Credit risk-inclusive reverse factoring model for textile supply chains

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ABSTRACT – REZUMAT

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This paper investigates a two-tier supply chain comprising a core retailer and a capital-constrained supplier within the textile industry. Utilising the Stackelberg game model, the study examines three distinct scenarios for implementing reverse factoring: unsecured, third-party external guarantees, and platform-mediated factoring. The research incorporates the reputation loss risk faced by retailers in the textile sector and analyses the optimal strategies for reverse factoring financing under conditions of random market demand. The findings indicate that external guarantees do not significantly mitigate the adverse effects of reputation loss risk when core retailers proactively engage in reverse factoring financing. This suggests that the introduction of external guarantees in reverse factoring offers limited utility. Conversely, platform-mediated reverse factoring financing proves to be an effective mechanism for reducing the impact of reputation loss risk, with its efficacy increasing as the factoring company's credit line decreases. Furthermore, the study concludes that when the platform's service fee rate is low, textile retailers should opt for platform-mediated reverse factoring financing to optimise their financial operations.

Keywords: *reverse factoring, risk of reputation loss, guarantee, platform*

Model de factoring invers bazat pe riscul de credit pentru lanțurile de aprovizionare din sectorul textil

Prezenta lucrare analizează un lanț de aprovizionare pe două niveluri, format dintr-un retailer principal și un furnizor cu resurse financiare limitate din industria textilă. Folosind modelul jocului Stackelberg, studiul examinează trei scenarii distincte de implementare a factoringului invers: fără garanții, cu garanții externe din partea unor terți și factoring mediat de o platformă. Cercetarea a luat în considerare riscul de pierdere a reputației cu care se confruntă retailerii din sectorul textil și analizează strategiile optime de finanțare prin factoring invers în condiții de cerere aleatorie pe piață. Rezultatele indică faptul că garanțiile externe nu atenuează în mod semnificativ efectele negative ale riscului de pierdere a reputației atunci când comercianții cu amănuntul principali se angajează în mod proactiv în finanțarea prin factoring invers. Acest lucru sugerează că introducerea garanțiilor externe în factoringul invers oferă o utilitate limitată. În schimb, finanțarea prin factoring invers mediată de platformă se dovedește a fi un mecanism eficient pentru reducerea impactului riscului de pierdere a reputației, eficacitatea sa crescând pe măsură ce linia de credit a companiei de factoring scade. În plus, studiul concluzionează că atunci când rata comisioanelor de serviciu ale platformei este scăzută, comercianții cu amănuntul din sectorul textil ar trebui să opteze pentru finanțarea prin factoring invers mediată de platformă pentru a-și optimiza operațiunile financiare.

Cuvinte-cheie: *factoring invers, risc de afectare a reputației, garanție, platformă*

INTRODUCTION

The financing difficulties of SMEs in the textile industry have been a major factor restricting the development of the supply chain and the real economy, especially in the volatile business environment caused by factors such as the COVID-19 pandemic. More and more SMEs are facing growing financing needs. As one of the main ways to address the financing problems of SMEs in the textile industry, supply chain finance has attracted widespread attention in recent years [1–3]. Among these solutions, reverse factoring financing based on accounts receivable and initiated by the buyer's core enterprise provides a new financing model for SMEs in the textile industry that primarily use accounts receivable notes as the main financing method [4–6]. Unlike general factoring financing, in reverse factoring, banks, factoring companies, and other financial credit institutions no longer passively accept accounts receivable from SMEs in the textile industry. Instead, they actively evaluate and select core enterprises, transferring the financing risk from high-risk sellers to buyers with good credit [7]. Through direct evaluation and selection of core enterprises, the reliability of accounts receivable sources is guaranteed, and credit default risk is reduced [8]. Reverse factoring financing enables SMEs in the previously high-risk textile industry to obtain financing from financial institutions, effectively expanding the financing channels and efficiency of the textile industry, and has become a primary solution to the financing problems of SMEs with limited capital [9].

Due to its advantages, such as low financing risk and fast transaction processes, as well as the successful application of some reverse factoring platforms (such as Mexico's Nafin financing platform), reverse factoring has attracted significant attention from both domestic and international scholars. Research has primarily focused on two perspectives. The first is the motivation and value for core enterprises to engage in reverse factoring. Elliot et al. [10] explored the increasing use by banks of supply chain finance in the form of reverse factoring (RF) and its impact on overall value creation in supply chains. Li et al. [11] through investigations of 11 cases and interviews with 28 stakeholders from buyers, banks, and textile suppliers, pointed out that the number of textile suppliers, their dependence on buyers, and the cost difference between internal refinancing and reverse factoring are key factors affecting the development of reverse factoring financing. Tunca et al. [12] analysed the role and efficiency of buyer intermediaries in textile supplier financing by building a game theory model and found that financing strategies with buyer intermediaries can significantly improve channel performance and benefit all supply chain participants. Chen and Zhan [13] analysed three typical application models of reverse factoring in practice, discussing five aspects of the internal mechanisms of reverse factoring: operation mechanism, risk control, credit transfer, credit creation, and channel effects.

The second perspective concerns the intersection of reverse factoring and operations management. In the context of reverse factoring financing. Babich and Kouvelis [14] proposed a research framework on the interaction between finance, operations, and risk management, highlighting the impact of reverse factoring on supply chain performance as a prevalent research topic. Van Der Vliet et al. [15] argued that the size of the payment term extension that a supplier can accommodate depends on demand uncertainty and the cost structure of the supplier. Wu et al. [16] compared the effects of three supply chain finance schemes, advance payment, delayed payment, and reverse factoring, on the financial performance of textile suppliers and retailers, indicating that when textile suppliers have financing advantages, delayed payment benefits both suppliers and retailers. When retailers have financing advantages, advance payment and reverse factoring are better options for both. Other studies compare reverse factoring with other supply chain financing strategies. For example, Gelsomino et al. [17] compared reverse factoring, inventory financing, and dynamic discounts, three financing methods with buyer involvement in core enterprises, and discussed their impact on buyer benefits, emphasising the importance of working capital demand and financial costs in evaluating financing schemes. Zhu and Ou [18] proposed a three-level Stackelberg game model in the reverse factoring financing scenario, internalising bank interest rates for the first time and comparing reverse factoring with traditional commercial loans and forward factoring financing, showing that reverse factoring can effectively resolve fraud issues. Kouvelis and Xu [19] compared forward and reverse factoring financing from a credit rating perspective, noting that reverse factoring can take advantage of the payment guarantees from textile retailers and the credit rating differences between small suppliers and large retailers, enabling suppliers to obtain financing at more favourable interest rates. This literature further suggests that optimised reverse factoring schemes can increase the profits of textile retailers, and even if retailers lack credit advantages, reverse factoring financing strategies can still help resolve the financing issues of upstream suppliers. The emergence and application of reverse factoring makes the risk of supply chain financing change from high risk for small and medium-sized enterprises to low risk for core enterprises. However, at the same time, as a core enterprise that initiates reverse factoring financing, the core enterprise's commercial credit to upstream textile suppliers is transformed into bank credit to financial credit institutions as the object of payment for the goods receivable changes from textile suppliers to banks, factoring companies and other financial credit institutions after the accounts receivable maturity. As a result, core enterprises are often faced with problems such as declining market sales and increasing pressure of capital withdrawal caused by reputation problems, such as product quality of textile suppliers in reverse factoring, and thus bear the risk of reputation loss. Hu et al. [20] analysed supply chain cooperation in reverse factoring financing and robust decision-making under demand disturbance under the premise of considering the risk of reputation loss of core enterprises, and discussed the reasons why core enterprises are still willing to take the initiative to carry out reverse factoring in the face of reputation loss risk. However, it should be pointed out that there is little literature on how to avoid the core enterprise reputation risk in reverse factoring, especially the optimal development strategy of reverse factoring considering the core enterprise reputation loss risk. Based on this, this part takes the two-level supply chain consisting of a textile retailer in a core-enterprise position and a textile supplier with limited capital as the research object. In view of the reputation loss risk faced by textile retailers in reverse factoring, the optimal strategy for textile retailers to carry out reverse factoring is discussed by considering the introduction of a guarantee or the use of a platform. Compared to existing literature, this study complements Liebl et al. (2016) by explaining why guarantees fail in reverse factoring and extends Babich's (2018) framework by quantifying the interaction between reputation risk and platform service fees.

PROBLEM DESCRIPTION AND BASIC FRAMEWORK

Problem description

The research problem addressed in this paper concerns a two-tier supply chain comprising a core retailer and a capital-constrained supplier. The retailer

purchases a single product from the supplier at a predetermined wholesale price, sells it in a variable market, and delays payment, resulting in accounts receivable. Due to capital constraints, the supplier is unable to meet optimal order quantities and faces difficulties in obtaining credit from financial institutions because of its limited size and low credit rating. In contrast, the retailer, as the core enterprise, can secure low-cost financing from financial institutions due to its strong credit rating. To help overcome financing constraints faced by upstream suppliers, retailers consider two reverse factoring strategies: proactively entering into agreements with banks or utilising supply chain management platforms (e.g., the Nafin platform in Mexico). In the proactive strategy, the retailer mitigates the risk of credibility loss by obtaining unsecured and partial credit guarantees from a third-party agency. In contrast, the supply chain management platform strategy focuses on the potential for financing facilitated through the platform. The flowcharts of financing decisions under different reverse factoring scenarios are shown in figures 1 and 2, respectively.

In reverse factoring, the supplier first sets the wholesale price, after which the retailer decides the order quantity and delays payment, creating accounts receivable. To maintain optimal supply chain performance, the core retailer plans to address the funding constraints of upstream suppliers through reverse factoring. As illustrated in figure 1, the retailer initiates the reverse factoring process by partnering with a bank. The retailer agrees to assign its suppliers' accounts receivable and negotiates the bank's credit limit and interest rate. Subsequently, suppliers with limited funds apply for financing from the bank using their accounts receivable notes. The bank verifies the authenticity of the notes and provides the credit. At maturity, the retailer repays the bank, which collects the payment based on the agreed credit limit. Ultimately, the retailer settles the payment with the bank, which then compensates the supplier according to the agreed credit terms. The retailer may also involve a third-party guarantor to ensure the credibility of the financing.

As shown in figure 2, a platform-assisted reverse factoring strategy connects the core retailer, the capital-constrained supplier, and the bank. Once the supplier provides the accounts receivable, the retailer confirms the bill on the platform. The platform then auctions the factored accounts receivable, selects a bank, and determines the factoring amount based on the bidding results. At this stage, the bank becomes the creditor of the accounts receivable and provides credit to the supplier. The retailer then repays the bank directly when due. Throughout the financing process, the supply chain management platform charges a handling fee, which is based on the bank's granted credit.

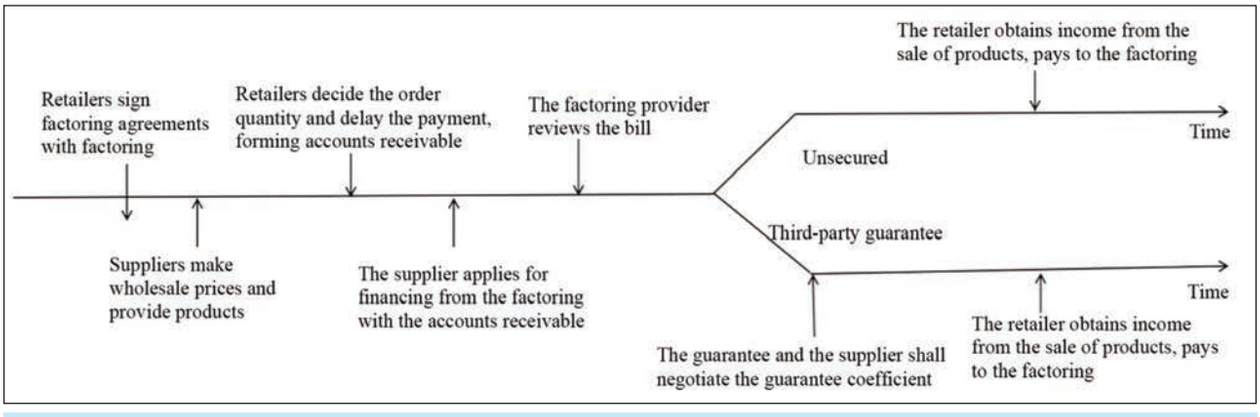

Fig. 1. Decision-making flowchart for retailer-initiated factoring strategy

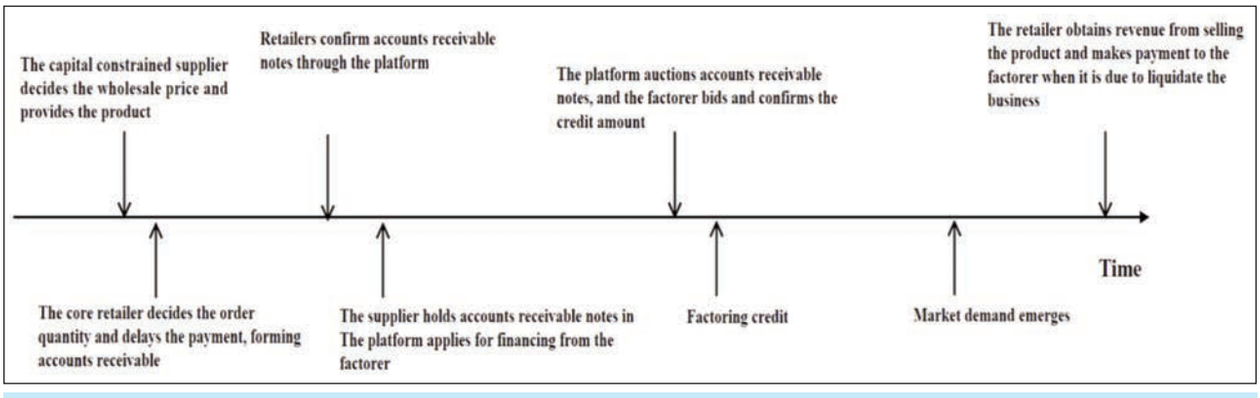

Fig. 2. Decision-making process framework for supply chain financing intermediation through reverse factoring platforms

Table 1

PARAMETERS AND VARIABLES	
Parameters	**Decision variables**
p: Retailer's market selling price per unit of product	w: supplier's wholesale price
c: The supplier's production cost per unit of product	q: Retailer's order quantity
l: Coefficient to measure the risk of loss of creditworthiness of the retailer	Function:
A: Credit lines granted by banks to core businesses (retailers)	Π: Profit function for each participant in financing
r: The bank's credit rate (generally a fixed value above the bank's interest rate)	R: Retailer; Supplier
ξ: The service fee rate of the supply chain management platform	SC: The overall supply chain (Supply Chain)
λ: The guarantee coefficient of the external third-party guarantee institution	1,2,3: Represent the active reverse factoring strategy under an unsecured and third-party external guarantee, and the reverse factoring strategy under a supply chain management platform facilitated financing, respectively.
β: Guarantee rate of external third-party guarantee institutions for unit financing	
D: Demand in the retail market	
f(D), F(D): probability density function of random market demand, cumulative distribution function	

Description of symbols and model assumptions

The symbols and descriptions used in this paper are shown in table 1 below.

The basic Model Assumptions of this paper are as follows:

(1) All participants in the financing business are risk-neutral and possess symmetric information.

(2) The retailer orders in a single period and faces random market demand with a probability density function $f(D)$ and cumulative distribution function $F(D)$, and it satisfies the generalised increasing failure rate (Increasing Generalised Failure Rate, IGFR), $H(D) = \frac{Df(D)}{1-F(D)}$ which represents the generalised increasing failure rate.

(3) The initial capital of the capital-constrained supplier is assumed to be zero.

(4) At the end of the sales period, the retailer's out-of-stock costs and the salvage value of unsold products are assumed to be zero.

CREDIT RISK-EMBEDDED REVERSE FACTORING FINANCING MODEL

Benchmark model: no guarantee

The decision flow diagram for this scenario is presented in figure 1. First, the capital-constrained supplier determines its wholesale price by solving the optimisation problem presented in equation 1 below.

$$\max_{w_1} \prod_1^S(w_1) = w_1 q_1 - c q_1(1+r) \qquad (1)$$

Second, the retailer decides the order quantity and delays payment, which can be formulated as the optimisation problem shown in equation 2 below:

$$\max_{q_1} \prod_1^R(q_1) = pE_D \min\{D, q_1\} - w_1 q_1 - \frac{cq_1}{A} l \qquad (2)$$

The problems in equations 1 and 2 represent a typical Stackelberg game, solved using the inverse order method to derive the optimal solution presented in Lemma 1.

Lemma 1: In unsecured active reverse factoring, the optimal decisions for each financing participant are:

(1) The supplier's optimal wholesale price w_1^* satisfies the equation: $w_1^* = p\bar{F}(q_1^*) - \frac{cl}{A}$;

(2) The retailer's optimal order quantity q_1^* satisfies the equation:

$$p\bar{F}(q_1^*)\left(1 - H(q_1^*)\right) = c\left(1 + r + \frac{l}{A}\right)$$

Proof: Differentiate equation 2 with respect to q_1, let $\frac{d\prod_1^R}{dq_1} = p\bar{F}(q_1) - w_1 - \frac{cl}{A} = 0$, we get: $w_1 = p\bar{F}(q_1) - \frac{cl}{A}$. Substitute it back into equation 1, continue to differentiate with respect to q_1, let

$$\frac{d\prod_1^S}{dq_1} = p\bar{F}(q_1)\left(1 - H(q_1)\right) - c\left(1 + r + \frac{l}{A}\right) = 0,$$

and solve the system of equations to prove Lemma 1. Lemma 1 indicates that the factor's credit line, financing rate, and the retailer's credit loss risk significantly influence the optimal decisions of stakeholders, as formalised in Proposition 1.

Proposition 1: In unsecured active reverse factoring, three key factors are: $w_1^* \propto r$, $q_1^* \propto \frac{1}{r}$, $q_1^* \propto A$, and $q_1^* \propto \frac{1}{l}$; in addition, there are two further factors: $\prod_1^R \propto \frac{1}{r}$, $\prod_1^R \propto A$, and $\prod_1^R \propto \frac{1}{l}$, where the symbol '$\propto$' denotes a positive relationship.

Proof: Based on the optimal solutions derived in Lemma 1 and the Increasing Generalised Failure Rate (IGFR) property, we conclude $q_1^* \propto \frac{1}{r}$, $q_1^* \propto \frac{1}{l}$, $q_1^* \propto A$, $w_1^* \propto r$. Simplifying equation 2, we obtain

$\prod_1^R = pE_D \min\{D, q_1^*\} - pq_1^* \bar{F}(q_1^*)$, and setting $K(x) = pE_D \min\{D, x\} - px\bar{F}(x)$, we derive $\frac{dK(x)}{dx} = pxf(x) > 0$. Thus, $\prod_1^R \propto q_1^*$, $\prod_1^R \propto A$, $\prod_1^R \propto \frac{1}{l}$.

Proposition 1 highlights two key findings. First, an increase in the financing rate raises the supplier's wholesale price while reducing the retailer's order quantity and profit. This occurs because higher financing costs compel the supplier to increase wholesale prices, which subsequently suppresses the retailer's ordering incentive. Second, the retailer's order quantity and profit increase with the factor's credit line but decrease with the credit loss coefficient. A higher credit loss risk exacerbates market demand volatility and liquidity pressure, dampening the retailer's operational flexibility. Conversely, a larger credit line mitigates the adverse effects of credit risk, fostering higher order quantities and profitability.

Reverse factoring financing model with a third-party external guarantee

As indicated by Proposition 1, the credit loss risk borne by the retailer significantly undermines their incentive to actively engage in reverse factoring without guarantees. To mitigate this impact, therefore, the introduction of third-party agencies to guarantee financing for businesses is considered to reduce the impact of reputation loss risk on retailers.

The decision flowchart with a third-party external guarantee is shown in figure 1.

$$\max_{w_2} \prod_2^S(w_2) = w_2 q_2 - cq_2(1 + r) - \beta cq_2 \qquad (3)$$

Second, the retailer's decision on order quantity and payment delay can be formulated as an optimisation problem, as shown in equation 4 below:

$$\max_{q_2} \prod_2^R(q_2) = pE_D \min\{D, q_2\} - w_2 q_2 - \frac{cq_2}{A} l + \lambda \frac{cq_2}{A} l \qquad (4)$$

The supplier then reaches an agreement with the external third-party guarantor on the guarantee coefficients and rates.

This is expressed as a solution to the problem in equation 5 below:

$$\beta cq_2 = \lambda \frac{cq_2}{A} l \qquad (5)$$

Similarly, the problem in equations 3 to 5 is a typical Stackelberg game. It can be solved using the reverse order method to find the optimal solution, as shown in Lemma 2.

Lemma 2: In reverse factoring involving a third-party external guarantor, the optimal decisions of financing participants are as follows:

(1) The optimal wholesale price w_2^* for the supplier is given by the following equation:

$$w_2^* = p\bar{F}(q_2^*) - (1 - \lambda)\frac{cl}{A}.$$

(2) The optimal order quantity q_2^* for the retailer is given by the following equation:

$$p\bar{F}(q_2^*)\left(1 - H(q_2^*)\right) = c\left(1 + r + \frac{l}{A}\right).$$

(3) The guarantee rate and guarantee coefficient of the external third-party guarantee institution are given by the following: $\beta = \frac{\lambda l}{A}$.

Proof: From Eq. (5), it is evident that $\beta = \frac{\lambda l}{A}$. Taking the derivative of equation 4 with respect to q_2 and setting $\frac{d\prod_2^R}{dq_2} = p\bar{F}(q_2) - w_2 - \frac{cl}{A} + \lambda\frac{cl}{A} = 0$, we obtain $w_2 = p\bar{F}(q_2) - (1 - \lambda)\frac{cl}{A}$.

Substituting this into equation 3, taking the derivative with respect to q_2, and setting

$$\frac{d\prod_2^S}{dq_2} = p\bar{F}(q_2)\left(1 - H(q_2)\right) - c\left(1 + r + \frac{l}{A}\right) = 0,$$

By solving these equations simultaneously, we thereby prove Lemma 2.

Similar to Lemma 1, Lemma 2 states that when an external third-party guarantor is introduced for reverse factoring, the bank's credit limit and rate for the core retailer, the retailer's risk of creditworthiness loss, and the guarantor's coefficient significantly impact each participant's optimal decision-making, as shown in Proposition 2.

Proposition 2: In the case of reverse factoring with partial credit guarantee from a third-party external guarantor, the following relationships hold: $w_2^* \propto r$, $q_2^* \propto \frac{1}{r}$, $w_2^* \propto \lambda$, $q_2^* \perp \lambda$, and $q_2^* \propto A$, $q_2^* \propto \frac{1}{l}$. Furthermore, $\prod_2^R \propto \frac{1}{r}$, $\prod_2^R \propto A$, $\prod_2^R \propto \frac{1}{l}$, but $\prod_2^R \perp \lambda$, $\prod_2^S \perp \lambda$. Here, the symbol $\propto$ denotes a proportional relationship and $\perp$ indicates that the two variables are unrelated.

Proof: Based on the optimal solutions derived from Lemma 2 and the proof of Proposition 1, it is evident that $w_2^* \propto r$, $q_2^* \propto \frac{1}{r}$, $w_2^* \propto \lambda$, $q_2^* \perp \lambda$, $q_2^* \propto A$, $q_2^* \propto \frac{1}{l}$, $\prod_2^R \propto \frac{1}{r}$, $\prod_2^R \propto A$, $\prod_2^R \propto \frac{1}{l}$, $\prod_2^S \perp \lambda$. Since

$$\prod_2^S = pq_2^*\bar{F}(q_2^*) - cq_2^*\left(1 + r + \frac{l}{A}\right), \text{ and } q_2^* \perp \lambda,$$

it follows that $\prod_2^S \perp \lambda$.

Proposition 2 presents the following conclusions. First, similar to Proposition 1, the supplier's optimal wholesale price increases with the reverse factoring interest rate, while the retailer's optimal order quantity and its own profit decrease with the reverse factoring interest rate. Additionally, the retailer's order quantity and optimal profit increase with the factor's credit line and decrease with the credit loss risk coefficient, for reasons consistent with those explained in Proposition 1.

Second, it is noteworthy that Proposition 2 indicates that even when a third-party external guarantor is introduced to provide a partial credit guarantee to mitigate the retailer's credit loss risk, the retailer's optimal decisions and profits remain unaffected by changes in the guarantee coefficient. This is because the guarantee fee is borne by the supplier, which increases the supplier's financing costs and consequently leads to a higher wholesale price. This higher wholesale price offsets the positive effect of the guarantee in reducing the retailer's credit loss risk. Although the retailer benefits from a reduced credit

loss risk through the guarantee, it faces a higher wholesale price, ultimately resulting in no change in the optimal order quantity. Moreover, the increase in ordering costs is offset by the reduction in credit loss risk, leaving the retailer's optimal profit unchanged.

Proposition 2 leads to the following conclusions: First, similar to Proposition 1, the supplier's wholesale price increases with a higher factoring rate, while the retailer's order quantity and optimal profit decrease. Additionally, the retailer's order quantity and optimal profit increase with the bank credit limit and decrease with the creditworthiness loss coefficient, as explained in Proposition 1.

Second, Proposition 2 highlights that despite introducing a third-party guarantor to partially guarantee the financing and reduce the retailer's creditworthiness risk, the guarantee coefficient does not affect the retailer's optimal decision or profit. This is because the supplier bears the financial burden of the guarantee. The supplier's financing costs increase due to the guarantee, leading to higher wholesale prices. This cancels out the positive effect of the guarantee in reducing the retailer's reputational risk. The reduction in reputational risk is offset by the higher wholesale price, leading to a constant optimal order quantity and increased ordering costs. However, the constant optimal profit is maintained due to the reduction in reputational risk.

Based on the preceding lemmas and propositions, Proposition 3 is derived through a comparative analysis of Propositions 1 and 2.

Proposition 3: In the active reverse factoring financing model, the following relationships hold: $w_1^* < w_2^*$, $q_1^* = q_2^*$, but $\Pi_1^S = \Pi_2^S$, $\Pi_1^R = \Pi_2^R$, $\Pi_1^S + \Pi_1^R = \Pi_1^{SC} = \Pi_2^{SC} = \Pi_2^S + \Pi_2^R$.

Proof: According to Lemma 1 and Lemma 2, it is evident that $q_1^* = q_2^*$, and thus

$$w_1^* = p\bar{F}(q_1^*) - \frac{cl}{A} < p\bar{F}(q_1^*) - (1-\lambda)\frac{cl}{A} = w_2^*.$$

By simplifying the profit functions

$$\Pi_1^S = pq_1^*\bar{F}(q_1^*) - cq_1^*\left(1 + r + \frac{l}{A}\right),$$

$$\Pi_1^R = pE_D \min\{D, q_1^*\} - pq_1^*\bar{F}(q_1^*),$$

$$\Pi_2^S = pq_2^*\bar{F}(q_2^*) - cq_2^*\left(1 + r + \frac{l}{A}\right),$$

$$\Pi_2^R = pE_D \min\{D, q_2^*\} - pq_2^*\bar{F}(q_2^*),$$

we have $\Pi_1^R = \Pi_2^R$, $\Pi_1^S + \Pi_1^R = \Pi_1^{SC} = \Pi_2^{SC} = \Pi_2^S + \Pi_2^S$.

Proposition 3 illustrates that in the reverse factoring financing model, the introduction of a third-party guarantee does not increase the profits of either the retailer or the overall supply chain. Furthermore, Proposition 3 indicates that the introduction of a third-party guarantee leads to an increase in the supplier's wholesale price, without enhancing the supplier's profit. Therefore, Proposition 3 concludes that in the context of supply chain accounts receivable reverse factoring financing, if the core enterprise actively provides reverse factoring to capital-constrained small and medium-sized enterprises, the partial credit guarantee provided by a third-party external guarantor cannot effectively mitigate the credit loss risk borne by the core enterprise in the financing process. Additionally, the supplier's assumption of the guarantee fee forces the supplier to increase the wholesale price. Although the introduction of the guarantee maintains the operational efficiency of all participating entities and the supply chain, there are many hidden costs in supply chain operations, such as labour and time. Therefore, in the active reverse factoring financing model, it is not advisable to mitigate the credit loss risk by introducing a third-party external guarantor, or if such a method is adopted, the capital-constrained small and medium-sized enterprises should not bear the guarantee fee.

Platform-mediated reverse factoring financing model

The decision flowchart for this scenario is shown in figure 2. First, the capital-constrained supplier decides the wholesale price w_3, which can be expressed as solving the optimisation problem shown in equation 6.

$$\max_{w_3} \Pi_3^S(w_3) = w_3 q_3 - cq_3(1 + r) \qquad (6)$$

Second, the retailer decides the order quantity with delayed payment. In this scenario, the platform acts as an intermediary and charges a certain percentage of the financing service fee, but also transfers the retailer's credit loss risk to the factoring platform. The retailer's decision can be expressed as solving the optimisation problem shown in equation 7.

$$\max_{q_3} \Pi_3^R(q_3) = pE_D \min\{D, q_3\} - w_3 q_3 - \xi c q_3 \qquad (7)$$

Similarly, equations 6 and 7 represent a typical Stackelberg game problem, which is solved using backward induction, with the optimal solution shown in Lemma 3.

Lemma 3: In platform-mediated reverse factoring, the optimal decisions of the financing participants are as follows:

The supplier's optimal wholesale price w_3^*:

$$w_3^* = p\bar{F}(q_3^*) - \xi c.$$

The retailer's optimal order quantity q_3^*:

$$p\bar{F}(q_3^*)\left(1 - H(q_3^*)\right) = c(1 + r + \xi).$$

Proof: Differentiating equation 7 with respect to q_3, setting $\frac{d\Pi_3^R}{dq_3} = p\bar{F}(q_3) - w_3 - \xi c = 0$, yields $w_3 = p\bar{F}(q_3) - \xi c$. Substituting this into equation 6 and differentiating with respect to q_3, setting

$$\frac{d\Pi_3^S}{dq_3} = p\bar{F}(q_3)\left(1 - H(q_3)\right) - c(1 + r + \xi) = 0,$$

Lemma 3 is proved by combining these results.

Lemma 3 shows that by leveraging the reverse factoring platform, the core retailer transfers its credit loss risk in the financing process to the reverse factoring platform by paying a certain service fee, making the decisions of the supply chain participants

independent of the credit loss risk. Similarly, the analysis of the optimal solution in Lemma 3 leads to Proposition 4.

Proposition 4: In platform-mediated reverse factoring, the following relationships hold: $w_3^* \propto r$, $q_3^* \propto \frac{1}{r}$, $q_3^* \propto \frac{1}{\xi}$. Additionally, $\Pi_3^R \propto \frac{1}{r}$, $\Pi_3^R \propto \frac{1}{\xi}$, where the symbol $\propto$ denotes a proportional relationship.

Proof: Based on Lemma 3, $w_3^* = p\bar{F}(q_3^*) - \xi c$, and q_3^* satisfies $p\bar{F}(q_3^*)(1 - H(q_3^*)) = c(1 + r + \xi)$. Similarly, since $p\bar{F}(q_3^*)(1 - H(q_3^*)) \propto \frac{1}{q_3^*}$. It follows that $q_3^* \propto \frac{1}{r}$, $q_3^* \propto \frac{1}{\xi}$, $w_3^* \propto r$. Substituting the optimal solution, $\Pi_3^R = pE_D \min\{D, q_3^*\} - pq_3^*\bar{F}(q_3^*)$, and similar to the proof of Proposition 1, $\Pi_3^R \propto \frac{1}{r}$, $\Pi_3^R \propto \frac{1}{\xi}$.

Unlike the conclusions presented in Propositions 1 and 2, Proposition 4 indicates that platform-mediated financing can effectively mitigate the credit loss risk borne by the retailer in the financing process, making the decisions of the supplier and retailer independent of the credit loss risk coefficient. However, since the platform charges a certain percentage of the service fee based on the financing amount, the retailer's order quantity decreases, ultimately leading to a decrease in the retailer's optimal profit as the platform's service fee rate increases.

OPTIMAL STRATEGY ANALYSIS FOR REVERSE FACTORING FINANCING

Model analysis

From the optimal solutions shown in Lemma 1 to Lemma 3 above and the analyses of Proposition 1 to Proposition 4, Proposition 5 can be obtained as follows.

Proposition 5: In reverse factoring considering the retailer's credit loss risk, if $0 < \xi < \hat{\xi}$, then $q_1^* = q_2^* < q_3^*$, $\Pi_1^R = \Pi_2^R < \Pi_3^R$.

Conversely, if $\hat{\xi} < \xi < 1$, then $q_1^* = q_2^* > q_3^*$, $\Pi_1^R = \Pi_2^R > \Pi_3^R$, where $\hat{\xi} = \frac{I}{A}$, and it is evident that $\hat{\xi} \propto 1$, $\hat{\xi} \propto \frac{1}{A}$.

Proof: Based on the optimal solutions derived from Lemmas 1, 2, and 3, we have:

In the no-guarantee scenario: $w_1^* = p\bar{F}(q_1^*) - \frac{cI}{A}$, q_1^* satisfies $p\bar{F}(q_1^*)(1 - H(q_1^*)) = c(1 + r + \frac{I}{A})$.

In the third-party guarantee scenario: $w_2^* = p\bar{F}(q_2^*) - (1-\lambda)\frac{cI}{A}$, q_2^* satisfies $p\bar{F}(q_2^*)(1-H(q_2^*)) = c(1 + r + \frac{I}{A})$.

In the platform-mediated scenario: $w_3^* = p\bar{F}(q_3^*) - \xi c$, q_3^* satisfies $p\bar{F}(q_3^*)(1 - H(q_3^*)) = c(1 + r + \xi)$.

Thus, it is evident that $q_1^* = q_2^*$, and $w_1^* < w_2^*$. Since $\bar{F}(q)(1-H(q)) \propto \frac{1}{q}$, if $\xi < \hat{\xi} = \frac{I}{A}$, then $q_3^* > q_1^* = q_2^*$.

Conversely, if $\hat{\xi} < \xi < 1$, then $q_1^* = q_2^* > q_3^*$. Since:

$$\Pi_1^S = pq_1^*\bar{F}(q_1^*) - cq_1^*(1 + r + \frac{I}{A}),$$

$$\Pi_1^R = pE_D \min\{D, q_1^*\} - pq_1^*\bar{F}(q_1^*).$$

$$\Pi_2^S = pq_2^*\bar{F}(q_2^*) - cq_2^*(1 + r + \frac{I}{A}),$$

$$\Pi_2^R = pE_D \min\{D, q_2^*\} - pq_2^*\bar{F}(q_2^*).$$

$$\Pi_3^S = pq_3^*\bar{F}(q_3^*) - cq_3^*(1 + r + \xi),$$

$$\Pi_3^R = pE_D \min\{D, q_3^*\} - pq_3^*\bar{F}(q_3^*).$$

when $0 < \xi < \hat{\xi} = \frac{I}{A}$, $\Pi_1^R = \Pi_2^R < \Pi_3^R$, conversely, $\Pi_1^R = \Pi_2^R > \Pi_3^R$.

Proposition 5 presents the following conclusions. Firstly, in the reverse factoring financing model that accounts for the retailer's (the core enterprise's) credit loss risk, the retailer's order quantity via the platform for reverse factoring financing increases when the service fee rate charged by the platform for facilitating transactions between the retailer and the supplier is low. This low fee incentivises the retailer to utilise the platform for reverse factoring financing. Conversely, when the platform's service fee rate is high, the retailer tends to engage directly in reverse factoring financing; however, this approach does not alleviate the impact of credit loss risk on financing efficiency, even with the introduction of external guarantees. This is due to the fact that platform-facilitated financing effectively reduces the negative effects of credit loss risks on the operational and financial efficiency of various entities within the supply chain. A relatively low service fee rate for platform-facilitated financing can significantly enhance the retailer's willingness to place orders, subsequently increasing their profits, and vice versa.

Secondly, as the retailer's credit loss risk escalates or the factoring company's credit limit diminishes, retailers are increasingly inclined to pursue reverse factoring financing through the platform. The analysis indicates that heightened reputational loss risk drives retailers to favour platform-mediated reverse factoring financing. Furthermore, a decrease in the credit line offered by the factoring company leads to an increase in the supplier's unit financing amount, which indirectly intensifies the adverse effects of reputational loss risk on the retailer's profits. Consequently, this shift in the retailer's strategy towards platform-mediated financing reflects a willingness to accept higher service fees in order to mitigate the negative impacts of reputational loss risk.

Proposition 5 outlines the optimal strategy for core enterprises to engage in reverse factoring while considering the potential risk of reputational loss. It also clarifies why core enterprises rarely introduce guarantees to facilitate reverse factoring financing. Additionally, it highlights that guarantee institutions should not prioritise collaboration with core enterprises in reverse factoring financing. For reverse factoring platforms, if the factoring institution's credit line to the core enterprise is significant or if the risk of reputational loss for the core enterprise is minimal, the platform should consider reducing the service fee rate charged for facilitating financing. This approach can effectively broaden the platform's client base.

Managerial implications of platform fee rate optimisation

From a policy perspective, governments and industry regulators should establish a dynamic guidance mechanism for platform service fees to balance the interests of all stakeholders. Specifically, when factoring companies have low credit lines or retailers face high reputation loss risks, regulators could provide subsidies to reverse factoring platforms to offset part of their service costs, enabling platforms to lower the fee rate below the threshold. This policy intervention would encourage more retailers to adopt platform-mediated financing, thereby alleviating financing constraints for suppliers in the textile industry. Additionally, regulators should mandate transparency in platform fee structures, requiring platforms to disclose how fees are calculated relative to risk transfer (e.g., the ratio of fees to reputation loss risk mitigation), which helps suppliers make informed financing decisions.

For suppliers, the key is to leverage platform-mediated financing when the service fee rate is low. Since platform financing decouples its wholesale pricing from retailers' reputation risk (Proposition 4), suppliers can avoid increasing wholesale prices to cover guarantee costs (unlike the third-party guarantee scenario). To further reduce costs, suppliers could form alliances to negotiate with platforms for group-based fee discounts. Larger transaction volumes from alliances can give suppliers more bargaining power to lower prices, thereby increasing their profit margins. Moreover, suppliers should prioritise platforms that offer flexible fee adjustments based on transaction history; for example, platforms that reduce fees for long-term, low-default clients can help suppliers build sustainable financing relationships.

Numerical analysis

First, a numerical analysis is conducted for the reverse factoring financing models under the scenarios of no guarantee and partial credit guarantee by a third-party external guarantor, as shown in Example 1.

Example 1: Assume that the retailer's market demand for the product follows a normal distribution with a mean of 1000 and a variance of 300. The unit price of the product is p = 1. The capital-constrained supplier has an internal capital level of 0, and the unit production cost of the product is c = 0.2. The factoring company's credit line is A = 3000, and the credit interest rate is r = 0.1.

(1) The guarantee coefficient in the case of external guarantee is λ = 0.2. The retailer's optimal decisions and profits as a function of the credit loss risk are shown in figure 3.

(2) The retailer's credit loss risk coefficient is l = 30. The optimal decisions and profits of the supplier and retailer as a function of the guarantee coefficient are shown in figures 4 and 5, respectively.

From figures 3 to 5, it can be observed that, consistent with Propositions 1 to 3, regardless of whether there is an external guarantee, the retailer's order quantity and optimal profit decrease as the credit loss risk increases (figure 3). Additionally, in the case of a third-party external guarantee, the supplier's wholesale price increases with the guarantee coefficient (figure 4, *a*), but the retailer's order quantity (figure 4, *b*) and the profits of all parties (figure 5) do not change with the guarantee coefficient. Compared to the no-guarantee scenario, the supplier's wholesale price is higher in the third-party external guarantee scenario (figure 4, *a*), and the profits of the financing participants and the overall supply chain do not improve (figure 5).

Next, a numerical analysis is conducted for the optimal strategy of platform-mediated reverse factoring financing, as shown in Example 2. For simplicity and accuracy, based on Proposition 3 and the conclusions from Example 1, the following analysis mainly compares the optimal decisions and profits under the

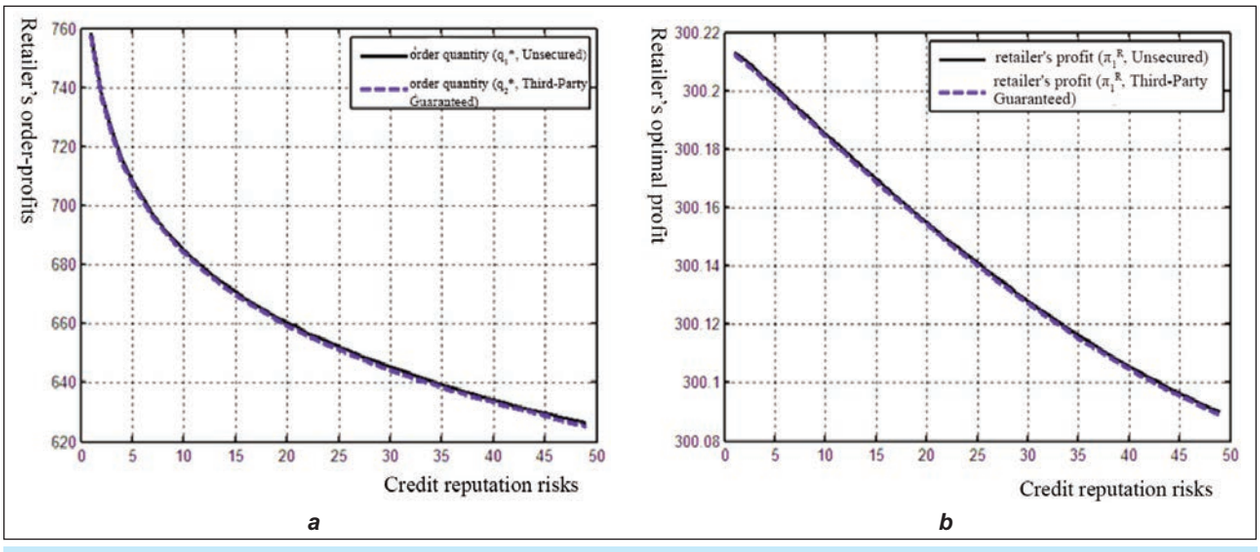

Fig. 3. Retailer's order-profits dynamics under credit reputation risks with unsecured third-party guaranteed financing: *a* – order quantity (q_1, q_2); *b* – profit (Π_1^R, Π_2^R)

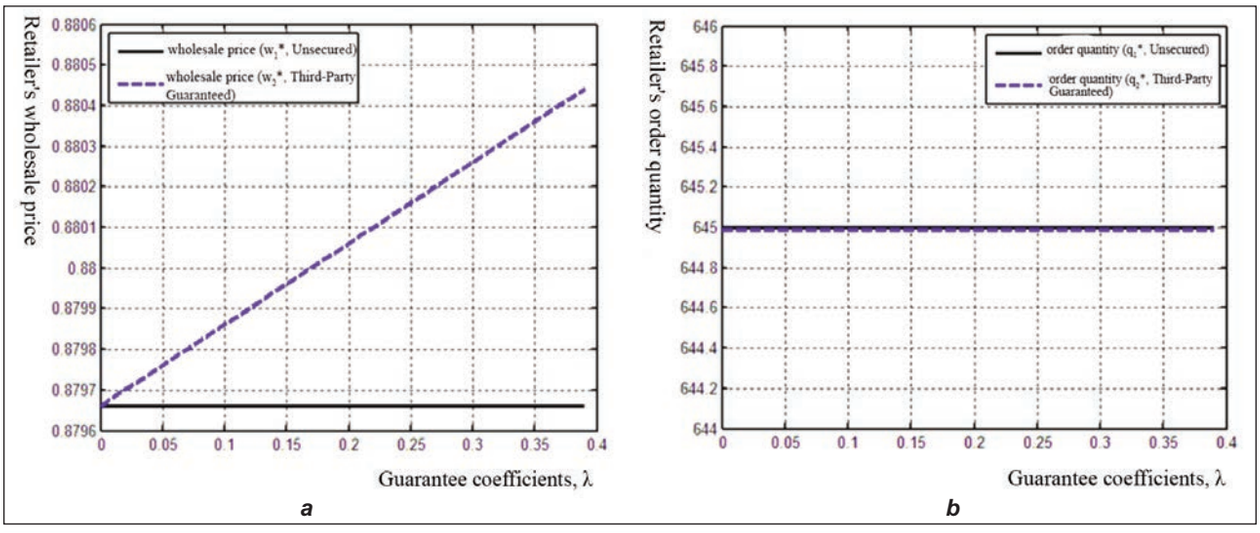

Fig. 4. Optimal supplier-retailer decisions under unsecured and third-party guarantees across guarantee coefficients: *a* – wholesale price (w_1, w_2); *b* – order quantity (q_1, q_2)

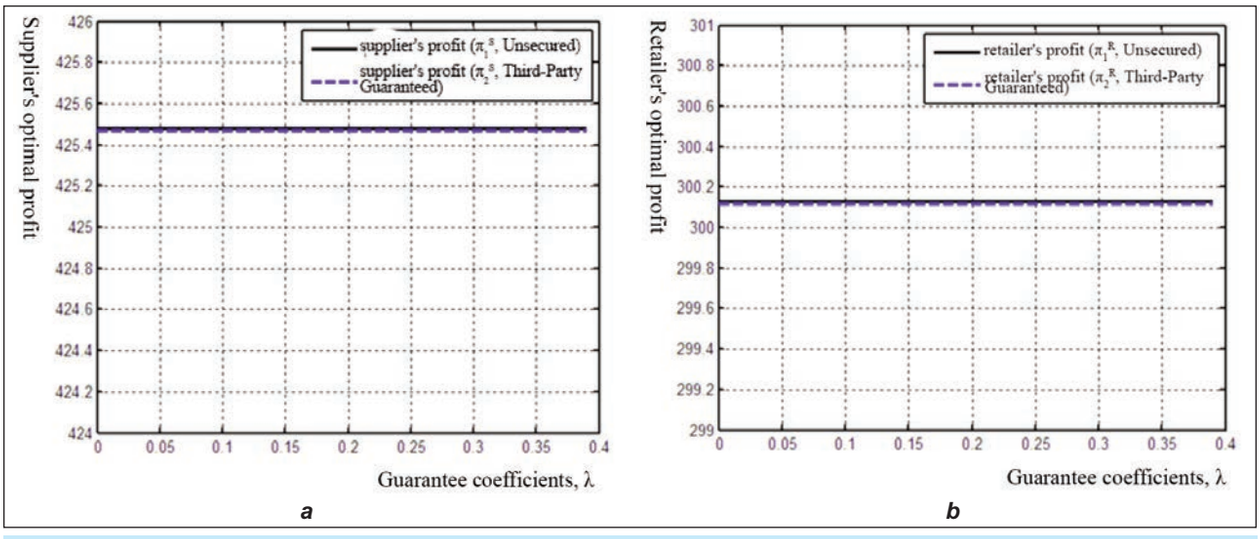

Fig. 5. Optimal supplier-retailer profits under unsecured and third-party guarantees across guarantee coefficients: *a* – supplier's profit (Π_1^S, Π_2^S); *b* – retailer's profit (Π_1^R, Π_2^R)

no-guarantee and platform-mediated financing scenarios.

Example 2: Assume that the retailer's market demand for the product follows a normal distribution with a mean of 300 and a variance of 120. The unit price of the product is p = 1. The capital-constrained supplier has an internal capital level of 0, and the unit production cost of the product is c = 0.2. The factoring company's credit interest rate is r = 0.1. The retailer's optimal decisions and profits as a function of the platform's service fee rate are shown in figure 6.

From figure 6, it can be observed that, consistent with Propositions 4 and 5, in the case of platform-mediated reverse factoring, the retailer's order quantity and optimal profit decrease as the service fee rate increases. Additionally, when the platform's service fee rate is low ($\xi < \hat{\xi} = \frac{I}{A}$), the retailer's order quantity and profit are higher under platform-mediated financing, and the service fee threshold increases with the credit loss risk (or decreases with the credit line).

CONCLUSION

This study investigates a two-tier supply chain comprising a core textile retailer and a capital-constrained textile supplier, analysing how reverse factoring based on accounts receivable can address upstream financing constraints. The paper specifically analyses the impact of the reputation loss risk faced by retailers when engaging in reverse factoring financing and explores the optimal strategies for textile retailers under random market demand conditions.

The paper first clarifies the negative impact of reputation loss risk on financing efficiency. It highlights that external guarantees do not effectively mitigate the reputational risk in reverse factoring financing. Additionally, the study demonstrates that platform-matching reverse factoring financing can reduce the adverse effects of reputation loss risk. The advantage of using platforms increases as the credit limit declines, suggesting that when the platform's service

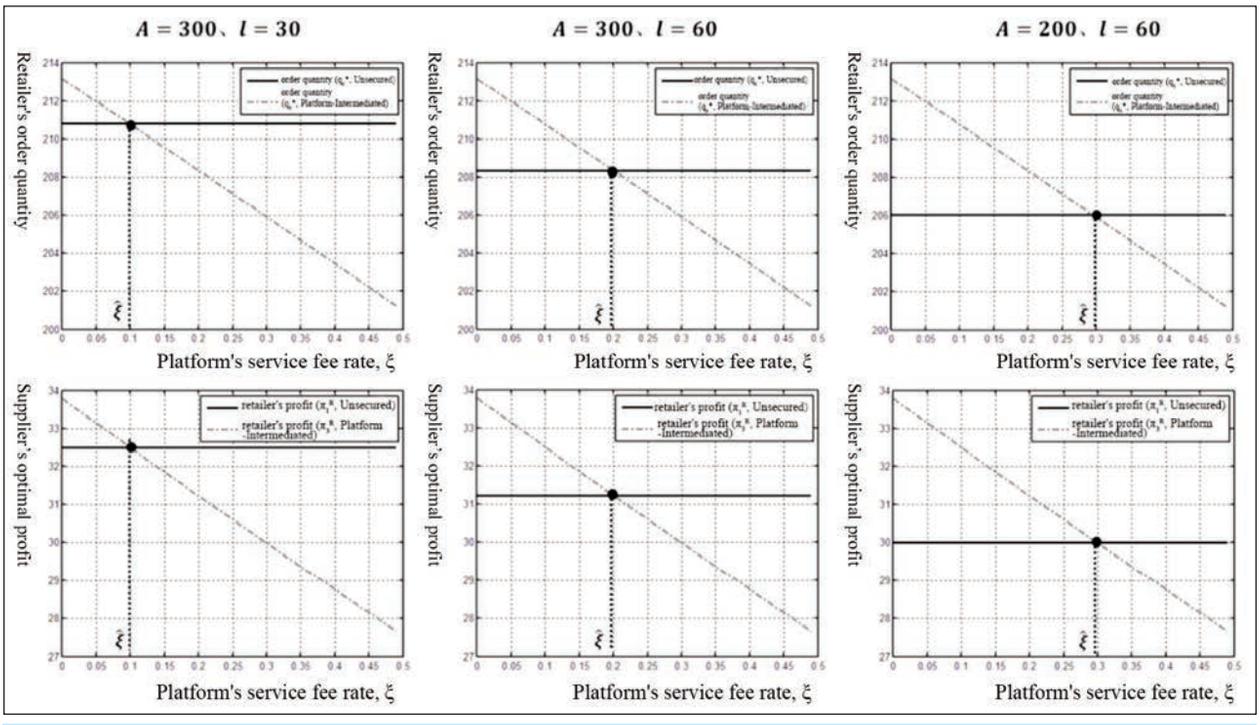

Fig. 6. Retailer's optimal decisions and profitability under unsecured platform-intermediated financing

rate is low, textile retailers should opt for reverse factoring financing through the platform.

The findings provide insights into the optimal approach for core textile enterprises to implement reverse factoring while accounting for reputational risk. The paper also explains why collaborations between core textile enterprises and guarantee companies are rarely seen in reverse factoring financing practices. Moreover, it advises guarantee institutions to refrain from focusing on partnering with core textile enterprises for reverse factoring and suggests that for reverse factoring platforms, reducing service rates when the core enterprise has a high credit limit or a low reputation loss risk can help expand the financing business more effectively.

From a policy standpoint, subsidising platforms with the goal of supporting textile suppliers' development. For suppliers, actively participating in platform financing under low fee rates not only reduces their financing costs but also stabilises their relationships with core textile retailers by avoiding wholesale price hikes.

Despite the contributions of this study, it does have some limitations. For instance, it assumes that financing participants, such as guarantee companies, are risk-neutral and does not take into account the residual value of unsold products at the end of the marketing period. These aspects represent potential directions for future research.

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