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Default risk management in factoring with guarantee and random demand

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KEYWORDS

Risk management; default risks; degree of centralization; partial credit guarantee; financing efficiency.

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ABSTRACT

Small and medium-sized enterprises generally have high default risk due to the characteristics of low concentration, long chain and large seasonal fluctuations. The implement of supply chain finance and factoring mainly relies on core enterprises in supply chain. However, the development of platform economy has transformed the supply chain structure from independence to coupled based on the core enterprise, namely degree of centralization. Therefore, with respect to a two-echelon supply chain which comprised of a capital-constrained supplier and a core retailer, this paper analyzed the effect of degree of centralization and guarantee to the factoring financing in the context of financing default risk based on the Stackelberg game and numerical simulations. Three guarantee scenarios are considered: no guarantee, third-party partial credit guarantee when guarantee fee is borne by the supplier, or retailer. The outcomes reveal that guarantee can efficiently reduce the supplier's financing interest rate and financing costs, but a higher degree of centralization is not always beneficial to financing efficiency and supply chain operations. In addition, it is worth noting that the retailer's profit and profit ratio is decrease with the degree of centralization, even the increase in degree of centralization means that the operating structure is more centralized. Furthermore, the absolute profit of the supplier is higher and the relative profit is lower when retailer bears the guarantee fee. With the jointly consideration of degree of centralization and guarantee coefficient, our analysis shows that the optimal default risk management mechanism is retailer bears the guarantee fee when there is partial credit guarantee from third-party..

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1. INTRODUCTION

Factoring, a type of financing in which the supplier sells their accounts receivable at a discount (known as the loan-to-value ratio) to a factor, such as a bank or financial services company, in exchange for immediate cash (Kouvelis and Xu, 2021). For capital-constrained suppliers, especially small and medium-sized enterprises (SMEs), it is an effective way to optimize cash flow, meet working capital needs, and reduce liquidity risk during delayed payment periods. Therefore, its growing popularity is evident in recent trends. According to the Factors Chain International (FCI) Annual Review, factoring and commercial finance volumes in the European Union increased by 7.9% in 2019, reaching 1.91 trillion euros, and its volumes increased by 10% to 24 billion euros in the Americas [1]. According to data from the People's Bank of China, at the end of 2020, the financing amounts of accounts receivable for Chinese industrial enterprises reached 16.7 trillion yuan, an increase of 10.3%. In addition, according to the World Bank's 2022 annual financial report, the global factoring market size has exceeded $100 billion in 2022. Furthermore, the global factoring market is projected to grow by 14.6% and reach 9,275 billion dollars by 2025. In particular, it is worth noting that most accounts receivable is concentrated in SMEs and private

[1] https://online.fliphtml5.com/uzvev/hfuf/#p=14
https://www.laitimes.com/en/article/662b4_6mem5.html

enterprises. Unlike traditional financing that require collateral, factoring reduces the risk and threshold of financing by converting accounts receivable into cash flow, providing enterprises with more convenient and flexible financing channels. Therefore, more and more enterprises are choosing factoring as one of the main financing methods.The implement of supply chain finance and factoring relies on core enterprises in supply chain (Kouvelis and Xu, 2021; Zhou et al., 2020; Lu et al., 2019). However, under the impact of factors such as the COVID-19 pandemic and trade frictions, global supply chain competition continues to intensify (Bag et al., 2023). That competition reshaped the supply chain structure between internal and external supply chains which led by core enterprises. Particularly with the rapid development of the platform economy where core enterprises play a central role, the supply chain operation structure is being reconfigured to be more flexible and interconnected (Caiado et al., 2021). In the context of platform economy, the operation structure of the supply chain has gradually transformed from *individual "mutual independence"* to *overall "coupling"* based on the core enterprises. That is, the upstream and downstream of the supply chain gradually have a certain content of correlation, namely *degree of centralization.* For example, the success operation of Xiaomi Corporation's business ecosystem, and the operation models which surrounding Tencent and Alibaba Group.Similarly changes in upstream and downstream relationships in the supply chain, namely degree of centralization, will have a significant impact on traditional factoring financing which implemented based on core enterprises.Factoring financing not only solves the financial difficulties of SMEs, but also opens up new business for banks and other financial institutions, achieving a "win-win" situation. However, even if factoring has advantages such as easily diffusible and structured, there also appeared a variety of defaults and loan frauds. For example, the 61 transactions between Chengxing and Nuoya in 2019 involved around 3.4 billion yuan of accounts receivable in total. Evidences showed that Chengxing fabricated the contract with companies, including JD.com, thus resulting in defaults of Nuoya [2]. Moreover, since the exposure of Evergrande's debt risk, the company's accounts payable to small and medium-sized suppliers have rapidly increased from 16.94% at 2017 to 33.91% in 2021 (the amount has increased from 0.26 trillion yuan to 0.67 trillion yuan). The debt crisis of Evergrande has led to a large number of suppliers and their upstream enterprises struggling to recover their accounts receivable, resulting in operational difficulties and bankruptcy. Specifically, the development of such platform economy which based on core enterprises is reshaping the structure of the supply chain, namely degree of centralization, Therefore, clarifying the transmission mechanism of credit and risk in the coupled supply chain, and then designing efficiency mechanisms such as guarantees to avoid the risks, has gradually becomes an important issue in factoring financing and supply chain operation management.As the core support of supply chain financing, risk management has always been an important factor in supply chain operations and financing business (Lai et al., 2009; Zhang et al., 2014; Babich and Kouvelis, 2018). Guarantee is one of the efficient risk management strategies in financing business, especially partial credit guarantee (PCG) from external third-party (Luo et al., 2016; Lu et al., 2019; Yu et al., 2021), guarantee from internal core enterprises in supply chain (Yan et al., 2016; Yan et al., 2017; Huang et al., 2019; Xu and Fang, 2020), and both of them (Zhou et al., 2020). However, most of these literatures focused on scenarios that downstream retailer's is capital-constrained, and the supply chain structure is completely centralized or decentralized. With the increasing of fluctuations in random market demand, default risk has also gradually become one of the critical risks in factoring that the upstream supplier is capital-constrained. In the context of factoring that there is a certain correlation between upstream and downstream enterprises, it is evident that the granted and transmission of credit, risk and guarantee input will be nonlinearity affected by degree of centralization, in turn affects financing decisions, financing efficiency, profit distribution and supply chain coordination.Based on the above discussion, this paper is motivated by the changes of supply chain structure in the context of platform economy, and mainly analyzes the effect of degree of centralization and guarantee to the factoring. We provide a game-theoretic analysis framework in this paper and answer two questions:

How does credit and risk transmit along the supply chain with the consideration of degree of centralization?

What is the optimal guarantee mechanism for capital-constrained supplier in factoring financing business in the context of platform economy??

We focus on a two-echelon supply chain which comprises a capital-constrained supplier and a core retailer. By taking into consideration of PCG from third-party, the impact of supply chain's degree of centralization and guarantee on factoring financing decisions, financing efficiency and profit distribution is analyzed based on the Stackelberg game model. First, PCG from third-party can effectively reduce the supplier's financing interest rate from the financial institutions such as banks. However, whether the guarantee fee is borne by the supplier or the retailer has a different effect on the financing decisions. When supplier bears the guarantee fee, although the decrease of financing interest rate reduces the supplier's financing cost, the optimal wholesale price keeps unchanged because the supplier bears the guarantee fee. When the retailer bears the guarantee fee, PCG from third-party reduces the financing risks and financing costs borne by the supplier, then the supplier will set a lower wholesale price, and then promotes the financing efficiency. In addition, degree of centralization has a significant effect on the profit distribution and supply chain coordination. The increase of degree of centralization will leads to a higher wholesale price and lower orders, and finally a lower financing efficiency. Furthermore, it is worth noting that the retailer's profit and profit ratio is decrease with the degree of centralization, even the increase in degree of centralization means that the operating structure is more centralized. In the context of platform economy with the consideration of degree of centralization, our analysis shows that the optimal guarantee mechanism is retailer bears the guarantee fee when there is PCG from third-party.

To the best of our knowledge, our research is the first to study the impact of degree of centralization on factoring financing decision and profit distribution in the context of platform economy. This work contributes to the growing body of literature on factoring, supply chain finance and operations management. Prior literature on factoring has discussed the guarantee mechanism (Yan et al., 2016; Lu et al., 2019), risk management (Klapper, 2006; Zheng et al., 2022), and financing methods (Kouvelis and Xu, 2021). Our study introduces a new perspective by considering the interconnectedness of suppliers and retailers, namely degree of centralization. On the other hand, literatures in the field of platform economy and ecosystem business mainly examine the problems related to business ecosystem (Adner and Kapoor, 2010; Kapoor and Lee, 2013; Rong et al., 2015; Joo and Shin, 2017) and value co-creation (Pera et al., 2016; Balaji and Roy, 2017; Payne et al., 2021) in the strategic level. The impact of changes in supply chain structure brought about by platform economy on corporate financing at the operational level has been rarely discussed. This work novelty lies in discussing the optimal guarantee mechanism of factoring financing in the context of platform economy with the consideration of degree of centralization.

By using the classic Stackelberg game model, our research also yields several relevant managerial implications for factoring in the context of platform economy. First, guarantee can effectively reduce the bank's financing interest rate and the negative effect of retailer's default risk. With the consideration of degree of centralization, the optimal guarantee mechanism is retailer bears the guarantee fee when there is PCG from third-party. In addition, degree of centralization should be considered when financing through factors. And it is worth to noting that a lower degree of centralization is actually more profitable for the core enterprises and whole supply chain.

The rest of the paper is organized as follows. Section 2 reviews the related literature. Section 3 defines notations, specifies assumptions and sequence of events. Sections 4-5 present mathematical analysis of factoring with the consideration of degree of centralization under different guarantee scenarios. In Section 6, theoretic and managerial implications for factoring and supply chain coordination with the jointly considered of degree of centralization and guarantee are discussed. Section 7 verifies our analysis with numerical experiments. Finally, Section 8 concludes the study and presents future directions.

2. LITERATURE REVIEW

Our study mainly touches upon two streams of literature: factoring financing (accounts receivable financing) and partial credit guarantee (PCG). We review the related studies of both streams separately in this section.

In the first research stream, existing literatures of factoring which based on account receivables has been extensively studied in corporate finance and operations management. For example, Summers and Wilson (2000) found that the motivation for using accounts receivable financing among firms is the demand for asset-based finance, based on a cross-sectional sample of 655 manufacturing companies. Asselbergh (2002) conducted a comparative study on trade credit and factoring, which showed that factoring is more suitable for SMEs with significant capital expenditures. Furthermore, Vliet et al. (2015) examined the impact of payment terms on the supplier's profit in the context of reverse factoring through simulation optimization, revealing that an extension of payment terms induces a non-linear financing cost for the supplier. Schwab et al. (2019) investigated the impact of accounts receivable flow time and credit limit allowed by financial partners on the financial sustainability of SMEs during the business growth period. Zheng et al. (2022) demonstrated that factoring can be used by suppliers to optimize their cash flow and reduce the default risk caused by delayed payments. Additionally, Cheng and Tu (2013), Li et al. (2018), Chod et al. (2020), and Zheng et al. (2022) discussed how to empower factoring through new information technologies such as blockchain and big data.

In the second research stream, we mainly discuss the impact of guarantee on risk management in the field of supply chain finance. As one of the main strategies to control financing risks, the literature on guarantee of SMEs' financing has been the richest (Boschi et al., 2014; Cowan et al., 2015; Yan et al., 2016; Lu et al., 2019; Xu and Fang, 2020; Zhou et al., 2020). The research on the financing guarantee problem is mainly focused on partial credit guarantee (PCG). For example, Yan et al. (2017) discussed the impact of bank neutral risk and downside risk on supply chain financing equilibrium under the core enterprise PCG model, and analyzed the optimal decision under different risk preference scenarios. Bi et al. (2018) studied the impact of core manufacturer collateral on the financing decisions of bank credit, trade credit and the supply chain's operational collaboration. Relative to the PCG by the core enterprise, Shi et al. (2020) analyzed the guarantee mechanism from the perspective of the core enterprise's buyback, and confirmed the substitutability of these financing guarantee mechanism by comparing with the research of Yan et al. (2016). Moreover, Huang et al., (2018), Tunca and Zhu (2018) pointed out that buyer PCG can reduce the financing risk of banks, thus facilitating loan applications and improving the financing efficiency of SMEs. In addition, by introducing a third-party offers PCG to reduces the loss caused by default risks, Boschi et al. (2014) analyzed the impact of PCG on corporate financing by using data from the Italian Central Guarantee Fund for SMEs. Xiang and Yang (2015) derived the optimal investment and financing strategies when loan guarantees are made in a real options framework. Luo et al. (2016) developed an investment and financing model with a PCG from an insurance company by using a real options approach, and derived a pricing decision for the real options. Under two different scenarios: information symmetry and information asymmetry, Lu et al. (2019) analyzed the impact of PCG on supply chain financing risk and financing efficiency. Yan et al. (2020) analyzed a financing model in which suppliers provide PCG to retailers by the Starkelberg game. Furthermore, by introducing a third-party insurance guarantee, Yu et al. (2021) analyzed the optimal decisions of each part under two financing models: trade credit and bank credit. Considering the CVaR model,

Ge et al. (2024) compared the impact of PCG and blockchain technology on supply chain financing decisions and risk management efficiency.

It is worth highlighting the differences between our study and the existing literatures. Most existing literatures studied financing guarantee issues in the context of the downstream of the supply chain is capital-constrained (Bi et al., 2018; Lu et al., 2019). However, less of them researched the guarantee mechanism when the upstream of supply chain face capital constraint in the field of factoring. In addition, the consideration of supply chain structure mainly focused on completely centralized or decentralized, none of them considered the reshaping of supply chain structure due to the development of platform economy, and does not further investigate the impact guarantee on factoring in the context of stochastic market demand and possible default risk from retailers. The development of platform economy reshaped the supply chain operation structure based on core enterprises, making the supply chain structure gradually become flexible and fuzzy (Caiado et al., 2021). The operation structure of the supply chain has gradually transformed from *individual "mutual independence"* to *overall "coupling"* based on the core enterprises, namely *degree of centralization*. Therefore, this paper firstly analyzes the financing decisions of factoring under the jointly consideration of PCG and degree of centralization. This study's novelty lies in discussing the impact of degree of centralization and guarantee on factoring financing model. It fills the gap in literature concerning guarantee, factoring financing and platform economy in the field of supply chain finance.

3. MODEL SETUP

In this study, we examine a two-echelon supply chain comprising a capital-constrained supplier (S) and a core retailer (R). The degree of centralization between retailer and supplier is ξ. At time zero, the supplier offers specific products to the retailer at the wholesale price w. The retailer places q orders for these products, leading to a delayed payment of wq, which generates accounts receivable for the supplier. To finance these accounts receivable, the supplier obtains funding from the factors such as bank. At the end of the sales period, if the market demand is low, the retailer may not sell all the products, and then generates default risks. In order to reducing their own financing risks that caused by default risk, in addition to granting credit to the supplier at a loan-to-value ratio θ and an interest rate r, the bank also required a partial credit guarantee (PCG) from third-party during factoring. The guarantee fee is borne by the supplier or retailer. Based on the Stackelberg game, this paper mainly investigates how the degree of centralization (ξ) and PCG coefficient (λ) impacts the decision-making regarding the supplier's wholesale price, the retailer's order quantity, the bank's interest rate, the supply chain's financing efficiency and profit allocation from a game-theoretical perspective.

For the reader's convenience, the key notations are summarized Table 1.

In addition, our analysis is based on several conventional assumptions.

1.The bank, supplier, retailer, and third-party are all risk-neutral. The bank's market is competitive. The supplier is limited-ability and the internal capital level is zero after supplying to the retailer. The retailer's default risk is exogenous, which may be caused by the exogenous credit shock associated with the credit rating, or drastically changed of operations environment (Devalkar and Krishnan, 2019; Kouvelis and Xu, 2021).

2.The salvage value of unsold products at the end of the sales period is zero.

3. Define $H(D) = \frac{Df(D)}{1-F(D)}$ represents Increasing Generalized Failure Rate (IGFR), and we assume that the retailer's random demand obeys IGFR (Lariviere and Porteus, 2001).

Table 1. Notations

Parameters:	**Decision variables:**
p: Retailer's unit product retail price	w: Supplier's wholesale price
c: Supplier's unit production cost	e: Retailers' order quantity
θ: Bank's loan-to-value ratio of accounts receivable	λ: Third-party's PCG coefficient
α: Retailer's probability of default	r: Bank's interest rate
ξ: Degree of centralization between retailer and supplier	**Functions:**
λ: PCG coefficient of third-party	Π: The expected profit
ε: The unit guarantee fee	**Abbreviations:**
r_f: Risk-free interest rate	R: Retailer; S: Supplier; SC: Whole supply chain
D: Random demand in retail market	0: No guarantee
f(D): The probability density function	1: PCG when guarantee fee is borne by supplier

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As illustrated in Figures 1-3, this paper mainly investigates three guarantee scenarios in factoring financing: No guarantee, PCG when guarantee fee is borne by the supplier, PCG when guarantee fee is borne by the retailer

Scenario 0: No guarantee. The sequence of events in this scenario is shown in Figure 1.

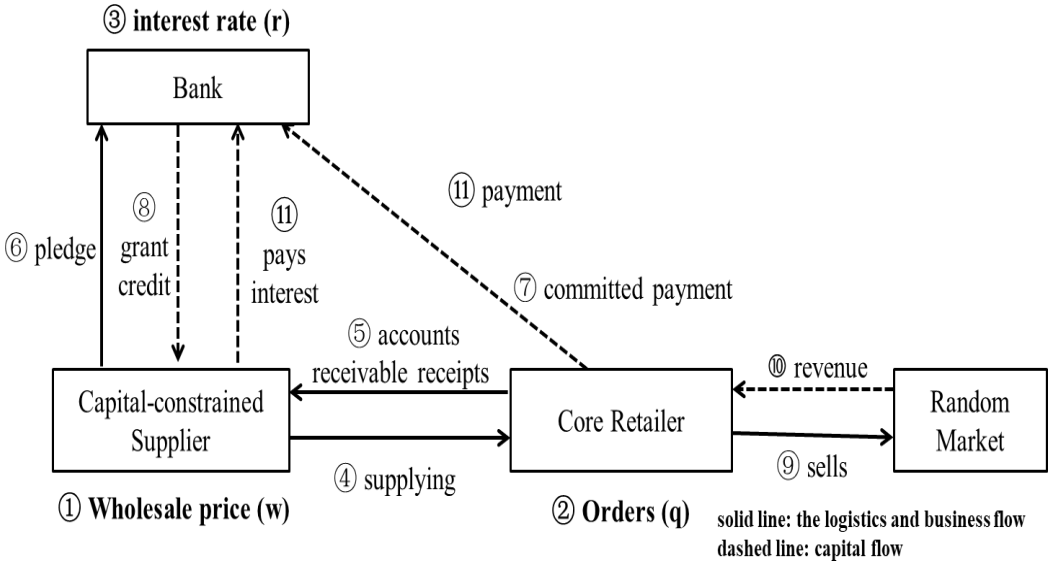


Figure 1. The sequence of events when no guarantee

As shown in the Figure 1, the supplier first announces wholesale price, then the retailer makes orders. Then the supplier holds an account receivable receipt due to the retailer's delay payment. Afterwards, the capital-constrained supplier financing from the bank with an interest rate. The retailer sells and earns revenue during the sales period. If the retailer full pays the bank at end of the sales period, then the bank pays the remaining credit to the supplier, the supplier pays the financing interest to the bank. Otherwise, if the retailer defaults, the bank claims financing interest from the supplier does not pay the remaining credit.

It is obviously that bank bears all financing risks when no guarantee. Therefore, the bank required a PCG from third-party to avoid financing risks in factoring.

Scenario 1: PCG when guarantee fee is borne by the supplier. The sequence of events in this scenario is shown in Figure 2.

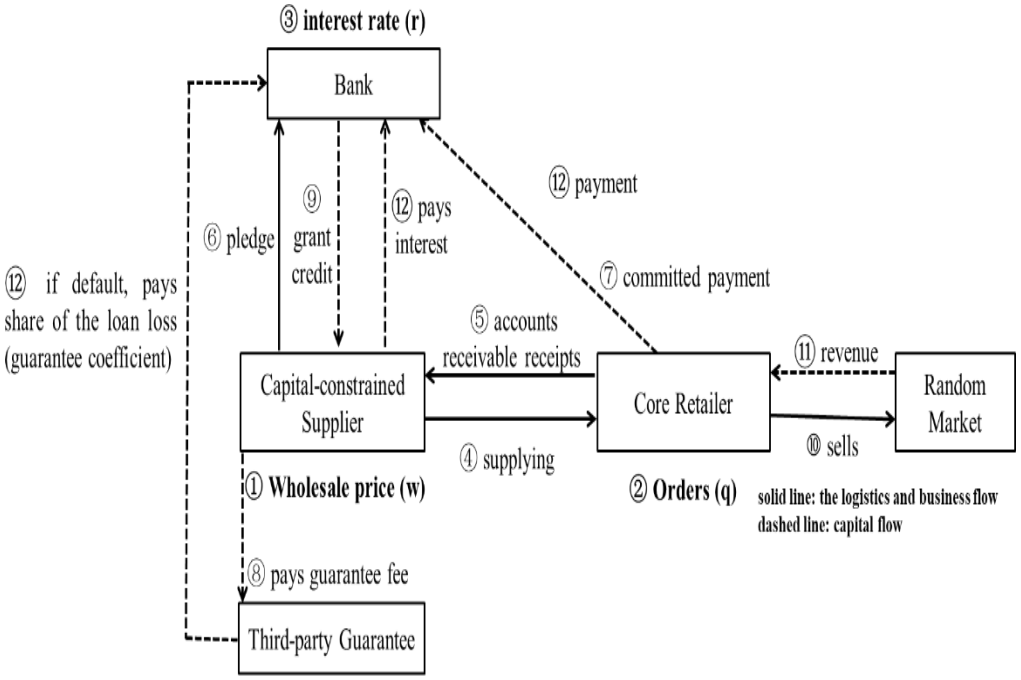


Figure 2. The sequence of events when third-party offers PCG and supplier bears guarantee fee

Scenario 2: PCG when guarantee fee is borne by the retailer. The sequence of events in this scenario is shown in Figure 3.

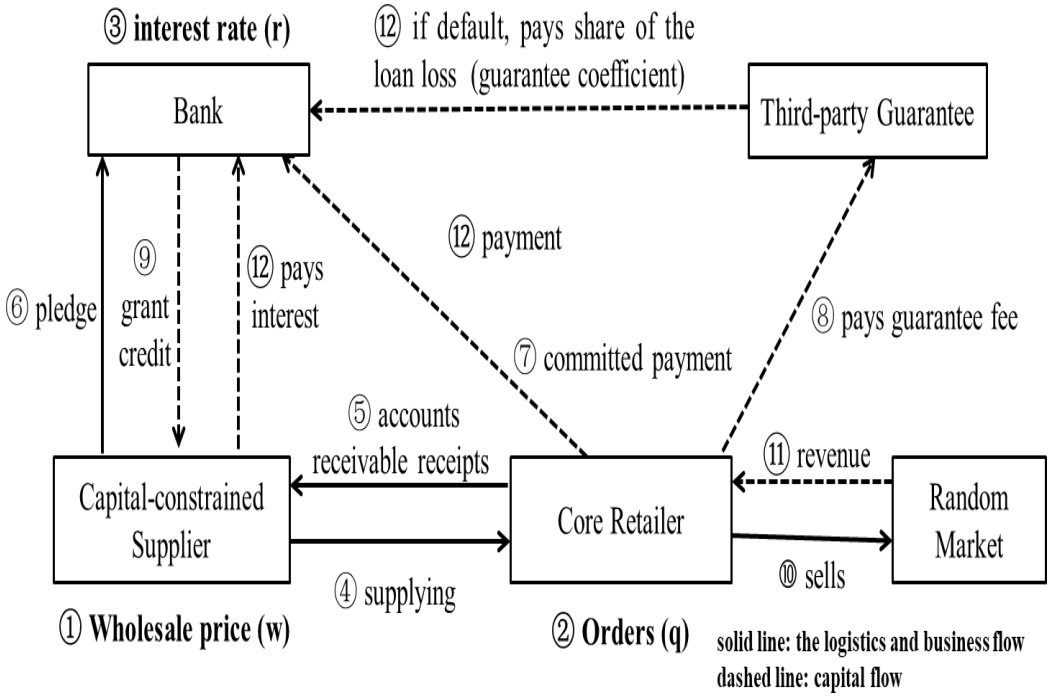


Figure 3. The sequence of events when third-party offers PCG and supplier bears guarantee fee

Similarly, as shown in the Figure 2 and Figure 3, there also the supplier first announces wholesale price and then the retailer makes orders with delayed payment, then the supplier financing from the bank under PCG. In this scenario, the guarantee fee is borne by the supplier or the retailer. At the end of sales period, if the retailer defaults, the bank claims financing interest from the supplier and share (guarantee coefficient) of the loan loss from the third-party, and does not pay the remaining credit.

Benchmark: factoring when no guarantee

To simplify the mathematical expression, we use subscript "0" to denote this scenario. According to Figure 1, the supplier first proposes the wholesale price w_0 that aims to maximize its profit, and the retailer then decides its order quantity q_0 that can maximize its profit. The supplier pledges the retailer's accounts receivable receipts to the bank, who grants credit to the supplier with a loan-to-value ratio θ and decides the financing interest rate r_0 based on the risk-free interest rate. The decision making of the three participants can be formulated as equations (1)-(3) follows.

$$\Pi_0^S(w_0) = \max_{w_0 \geq c} \{(1-\xi)(\theta w_0 q_0 + (1-\alpha)(1-\theta)w_0 q_0 - w_0 q_0 r_0 - c q_0)\} \quad (1)$$

$$\Pi_0^R(q_0) = \max_{q_0} \{pE_D\, min\{D, q_0\} - w_0 q_0(1-\alpha) + \xi(\theta w_0 q_0 + (1-\alpha)(1-\theta)w_0 q_0 - w_0 q_0 r_0 - c q_0)\} \quad (2)$$

$$\theta w_0 q_0 (1 + r_f) = (1-\alpha)(w_0 q_0 + w_0 q_0 r_0 - (1-\theta) w_0 q_0) + \alpha w_0 q_0 r_0 \quad (3)$$

To simplify the mathematical analysis and without loss of generality, we assume that the risk-free interest rate $rf = 0$. Then we proceed backwards and have Lemma 1 by integrating equations (1)-(3). (Hereinafter, for all proofs please refer to the appendix.)

Lemma 1. In factoring when no guarantee, the optimal solutions are:

(a) The supplier's optimal wholesale price is: $w_0^* = \frac{p\bar{F}(q_0^*) - \xi c}{(1-\alpha)(1-\xi)}$;

(b) The retailer's optimal orders satisfies: $p\bar{F}(q_0^*)\left(1 - H(q_0^*)\right) = c$;

(c) The bank's optimal interest rate is: $r_0^* = \theta\alpha$.

Lemma 1 shows that not only the possibility of retailer's default, but also the degree of centralization has a significant effect to the decision making of factoring.

Proposition 1. In factoring when no guarantee,

(a) $w_0^* \propto \xi$, $q_0^* \propto \frac{1}{\xi}$, $r_0^* \perp \xi$; (b) $w_0^* \propto \alpha$, $q_0^* \propto \frac{1}{\alpha}$, $r_0^* \propto \alpha$.

Proposition 1 shows the supplier's financing interest rate keeps unchanged with the degree of centralization. However, it is worth noting that a high wholesale price and a low order quantity can be expected in a high degree of centralization, which will aggravate the double marginalization effect between the supplier and the retailer. The rationale behind this is as follows. When there is a certain relationship between the upstream supplier and downstream retailer (namely degree of centralization), the purpose of supplier's decision in wholesale price changes from the traditional maximization of its own profits to the optimization problem after considering dividends (ξ) paid to the retailer. In this scenario, a higher degree of centralization takes away a larger part of the supplier's profit and weakening the supplier's profit level, which will lead to a higher wholesale price and then a lower order quantity, and finally weakens the whole supply chain's operational efficiency. Therefore, in an independent decision-making supply chain, a higher degree of centralization is not conducive to improving the factoring efficiency and supply chain's operational efficiency.

In addition, Proposition 1 also illustrates that the probability of the retailer's default, α, has a significant impact on factoring model when no PCG. With the increase of α, the bank will increase its interest rate to reduce the financing risk. Then it will increase the supplier's financing cost and leads to higher wholesale price and lower order quantity, and finally reducing the factoring financing efficiency.

Proposition 1 indicates that degree of centralization ξ and retailer's default α are two critical issues of factoring in the context of platform economy. Therefore, we consider PCG in factoring, and further analyze the impact of degree of centralization and guarantee on factoring financing decisions and financing efficiency.

Factoring with PCG from third-party

Guarantee fee is borne by the supplier

We use subscript "1" to denote this scenario, and the sequence of events is shown in Figure 2. Similarly, the supplier first proposes the wholesale price w_1 that aims to maximize its profit, and the retailer then decides its order quantity q_1 that can maximize its profit. Afterwards, the third-party decides the guarantee coefficient λ_1 based on the unit guarantee fee ε. Finally, the bank decides the financing interest rate r_1 based on the risk-free interest rate. The decision making can be formulated as equations (4)-(7) follows.

$$\Pi_1^S(w_1) = \max_{w_1 \geq c} \{(1-\xi)(\theta w_1 q_1 + (1-\alpha)(1-\theta) w_1 q_1 - c q_1 - w_1 q_1 r_1 - \varepsilon w_1 q_1)\} \quad (4)$$

$$\Pi_1^R(q_1) = \max_{q_1} \{pE_D \min\{D, q_1\} - w_1 q_1 (1-\alpha) + \xi(\theta w_1 q_1 + (1-\alpha)(1-\theta) w_1 q_1 - c q_1 - w_1 q_1 r_1 - \varepsilon w_1 q_1)\} \quad (5)$$

$$\varepsilon w_1 q_1 = \lambda_1 w_1 q_1 \alpha \quad (6)$$

$$\theta w_1 q_1 (1 + r_f) = (1-\alpha)(w_1 q_1 + w_1 q_1 r_1 - (1-\theta) w_1 q_1) + \alpha(w_1 q_1 r_1 + \lambda_1 w_1 q_1) \quad (7)$$

Similarly, we derive Lemma 2 by integrating equations (4)-(7).

Lemma 2. In factoring when third-party offers PCG and guarantee fee is borne by the supplier, the optimal solutions are:

(a) The supplier's optimal wholesale price is: $w_1^* = \frac{p\bar{F}(q_1^*) - \xi c}{(1-\alpha)(1-\xi)}$;

(b) The retailer's optimal orders satisfies: $p\bar{F}(q_1^*)\left(1 - H(q_1^*)\right) = c$;

(c) The third-party's optimal guarantee coefficient is: $\lambda_1 = \frac{\varepsilon}{\alpha}$;

(d) The bank's optimal interest rate is: $r_1^* = \alpha\theta - \varepsilon$.

Similar with Lemma 1, Lemma 2 indicates that both the default risk α and degree of centralization ξ have significant effects on the optimal decision making of all participants

Proposition 2. In factoring when third-party offers PCG and guarantee fee is borne by the supplier,

(a) For a given α, $w_1^* \propto \xi$, $q_1^* \propto \frac{1}{\xi}$, $r_1^* \perp \xi$;

(b) For a given ξ, $w_1^* \propto \alpha$, $q_1^* \propto \frac{1}{\alpha}$, $r_1^* \propto \alpha$.

Similar with Proposition 1 in scenario no PCG above, Proposition 2 also indicates that a higher degree of centralization ξ or default risk α will leads to a higher wholesale price and

order quantity. The rationale behind these is consistent with Proposition 1 above. It is worth noting that both the supplier's wholesale price and retailer's orders are not affected by the PCG coefficient even the guarantee cost is borne by the supplier. This is because PCG reduces the interest rate provided by the bank, and then reduces the supplier's financing cost, thus finally enabling the supplier and retailer to maintain an optimal wholesale price and orders.

Guarantee fee is borne by the retailer

We use subscript "2" to denote this scenario and the sequence of events is shown in Figure 3. Similarly, the decision making of the four participants can be formulated as equations (8)-(11) follows

$$\Pi_2^S(w_2) = \max_{w_2 \geq c} \{(1-\xi)(\theta w_2 q_2 + (1-\alpha)(1-\theta)w_2 q_2 - cq_2 - w_2 q_2 r_2)\} \quad (8)$$

$$\Pi_2^R(q_2) = \max_{q_2} \{pE_D\, min\{D, q_2\} - w_2 q_2(1-\alpha) - \varepsilon w_2 q_2 + \xi(\theta w_2 q_2 + (1-\alpha)(1-\theta)w_2 q_2 - cq_2 - w_2 q_2 r_2)\} \quad (9)$$

$$\varepsilon w_2 q_2 = \lambda w_2 q_2 \alpha \quad (10)$$

$$\theta w_2 q_2 (1 + r_f) = (1-\alpha)(w_2 q_2 + w_2 q_2 r_2 - (1-\theta)w_2 q_2) + \alpha(w_2 q_2 r_2 + \lambda w_2 q_2) \quad (11)$$

Similarly, we derive Lemma 3 by integrating equations (8)-(11)

Lemma 3. In factoring when third-party offers PCG and guarantee fee is borne by the retailer, the optimal solutions are:

(a) The supplier's optimal wholesale price is: $w_2^* = \frac{p\bar{F}(q_2^*) - \xi c}{(1-\alpha+\alpha\lambda)(1-\xi)}$;

(b) The retailer's optimal orders satisfies: $p\bar{F}(q_2^*)\left(1 - H(q_2^*)\right) = c$;

(c) The third-party's optimal guarantee coefficient is: $\lambda = \frac{\varepsilon}{\alpha}$;

(d) The bank's optimal interest rate is: $r_2^* = \alpha\theta - \varepsilon$.

Similar with Lemmas 1-2, Lemma 3 indicates that both the default risk α and degree of centralization ξ have significant effects on the optimal decision making of all participants. In addition, the third-party's PCG coefficient also affects the optimal decisions.

Proposition 3. In factoring when third-party offers PCG and guarantee fee is borne by the retailer,

(a) $w_2^* \propto \xi$, $q_2^* \propto \frac{1}{\xi}$, $r_2^* \perp \xi$;

(b) $w_2^* \propto \alpha$, $q_2^* \propto \frac{1}{\alpha}$, $r_2^* \propto \alpha$;

(c) $w_2^* \propto \frac{1}{\lambda}$, $q_2^* \propto \lambda$, $r_2^* \propto \frac{1}{\lambda}$.

First, similar with Proposition 2, Proposition 3 also indicates that a higher degree of centralization ξ or default risk α will leads to a higher wholesale price and order quantity. The rationale behind these is consistent with Propositions 1-2 above. It is worth noting that PCG reduces the bank's interest rate and supplier's wholesale price, thus increasing the retailer's order quantity in this scenario. Different from the guarantee fee borne by the supplier, the guarantee fee borne by the retailer reduces the possibility or the negative effect of retailer's default risk in factoring, and then further reduces the financing costs borne by capital-constrained supplier.

4. DISCUSSION

We have separately discussed the optimal solutions under three factoring financing scenarios: no guarantee, PCG when supplier bears the guarantee fee, PCG when retailer bears the guarantee fee. We mainly investigated the impact of degree of centralization and guarantee on the optimal financing decisions. Base on the analysis in Sections 4-5, we then continue to explore the financing efficiency and profit distribution in factoring model in the context platform economy. We further deduce Proposition 4.

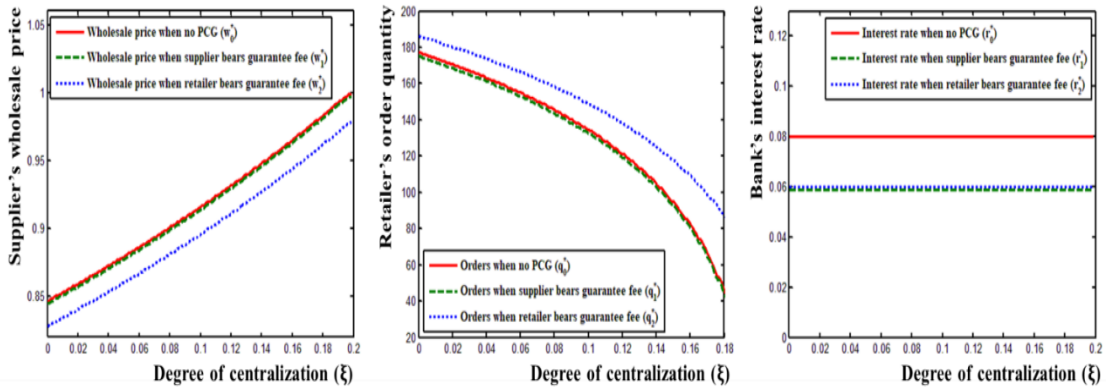
Proposition 4. In factoring with PCG in the context of platform economy, $w^* = w^* >$

$w_2^*, q_0^* = q_1^* < q_2^*, r_0^* > r_1^* = r_2^*; \Pi_0^S = \Pi_1^S < \Pi_2^S, \Pi_0^R = \Pi_1^R < \Pi_2^R, \Pi_0^{SC} = \Pi_1^{SC} < \Pi_2^{SC}$. And $\Pi_i^R \propto \frac{1}{\xi}$, $\Pi_i^S \propto \xi$, $\Pi_i^{SC} \propto \frac{1}{\xi}$. Define $L_i^j = \frac{\Pi_i^j}{\Pi_i^{SC}} (i = 0, 1, 2, j = R, S)$ represents j's profit ratio in scenario i, then $L_0^S = L_1^S > L_2^S$, $L_0^R = L_1^R < L_2^R$, and $L_i^S \propto \xi$, $L_i^R \propto \frac{1}{\xi}$.

The statement of Proposition 4 gives a comparison analysis of the optimal decisions and financing efficiency of each participant in factoring financing under above three scenarios. First, PCG from third-party can effectively reduce the supplier's financing interest rate from the bank. However, whether the guarantee fee is borne by the supplier or the retailer has a different impact on the financing decision. When supplier bears the guarantee fee, although the decrease of financing interest rate reduces the supplier's financing cost, the optimal wholesale price keeps unchanged because the supplier bears the guarantee fee. When the retailer bears the guarantee fee, PCG from third-party reduces the financing risks and financing costs borne by the supplier, then the supplier will set a lower wholesale price, and then promotes the financing efficiency.Second, Proposition 4 points out that degree of centralization will affect the profit distribution and supply chain coordination. According to Lemmas 1-3, the increase of degree of centralization will leads to a higher wholesale price and lower orders. Therefore, the whole supply chain's profit decreases with the degree of centralization. However, it is worth noting that the supplier's profit and profit ratio is increase with the degree of centralization. In addition, the retailer's profit ratio is decrease with the degree of centralization. That is, Proposition 4 indicates that in an independent decision-making supply chain, a higher degree of centralization will lead to a lower factoring financing efficiency. Although the supplier takes most of the profits of the whole supply chain by deciding a higher wholesale price, the profit of the whole supply chain is still lower. Finally, in the context of platform economy with the consideration of degree of centralization, Proposition 4 points out that the optimal guarantee mechanism is retailer bears the guarantee fee when there is PCG from third-party. In this scenario, the absolute profit of the supplier is higher, but the relative profit is lower, which further explains the advantage of the scenario that the retailer bears the guarantee fee.

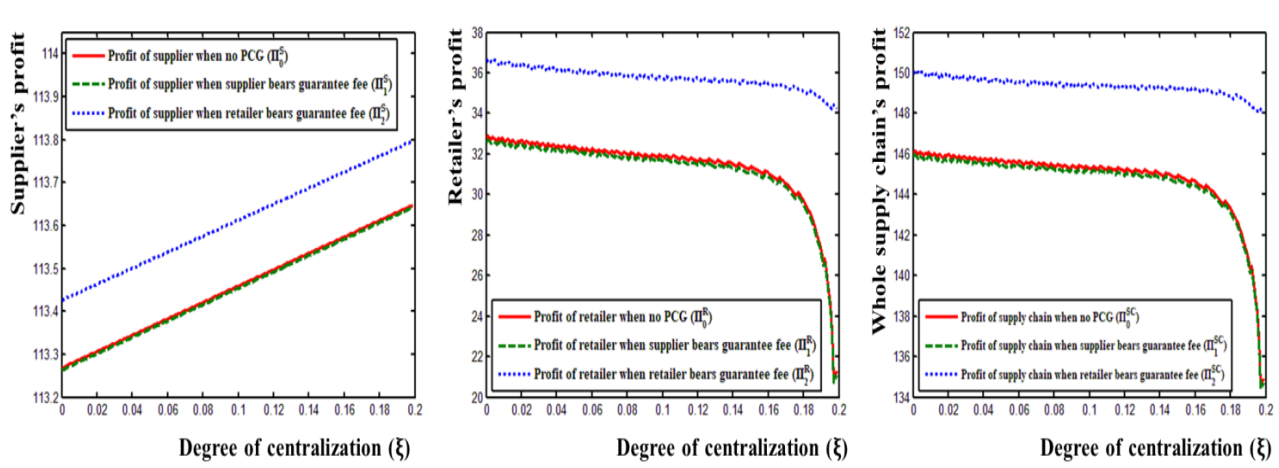
Numerical experiments

Due to commercial data protection, we provide numerical experiments to further validate and illustrate our analytical findings in this section. We adopt the same setting of the related literature (Jing et al., 2012; Kouvelis and Zhao, 2018) and normalize the product's unit sale price to be one (p = 1). In addition, the bank's loan-to-value ratio is then set to be 80% (θ = 0.8), which is based on the real data from China Xi'an Wuxiu Commercial Factoring Co., Ltd [3]. We assume the retailer's random market demand obeys the normal distribution, where the mean (variance) is 300(120). The retailer's default risk is α = 0.1. The supplier's unit production cost and initial capital level after supplying products is c = 0.2 and zero, respectively. The bank's risk free interest rate is rf = 0. The third-party's PCG coefficient is 3 Xi'an Wuxiu Commercial Factoring Co., Ltd. has offered many supply chain finance products at the same loan-to-value ratio 80%. The company's internal account and password are required in order to log in and download the data and we are not allowed to provide the product contract data alongside the paper.λ = 0.2. Then Figures 4-6 verifies the statement of Propositions 1-4.



(a) Wholesale price (w_i^*) (b) Order quantity (q_i^*) (c) Interest rate (r_i^*)

Figure 4. Impact of degree of centralizaiton on the optimal decisions



(a) Supplier's profit (Π_i^S) (b) Retailer's profit (Π_i^R) (c) Supply chain's profit (Π_i^{SC})

Figure 4 verifies the first statement of Propositions 1-4. The optimal wholesale price increase with the degree of centralization (ξ) and the optimal orders decrease. In addition, there also have $w^* = w^* > w^*$, $q^* = q^* < q^*$ and $r^* > r^* = r^*$ in Figure 4.

Figure 5. Impact of degree of centralizaiton on the optimal profits

Figure 5 verifies the first statement of Proposition 4. In factoring in the context of platform economy, it is worth noting that the supplier's profit increases with the degree of centralization, but profit of both the retailer and whole supply chain are decrease. In addition,

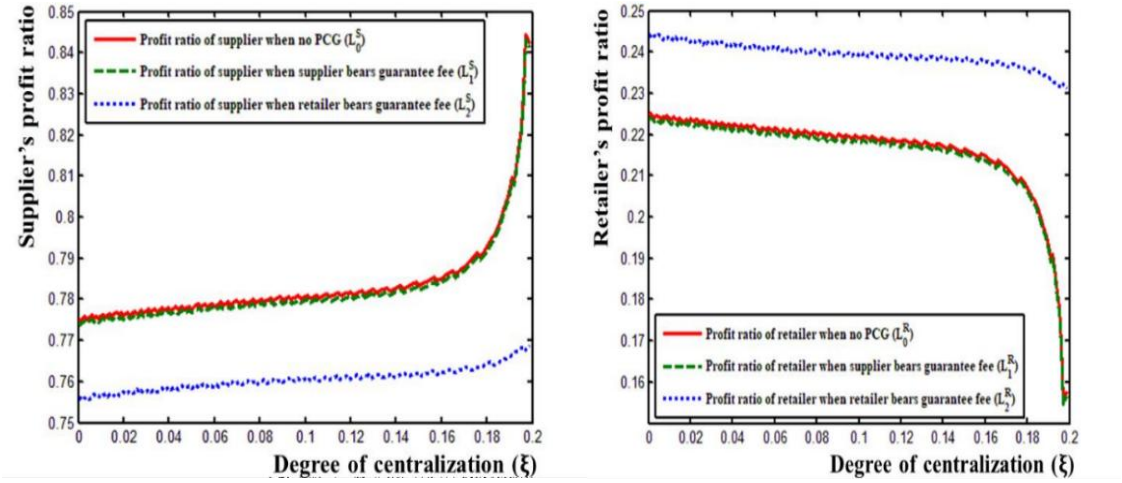
all participants are more profitable when the retailer bears the guarantee fee ($\Pi^S = \Pi^S < \Pi^S$,

0 1 2

$\Pi^R = \Pi^R < \Pi^R$, $\Pi^{SC} = \Pi^{SC} < \Pi^{SC}$), which means that the optimal guarantee mechanism is

0 1 2 0 1 2

retailer bears the guarantee fee when considering third-party's PCG in factoring.



(a) Supplier's profit ratio (L^S, $i = 0,1,2$) (b) Retailer's profit ratio (L^R, $i = 0,1,2$)

Figure 6. Impact of degree of centralizaiton on profit distribtion

Figure 6 validate Proposition 4. With the increase of degree of centralization, the supplier's profit ratio of the supply chain is increase ($L_i^S \propto \xi$), but the retailer's profit ratio of the supply chain is decrease ($L_i^R \propto \frac{1}{\xi}$). Furthermore, Figure 5 and Figure 6 jointly illustrate that in the scenario where the retailer bears the guarantee fee, the absolute profit of the supplier is higher, but the relative profit is lower, which further illustrates the advantage of this scenario.

5. CONCLUSION

Capital-constrained suppliers usually financing based on the core enterprises' accounts receivable, while the development of platform economy reshaped the structure of supply chain. With respect to a two-echelon supply chain which comprises a capital-constrained supplier and a core retailer, this study investigated the impact of degree of centralization and guarantee on the optimal factoring financing decisions, efficiency and profit distribution. We find that a higher degree of centralization is not conducive to factoring and supply chain operations. The supplier's wholesale price increases with the degree of centralization and then reducing the financing efficiency. Moreover, it is worth noting that both the retailer's profit and profit ratio are decreases with the degree of centralization. In addition, we also reveal that guarantee can effectively reduce the supplier's financing interest rate and financing costs, and then improve the financing efficiency. Furthermore, the absolute profit of the supplier is higher and the relative profit is lower when retailer bears the guarantee fee. Our analysis provides managerial guidance for capital-constrained divisions in their financing decisions and profit allocation in factoring under platform economy. First, degree of centralization should be considered when financing through factors, and it is worth to noting that a lower degree of centralization is more profitable for the core enterprises and supply chain. Additionally, in the context of platform economy with the consideration of degree of centralization, the optimal guarantee mechanism in factoring financing is retailer bears the guarantee fee when there is PCG from third-party.We conclude by discussing some possible extensions to our current model. First, we assume that the bank is in a competitive market, and we don't consider the salvage value of unsold products at the end of the sales period. Second, it is worthwhile analyzing the financing decisions and profit distribution in channels with asymmetric information. Finally, the theoretical propositions in the paper have not been studied empirically, collecting industry evidence and data to demonstrate theoretical findings comes as a future research priority.

6. ACKNOWLEDGMENTS

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7. CONFLICTS OF INTEREST

We declare that there are no conflicts of interest related to this study

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