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ORIGINAL PAPER

Credit financing and channel encroachment: analysis of distribution choice in a dual-channel supply chain

Lang Xu[1] · **Yuqi Luo**[1] · **Jia Shi**[1] · **Lin Liu**[2]

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Abstract

Supply chain finance plays a significant role in alleviating capital shortage, which optimizes supply chain performance. In this paper, we discuss the interaction of credit financing and channel encroachment in a dual-channel supply chain structure consisting of a supplier and a retailer. Under the Stackelberg structure, we observe the interaction between credit financing and channel encroachment is heavily dependent on the substitution degree, potential online market, and production cost. Intuitively, the supplier is more likely to choose trade credit financing, except in the case where both the potential online market, substitution degree, and production cost are small; under these conditions, bank credit financing may be an equilibrium strategy. As long as the production cost is below a certain threshold, the supplier will choose the trade credit financing strategy.

Keywords Channel encroachment · Credit financing · Dual-channel supply chain · Game theory

✉ Lang Xu
xulang@shmtu.edu.cn

✉ Lin Liu
earnestliu@126.com

Yuqi Luo
yqluo2021@yeah.net

Jia Shi
jiashi0625@163.com

1 College of Transport and Communications, Shanghai Maritime University, Shanghai, China

2 Navy Medical Center of PLA, The Second Military Medical University, Shanghai, China

1 Introduction

Supply chain finance aims to optimize the capital flow across supply chain organizations through solutions implemented by financing institutions to align the flow of logistics. Thus, improving capital flow from the perspective of the supply chain system effectively promotes supply chain development. Reasonable use of supply chain finance can not only significantly alleviate the financial pressure faced by small- and medium-sized enterprises (Bernabucci 2008), but also enhance trade relationships and strengthen competitive advantage (Seifert and Seifert 2011). For example, to relieve the upstream financial pressure, Wal-Mart, the largest supermarket, facilitated their cooperators' access to bank loans as ***bank credit financing***; furthermore, Wal-Mart also offered finance directly to upstream firms in the form of ***trade credit financing*** (e.g., paying an early discount scheme, sharing suppliers' inventory costs). After more than 20 years of rapid development, supply chain finance plays a significant role in alleviating capital shortages and optimizing capital flows (Ding and Wan 2020; Li et al. 2019).

However, because of the accelerated effect of the Internet on the global economy, the development of supply chain finance is facing an important challenge. In the e-commerce age, suppliers (e.g., *Apple* and *Nike*) can offer products via retailers or online platforms, which causes competition to arise between the upstream supplier and retail partners (Zhang et al. 2019a, b, c). In addition to this, a noted phenomenon is that retailers can open their own direct-to-consumer online platforms to compete with the supplier's online sales if their advantage disappears because of the adverse impact of channel conflict. How the retailer encroaches on the direct channel and how supply chain management will be affected are significant questions. In addition, the supplier's wholesale price and direct price are influenced by the choice of credit financing, which further impacts whether the retailer encroaches on the online market and determines pricing decisions. Therefore, platform encroachment makes the original problem of financing choice more complex.

The interaction between credit financing and channel encroachment is particularly significant in the freight forwarding market. Since the outbreak of COVID-19 in early 2020, the container liner market has undergone a sharp change from low to high (Xu et al. 2021). Especially during the fourth quarter of 2020, the market experienced tight space and a shortage of empty containers, which led to a dramatic increase in the prices of the container international shipping. Hence, the freight forwarding market is facing a series of problems for freighters, such as capital shortage caused by huge advance payments and lack of financing channels, restricting its development. Besides, freighters also face the dilemma of shipping companies seizing a large market share through channel encroachment, e.g., Maersk launched a new online booking platform (ship.maerskline.com) in 2017. Under these conditions, many small- and medium-sized enterprises have considered adopting the credit financing strategy. It is these findings that inspire us to study the interaction between channel encroachment and credit financing.

According to the above background, we analyze the role of credit financing in a dual-channel supply chain with retailer encroachment. More specifically, we explore the following questions: (1) Under a Stackelberg–Nash game, what is the optimal equilibrium strategy for a supplier with capital shortage—bank credit financing or trade credit financing; and what is the equilibrium strategy for the retailer—to encroach or not? (2) For the individual and overall supply chain, what is the interaction between credit financing and channel encroachment, and how to deal with the rival's behavior in a dual-channel supply chain? (3) Will the encroachment benefit both participants if the supplier chooses bank credit financing? When channel encroachment has an undesirable effect on the supplier, can trade credit financing effectively achieve goals? If so, under what conditions?

To answer these questions, we observe the following managerial insights: (1) for the supplier with capital shortage, the share of online market and production costs are important factors that influence financing strategy; (2) if the supplier chooses bank credit financing, the retailer adopts the encroachment strategy; otherwise, the retailer refuses to encroach with an increase in production cost when the supplier chooses trade credit financing. (3) trade credit financing makes the supplier own more favorable situation than bank credit financing when the production cost is high or the online market share is over a certain threshold.

We organize the remainder of this paper as follows. Section 2 reviews the literature on supply chain finance and channel competition to highlight the differences and contributions. Then, we describe the problem and consider the assumption in Sect. 3. We discuss the equilibrium strategy of credit financing and the corresponding subgame of channel encroachment in Sect. 4. Section 5 presents the conclusions and future research. Proofs are provided in the "Appendix".

2 Literature review

The topic of credit financing has received significant attention in operations management, marketing management, and service management, with the existing literature has focused on how increasing interest rates affect pricing decisions and downstream profits (Chao et al. 2008; Lai et al. 2009). Depending on which kind of credit financing is considered, two strategies are described. When financing is sourced from a bank, it is known as bank credit financing (BCF strategy) which mainly focuses on the perspective of coordination contracts (Ding and Wan 2020; Shi et al. 2020), inventory decisions (Chakuu et al. 2020; Li et al. 2020a, b; He et al. 2020), information sharing (Li et al. 2019; Sang 2021), etc. For the BCF strategy, Zhou et al. (2020) explored the equilibrium of guarantor financing for retailers who can borrow bank credit in a four-stage supply chain structure. When the source of financing is the retailer, it is known as trade credit financing (TCF strategy) which mainly focuses on the perspective of product quality (Lee and Stowe 1993; Long et al. 1993), inventory decisions (Gupta and Wang 2009; Haley and Higgins 1973; Luo and Shang 2019), and moral hazard (Babich and Tang 2004; Kim and Shin 2012; Rui and Lai 2015). For the TCF strategy, Wu et al. (2018) introduced two unbalanced retailers into trade credit financing to reveal the influence of initial capital and exogenous price on interest rates. On this basis, Deng et al. (2021) extended the existing research to investigate the influence of trade credit financing on vertical and horizontal competition with multiple downstream firms. However, the existing literature only examines the options in bank credit financing or trade credit financing. This encourages us to explore the equilibrium solution and corresponding conditions between the two financing strategies.

The second stream of related research compares bank credit financing and trade credit financing wherein they serve to improve upstream financial performance but differ in the operational methods. Along these lines, Kouvelis and Zhao (2012) constructed the early payment discount scheme to decide the wholesale price when paying early or the interest rates when delaying payment, and found that the downstream firms preferred trade financing to bank financing. On this basis, Deng et al. (2018) derived the equilibriums for different financing scenarios to indicate the influence of initial capital and production cost on interest rate and corresponding conditions. Additionally, Chod (2017) investigated the combination of bank financing and trade financing to find an optimal way to make the downstream firms lower the loan and inventory quantities. Furthermore, Yang and Birge (2018) captured the relationships between the operations decision, capital constraint, and financing scenario to analyze the influence of risk-sharing on supply chain performance. Meanwhile, Zhen et al. (2020) found the upstream equilibrium of financing strategy to explore how the creditors' interest rate influences operations management in a dual-channel structure. Furthermore, many scholars compared the performances of bank credit financing and trade credit financing from risk tolerance (Yang et al. 2021; An et al. 2021), integrating sourcing (Tang and Li 2020; Yoo et al. 2021), game structure (Yan et al. 2020; Ding and Wan, 2020), and integrating inventory (Fu et al. 2020; Li et al. 2021). However, the upstream strategy affects the downstream equilibrium; no previous studies have examined the case of channel encroachment in credit financing. Therefore, our research examines the interactions between financing strategy and channel encroachment in the dual-channel supply chain to obtain managerial insights.

The third issue is the effect of channel encroachment on supply chain performance (e.g., as discussed in Frazier and Lassar 1996; Chiang et al. 2003; Liu and Zhang 2006; Zhang et al. 2019a, b, c; Sun et al. 2019). Intuitively, the majority of scholars examine upstream encroachment which often hurts the downstream firms because the original market share is divided up. Liu et al. (2016) provided an opposite observation, that channel encroachment may be disadvantageous to the upstream firms if the downstream firms have strong fairness concerns. Yan et al. (2018) explored the influences of product durability on the strategies of channel encroachment under the oligopoly market structure, and found that both members benefited from channel encroachment if the product durability is at a threshold level. On this basis, Li et al. (2020a, b) illustrated the interactions between channel encroachment and retail inventory under the scenarios of centralization and decentralization. In addition, for multiple downstream firms, Guan et al. (2019) analyzed the relationship between channel encroachment and retail inventory to find that each member could obtain more profit for retail competition. Further, some studies also focus on the interaction between chain competition and upstream encroachment (Li et al. 2015). However, unlike in this study, existing studies mainly investigate upstream encroachment, while ignoring the case where the retailer also encroaches on the online channel in a dual-channel supply chain structure.

To the best of our knowledge, Zhang et al. (2019a) is the only study discussing downstream encroachment. This research focuses on the influence of service investment and cost information on downstream encroachment to demonstrate the probability of prisoner's dilemma. In particular, our research differs from Zhang et al. (2019a) in two ways. On the one hand, the market structure is discrepant. Under this situation, we investigate downstream encroachment as an operational decision, especially the specific response of the encroachment strategy in the market demands. On the other hand, Zhang et al. (2019a) did not consider and analyze the interaction between two members, whereas we combine the strategic behaviors of credit financing and downstream encroachment.

We include some classical research related to our study in Table 1 and highlight the contributions of managerial insights. From the analysis, the outcomes of financing credit and channel encroachment allow us to relate and contribute to the research on operational practices, which highlights that the strategic decision is significant enough to affect supply chain performance. Under this situation, we investigate a model in which a supplier with capital shortage offers products via both retailer and self-constructed platform, whereas the retailer considers whether to encroach or not. Utilizing the game-theoretic model, we explore the equilibrium conditions between two credit financing scenarios to indicate how the potential online market,

Table 1 Comparisons of closely related literature

	Trade credit	Bank credit	Capital- shortage		Dual channel	Channel encroachment
			Upstream	Downstream		
An et al. (2021)	√	–	–	√	–	–
Chod (2017)	√	–	–	–	–	–
Ding and Wan (2020)	√	√	√	–	–	–
Deng et al. (2021)	√	–	–	√	√	–
He et al. (2018)	–	–	–	–	√	–
Huang et al. (2018)	–	–	–	–	√	√
Kouvelis and Zhao (2012)	√	√	–	–	–	–
Li et al. (2020a, b)	–	–	–	–	√	√
Tang and Li (2020)	√	–	–	–	√	√
Taleizadeh et al. (2019)	√	–	–	–	–	–
Wang and Zhang (2019)	√	–	–	√	–	–
Yan et al. (2020)	√	–	√	–	–	–
Zhen et al. (2020)	√	√	√	–	√	–
Zhang et al. (b, c2019a)	√	–	–	–	–	–
Our paper	√	√	√	–	√	√

production cost, and substitution degree affect the interaction between credit financing and channel encroachment.

3 Problem description and assumptions

In this paper, we discuss the interaction of credit financing and channel encroachment in a dual-channel supply chain structure consisting of a supplier and a retailer. Under this situation, the supplier can provide products to the retailer at an endogenous wholesale price w and production cost c, and the retailer, in turn, sells to the consumer at a retail price p. Beyond that, the supplier can sell through an online platform at the direct price d. This setting focuses on a point where both the supplier and retailer are potential sellers. To deal with the shared market, the retailer considers whether to encroach on the online market at a booking price b. Without loss of generality, we can normalize the potential demand to 1 (Nalca 2017; Niu et al. 2020). Based on the assumption that the demand mainly depends on price, we construct the linear-price demand functions to analyze this problem (Deo and Corbett 2009; Shen et al. 2018; Zhen et al. 2020).

Similar to Singh and Vives (1984) and Li et al. (2020a, b), we assume the utility-based function of representative consumers is $U(q_s, q_r, d_r) = \alpha_s(q_s + q_r) + \alpha_r d_r - \frac{\beta_1}{2}q_s^2 - \frac{\beta_2}{2}q_r^2 - \frac{\beta_3}{2}d_r^2 - \gamma(q_s q_r + q_s d_r + q_r d_r)$, and derive each channel's demand function. More specifically, we assume that the market share can be divided into an online part and offline part, where $\alpha_s + \alpha_r = 1$. Further, for simplification, the total online demand is considered a. Without loss of generality, based on the first-order conditions for utility maximization, we consider the price-sensitive degree $\beta_i = 1$ because otherwise a_i is replaced by $a_i - \beta_i v_i - \gamma v_{3-i}/n$, where v_i is the channel demand and n is the channel quantity. On this basis, when the retailer encroaches, there exist three channels to offer products (McGuire and Staelin 1983; Granot and Sosic 2005); then, the online demand for the supplier (D_s^{E}) and retailer (Q_r^{E}) is $D_s^{\mathrm{E}} = \frac{a}{2} - d + \frac{\delta(b+p)}{2}$ and $Q_r^{\mathrm{E}} = \frac{a}{2} - b + \frac{\delta(d+p)}{2}$, respectively, whereas the offline demand for the retailer is $D_r^{\mathrm{E}} = 1 - a - p + \frac{\delta(b+d)}{2}$, where a indicates the potential market for the supplier without encroachment and δ is the substitution degree. According to the survey, the offline channel is still dominant in the consumer market; thus, we suppose $0 < a < \overline{a} = \frac{1}{2}$ (Lei et al. 2014; Xu et al. 2021). Because the price from the supplier (retailer) has a larger influence on demand than other channels, the substitution degree meets $\delta \in (0, 1)$, which is referred to as the dominant impact of own price on demand (Maglaras and Meissner 2006; Huang et al. 2018). However, when encroachment does not occur, we get $D_s^{\mathrm{N}} = a - d + \delta p$, $D_r^{\mathrm{N}} = 1 - a - p + \delta d$ and $Q_r^{\mathrm{N}} = 0$, respectively.

Meanwhile, to design two options of credit financing, we considered that the supplier's initial capital is K. Because we mainly focus on the interaction between credit financing and channel encroachment, the initial capital can be ignored as $K = 0$ (Tang et al. 2017; Li et al. 2018; Zhen et al. 2020). For the BCF scenario, the bank is a creditor while the supplier borrows a loan from bank with the interest rate I_{BN} or I_{BE}. Further, the supplier announces the TCF scenario from the retailer with the interest rate I_{TN} or I_{TE}, where the retailer is not merely a reseller but also a creditor. First, the supplier seeks credit financing $c\left(D_s^j + D_r^j + Q_r^j\right)$; then, the supplier must repay the loan $c(1 + I_k)\left(D_s^j + D_r^j + Q_r^j\right)$ to the creditor at the end of the period, where $k = BN, BE, TNorTE$ and $j = NorE$. We assume that in order to avoid bankruptcy, the production cost meets $c \leq \overline{c}$. The list of all parameters involved in the text is shown in Table 2.

To discuss the interactions between credit financing and channel encroachment, we divide the event into three subgames: *a credit-financing game*, *an encroachment game*, and *a Stackelberg game*. The supplier first considers the option of credit financing. Then, the retailer considers whether to encroach on the online market or not. Further, the creditor sets the interest rate. In the fourth stage, the supplier, as a leader in the Stackelberg game, decides the direct price and wholesale price. Finally, the retailer determines the retail price, and the booking price if she encroaches. In what follows, the backward induction can be employed to identify the equilibriums. We summary the sequence of events in Fig. 1. In the rest of this work, we refer to the supplier as "him" and the retailer as "her" where each firm is risk-neutral and maximizes their individual profits.

4 Model analysis

Based on the supplier's behavior, the two possible scenarios of BCF Strategy and TCF Strategy exist. Further, for the retailer, each subgame has two options, i.e., whether to encroach the online market or not. For the benchmark, we first analyze the equilibriums

Table 2 Model notations

Notation	Explanation
a	Potential market for supplier without encroachment, while that of retailer is $1 - a$, where $a \in [0, 0.5)$
δ	Substitution degree
w	Wholesale price
c	Production cost
b	Booking price charged by retailer with encroachment
d	Direct price charged by supplier
p	Retail price charged by retailer
I_k	Interest rate, where $k = BN, BE, TN, TE$
D_s^j	Online demand for supplier, where $j = N, E$
Q_r^j	Online demand for retailer, where $j = N, E$
D_r^j	Offline demand for retailer, where $j = N, E$
π_s^k	Supplier's profit under different strategies, where $k = NN, NE, BN, BE, TN, TE$
π_r^k	Retailer's profit under different strategies, where $k = NN, NE, BN, BE, TN, TE$
π_b^k	Bank's profit under different strategies, where $k = BN, BE$

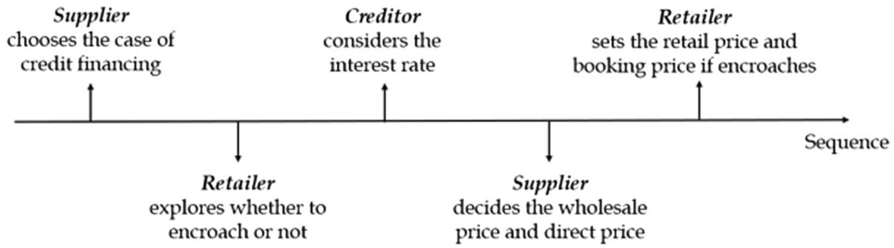


Fig. 1 The sequence of events

without credit financing, which indicates that the supplier's initial capital is sufficient. If she refuses to encroach, the supplier decides the wholesale price w and direct price d; thus, for the supplier, the revenue is $dD_s^{\mathrm{N}} + wD_r^{\mathrm{N}}$ and the profit is $\pi_s^{\mathrm{NN}} = (d-c)D_s^{\mathrm{N}} + (w-c)D_r^{\mathrm{N}}$. Observing the supplier's best response, the retailer announces the retail price where the profit function is $\pi_r^{\mathrm{NN}} = (p-w)D_r^{\mathrm{N}}$. Therefore, we obtain pricing decisions as $w^{\mathrm{NN}} = \frac{1-a(1-\delta)}{2(1-\delta^2)} + \frac{c}{2}$, $d^{\mathrm{NN}} = \frac{\delta+a(1-\delta)}{2(1-\delta^2)} + \frac{c}{2}$ and $p^{\mathrm{NN}} = \frac{3-\delta^2-a(1-\delta)(3+\delta)}{4(1-\delta^2)} + \frac{c(1+\delta)}{4}$. In contrast, if she encroaches, the profits for the supplier and retailer are $\pi_s^{\mathrm{NE}} = (d-c)D_s^{\mathrm{E}} + (w-c)\left(D_r^{\mathrm{E}} + Q_r^{\mathrm{E}}\right)$ and $\pi_r^{\mathrm{NE}} = (p-w)D_r^{\mathrm{E}} + (b-w)Q_r^{\mathrm{E}}$. Thus, we obtain the decisions as $w^{\mathrm{NE}} = \frac{2-a(1-\delta)}{4(1+\delta)(2-\delta)} + \frac{c}{2}$, $d^{\mathrm{NE}} = \frac{\delta+a(1-\delta)}{2(1+\delta)(2-\delta)} + \frac{c}{2}$, $p^{\mathrm{NE}} = \frac{2(10-9\delta+\delta^2)-a(1-\delta)(18-7\delta)}{8(1-\delta)(4-\delta^2)} + \frac{c}{2(2-\delta)}$, and $b^{\mathrm{NE}} = \frac{2(2+3\delta-3\delta^2)+a(1-\delta)(6-5\delta)}{8(1-\delta)(4-\delta^2)} + \frac{c}{2(2-\delta)}$. When the supplier is well capitalized, upon comparing the non-encroachment and encroachment case, we find $\pi_r^{\mathrm{NE}} > \pi_r^{\mathrm{NN}}$. Therefore, we have the sub-equilibrium of the retailer's optimal strategy where channel encroachment is the only choice.

The following section explores two financing strategies where the supplier with capital shortage borrows credit from the bank or retailer. In each strategy, we separate the subgame into the two cases based on whether the retailer encroaches on the online market or not.

4.1 BCF scenario

Under the BCF scenario, we investigate the subgame without channel encroachment. At the beginning, the bank first sets the interest rate I_{BN} to maximize $cI_{\mathrm{BN}}\left(D_s^{\mathrm{N}} + D_r^{\mathrm{N}}\right)$. Then, the supplier determines the wholesale price and direct price to borrow a loan whereas the repayment is $c\left(1+I_{\mathrm{BN}}\right)\left(D_s^{\mathrm{N}} + D_r^{\mathrm{N}}\right)$. Therefore, the supplier's profit is $\pi_s^{BN} = (d-c)D_s^{\mathrm{N}} + (w-c)D_r^{\mathrm{N}} - cI_{\mathrm{BN}}\left(D_s^{\mathrm{N}} + D_r^{\mathrm{N}}\right)$. In addition, the retailer announces the retail price where the profit function is $\pi_r^{BN} = (p-w)D_r^{\mathrm{N}}$.

Proposition 1 *Under the BCF scenario without the encroachment case,*

(*i*) *the bank's interest rate is* $I_{\mathrm{BN}} = \frac{1+\delta+a(1-\delta)}{2c(1-\delta)(3+\delta)} - \frac{1}{2}$;

(*ii*) *the wholesale price is* $w^{\mathrm{BN}} = w^{\mathrm{NN}} + \frac{c}{2}I_{\mathrm{BN}}$, *direct price is* $d^{\mathrm{BN}} = d^{\mathrm{NN}} + \frac{c}{2}I_{\mathrm{BN}}$, *and retail price is* $p^{\mathrm{BN}} = p^{\mathrm{NN}} + \frac{c(1+\delta)}{4}I_{\mathrm{BN}}$;

(*iii*) *bank's profit is* $\pi_b^{\mathrm{BN}} = \frac{c^2(1-\delta)(3+\delta)}{4}I_{\mathrm{BN}}^2$, *supplier's profit is* $\pi_s^{\mathrm{BN}} = \pi_s^{\mathrm{NN}} - \frac{3c^2(1-\delta)(3+\delta)}{8}I_{\mathrm{BN}}^2$, *and retailer's profit is* $\pi_r^{\mathrm{BN}} = \frac{\left[1-a-c(1-\delta)\left(1+I_{\mathrm{BN}}\right)\right]^2}{16}$.

As we derive in the proof of Proposition 1, the supplier's profit under the BCF scenario is below that if he is not capital constrained, which is mainly because the bank has incentive to increase the interest rate to the upper limit as long as the supplier does not borrow a loan in this game. In addition, the optimal decisions of direct price, retail price, and wholesale price increase with the bank's interest rate. Under the BCF strategy without channel encroachment, the interest rate and bank's profit are also positively associated with online market share—the reason being that the increase of online market share promotes the demand via the online channel, resulting in increased total production cost and supplier's profit. However, the retailer's profit is negatively affected by the online market share. We further discuss the case of channel encroachment to obtain the perfect Nash equilibrium. Unlike the above-mentioned case, the profit of the supplier is $\pi_s^{\mathrm{BE}} = (d-c)D_s^{\mathrm{E}} + (w-c)\left(D_r^{\mathrm{E}} + Q_r^{\mathrm{E}}\right) - cI_{BE}\left(D_s^{\mathrm{E}} + D_r^{\mathrm{E}} + Q_r^{\mathrm{E}}\right)$. However, the retailer's profit is $\pi_r^{\mathrm{BE}} = (p-w)D_r^{\mathrm{E}} + (b-w)Q_r^{\mathrm{E}}$. Thus, the bank first sets the interest rate to maximize $cI_{\mathrm{BE}}\left(D_s^{\mathrm{E}} + D_r^{\mathrm{E}} + Q_r^{\mathrm{E}}\right)$.

Proposition 2 *Under the BCF scenario with encroachment case,*

(i) *the bank's interest rate is* $I_{\mathrm{BE}} = \frac{a(1-\delta)+2}{4c(1-\delta)(4-\delta)} - \frac{1}{2}$;

(ii) *the wholesale price is* $w^{\mathrm{BE}} = w^{\mathrm{NE}} + \frac{1}{2}I_{\mathrm{BE}}$, *direct price is* $d^{\mathrm{BE}} = d^{\mathrm{NE}} + \frac{1}{2}I_{\mathrm{BE}}$, *retail price is* $p^{\mathrm{BE}} = p^{\mathrm{NE}} + \frac{c}{2(2-\delta)}I_{\mathrm{BE}}$, *and booking price is* $b^{\mathrm{BE}} = b^{\mathrm{NE}} + \frac{c}{2(2-\delta)}I_{\mathrm{BE}}$;

(iii) *bank's profit is* $\pi_b^{\mathrm{BE}} = \frac{c^2(1-\delta)(4-\delta)}{2(2-\delta)}I_{\mathrm{BE}}^2$, *supplier's profit is* $\pi_s^{\mathrm{BE}} = \pi_s^{\mathrm{NE}} - \frac{3}{2}\pi_b^{\mathrm{BE}}$, *and retailer's profit is* $\pi_r^{BE} = \pi_r^{NE} + \frac{1}{8(2-\delta)}\left[\frac{3a(3-\delta)+4\delta-14}{2(4-\delta)} + 3c^2(1-\delta)^2\right]I_{BE}$.

From Proposition 2, we find that the factors (e.g., online market share and substitution degree) have a significant impact on the bank's interest rate. Further, the bank also considers the production cost in deciding the interest rate, which is mainly because the benefit to the bank is from the loan borrowed to avoid the bankruptcy. From the above analysis, we observe that the interest rate plays an important role in the optimal pricing decisions. Specifically, the encroachment results in a low direct price and wholesale price, thus leading to a decrease in retail price and booking price (e.g., $w^{\mathrm{BN}} > w^{\mathrm{BE}}$, $d^{\mathrm{BN}} > d^{\mathrm{BE}}$, and $p^{\mathrm{BN}} > p^{\mathrm{BE}}$). It should be noted that the increase in the interest rate may harm the consumer's interests; therefore, the total quantities from the dual channels decrease. Next, under the BCF scenario, we compare the equilibrium strategy under the non-encroachment case and encroachment case.

Lemma 1 *Under the BCF scenario, upon comparing the non-encroachment and encroachment case, we find that* $\pi_r^{\mathrm{BE}} > \pi_r^{\mathrm{BN}}$.

Based on Lemma 1, we have the sub-equilibrium of the retailer's optimal strategy where channel encroachment is the only choice under the BCF scenario. This is consistent with the choice of the retailer when the supplier is well capitalized. Intuitively, we observe that the retailer can more effectively create demand by channel encroachment in the online market, which significantly improves the benefit. Interestingly, the optimal decision of interest rate is a significant factor that affects the retailer's strategy, wherein we find that the bank's interest rate if encroachment occurs is obviously lower than that in the non-encroachment case (e.g., $I_{\mathrm{BN}} > I_{\mathrm{BE}}$). When other conditions are unchanged, with the improvement of interest rate, the supplier correspondingly increases the direct price and wholesale price, which indirectly reduces the retailer's profit when she refuses to encroach. However, channel encroachment effectively prevents this situation; the reason is the retailer entering online market directly shocks the original share of supplier and forces to lower direct price and wholesale price. Hence, under the BCF scenario, channel encroachment is the unique strategy for retailer.

4.2 TCF scenario

We next consider the TCF scenario where the supplier chooses TCF from the retailer with the interest rate. Additionally, the retailer has two options in regard to whether to encroach the online market. As mentioned in Sect. 4.1, we analyze each subgame by backward induction. For the non-encroachment case, the retailer first decides the interest rate. Then, the supplier determines the direct price d and the wholesale price w to borrow the loan $I_{\mathrm{TN}}\left(D_r^{\mathrm{N}} + D_s^{\mathrm{N}}\right)$; thus, the revenue is $dD_s^{\mathrm{N}} + wD_r^{\mathrm{N}}$ and the repayment is $c\left(1 + I_{\mathrm{TN}}\right)\left(D_s^{\mathrm{N}} + D_r^{\mathrm{N}}\right)$ where the supplier's profit is $\pi_s^{\mathrm{TN}} = (d-c)D_s^{\mathrm{N}} + (w-c)D_r^{\mathrm{N}} - cI_{\mathrm{TN}}\left(D_s^{\mathrm{N}} + D_r^{\mathrm{N}}\right)$. Observing d and w, the retailer decides the retail price where the profit is $\pi_r^{\mathrm{TN}} = (p-w)D_r^{\mathrm{N}} + cI_{TN}\left(D_s^{\mathrm{N}} + D_r^{\mathrm{N}}\right)$.

Proposition 3 *Under the TCF scenario without encroachment case,*

(i) *the retailer's interest rate is* $I_{\mathrm{TN}} = \frac{\delta + a(1-\delta)}{2c(1-\delta)(1+\delta)} - \frac{1}{2}$;

(ii) *the wholesale price is* $w^{\mathrm{TN}} = w^{\mathrm{NN}} + \frac{c(2-\delta)}{2} I_{\mathrm{TN}}$, *direct price is* $d^{\mathrm{TN}} = d^{\mathrm{NN}} + \frac{c}{2} I_{\mathrm{TN}}$*, and retail price is* $p^{\mathrm{TN}} = p^{\mathrm{NN}} + \frac{c\delta}{2} I_{\mathrm{TN}}$;

(iii) *the supplier's profit is* $\pi_s^{\mathrm{TN}} = \pi_s^{\mathrm{NN}} - \frac{3c^2\left(1-\delta^2\right)}{4} I_{\mathrm{TN}}^2$ *and retailer's profit is* $\pi_r^{\mathrm{TN}} = \pi_r^{\mathrm{NN}} + \frac{c^2\left(1-\delta^2\right)}{2} I_{\mathrm{TN}}^2$.

Unlike the BCF scenario, the retailer is both a lender and a participant in the dual channel structure; thus, the interest rate is affected by both loan quantity and supplier's decision in the TCF scenario. From Proposition 3, we find that the interest rate is directly influenced by the substitution degree and potential online market. In contrast, the cost of TCF may be transferred from supplier to retailer by increasing the direct price and wholesale price, and then to the final consumers. Accordingly, we further discuss the case of channel encroachment to obtain the perfect Nash equilibrium. Hence, the supplier's loan from retailer is $cI_{\mathrm{TE}}\left(D_s^{\mathrm{E}} + D_r^{\mathrm{E}} + Q_r^{E}\right)$ and the revenue $dD_s^{\mathrm{E}} + w\left(D_r^{\mathrm{E}} + Q_r^{\mathrm{E}}\right)$, and we obtain the retailer's profit as $\pi_r^{\mathrm{TE}} = (p-w)D_r^{\mathrm{E}} + (b-w)Q_r^{\mathrm{E}} + cI_{\mathrm{TE}}\left(D_s^{\mathrm{E}} + D_r^{\mathrm{E}} + Q_r^{\mathrm{E}}\right)$.

Proposition 4 *Under TCF scenario with encroachment case,*

(i) *the retailer's interest rate is* $I_{\mathrm{TE}} = \frac{\delta+a(1-\delta)}{2c(1-\delta)(2+\delta)} - \frac{1}{2}$;

(ii) *the wholesale price is* $w^{\mathrm{TE}} = w^{\mathrm{NE}} + \frac{c(4-3\delta)}{2(2-\delta)}I_{TE}$, *direct price is* $d^{\mathrm{TE}} = d^{\mathrm{NE}} + \frac{c}{2}I_{\mathrm{TE}}$, *retail price is* $p^{\mathrm{TE}} = p^{\mathrm{NE}} + \frac{c\delta}{2(2-\delta)}I_{\mathrm{TE}}$, *and booking price is* $b^{\mathrm{TE}} = b^{\mathrm{NE}} + \frac{c\delta}{2(2-\delta)}I_{\mathrm{TE}}$;

(iii) *the supplier's profit is* $\pi_s^{\mathrm{TE}} = \pi_s^{\mathrm{NE}} - \frac{3c^2(1-\delta)(2+\delta)}{4(2-\delta)}I_{\mathrm{TE}}^2$ *and retailer's profit is* $\pi_r^{\mathrm{TE}} = \pi_r^{\mathrm{NE}} + \frac{c^2(1-\delta)(2+\delta)}{2(2-\delta)}I_{\mathrm{TE}}^2$.

Similar to Proposition 3, the retailer comprehensively considers the potential online market, substitution degree, and production cost when she sets the interest rate. In addition, given that the retailer is both the lender and participant in this case, the loan quantities from the supplier also affect the retailer's decision in regard to the interest rate. Further, under the TCF scenario, for the two subgames, the interest rate is positively correlated with the potential online market and substitution degree, but negatively correlated with production cost. Meanwhile, we observe that the retailer's interest rate when she encroaches is obviously lower than that in the non-encroachment case (e.g., $I_{\mathrm{TN}} > I_{\mathrm{TE}}$) which caters to the BCF scenario. From the above, channel encroachment clearly results in fierce competition; thus, results in decreasing in prices (e.g., $b^{\mathrm{TN}} > b^{\mathrm{TE}}$, $d^{\mathrm{TN}} > d^{\mathrm{TE}}$, $p^{\mathrm{TN}} > p^{\mathrm{TE}}$, and $w^{\mathrm{TN}} > w^{\mathrm{TE}}$). Next, under the TCF scenario, we compare the equilibrium strategy under the non-encroachment case and the encroachment case.

Lemma 2. *Under the TCF scenario, upon comparing the non-encroachment and encroachment case, the following strategy is found to exist:*

(1) *consider the substitution degree* $\delta \in [0, 0.319)$, *(i) if the production cost* $c \in [0, c_1)$ *and potential online market* $a \in [0, a_1)$ *or production cost* $c \in [c_1, \overline{c})$ *and potential online market* $a \in [0, \overline{a})$, *the equilibrium exists under encroachment;*

(ii) if the production cost $c \in [0, c_1)$ *and potential online market* $a \in [a_1, \overline{a})$, *the equilibrium exists under non-encroachment;*

(2) *consider the substitution degree* $\delta \in [0.319, 0.749)$*, (i) if the potential online market* $a \in [0, a_1)$*, the equilibrium exists under encroachment; (ii) if the potential online market* $a \in [a_1, \overline{a})$*, the equilibrium exists under non-encroachment;*

(3) *consider the substitution degree* $\delta \in [0.749, 0.781)$*, (i) if the production cost* $c \in [0, c_2)$ *and potential online market* $a \in [0, \overline{a})$ *or production cost* $c \in [c_2, \overline{c})$ *and potential online market* $a \in [a_1, \overline{a})$*, the equilibrium exists under non-encroachment; (ii) if the production cost* $c \in [c_2, \overline{c})$ *and potential online market* $a \in [0, a_1)$*, the equilibrium exists under encroachment;*

(4) *consider the substitution degree* $\delta \in [0.781, 1)$*, the equilibrium exists under non-encroachment.*

From Lemma 2, we obtain the sub-equilibrium of the retailer's optimal strategy. Unlike in the BCF scenario, channel encroachment is not the only choice for the retailer. On this basis, the production cost and potential online market are important factors that influence the retailer's decisions. In general, the higher the production cost, the greater the possibility of the retailer encroaching on the online market; this may be closely related to the disadvantages of high production cost. Further, if the potential online market is below a certain threshold, the

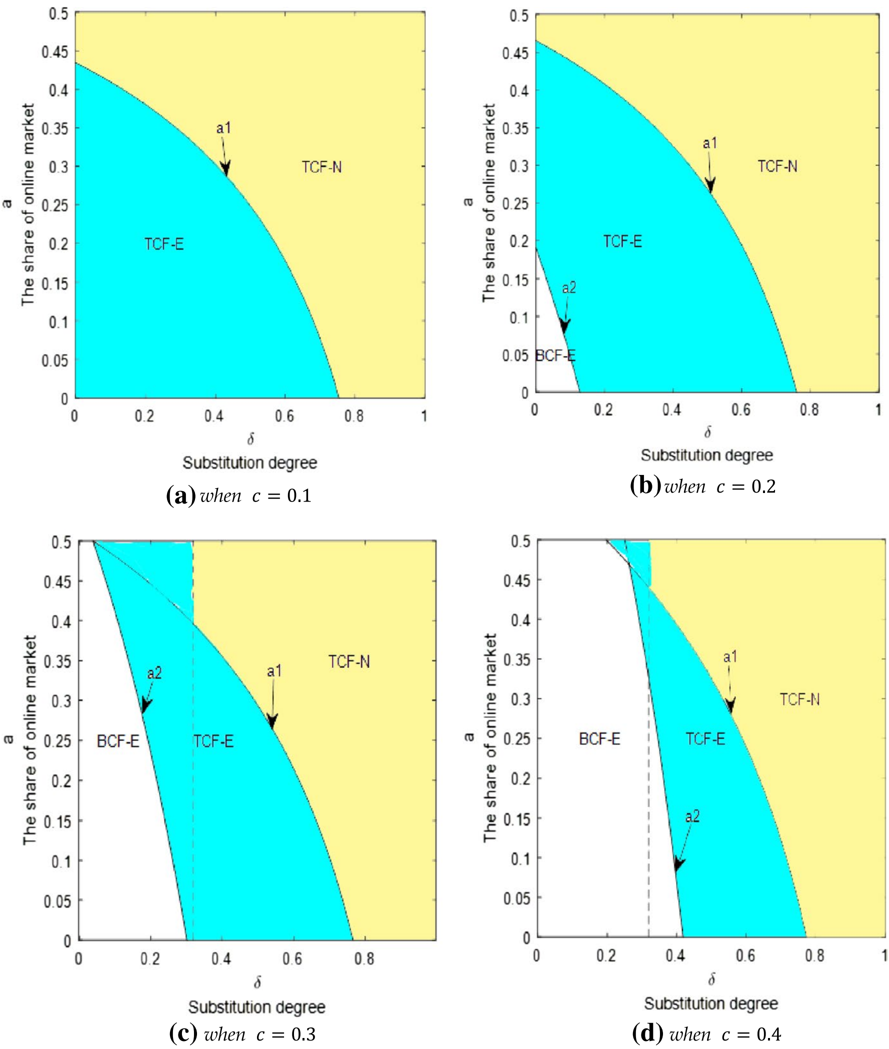
Table 3 The interactions between credit financing and channel encroachment

Conditions			Equilibrium strategy
δ	c	a	
$0 < \delta < 0.319$	$0 < c < c_3$	$0 < a \le a_1$	*TCF-E*
		$a_1 < a < \overline{a}$	*TCF-N*
	$c_3 < c < c_1$	$0 < a < \min\{a_1, a_2\}$	*BCF-E*
		$\min\{a_1, a_2\} < a < a_1$	*TCF-E*
		$a_1 < a < \overline{a}$	*TCF-N*
	$c_1 < c < \overline{c}$	$0 < a \le \min\{\overline{a}, a_2\}$	*BCF-E*
		$\min\{\overline{a}, a_2\} < a \le \overline{a}$	*TCF-E*
$0.319 < \delta < 0.505$	$0 < c < c_3$	$0 < a < a_1$	*TCF-E*
		$a_1 < a < \overline{a}$	*TCF-N*
	$c_3 < c < \overline{c}$	$0 < a < \min\{a_1, a_2\}$	*BCF-E*
		$\min\{a_1, a_2\} < a < a_1$	*TCF-E*
		$a_1 < a < \overline{a}$	*TCF-N*
$0.505 < \delta < 0.749$	$0 < c < \overline{c}$	$0 < a < a_1$	*TCF-E*
		$a_1 < a < \overline{a}$	*TCF-N*
$0.749 < \delta < 0.781$	$0 < c < c_2$	$0 < a < \overline{a}$	*TCF-N*
	$c_2 < c < \overline{c}$	$0 < a < a_1$	*TCF-E*
		$a_1 < a < \overline{a}$	*TCF-N*
$0.781 < \delta < 1$	$0 < c < \overline{c}$	$0 < a < \overline{a}$	*TCF-N*

retailer considers encroaching. In the previous discussion, the sub-equilibrium encroachment strategies under the BCF scenario and TCF scenario are characterized. Next, we discuss which form of credit financing is better for the supplier and derive the corresponding conditions.

Lemma 3 *Comparing the BCF scenario and TCF scenario, we obtain the interactions between credit financing and channel encroachment, as shown in Table 3.*

Lemma 3 demonstrates the equilibrium strategy of credit financing, which is heavily dependent on the substitution degree, potential online market, and



(a) *when* $c = 0.1$

(b) *when* $c = 0.2$

(c) *when* $c = 0.3$

(d) *when* $c = 0.4$

Fig. 2 The region of strategy equilibrium production cost. Figure 2 shows a visual representation of above analysis. Intuitively, the supplier is more likely to choose TCF; however, in the case where the potential online market, substitution degree, and production are simultaneously small, BCF-E may serve as an equilibrium strategy. The retailer is both the seller and creditor, which causes a disadvantage for the supplier; otherwise, compared with the BCF strategy, the retailer sets the pricing decision by considering the impact of individual behaviors on the upstream supply chain.

Recall from Lemma 1 and Lemma 2 that we observe that the thresholds in Fig. 2 provide the equilibrium strategy of credit financing. We use colorless and colored areas to represent the BCF strategy and TCF strategy, respectively, in which the colored part is divided into the cases of encroachment and non-encroachment. As shown in Fig. 2, as long as the production cost remains below a threshold, the supplier never chooses the BCF strategy. When the production cost increases to a threshold, the probability of the supplier choosing BCF may increase. In addition, the larger the substitution, the smaller the values of a_1 and a_2.

5 Conclusions

Although there is a large body of research on supply chain finance and channel encroachment, few studies have investigated the interplay between credit financing and channel encroachment. The retailer, as a participant in a traditional channel, may also lend to the supplier. Therefore, this study investigates the financing preferences of the supplier and analyzes how the dual roles of the retailer affect the choice of supplier.

In this paper, we assume a Nash–Stackelberg game model between a capital-constrained supplier and a retailer to study the combination strategy of credit financing and channel encroachment. As the leader, the supplier has two options, namely BCF or TCF. Correspondingly, the retailer, as the follower, determines whether to encroach or not. Our analysis provides the following managerial insights. First, for suppliers with capital shortage, the interaction between credit financing and channel encroachment is heavily dependent on the substitution degree, potential online market, and production cost. When the cost is high or the online market share exceeds a threshold, the supplier prefers to choose TCF. Further, when BCF is considered, the retailer definitely encroaches; otherwise, whether to encroach or not mainly depends on the production cost. As the production cost increases, the retailer tends to only operate the existing channel. Finally, regardless of the form of credit financing that the supplier chooses, when the retailer encroaches, the interest rate decreases.

However, in practice, demand may be influenced by other factors that remain to be explored in future research. In addition, channel encroachment involves higher costs, which affect the corresponding decision-making. Further, the competition among supply chains, upstream or downstream, is also an interesting topic and worth studying.

Appendix

Proof of Proposition 1

Under the scenario without capital constraint for supplier, we have

$$\pi_r^{NN} = \frac{[1-a-(1-\delta)c]^2}{16}$$
$$\pi_r^{NE} = \pi_r^{NN} + \frac{a}{64}\{8(1+c\delta)+a[-58+(35-4\delta)\delta]\} - \frac{1}{16}\left\{3(2-\delta)+\left[\delta+c\left(-2+\delta+\delta^2\right)\right]^2\right\} - \frac{a}{4}\left[\frac{1+2c}{4(2-\delta)}+\frac{3}{2+\delta}\right]$$
$$\pi_s^{NN} = \frac{1+\delta+(1-\delta)(1-2a)^2}{8\left(1-\delta^2\right)} + \frac{1}{8}\left\{-2c[1+\delta+(1-\delta)a]+c^2(1-\delta)(3+\delta)-(1-a)^2\right\}$$

$$\pi_s^{NN} = \frac{1+\delta+(1-\delta)(1-2a)^2}{8\left(1-\delta^2\right)} + \frac{1}{8}\left\{-2c[1+\delta+(1-\delta)a]+c^2(1-\delta)(3+\delta)-(1-a)^2\right\}$$

$$\pi_s^{NE} = \pi_S^{NN} + \frac{(2-3a)^2}{48(2+\delta)} - \frac{[2(1+2c)-a]^2}{32(2-\delta)} + \frac{1}{8}\left\{(1-a)(1-a+2c\delta)+c\left[2+c\left(3+\delta^2\right)\right] - \frac{1}{3(1-\delta)} - \frac{(1-2a)^2}{1+\delta}\right\}$$

Under *BCF* scenario and retailer does not encroach the online market. In this case, the retailer's profit is as $\pi_r = (p-w)D_r^{\mathrm{N}}$. In third stage, the retailer decides on her retail price. With $\partial^2\pi_r/\partial\left(p^{BN}\right)^2 < 0$ and $\partial\pi_r/\partial p^{BN} = 0$, we can derive expression of the optimal retail price in relation to the supplier's direct price and wholesale price is $p^{BN} = \frac{1-a+w+d\delta}{2}$. In second stage, the supplier decides on his direct price and wholesale price. With $\partial^2\pi_s/\partial(d^{BN})^2 < 0$ and $\partial^2\pi_s/\partial(w^{BN})^2 < 0$, $\partial\pi_s/\partial d^{BN} = 0$ and $\partial\pi_s/\partial w^{BN} = 0$, we can derive expressions of the optimal direct price and wholesale price in relation to the creditor's interest rate are $w^{BN} = \frac{-1+a-a\delta}{2\left(-1+\delta^2\right)} + \frac{c\left(1+I_{BN}\right)}{2}$, $d^{BN} = \frac{a(-1+\delta)-\delta}{2\left(-1+\delta^2\right)} + \frac{c\left(1+I_{BN}\right)}{2}$. In first stage, the creditor sets interest rate. With $\partial^2\pi_b/\partial\left(I_{BN}\right)^2 < 0$ and $\partial\pi_b/\partial I_{BN} = 0$, we solve the optimal interest rate $I_{BN} = \frac{1+\delta+a(1-\delta)}{2c(1-\delta)(3+\delta)} - \frac{1}{2}$. Then taking I_{BN} to w^{BN} and d^{BN}, we can get the optimal wholesale price $w^{BN} = -\frac{7+4\delta+\delta^2+a\left(-5+4\delta+\delta^2\right)}{4(3+\delta)\left(-1+\delta^2\right)} + \frac{c}{4}$ and direct price $d^{BN} = \frac{-1-8\delta-3\delta^2+a\left(-7+4\delta+3\delta^2\right)}{4(3+\delta)\left(-1+\delta^2\right)} + \frac{c}{4}$. Next, we take w^{BN} and d^{BN} to p^{BN}, we can get the optimal retail price $p^{BN} = \frac{-19-9\delta+3\delta^2+\delta^3-a\left(-17+7\delta+9\delta^2+\delta^3\right)}{8(3+\delta)\left(-1+\delta^2\right)} + \frac{c(1+\delta)}{8}$. Finally, we can derive out the participates' profits as $\pi_b^{\mathrm{BN}} = \frac{c^2(1-\delta)(3+\delta)}{4} I_{\mathrm{BN}}^2$, $\pi_s^{\mathrm{BN}} = \pi_s^{\mathrm{NN}} - \frac{3c^2(1-\delta)(3+\delta)}{8} I_{\mathrm{BN}}^2$ and $\pi_r^{\mathrm{BN}} = \frac{\left[1-a-c(1-\delta)\left(1+I_{\mathrm{BN}}\right)\right]^2}{16}$.

Proof of Proposition 2

Under *BCF* scenario and retailer encroaches the online market. In this case, the retailer's profit is as $\pi_r = (p-w)D_r^{\mathrm{E}} + (b-w)Q_r^{\mathrm{E}}$. In third stage, the retailer decides on her retail price and booking price. With $\partial^2 \pi_r / \partial \left(p^{BE}\right)^2 < 0$, $\partial^2 \pi_r / \partial \left(b^{BE}\right)^2 < 0$ and $\partial \pi_r / \partial p^{BE} = 0$, $\partial \pi_r / \partial b^{BE} = 0$, we can derive expression of the optimal retail price $p^{BE} = \frac{4+a(-4+\delta)+2d\delta+d\delta^2}{8-2\delta^2} + \frac{w}{2}$ and booking price $b^{BE} = \frac{2a(-1+\delta)-\delta(2+d(2+\delta))}{2\left(-4+\delta^2\right)} + \frac{w}{2}$ in relation to the supplier's direct price and wholesale price. In second stage, the supplier decides on his direct price and wholesale price. With $\partial^2 \pi_s / \partial (d^{BE})^2 < 0$ and $\partial^2 \pi_s / \partial (w^{BE})^2 < 0$, $\partial \pi_s / \partial d^{BE} = 0$ and $\partial \pi_s / \partial w^{BE} = 0$, we can derive expressions of the optimal direct price and wholesale price in relation to the creditor's interest rate are $d^{BE} = \frac{a(-1+\delta)-\delta}{2\left(-2+\delta+\delta^2\right)} + \frac{c\left(1+I_{BE}\right)}{2}$, $w^{BE} = \frac{-2+a-a\delta}{4\left(-2+\delta+\delta^2\right)} + \frac{c\left(1+I_{BE}\right)}{2}$. In first stage, the creditor sets interest rate. With $\partial^2 \pi_b / \partial \left(I_{BE}\right)^2 < 0$ and $\partial \pi_b / \partial I_{BE} = 0$, we solve the optimal interest rate $I_{\mathrm{BE}} = \frac{a(1-\delta)+2}{4c(1-\delta)(4-\delta)} - \frac{1}{2}$. Then taking I_{BE} to w^{BE} and d^{BE}, we can get the optimal wholesale price $w^{BE} = \frac{20-2\delta-3a\left(2-3\delta+\delta^2\right)}{8(-4+\delta)\left(-2+\delta+\delta^2\right)} + \frac{c}{4}$ and direct price $d^{BE} = \frac{4+18\delta-4\delta^2+3a\left(6-7\delta+\delta^2\right)}{8(-4+\delta)\left(-2+\delta+\delta^2\right)} + \frac{c}{4}$. Next, we take w^{BE} and d^{BE} to p^{BE}, we can get the optimal retail price $p^{BE} = \frac{-84+90\delta-26\delta^2+2\delta^3+a\left(70-117\delta+54\delta^2-7\delta^3\right)}{8(-4+\delta)(-1+\delta)\left(-4+\delta^2\right)} + \frac{c}{4(2-\delta)}$. Finally, we derive the participates' profits as $\pi_b^{\mathrm{BE}} = \frac{c^2(1-\delta)(4-\delta)}{2(2-\delta)} I_{\mathrm{BE}}^2$, $\pi_s^{\mathrm{BE}} = \pi_s^{\mathrm{NE}} - \frac{3}{2}\pi_b^{\mathrm{BE}}$ and.

Proof of Lemma 1

When $c \in [0, \overline{c})$, $a \in [0, \overline{a})$, the retailer will encroach the online market.

$$\pi_r^{BE} - \pi_r^{BN} = \frac{1}{(-4+\delta)^2(3+\delta)^2(-4+\delta)^2}\Big[-c^2(-4+\delta)^2(-1+\delta)^2(2+\delta)^2(3+\delta)^2$$
$$+2c(-4+\delta)(-1+\delta)(2+\delta)(3+\delta)\left(-4+26a+22\delta-32a\delta-3\delta^2+5a\delta^2-\delta^3+a\delta^3\right)$$
$$-3656+10424a-7682a^2+1052\delta-3436a\delta+2619a^2\delta+708\delta^2-2180a\delta^2$$
$$+1696a^2\delta^2-184\delta^3+580a\delta^3-441a^2\delta^3-29\delta^4+114a\delta^4-105a^2\delta^4$$
$$+10\delta^5-32a\delta^5+26a^2\delta^5-\delta^6+2a\delta^6-a^2\delta^6\Big].$$

We simplify its numerator to a quadratic function with c as its independent variable, then we write the numerator as f(c). We can obtain that $\Delta < 0$ and the quadratic coefficient $-(-4+\delta)^2(-1+\delta)^2(2+\delta)^2(3+\delta)^2 < 0$. According to the discriminant of the root of quadratic equation with one variable and the opening direction of function, we can know that $f(c)$ is always smaller than 0. But $\pi_r^{BE} - \pi_r^{BN} = \frac{1}{(-4+\delta)^2(3+\delta)^2\left(-4+\delta^2\right)} f(c)$ and $\frac{1}{(-4+\delta)^2(3+\delta)^2\left(-4+\delta^2\right)} < 0$. Therefore, $\pi_r^{BE} > \pi_r^{BN}$.

Proof of Proposition 3

Under *TCF* scenario and retailer does not encroach the online market. In this case, the retailer's profit is as $\pi_r = (p - w)D_r^{\mathrm{N}} + cI_{TN}\left(D_s^{\mathrm{N}} + D_r^{\mathrm{N}}\right)$. In third stage, the retailer decides on her retail price. With $\partial^2\pi_{\mathrm{r}}/\partial\left(p^{TN}\right)^2 < 0$ and $\partial\pi_{\mathrm{r}}/\partial p^{TN} = 0$, we can derive expression of the optimal retail price in relation to the supplier's direct price and wholesale price and interest rate is $p^{TN} = \frac{\left[1-a+w+cI_{TN}(-1+\delta)+d\delta\right]}{2}$. In second stage, the supplier decides on his direct price and wholesale price. With $\partial^2\pi_{\mathrm{s}}/\partial(d^{TN})^2 < 0$ and $\partial^2\pi_{\mathrm{s}}/\partial(w^{TN})^2 < 0$, $\partial\pi_{\mathrm{s}}/\partial d^{TN} = 0$ and $\partial\pi_{\mathrm{s}}/\partial w^{TN} = 0$, we can derive expressions of the optimal direct price and wholesale price in relation to the creditor's interest rate are $w^{TN} = \frac{1+a(-1+\delta)}{2\left(1-\delta^2\right)} - \frac{c\left[-1+I_{TN}(-2+\delta)\right]}{2}$, $d^{TN} = \frac{a(-1+\delta)-\delta}{2\left(-1+\delta^2\right)} + \frac{c\left(1+I_{TN}\right)}{2}$. In first stage, the retailer as a creditor sets interest rate. With $\partial^2\pi_{\mathrm{r}}/\partial\left(I_{TN}\right)^2 < 0$ and $\partial\pi_{\mathrm{r}}/\partial I_{TN} = 0$, we solve the optimal interest rate $I_{TN} = \frac{\delta+a(1-\delta)}{2c(1-\delta)(1+\delta)} - \frac{1}{2}$. Then taking I_{TN} to w^{TN} and d^{TN}, we can get the optimal wholesale price $w^{TN} = \frac{2+(2-a)\delta-(1-a)\delta^2}{4\left(1-\delta^2\right)} + \frac{c\delta}{4}$ and direct price $d^{TN} = \frac{3[a(1-\delta)+\delta]}{4\left(1-\delta^2\right)} + \frac{c}{4}$. Next, we take w^{TN}, d^{TN} and I_{TN} to p^{TN}, we can get the optimal retail price $p^{TN} = \frac{3[1-a(1-\delta)]}{4\left(1-\delta^2\right)} + \frac{c}{4}$. Finally, we derive the participates' profits as $\pi_s^{TN} = \pi_s^{NN} - \frac{3c^2\left(1-\delta^2\right)}{4}I_{TN}^2$ and $\pi_r^{TN} = \pi_r^{NN} + \frac{c^2\left(1-\delta^2\right)}{2}I_{TN}^2$.

Proof of Proposition 4

Under *TCF* scenario and retailer encroaches the online market. In this case, the retailer's profit is as $\pi_r = (p - w)D_r^{\mathrm{E}} + (b - w)Q_r^{\mathrm{E}} + cI_{\mathrm{TE}}\left(D_s^{\mathrm{E}} + D_r^{\mathrm{E}} + Q_r^{\mathrm{E}}\right)$. In third stage, the retailer decides on her retail price and booking price. With $\partial^2\pi_{\mathrm{r}}/\partial\left(p^{TE}\right)^2 < 0$, $\partial^2\pi_{\mathrm{r}}/\partial\left(b^{TE}\right)^2 < 0$ and $\partial\pi_{\mathrm{r}}/\partial p^{TE} = 0$, $\partial\pi_{\mathrm{r}}/\partial b^{TE} = 0$. We can derive expression of the optimal retail price $p^{TE} = \frac{4(1+w)+a(-4+\delta)+2d\delta+d\delta^2-w\delta^2+2cI_{TE}\left(-2+\delta+\delta^2\right)}{2\left(4-\delta^2\right)}$ and booking price $b^{TE} = \frac{4w-2a(-1+\delta)+2\delta+2d\delta+d\delta^2-w\delta^2+2cI_{TE}\left(-2+\delta+\delta^2\right)}{2\left(4-\delta^2\right)}$ in relation to the supplier's direct price, wholesale price and interest rate. In second stage, the supplier decides on his direct price and wholesale price. With $\partial^2\pi_{\mathrm{s}}/\partial(d^{TE})^2 < 0$ and $\partial^2\pi_{\mathrm{s}}/\partial(w^{TE})^2 < 0$, $\partial\pi_{\mathrm{s}}/\partial d^{TE} = 0$ and $\partial\pi_{\mathrm{s}}/\partial w^{TE} = 0$, we can derive expressions of the optimal direct price and wholesale price in relation to the creditor's interest rate are $w^{TE} = \frac{4-2\delta-a\left(2-3\delta+\delta^2\right)}{4(-2+\delta)\left(-2+\delta+\delta^2\right)} + \frac{cI_{TE}(4-3\delta)}{2(2-\delta)} + \frac{c}{2}$, $d^{TE} = \frac{a(-1+\delta)-\delta}{2\left(-2+\delta+\delta^2\right)} + \frac{c\left(1+I_{TE}\right)}{2}$. In first stage, the retailer as a creditor sets interest rate. With $\partial^2\pi_{\mathrm{r}}/\partial\left(I_{TE}\right)^2 < 0$ and $\partial\pi_{\mathrm{r}}/\partial I_{TE} = 0$, we solve the optimal interest rate $I_{TE} = \frac{\delta+a(1-\delta)}{2c(1-\delta)(2+\delta)} - \frac{1}{2}$. Then taking I_{TE} to w^{TE} and d^{TE}, we can get the optimal wholesale price $w^{TE} = \frac{4+2a(-1+\delta)^2+2(1+c)\delta-(3+c)\delta^2-c\delta^3}{4(-2+\delta)\left(-2+\delta+\delta^2\right)}$ and direct price $d^{TE} = \frac{3[a(-1+\delta)-\delta]}{4\left(-2+\delta+\delta^2\right)} + \frac{c}{4}$. Next, we take w^{TE}, d^{TE} and I_{TE} to p^{TE}, we get the optimal retail price $p^{TE} = \frac{-10-9a(-1+\delta)+4\delta}{8(-2+\delta+\delta^2)} + \frac{c}{4}$. Finally, we derive the participates' profits as $\pi_s^{\mathrm{TE}} = \pi_s^{\mathrm{NE}} - \frac{3c^2(1-\delta)(2+\delta)}{4(2-\delta)} I_{\mathrm{TE}}^2$ and $\pi_r^{\mathrm{TE}} = \pi_r^{\mathrm{NE}} + \frac{c^2(1-\delta)(2+\delta)}{2(2-\delta)} I_{\mathrm{TE}}^2$.

Proof of Lemma 2

When $\pi_r^{TE} - \pi_r^{TN} > 0$, the retailer will encroach the online market, otherwise, she doesn't encroach. $\pi_r^{TE} - \pi_r^{TN} = \frac{1}{64[(2-\delta)(1-\delta)(1+\delta)(2+\delta)]^2}\{24 - 72a - 12\delta - \}4a\delta - 44\delta^2 +128a\delta^2 + 20\delta^3 - 44a\delta^3 + 4\delta^4 - 8a\delta^4 + 4c^2(-1+\delta)^2\left(4 + 4\delta + \delta^2 + 2\delta^3 + \delta^4\right) + a^2 \left(34 + 21\delta - 86\delta^2 + 27\delta^3 + 4\delta^4\right) + c\left[-8a(-1+\delta)^3\left(2 + 3\delta + \delta^2\right) + 8(-1+\delta)^2\delta\left(2 + 3\delta + \delta^2\right)\right]$. As evidenced by *Lemma 1*, the equilibrium strategy is as summarized in the text.

Proof of Lemma 3

According to the retailer behavior equilibrium, we discuss how the supplier considers different credit financing strategies. Through the similar steps as before, we divide the range of δ, c and a into the following intervals

1. consider the substitution degree $\delta \in [0, 0.319)$, (i) if the production cost $c \in [0, c_3)$ and potential online market $a \in [0, \overline{a})$ or production cost $c \in [c_3, c_1)$ and potential online market $a \in [a_1, \overline{a})$ or $a \in [a_2, \overline{a})$ or $c \in [c_1, \overline{c})$ and $a \in [a_2, \overline{a})$, the supplier will choose trade credit financing strategy; (ii) if the production cost $c \in [c_3, c_1)$ and potential online market $a \in \min\{a_1, a_2\}$ or $c \in [c_1, \overline{c})$ and $a \in \min\{\overline{a}, a_2\}$ the supplier will choose bank credit financing strategy.
2. consider the substitution degree $\delta \in [0.319, 0.505)$, (i) if the production cost $c \in [0, c_3)$ and potential online market $a \in [0, \overline{a})$, the supplier will choose trade credit financing strategy; (ii) if $c \in [c_3, \overline{c})$ and potential online market $a \in \min\{a_1, a_2\}$, the supplier will choose bank credit financing strategy, otherwise, he will choose trade credit financing strategy.
3. consider the substitution degree $\delta \in [0.505, 1)$, if $c \in [0, \overline{c})$ and $a \in [0, \overline{a})$, the supplier will choose trade credit financing.

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