1+r-\theta(r-r_f)](B_M+B_R)$, we can obtain $\frac{\partial q_2^c}{\partial B_R} > \frac{\partial q_1^c}{\partial B_R}$. Due to $\theta < \frac{c(1+r)(B_R+B_M)-pB_M}{w(r-r_f)(B_R+B_M)}$, we have

$$[1+r-\theta(r-r_f)](B_M+B_R) > \left[(1+r)\left(1-\frac{c}{w}\right)+\frac{p}{w}\frac{B_M}{B_M+B_R}\right]\left(B_M+B_R\right) \geq$$
$$p(1+r)\left(1-\frac{c}{w}\right)+\frac{p}{w}\frac{pB_M}{B_M+B_R} > \frac{pB_M}{B_M+B_R}$$

Hence, $\frac{\partial q_2^c}{\partial B_R} > \frac{\partial q_1^c}{\partial B_R}$ and $\frac{\partial q^c}{\partial B_R} > 0$. Thus, we have $\frac{\partial\xi_3}{\partial B_R} < 0$ and $\frac{\partial\xi_3}{\partial B_M} < 0$. Besides, it is easy to verify $\frac{\partial q^c}{\partial B_M} > \frac{\partial q^c}{\partial B_R}$. Thus, we have $\left|\frac{\partial\xi_3}{\partial B_M}\right| > \left|\frac{\partial\xi_3}{\partial B_R}\right|$. Similarly, we can easily verify $\frac{\partial q^b}{\partial B_M} > \frac{\partial q^b}{\partial B_R} > 0$. Reminding that $\frac{\partial\xi_1}{\partial B_R} = \int_0^{\frac{c}{w}}\frac{\partial q^b}{\partial B_R}d\theta$ and $\frac{\partial\xi_1}{\partial B_M} = \int_0^{\frac{c}{w}}\frac{\partial q^b}{\partial B_M}d\theta$, we obtain $\frac{\partial\xi_1}{\partial B_M} > \frac{\partial\xi_1}{\partial B_R}$. Moreover, it is easy to verify $\frac{\partial\xi_2}{\partial B_M} > \frac{\partial\xi_2}{\partial B_R}$. To summarize, we conclude $\left|\frac{\partial\xi_i}{\partial B_M}\right| > \left|\frac{\partial\xi_i}{\partial B_R}\right|$. Therefore, we obtain Corollary 1.

Proof of Proposition 2. From Equation (Cerqueiro et al., 2016), the first derivative with respect to wholesale price, we have.

$\frac{\partial\pi_{M,T}}{\partial w} = -p\overline{F}(q_M)\frac{\partial q_M}{\partial w} + p\overline{F}(q_R)\frac{\partial q_R}{\partial w}$.

Recall that $\frac{\partial q_R}{\partial w} = \frac{1}{p}\left(q+w\frac{\partial q}{\partial w}\right) = \frac{1}{p}\left(q+\frac{p\left(1-qh(q_R)\frac{w}{p}\right)}{wh(q_R)-ph(q)}\right)$ and $\frac{\partial q_M}{\partial w} = \frac{1+r_f}{p}\frac{\frac{p}{w}\left[1-qh(q_R)\frac{w}{p}\right]}{wh(q_R)-ph(q)}$, when scenario I happens and $\frac{\partial q_M}{\partial w} = \frac{\theta(1+r_f)}{p}\left(q+w\frac{\partial q}{\partial w}\right)+\frac{1+r_M}{p}\left[(c-\theta w)\frac{\partial q}{\partial w}-\theta q\right]$ when scenario II happens. Besides, we have $\frac{\partial q}{\partial w} = \frac{\frac{p}{w}\left[1-qh(q_{R,T})\frac{w}{p}\right]}{wh(q_{R,T})-ph(q)}$ according to Proof of Lemma 1. Taking the second derivative of $\frac{\partial q_{R,T}}{\partial w}$, w.r.t, w. we obtain $\frac{\partial^2 q_{R,T}}{\partial w^2} = \frac{1}{p}\left(2\frac{\partial q}{\partial w}+w\frac{\partial^2 q}{\partial w^2}\right)$. The second-order condition of $\frac{\partial q_M}{\partial w}$, is $\frac{\partial^2 q_M}{\partial w^2} = \frac{(1+r_f)}{p}\frac{\partial^2 q}{\partial w^2}$ in scenario I and $\frac{\partial^2 q_M}{\partial w^2} =$

$\frac{\theta w(2+r_M+r_f)-c(1+r_M)}{p}\frac{\partial^2 q}{\partial w^2}+\frac{2\theta(r_f-r_M)}{p}\frac{\partial q}{\partial w}$ in scenario II. Then, we take the second-order derivation of $\frac{\partial \pi_{M,T}}{\partial w}$, we gain:

$$\frac{\partial^2 \pi_{M,T}}{\partial w^2}=p\overline{F}(q_M)\left[\frac{\partial^2 q_{R,T}}{\partial w^2}\frac{\partial q_M}{\partial w}\Big/\frac{\partial q_{R,T}}{\partial w}-\frac{\partial^2 q_M}{\partial w^2}-\frac{\partial q_M}{\partial w}\left[h\left(q_{R,T}\right)\frac{\partial q_{R,T}}{\partial w}-h(q_M)\frac{\partial q_M}{\partial w}\right]\right].$$

Remind that $\frac{\partial q}{\partial w}<0$, and $\frac{\partial^2 q}{\partial w^2}<0$. It is easy to verify $\left.\frac{\partial^2 \pi_{M,T}}{\partial w^2}\right|_{\overline{F}(q_M)\frac{\partial q_M}{\partial w}=\overline{F}(q_R)\frac{\partial q_R}{\partial w}}<0$.

Hence, the manufacturer's profit function is a concave w.r.t, wholesale price. The optimal wholesale price is given by $\frac{\partial \pi_{M,T}}{\partial w}=0$. By substituting $\frac{\partial q_R}{\partial w}$, $\frac{\partial q_M}{\partial w}$ and $\frac{\partial q}{\partial w}$ into $\frac{\partial \pi_{M,T}}{\partial w}=0$, we obtain follows:

$\frac{q_T^*\overline{F}(q_{R,T})}{w_T^*\overline{F}(q_{R,T})-c(1+r_f)\overline{F}(q_{M,I})}=\frac{\frac{p}{w_T^*}\left[1-q_T^*h(q_{R,T})\frac{w_T^*}{p}\right]}{ph(q_T^*)-w_T^*h(q_{R,T})}$ in scenario I; $\frac{\theta q_T^*(r_M-r_f)\overline{F}(q_{M,II})+q_T^*\overline{F}(q_{R,T})}{w_T^*\overline{F}(q_{R,T})-[(1+r_M)c-\theta w_T^*(r_M-r_f)]\overline{F}(q_{M,II})}=\frac{\frac{p}{w_T^*}\left[1-q_T^*h(q_{R,T})\frac{w_T^*}{p}\right]}{ph(q_T^*)-w_T^*h(q_{R,T})}$ in scenario II.

Proof of Proposition 3. From Equation (Gupta and Wang, 2008), we obtain the first derivative with respect to order quantity, giving as follow:

$$\frac{\partial \pi_{R,B}}{\partial q}=p\overline{F}(q)-w\left(1+\left(1+\lambda\frac{B_M}{B_R}\right)r\right)\overline{F}(q_{R,B}).$$

Let $\frac{\partial \pi_{R,B}}{\partial q}=0$, there is $p\overline{F}(q)=w\left(1+\left(1+\lambda\frac{B_M}{B_R}\right)r\right)\overline{F}(q_{R,B})$.

The second-order optimality condition of $\pi_{R,B}$ with respect to order quantity giving as:

$\frac{\partial^2 \pi_{R,B}}{\partial q^2}=\frac{w}{p}\left[w\left(1+\left(1+\lambda\frac{B_M}{B_R}\right)r\right)h(q_{R,B})-ph(q)\right]\left(1+\left(1+\lambda\frac{B_M}{B_R}\right)r\right)\overline{F}(q_{R,B})$.

Based on IFR property of demand distribution, we have $h(q_{R,B})<h(q)$. $\frac{\partial^2 \pi_{R,B}}{\partial q^2}<0$ can be obtained. Thus, it is convex for retailer's profit with order quantity. We have Proposition 3.

Proof of Lemma 4. Consider about Equation (Haley and Higgins, 1973), and take the first derivative with respect to wholesale price, we obtain

$$\frac{\partial q_B^*}{\partial w}=-\frac{p\left[1-\frac{w}{p}q_B^*\left(1+\left(1+\lambda\frac{B_M}{B_R}\right)r\right)h\left(q_{R,B}\right)\right]}{w\left[ph(q_B^*)-w\left(1+\left(1+\lambda\frac{B_M}{B_R}\right)r\right)h\left(q_{R,B}\right)\right]}.$$

Reminding that the IFR property and $\frac{w}{p}\left(1+\left(1+\lambda\frac{B_M}{B_R}\right)r\right)\langle 1$, we can obtain follows:

$1-\frac{w}{p}q_B^*\left(1+\left(1+\lambda\frac{B_M}{B_R}\right)r\right)h(q_{R,B})>1-q_B^*h(q_{R,B})>1-q_B^*h(q_B^*)=1-H(q_B^*)>0$. It is easy to obtain $\frac{\partial q_B^*}{\partial w}<0$.

Then, taking the first-order derivation of Equation (Haley and Higgins, 1973) with respect to B_M. We have

$\frac{\partial q_B^*}{\partial B_M}=-\frac{\lambda rp\left[1-\frac{wq_B^*-B_R}{p}\left(1+\left(1+\lambda\frac{B_M}{B_R}\right)r\right)h(q_{R,B})\right]}{\left(1+\left(1+\lambda\frac{B_M}{B_R}\right)r\right)B_R\left[ph(q_B^*)-w\left(1+\left(1+\lambda\frac{B_M}{B_R}\right)r\right)h(q_{R,B})\right]}$. Due to $1-\frac{wq_B^*-B_R}{p}\left(1+\left(1+\lambda\frac{B_M}{B_R}\right)r\right)h(q_{R,B})>1-\frac{wq_B^*}{p}\left(1+\left(1+\lambda\frac{B_M}{B_R}\right)r\right)h(q_{R,B})$. Reminding that $1-\frac{wq_B^*}{p}\left(1+\left(1+\lambda\frac{B_M}{B_R}\right)r\right)h(q_{R,B})>0$ and IFR property of demand distribution, it is easy to obtain $\frac{\partial q_B^*}{\partial B_M}<0$.

The first derivative of Equation (Haley and Higgins, 1973) with respect to r and λ respectively. We have the following equations as:

$$\frac{\partial q_B^*}{\partial r}=-\frac{p\left(1+\lambda\frac{B_M}{B_R}\right)\left[1-\frac{wq_B^*-B_R}{p}\left(1+\left(1+\lambda\frac{B_M}{B_R}\right)r\right)h\left(q_{R,B}\right)\right]}{\left(1+\left(1+\lambda\frac{B_M}{B_R}\right)r\right)\left[ph(q_B^*)-w\left(1+\left(1+\lambda\frac{B_M}{B_R}\right)r\right)h\left(q_{R,B}\right)\right]}$$

$$\frac{\partial q_B^*}{\partial \lambda}=-\frac{\frac{B_M}{B_R}rp\left[1-\frac{wq_B^*-B_R}{p}\left(1+\left(1+\lambda\frac{B_M}{B_R}\right)r\right)h\left(q_{R,B}\right)\right]}{\left(1+\left(1+\lambda\frac{B_M}{B_R}\right)r\right)\left[ph(q_B^*)-w\left(1+\left(1+\lambda\frac{B_M}{B_R}\right)r\right)h\left(q_{R,B}\right)\right]}$$

According to above proof, we can obtain $\frac{\partial q_B^*}{\partial r}<0$ and $\frac{\partial q_B^*}{\partial \lambda}<0$ freely.

When we take the first-order derivation with respect to retailer's initial capital B_R, it satisfies follows:

$$\frac{\partial q_B^*}{\partial B_R}=\frac{p\left[\frac{\lambda rB_M}{B_R^2}-\left[1+\left(1+\lambda\frac{B_M}{B_R}\right)r+\frac{\lambda rB_M\left(wq_B^*-B_R\right)}{B_R^2}\right]\left(1+\left(1+\lambda\frac{B_M}{B_R}\right)r\right)\frac{h\left(q_{R,B}\right)}{p}\right]}{\left(1+\left(1+\lambda\frac{B_M}{B_R}\right)r\right)\left[ph(q_B^*)-w\left(1+\left(1+\lambda\frac{B_M}{B_R}\right)r\right)h\left(q_{R,B}\right)\right]}$$

Due to $ph(q_B^*)-w\left(1+\left(1+\lambda\frac{B_M}{B_R}\right)r\right)h(q_{R,B})>0$, it is easy to prove $\frac{\partial q_B^*}{\partial B_R}<0$, if $\frac{B_M}{B_R}<\frac{(1+r_R)^2B_Rh(q_{R,B})}{\lambda r[p-(1+r_R)h(q_{R,B})(wq_B^*-B_R)]}$; and $\frac{\partial q_B^*}{\partial B_R}>0$, if $\frac{B_M}{B_R}>\frac{(1+r_R)^2B_Rh(q_{R,B})}{\lambda r[p-(1+r_R)h(q_{R,B})(wq_B^*-B_R)]}$. We define threshold of ratio of manufacturer's initial capital with retailer's initial capital $\widehat{\frac{B_M}{B_R}}=\frac{(1+r_R)^2B_Rh(q_{R,B})}{\lambda r[p-(1+r_R)h(q_{R,B})(wq_B^*-B_R)]}$. Considering the assumption that the manufacturer is capital-constrained, we obtain $cq-B_R-B_M>0$, which can be expressed as $\frac{B_M}{B_R}<\frac{cq-B_R}{B_R}$. Hence, we have Lemma 4.

Proof of Proposition 4. Recollect $\frac{\partial q_B^*}{\partial w}=-\frac{p\left[1-\frac{w}{p}q_B^*\left(1+\left(1+\lambda\frac{B_M}{B_R}\right)r\right)h(q_{R,B})\right]}{w\left[ph(q_B^*)-w\left(1+\left(1+\lambda\frac{B_M}{B_R}\right)r\right)h(q_{R,B})\right]}$. Taking the first derivative of Equation (Hosseini-Motlagh et al., 2021) with respect to wholesale price, we can obtain the follows:

$$\frac{\partial \pi_{M,B}}{\partial w}=(w-c)\frac{\partial q}{\partial w}+q$$

Simplifying the above equations, we have

$$\left.\frac{\partial \pi_{M,B}}{\partial w}\right|_{p\overline{F}\left(q_B^*\right)=w\overline{F}\left(q_{R,B}\right)\left[1+\left(1+\lambda\frac{B_M}{B_R}\right)r\right]} = \frac{\partial q_B^*}{\partial w}\left[\frac{pw\left(1-h\left(q_B^*\right)\right)}{1-\frac{\left[1+\left(1+\lambda\frac{B_M}{B_R}\right)r\right]wq_B^*h\left(q_{R,B}\right)}{p}} - c\right]$$

Let $\frac{\partial \pi_{M,B}}{\partial w} = 0$, we obtain $w = \frac{c}{1-q_B^*h(q_B^*)+\frac{c}{p}q_B^*\left(1+\left(1+\lambda\frac{B_M}{B_R}\right)r\right)h(q_{R,B})}$.

The second-order derivative of manufacturer's profit can be written as:

$\frac{\partial^2 \pi_{M,B}}{\partial w^2} = 2\frac{\partial q}{\partial w} + \frac{\partial^2 q}{\partial w^2}(w-c)$. Recall $\frac{\partial q}{\partial w} < 0$ and $\frac{\partial^2 q}{\partial w^2} < 0$, it is easy to verify $\frac{\partial^2 \pi_{M,B}}{\partial w^2}$. Thus, the manufacturer's expected profit function is a concave with respect to w. The optimal wholesale price can be given by $\frac{\partial \pi_{M,B}}{\partial w} = 0$.

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