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Research Article

Channel Selection Strategy for a Retailer with Finance Constraint in a Supply Chain Based on Complex Network Theory

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This paper establishes a two-echelon supply chain consisting of one manufacturer and one retailer. We consider the retailer buys a product from the manufacturer and sells it to consumers through a store channel and an online channel. The retailer needs to bear a fixed investment cost to running its store/online channel. We discuss the impact of the fixed investment cost, the operating cost for the product, and substitutive factor between the two channels on the optimal strategy for the retailer using complex network theory. The result shows that the ratio of net surplus and the ratio of the operating cost between the two channels play a significant role in the retailer's optimal decisions. Moreover, finance constraint and the fixed investment cost are also two vital factors for the retailer to channel selection strategy. Numerical experiment shows the effectiveness of the conclusion, and some meaningful insights are generated.

1. Introduction

With the rapid development of information technology and globalization, the supply chain structure becomes more complex. The supply chain network is a type of complex network consisting of the related firms such as suppliers, manufacturers, and retailers. There exist lots of the interaction and interdependency between different firms, which are highly nonlinear and complex. When a new firm enters the system or an incumbent runs a new selling channel, the supply chain structure changes and creates new connections between firms. As a result, the interaction and interdependency also become more complex. This leads to the self-organization movement of the supply chain network [1]. Based on complex network theory, the node represents firm unit which can make decision independently, and the link between nodes represents exchange relationship and underlined order. Thus, the complex network theory can be applied to the supply chain management [2, 3]. This paper studies the retailer's decision when the supply chain network changes through using complex network theory.

With the rapid development of e-commerce, a growing number of people have begun shopping directly online. Forrester Research [4] reported that there is $290 billion on online shopping in 2014 in the U.S., and can reach about $400 billion in 2018. In the recent Tmall "double eleven" shopping festival in 2019, the turnover was as high as $38.4 billion in just one day. The rapid increase in online shopping has attracted manufactures and retailers to adopt a dual-channel retail system, i.e., sell their products through a retail channel and an online channel. For instance, besides using traditional retail channels, many manufacturers, such as IBM, Hewlett Packard, and Nike, open their own online direct channels to sell products to customers. In addition, may retailers, such as Walmart, Carrefour, and RT-Mart, also open their own online direct channels to sell products to customers.

In the past two decades, operating a dual-channel retail system including a store channel and an online channel has been widely discussed by experts and scholars and achieved fruitful results. The research is mainly divided into two categories. The first category is the manufacturers sell their

products through both a retail channel and an online channel. It mainly focuses on the topics of price competition, inventory control, channel conflicts, and channel coordination. In price competition and inventory control, Sun et al. [5] showed that introducing a direct channel can force the retailer to lessen the pricing, thus weakening the double marginalization. Hua et al. [6] established the price competition model considering the factor of delivery lead time. Li et al. [7] discussed the impact of the retailer's risk indicator on the retail price and the ordering quantities and indicated an improved risk-sharing contract can coordinate the dual-channel supply chain and ensures that both supply chain members achieve a win-win outcome. Wei et al. [8] established five pricing models under decentralized decision cases with consideration of different market power structures among two manufacturers and one common retailer. Alptekinoglu and Tang [9] discussed the optimal inventory distribution policy to satisfy demand that should be handled by each fulfillment location without considering fixed operating costs. Netessine and Rudi [10] studied the conditions in which the drop-shipping mode was more effective than the traditional mode. Geng and Mallik [11] considered inventory competition between the retail channel and the direct channel and indicated that a mild capacity constraint could improve the situation of both agents and increase the profit of the whole supply chain. Yao et al. [12] study three different inventory strategies (centralized inventory strategy, Stackelberg inventory strategy, and online channel inventory outsourcing strategy) and obtained the optimal inventory levels in retail and online channels from the manufacturer's perspective. Based on a single-period news-vendor model [13], Roy et al. [14] discussed the optimal stock level, sales prices, promotional effort, and service level for the two channels. In channel conflict and channel coordination, Geyskens et al. [15] showed that less powerful firms with larger online market offerings would obtain less profit than powerful ones with a fewer online paths. Cai et al. [16] evaluated the impact of price discount contracts and pricing schemes on the dual-channel supply chain competition and found that the former scenarios can outperform the non-contract scenarios. Yan and Zaric [17] studied all possible coordinating contracts for a dual-channel supply chain and showed that different contract families have different levels of efficiency, flexibility, and required information for coordination.

In addition, much literature has shown that an online channel may lessen a retailer's effort to sell a product [5, 18–21] and can also sometimes target a different market segment, and these customers would buy elsewhere if there were no direct channel [22–24]. Bell et al. [25] and Li et al. [26] discuss the impact of showroom on the members' demand and profit in a dual-channel supply chain. They show that the showroom increases the sales through online channels. Similarly, based on a quantity competition model, Arya et al. [27] show that introducing an online channel not only increases the manufacturer's revenue but also motivates the manufacturer to offer a lower wholesale price to the retailer, which can reduce the retail price and mitigate double marginalization. Li et al. [28] and Huang et al. [29] expand the research of Arya et al. [27] by considering a retailer with private information about the market demand. They find that introducing an online channel can sometimes amplify the double marginalization and hurt both the manufacturer and retailer. However, the above studies focus only on the manufacturer's dual-channel decision in the two-echelon supply chain structure. Our work complements this stream of research by considering the retailer's dual-channel strategy.

The second category is that the retailer sells through a physical channel and an online channel. With the rapid development of e-commerce, about 80% of retailers in the US have adopted a dual-channel retail strategy [30]. Such a strategy can allow retailers to reach wider segments of customers and increase revenue [31] and can add flexibility to a retailer's dual channel. This flexibility allows customers to order a product online and pick it up from a physical store or purchase a product online and return it to a physical store [32]. Undoubtedly, adding another channel can not only improve retailer' profitability but can also lead to a better bargaining power with upstream manufacturers [8, 27, 33]. However, retailers must take the loss of the vested benefit from the existing channel. Generally, both the store channel and the online channel are intersubstitutive, so the demand transfers the existing channel to the new opening channel, which does not increase the retailer's profit. In additional, the retailer must pay a large fixed capital (the investment cost) to develop a new channel before selling its product through this channel. This is a vital factor for the retailer to whether open a new channel or not. Finance constraint has also significant influence on the firms' operations [34–36], and the retailer needs to determine how to maximize the utilizing efficiency of the finite finance.

To the best of our knowledge, there is no research on the operational decisions in capital-constrained retailer considering the fixed investment cost. This paper attempts to fill the gap by introducing the fixed cost into a capital-constrained retailer's channel selection model. This pare is different from the existing literature in the following two aspects. One is that the existing literature on channel selection has regarded the traditional store channel as an incumbent channel and discussed whether to introduce an online channel besides the store channel. In fact, with the development of e-commerce, many pure e-retailers have begun to develop an offline channel in addition to their existing online channel. In this paper, we assume that the retailer can adopt one of three retail modes: only a store channel, only an online channel, and both the two channels. The other difference is that the existing literature on capital-constrained supply chain focuses on financing strategy such as bank credit financing and trade credit financing [34, 37]. However, many small- and medium-sized firms in China have difficulty to solve fund shortage through bank credit financing and trade credit financing because of their low credit rate and high default risk. Thus, this paper discusses how a capital-constrained retailer chooses retail channel to sell its product when borrowing is forbidden. Besides, the fixed cost for developing a new channel has a significant effect on channel selection when

capital is constrained, so this paper considers a nonzero fixed cost, while it is normalized to be zero in much literature. The paper considers a capital-constrained retailer buys a product from its upstream manufacturers and sells it through the two alternative channels: store channel and online channel. We assume that the upstream manufacturer who does not play any strategy with the retailer. We investigate the optimal quantity strategy and channel selection decision for the retailer. We discuss the impacts of the ratio of net surplus between the two channels, the cost for developing and operating the channel, and finance constraint on the retailer's optimal decision. The results shows that when borrowing is allowed, the retailer's optimal strategies depend on the ratios of the maximum achievable surplus and the ratios of substitution factors of the online channel and the store channel. When borrowing is prohibited, the retailer can improve the efficiency of capital by reducing the quantity demanded level of more expensive channel and replacing them with the cheaper one. Besides, the nonzero-investment cost makes the probability of the retailer simultaneously running the two channels small.

The rest of this paper is organized as follows. Section 2 provides a basic model and assumption. Section 3 and Section 4 analyze the retailer's optimal strategy considering capital constraint and the fixed cost when borrowing is permitted and is forbidden, respectively. Section 5 employs numerical studies to gain more managerial insights. Section 6 provides concluding remarks. All the proofs are presented in the Appendix.

2. Model Description

Consider one retailer (she) who buys a product from an independent manufacturer and sells it to consumers through the store (hereafter "s-channel") and online (hereafter "o-channel") channels. We assume that the independent manufacturer does not play any strategic role with the retailer, so the wholesale price charged by the independent manufacturer is normalized to zero for brevity. The retailer incurs the per-unit selling cost of c_s/c_o for the "s-channel"/"o-channel." Besides, the retailer needs to pay a fixed cost C_s/C_o for opening the "s-channel"/the "o-channel."

We assume that the market demand satisfies a linear and downward-sloping demand function which is in line with Cui et al. [38] and Wang et al. [36]. The inverse demand functions are

$$\begin{aligned} p_s &= a - q_s - \gamma q_o, \\ p_o &= a - q_s - q_o, \end{aligned} \tag{1}$$

where q_s/q_o represents the quantity demanded in the "s-channel"/"o-channel," $a > 0$ represents the market size (i.e., the maximum achievable retail price), and $\gamma \in (0, 1)$ denotes the degree of affect the quantity of the "o-channel" to the "s-channel." We consider the price of the "s-channel" is higher than the "o-channel" because consumers usually believe the product in the "o-channel" is inferior than in the "s-channel."

For the retailer, the total cost is $C_T = c_s q_s + c_o q_o + C_s + C_o$ when $q_s > 0$ and $q_o > 0$, $C_T = c_s q_s + C_s$ when $q_s > 0$ and $q_o = 0$, and $C_T = c_o q_o + C_o$ when $q_s = 0$ and $q_o > 0$. We assume that the retailer has a self-owned finance $F > C_s + C_o$, and there exists a perfect bank who provides an identical risk-free rate, $\rho - 1 > 0$, for saving and borrowing. Thus, the retailer can gain the interest when $F > C_T$ and takes a loan from the perfect bank when $F < C_T$. The profit function of the retailer is

$$\pi_R(q_s, q_o) = (a - q_s - \gamma q_o)q_s + (a - q_o - q_s)q_0 - F + \rho(F - C_T), \tag{2}$$

where the first two terms are the revenue of the retailer selling through both the channels and the last term includes the total costs and the financial expense for $F < C_T$ (or income for $F > C_T$).

From the inverse demand function in (1), when both the quantities the s-channel and the o-channel increase one unit, the price of o-channel decreases $1 + \gamma$, while the price of s-channel increases 2, thus we denote $1 + \gamma/2$ to represent the ratio of the substitution factor of o-channel to s-channel (conversely, $2/1 + \gamma$ represents the ratio of the substitution factor of s-channel to o-channel). Moreover, a is the maximum achievable price of selling the unit product and ρc_i is the return for the retailer when he puts capital c_i in the bank. Thus, $A_i = a - \rho c_i$ is the maximum achievable surplus of selling a per-unit product through the i-channel, $i \in \{s, o\}$. Let $\Delta \equiv A_o/A_s$ represent the ratio of the surplus of selling through the o-channel to the s-channel and reflect the relative competitiveness of the o-channel over the s-channel [39]. The larger the Δ is, the stronger the relative competitiveness of the o-channel over the s-channel will be. This means that selling the product through the o-channel is more profitable than through the s-channel.

3. Optimal Strategy When Borrowing Is Permitted

In this section, we discuss how the substitution factor γ, the operating cost c_i, the investment cost C_i, and the self-owned finance F affect the optimal decision for the retailer. In practice, opening a channel usually is a long-term plan for the retailer and, once implemented, cannot be altered as easily as an order/pricing decision. Before the order/pricing decision, the retailer needs to invest a huge capital, which is regarded as the investment cost, to construct a new channel. Thus, the fixed investment cost and the operating cost for selling the products are separate, and much literature on dual-channel supply chain has not considered the investment cost and normalized it to zero. In this paper, we consider the following two cases. The first case is that we do not consider the fixed investment cost, i.e., normalize it to zero, which is consistent with that of much literature. On the other hand, when the retailer's capital is restricted, the investment cost has a significant effect on opening a new channel, so we consider a nonzero-investment cost in the second case. Thus, we first discuss the effects of other factors on the optimal decisions for the retailer under the zero-

investment cost ($C_s = 0$ and $C_o = 0$) in Section 3.1 and then investigate the effects under the nonzero-investment cost ($C_s > 0$ or $C_o > 0$) in Section 3.2.

3.1. Zero-Investment Costs. In this subsection, we discuss the optimal strategy for the retailer when both of the investment costs are zero, i.e., $C_s = 0$ and $C_0 = 0$. In such a case, the retailer has three alternative strategies: (i) only running the "s-channel" ($q_s > 0$, $q_o = 0$), (ii) only running the "o-channel" ($q_s = 0$, $q_o > 0$), and (iii) running both of the "s-channel" and the "o-channel" ($q_s > 0$, $q_o > 0$).

From (2), the retailer determines the selling quantities of q_s and q_o to maximize her profit as the solution to

$$\max_{q_s \geq 0, q_o \geq 0} \pi(q_s, q_o) = (a - q_s - \gamma q_o)q_s + (a - q_o - q_s)q_0 - F + \rho(F - C_T). \tag{3}$$

It is easy to prove that $\pi(q_s, q_o)$ is the concave function on (q_s, q_o). Solving the first-order conditions obtain the optimal solutions (indexed by superscript BA), which is shown in Proposition 1.

Proposition 1. *Suppose that borrowing is permitted and the investment costs are zero, the optimal decisions for the retailer are as follows.*

(1) $q_s^{BA} = A_s/2$, $q_o^{BA} = 0$ *when* $\Delta \leq 1 + \gamma/2$

(2) $q_s^{BA} = A_s(2 - (1+\gamma)\Delta)/4 - (1+\gamma)^2$, $q_o^{BA} = A_s(2\Delta - (1+\gamma))/4 - (1+\gamma)^2$ *when* $1 + \gamma/2 < \Delta \leq 2/1 + \gamma$

(3) $q_s^{BA} = 0$, $q_o^{BA} = A_o/2$ *when* $\Delta > 2/1 + \gamma$

From Proposition 1, we draw the following conclusions. (i) A big/small Δ means that selling through the o-channel/s-channel is more profitable for the retailer. Therefore, q_s is increases with Δ, while q_s decreases with Δ. (ii) The channel selection strategy for the retailer depends on the ratio (Δ) of surplus of product and the ratio ($1 + \gamma/2$ and $2/1 + \gamma$) of the substitution factor. Specifically, the retailer would only run the s-channel/o-channel when Δ is big/small enough. Moreover, the larger the substitution factor γ, the stronger the effect of the o-channel on the s-channel will be, so the probability that the retailer simultaneously running the two channel becomes small. (iii) The threshold of sufficient finance is $F_s = c_s q_s^{BA} = A_s c_s/2$ when the retailer only runs the s-channel ($q_s^{BA} > 0$, $q_o^{BA} = 0$), $F_{so} = c_s q_s^{BA} + c_o q_o^{BA} = A_s[(2 - (1+\gamma)\Delta)c_s + (2\Delta - (1+\gamma))c_o]/4 - (1+\gamma)^2$ when the retailer runs both of the s-channel and the o-channel ($q_s^{BA} > 0$, $q_o^{BA} > 0$), and $F_o = c_o q_o^{BA} = A_o c_o/2$ when the retailer only runs the o-channel ($q_s^{BA} = 0$, $q_o^{BA} > 0$).

According to the channel selection strategy for the retailer in Proposition 1, the retailer's profit $\pi^{BA}(q_s^{BA}, q_o^{BA})$ can be obtained as follows:

$$\pi^{BA}\left(q_s^{BA}, q_o^{BA}\right) = \begin{cases} \pi_s^{BA}\left(\frac{A_s}{2}, 0\right) = \frac{A_s^2}{4} + (g-1)F, & \Delta \leq \frac{1+\gamma}{2}, \\ \pi_{so}^{BA}\left(\frac{A_s(2-(1+\gamma)\Delta)}{4-(1+\gamma)^2}, \frac{A_s(2\Delta-(1+\gamma))}{4-(1+\gamma)^2}\right) & \\ = \frac{A_s^2(1-(1+\gamma)\Delta+\Delta^2)}{3-2\gamma-\gamma^2} + (g-1)F, \frac{1+\gamma}{2} < & \Delta \leq \frac{2}{1+\gamma}, \\ < \pi_o^{BA}\left(0, \frac{A_o}{2}\right) = \frac{A_o^2}{4} + (g-1)F, & \Delta > \frac{2}{1+\gamma}, \end{cases} \tag{4}$$

3.2. Nonzero-Investment Costs. In Section 3.1, we discuss the optimal strategy for the retailer when the channel investment costs are zero. In practice, the retailer needs to pay a finance to develop the s-channel/o-channel before selling the product through s-channel/o-channel; we regard the finance as the investment cost for developing the channel. In this section, we study the optimal strategy for the retailer when the channel investment costs are nonzero. Note that the investment costs are the fixed cost and does not affect the decisions for the selling quantity in the each channel. According to (4), we can obtain the retailer's profit (index by superscript "FA") in three channel selection strategies.

If the retailer only runs the s-channel, then her profit is

$$\pi_s^{FA}\left(q_s^{FA}, q_o^{FA}\right) = \pi_s^{FA}\left(\frac{A_s}{2}, 0\right) = \frac{A_s^2}{4} + (\rho - 1)F - \rho C_s. \tag{5}$$

If the retailer only runs the o-channel, then her profit is

$$\pi_o^{FA}\left(q_s^{FA}, q_o^{FA}\right) = \pi_o^{FA}\left(0, \frac{A_o}{2}\right) = \frac{A_o^2}{4} + (\rho - 1)F - gC_o. \tag{6}$$

If the retailer only runs the o-channel, then her profit is

$$\pi_{so}^{FA}\left(q_s^{FA}, q_o^{FA}\right) = \pi_{so}^{FA}\left(\frac{A_s(2-(1+\gamma)\Delta)}{4-(1+\gamma)^2}, \frac{A_s(2\Delta-(1+\gamma))}{4-(1+\gamma)^2}\right)$$
$$= \frac{A_s^2\left(1-(1+\gamma)\Delta+\Delta^2\right)}{3-2\gamma-\gamma^2} + (\rho-1)F - \rho\left(C_s + C_o\right), \tag{7}$$

where the subscripts "s," "o," and "so" represent the s-channel, o-channel, and the two channels, respectively.

Comparing π_s^{FA}, π_o^{FA}, and π_{so}^{FA} in (5)–(7), we can obtain the following conclusion, shown in Proposition 2.

Proposition 2. *Suppose that borrowing is permitted and the investment is nonzero, the retailer's optimal decision is as follows:*

(1) If $\{1+\gamma/2 < \Delta < 2/1+\gamma\} \wedge \{C_o < [2A_o - (1+\gamma)A_s]^2/4\rho(3-2\gamma-\gamma^2)\} \wedge \{C_s < {}^{[2A_s-(1+\gamma)}A_o]2/4\rho(3-2\gamma-\gamma^2)\}$, *then the retailer chooses simultaneously to run the s-channel and the o-channel, and the selling quantities are* $q_s^{BA} = A_s(2-(1+\gamma)\Delta)/4-(1+\gamma)^2$ *and* $q_o^{BA} = A_s(2\Delta-(1+\gamma))/4-(1+\gamma)^2$

(2) If condition in (1) fails, then retailer chooses only to run the s-channel/o-channel when $C_s - C_o < A_s^2 - A_o^2/4\rho/C_s - C_o > A_s^2 - A_o^2/4\rho$, *and the selling quantity is* $q_s = A_s/2/q_o = A_s/2$

Proposition 2 shows that only when the ratio (Δ) of surplus of the o-channel to the s-channel is medium and both the investment costs (C_s and C_o) for the two channels are low, the retailer chooses to run the two channel. This means that the probability of running simultaneously the two channels becomes smaller than that when the investment costs are zero. In additional, the investment cost C_o/C_s has a positive effect on running an o-channel/s-channel and a negative impact on running a s-channel/o-channel. This is consistent with our intuition.

4. Optimal Strategy When Borrowing Is Forbidden

In Section 3, we study the retailer's optimal decisions in the presence of sufficient finance, or the self-owned finance is insufficient while the retailer can obtain a loan from the bank. In practice, finance constraint is a popular phenomenon for firms, so it is very necessary to explore the retailer's optimal decisions when she has no sufficient finance and cannot obtain a loan from the bank. We first gives the finance threshold of the three alternative strategies and then discuss the optimal channel selection strategy.

4.1. Zero-Investment Costs. From Proposition 1, we have known the thresholds of sufficient finance are F_s, F_o, and F_{so} when the retailer runs the s-channel, o-channel, and the two channels, respectively. In this section, we will discuss the impact of finance constraint on the optimal strategy. In order to analyze the impact of finance constraint, we assume that the self-owned finance is not larger than the finance threshold, i.e., $F \le F_s$, $F \le F_o$, and $F \le F_{so}$; otherwise, the finance constraint is not an ineffective for the optimal strategy for the retailer.

If she does not takes a loan from the perfect bank when her finance is insufficient, the retailer determines the quantities of q_s and q_o to maximize her profit as the solution to

$$\max \pi_R(q_s, q_o) = (a - q_s - \gamma q_o)q_s + (a - q_o - q_s)q_0 - F + \rho(F - C_T),$$
$$\text{s.t.} \quad \begin{cases} q_s \ge 0,\ q_o \ge 0, \\ F - c_s q_s - c_o q_o \ge 0. \end{cases} \tag{8}$$

According to the K-T conditions, we can obtain the retailer's optimal decisions as follows.

Proposition 3. *Suppose that the self-owned finance is not larger than the sufficient finance threshold, i.e.,* $F = c_s q_s + c_o q_o$ *and borrowing is forbidden, then the retailer's optimal decision (index by superscript "BF") is as follows:*

(1) $q_s^{BF} = F/c_s$, $q_o^{BF} = 0$ *when* $\{F \le F_s\} \wedge \{(c_o/c_s - 1 + \gamma/2) F \le A_s c_s/2(c_o/c_s - \Delta)\}$

(2) $q_s^{BF} = 0$, $q_o^{BF} = F/c_o$ *when* $\{F \le F_o\} \wedge \{(2/1+\gamma - c_o/c_s) F \le A_s c_o/1+\gamma\ (\Delta - c_o/\ c_s)\}$

(3) $q_s^{BF} = [2c_s - (1+\gamma)c_o]F - A_o c_s c_o + A_s c_o^2/2[c_s^2 + c_o^2 - (1+\gamma)c_s c_o]$, $q_o^{BF} = [2c_s - (1+\gamma)c_s]F - A_s c_s c_o + A_o c_s^2/2[c_s^2 + c_o^2 - (1+\gamma)c_s c_o]$ *when* $\{F \le F_{so}\} \wedge \{(c_o/\ c_s - 1 + \gamma/2)F > A_s c_s/2(c_o/c_s - \Delta)\} \wedge \{(2/1+\gamma - c_o/c_s)F > A_s c_o/1+\gamma(\Delta - c_o/c_s)\}$

From Proposition 3, we can obtain that the retailer's optimal decisions depend on not only the ratios of surplus (Δ) and substitution factors $(1+\gamma/2, 2/1+\gamma)$ for the two channels but also the ratio of operating costs (c_o/c_s) for the two channels. The ratio of operating costs (c_o/c_s) is involved because the utilizing efficiency of self-owned finance becomes very important when borrowing is forbidden. In order to better understand the effects of these parameters on the retailer's optimal decision, we give the feasible range of F for the optimal strategy in different situations, shown in Table 1.

From Table 1, we draw the following conclusions. (1) When the ratio of surplus for the two channels is very small (i.e., $\Delta \le 1+\gamma/2$), it induces $c_o > c_s$, which means the operating cost for the o-channel is higher than for the s-channel. In such case, the retailer only runs the s-channel. Conversely, when the ratio of surplus for the two channels is very high (i.e., $\Delta > 2/1+\gamma$), it induces $c_o < c_s$, which means the operating cost for the o-channel is lower than for the s-channel. In such case, the retailer only runs the o-channel. This is consistent with the sufficient finance, shown in Proposition 1. (2) When the ratio of surplus for the two channels is medium (i.e., $1+\gamma/2 < \Delta \le 2/1+\gamma$), the retailer does not choose the o-channel/s-channel if $c_o > c_s/c_o < c_s$. In such case, the retailer chooses both the two channels when the self-owned finance is not small. If the self-owned finance is very small, the retailer only chooses the o-channel/s-channel if $c_o < c_s/c_o > c_s$.

From Table 1, the retailer's profit $\pi^{BF}(q_s^{BF}, q_o^{BF})$ is given as follows:

Table 1: The optimal strategy in different cases.

Channel selection	Only o-channel	Both channels	Only s-channel
$\Delta \le 1+\gamma/2\,(\Rightarrow c_o > c_s)$	—	—	$F \le F_s$
$1+\gamma/2 < \Delta \le 1\,(\Rightarrow c_o \ge c_s)$	—	$F_1 < F \le F_{so}$	$F \le F_1$
$1 < \Delta \le 2/1+\gamma\,(\Rightarrow c_o < c_s)$	$F \le F_2$	$F_2 < F \le F_{so}$	—
$2/1+\gamma \le \Delta\,(\Rightarrow c_o < c_s)$	$F \le F_o$	—	—

$F_1 = A_s c_s c_o - A_o c_s^2/2c_o - (1+\gamma)c_s$, $F_2 = A_o c_s c_o - A_s c_o^2/2c_s - (1+\gamma)c_o$.

$$\pi^{BF}\left(q_s^{BF}, q_o^{BF}\right) = \begin{cases} \pi_s^{BF}\left(\dfrac{F}{c_s}, 0\right) = \left(A_s - \dfrac{F}{c_s}\right)\dfrac{F}{c_s} + (\rho-1)F, \\ \pi_{so}^{BF}\left(\dfrac{[2c_s-(1+\gamma)c_o]F - A_o c_s c_o + A_s c_o^2}{2[c_s^2+c_o^2-(1+\gamma)c_s c_o]}, \dfrac{[2c_s-(1+\gamma)c_s]F - A_s c_s c_o + A_o c_s^2}{2[c_s^2+c_o^2-(1+\gamma)c_s c_o]}\right) \\ = \dfrac{(A_s c_o - A_o c_s)^2 + 2F[A_s(2c_s-(1+\gamma)c_o) + A_o(2c_o-(1+\gamma)c_s)] - (3-2\gamma-\gamma^2)F}{4(c_s^2-(1+\gamma)c_s c_o + c_o^2)} + (\rho-1)F, \\ \pi_o^{BF}\left(0, \dfrac{F}{c_o}\right) = \left(A_o - \dfrac{F}{c_o}\right)\dfrac{F}{c_o} + (\rho-1)F. \end{cases} \tag{9}$$

4.2. Nonzero-Investment Costs. In this subsection, we discuss the effect of the nonzero-investment costs C_s and C_o on the optimal decision for the retailer when borrowing is forbidden, i.e., the retailer cannot take a loan from the bank. We first give the retailer's profit under three alternative channel strategies and then discuss the optimal channel selection strategy.

Because the investment costs are fixed and does not affect the decision on selling quantities, according to (9), we can obtain the retailer's profit in there alternative channel strategies.

If she only runs the s-channel, the retailer's profit is

$$\pi_s^{FF}\left(\frac{F-C_s}{c_s}, 0\right) = \left(A_s - \frac{F-C_s}{c_s}\right)\frac{F-C_s}{c_s} + (\rho-1)F - \rho C_s. \tag{10}$$

If she only runs the o-channel, the retailer's profit is

$$\pi_o^{FF}\left(0, \frac{F-C_o}{c_o}\right) = \left(A_o - \frac{F-C_o}{c_o}\right)\frac{F-C_o}{c_o} + (\rho-1)F - \rho C_o. \tag{11}$$

If she runs the two channels, the retailer's profit is

$$\begin{aligned} &\pi_{so}^{FF}\left(\frac{[2c_s-(1+\gamma)c_o](F-C_o-C_s) - A_o c_s c_o + A_s c_o^2}{2[c_s^2+c_o^2-(1+\gamma)c_s c_o]}, \frac{[2c_s-(1+\gamma)c_s](F-C_o-C_s) - A_s c_s c_o + A_o c_s^2}{2[c_s^2+c_o^2-(1+\gamma)c_s c_o])}\right) \\ &= \frac{(A_s c_o - A_o c_s)^2 + 2(F-C_o-C_s)[A_s(2c_s-(1+\gamma)c_o) + A_o(2c_o-(1+\gamma)c_s)] - (3-2\gamma-\gamma^2)(F-C_o-C_s)}{4(c_s^2-(1+\gamma)c_s c_o + c_o^2)} \\ &\quad + (\rho-1)F - \rho(C_o+C_s). \end{aligned} \tag{12}$$

Comparing the profits under three alternative channel strategies, we can obtain the channel selection strategies for the retailer.

Proposition 4. *Suppose that borrowing is forbidden and the self-owned finance is not large than the finance threshold, i.e., $F - C_s - C_o = c_s q_s + c_o q_o$, the retailer's channel selection strategy is as follows:*

(1) If $\{1+\gamma/2 < \Delta < 2/1+\gamma\} \wedge \{\max(F_1, F_2) < F - C_s - C_o < F_{so}\} \wedge \{\pi_{so}^{FF} \ge \max(\pi_s^{FF}, \pi_o^{FF})\}$, then the retailer simultaneously runs the two channels, and the selling quantities are $q_s = [2c_s - (1+\gamma)c_o]\ (F - C_o - C_s) - A_o c_s c_o + A_s c_o^2/2[c_s^2 + c_o^2 - (1+\gamma)c_s c_o]$ and $q_o = [2c_s - (1+\gamma)c_s](F - C_o - C_s) - A_s c_s \quad c_o + A_o c_s^2/2[c_s^2 + c_o^2 - (1+\gamma)c_s c_o]$, respectively

(2) If the condition in (1) fails, then retailer chooses only to run the s-channel/o-channel when $\pi_s^{FF} > \pi_o^{FF}/\pi_s^{FF} < \pi_o^{FF}$, and the selling quantity is $q_s = F - C_s/c_s/q_o = F - C_o/c_o$.

Proposition 4 shows that only when the ratio (Δ) of surplus of the o-channel to the s-channel is medium and both the investment costs (C_s and C_o) for the two channels are low, the retailer chooses to run the two channels. This means that the probability of running simultaneously the two channels becomes smaller than that when the

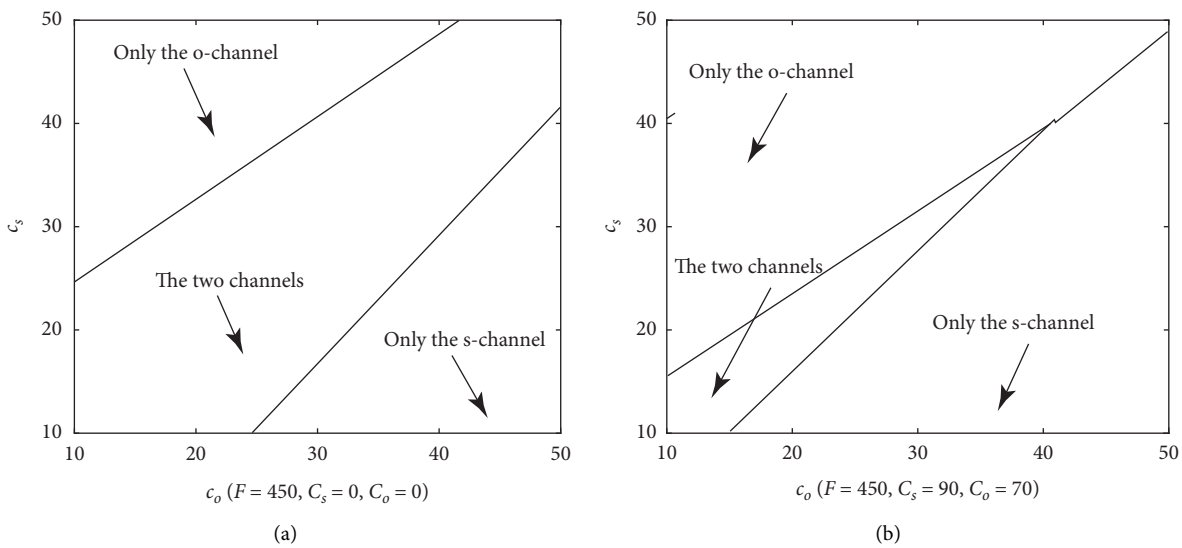

Figure 1: The channel selection strategy when borrowing is permitted.

investment costs are zero. The reason is that the retailer needs to pay a finance to develop a channel before selling the product through the channel, so the retailer will not open a channel until the investment cost for the channel is small. This is consistent with our intuition. Moreover, the investment cost C_o/C_s has a positive effect on running an o-channel/s-channel and a negative impact on running a s-channel/o-channel.

5. Numerical Example

Consider the following data: $a = 100$, $\gamma = 0.6$, $\rho = 1.2$, and $F = 450$. Figure 1 shows the impact of the operating costs (c_o and c_s) on the channel selection strategy for the retailer when borrowing is permitted. (a) The case with zero-investment costs and (b) the case with nonzero-investment costs. From Figure 1, we can obtain the following conclusions. Only when the difference between the operating costs is small, the retailer chooses to run the two channels. If the difference between the operating costs is large, the retailer will choose to the channel with the lower operating cost. In addition, the nonzero-investment cost has a negative effect on running the two channels. The larger the investment costs are, the probability that the retailer runs the two channels will become smaller. The reason is that the utilizing efficiency of the finance is very important for the retailer and the s-channel and the o-channel are substituted for each other. Thus, only when both the operating costs are not large, the retailer chooses to run the two channels.

Figure 2 shows the impact of the operating costs on the optimal strategies for the retailer when borrowing is forbidden. (a) The case with the zero-investment costs and (b) the case with the nonzero-investment costs. From Figure 2, we can obtain as follows. Only when the difference between the operating costs is very small, the retailer chooses to run both channels. Because the self-owned finance is limited and the loan from the bank cannot be obtained, the retailer must use the finite finance to produce/buy more product and the probability of running the two channels becomes very small. Moreover, the investment cost has a significant influence on the channel selection strategy for the retailer. The retailer always runs the channel that the investment cost for this channel is lower than another channel even if the operating cost for this channel is slightly higher than that for another channel.

5.1. Discussion and Implications. The prior literature mainly focused on inventory control, pricing, channel selection, and coordination in a dual-channel supply chains [5, 6, 9, 14, 28, 29], ignoring the impact of capital constraint. Lots of literature in a capital-constraint supply chain focuses on financing strategy such as bank credit financing and trade credit financing but does not consider small- and medium-sized firms which do not ability to finance because of their low credit rate and high default risk. This study has concentrated on how capital constraint affects a retailer's channel selection, thereby enriching literature in this area. The managerial insights of this paper are shown as follows.

When borrowing is permitted and the investment cost is zero, the retailer's optimal strategies depend on the ratio of the surplus of selling through the o-channel to the s-channel. When the ratio is close to one, the retailer chooses both the two channels to sell her product. This means that if the differentiation of the two channels is small, the retailer should adopt dual-channel strategy to increase his profit. If the differentiation of the two channels is large, the retailer prefers to sell through the single channel. In addition, when the investment cost is nonzero, because the retailer can obtain finance from bank loan, the optimal strategy is not unchanged. That is, the differentiation of the two channels is small, and the retailer prefers to sell through the two channels. Different from the zero-investment cost, if the investment costs for the two channels are large, the retailer prefers to sell through a single channel even if the ratio of the

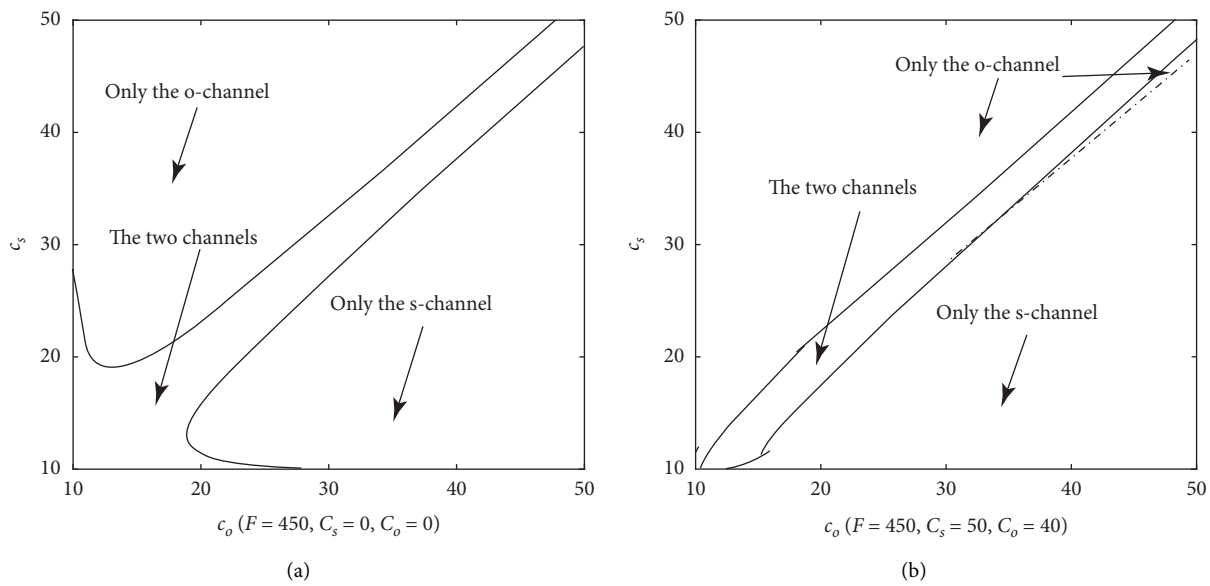

Figure 2: The channel selection strategy when borrowing is forbidden.

surplus of selling through the o-channel to the s-channel is close to one. This means that the retailer becomes cautious to adopt the two channels in order to reduce expenditure of the investment costs. When borrowing is forbidden, the limited capital is a significant resource for the retailer, so the feasible area of adopting the two channels becomes smaller. This means that only when the ratio of the surplus of selling through the o-channel to the s-channel is close to one, the retailer prefers to adopt the two channels.

6. Conclusion

This paper considers a dual-channel retailer's potential channel selection topic. The retailer can sell a product provided by an independent manufacturer who does not play any strategy through a traditional store channel or a fashionable online channel. We investigate how the investment cost (fixed cost), the operating cost, the substitution factor, and the finance constraint between the two channels affect the retailer's selling quantity strategy and the channel selection decision. The results show the following. (i) The operating cost has a significant influence on the retailer's channel selection strategy. The retailer always runs the channel with the lower operating costs. It is cautious for the retailer to simultaneously run the two channels. Only if the difference of the operating cost between the two channels is very small, the retailer opens the two channels. (ii) The two channels are substitution for each other and there exists the competition, so the retailer runs the channel with the competitive channel. The larger the substitution factor is, the stronger the competition between the two channel will be, so the smaller the probability that the retailer runs the two channel will be. (iii) The nonzero-investment cost makes the retailer running the two channels become small. The retailer always opens the channel with a lower investment cost whether borrowing is permitted or not.

This paper has a few limitations. In this paper, we assume that the manufacturer is an independent partner and does not play any strategy with the retailer. In practice, the wholesale price charger by the manufacturer is a significant factor for the retailer to determine the selling quantity, thus the further research may consider a two-echelon supply chain that consists of the manufacturer and the retailer. Moreover, there exists a certain risk in opening the new-fashioned online channel. It would be interesting to incorporate the risk element into the model in the future research.

Appendix

Proof of Proposition 1. From equation (3), the Hessian matrix of $\pi(q_s, q_o)$ is $\begin{bmatrix} -2 & -(1+\gamma) \\ -(1+\gamma) & -2 \end{bmatrix}$. Obviously, the Hessian matrix is a negative definite matrix, so the critical point of $\pi(q_s, q_o)$ is a local maximum. The only critical point from $[\partial\pi(q_s, q_o)/\partial q_s, \partial\pi(q_s, q_o)/\partial q_o] = [0, 0]$ is $[q_s^{BA}, q_o^{BA}] = [A_s(2-(1+\gamma)\Delta)/4-(1+\gamma)^2, A_s(2\Delta-(1+\gamma))/4-(1+\gamma)^2]$. If $1+\gamma/2 < \Delta \le 2/1+\gamma$, we have $q_s^{BA} > 0$ and $q_o^{BA} > 0$. If $\Delta \le 1+\gamma/2$, we have $q_s^{BA} = A_s/2$ and $q_o^{BA} = 0$. If $\Delta > 2/1+\gamma$, we have $q_s^{BA} = 0$ and $q_o^{BA} = A_o/2$. □

Proof of Proposition 2. The proof is straightforward, so it is omitted. □

Proof of Proposition 3. Suppose the self-owned finance F is not higher than the sufficient finance threshold and borrowing is forbidden, the retailer determines the optimal quantities for the two channels by solving the following optimization problem:

$$\max \pi_R(q_s, q_o) = (a - q_s - \gamma q_o)q_s + (a - q_o - q_s)q_0 - F + \rho(F - C_T), \tag{A.1}$$

$$\text{s.t.} \quad \begin{cases} q_s \geq 0,\ q_o \geq 0, \\ F - c_s q_s - c_o q_o \geq 0. \end{cases} \tag{A.2}$$

The corresponding Lagrangian function is

$$L(q_s, q_o, \lambda) = (a - q_s - \gamma q_o)q_s + (a - q_o - q_s)q_0 - F + \rho(F - c_s q_s - c_o q_o) + \lambda(F - c_s q_s - c_o q_o). \tag{A.3}$$

According to K-T conditions, we have

$$\begin{cases} \dfrac{\partial L}{\partial q_s} = a - 2q_s - (1+\gamma)q_o - \rho c_s - \lambda c_s \leq 0, & \dfrac{\partial L}{\partial q_s} q_s = 0, \\ \dfrac{\partial L}{\partial q_o} = a - 2q_o - (1+\gamma)q_s - \rho c_o - \lambda c_o \leq 0, & \dfrac{\partial L}{\partial q_o} q_o = 0, \\ \dfrac{\partial L}{\partial \lambda} = F - c_s q_s - c_o q_o \geq 0, & \dfrac{\partial L}{\partial \lambda} \lambda = 0. \end{cases} \tag{A.4}$$

(1) The condition $F \leq F_s$ and $q_s > 0$, $q_o = 0$ is equivalent to

$$\begin{cases} a - 2q_s - \rho c_s - \lambda c_s = 0, \\ a - (1+\gamma)q_s - \rho c_o - \lambda c_o \leq 0, \\ F - c_s q_s = 0. \end{cases} \tag{A.5}$$

Thus, we have $q_s^{BF} = F/c_s$ and $q_o^{BF} = 0$ when $\{F \leq F_s\} \wedge \{(c_o/c_s - 1 + \gamma/2)F \leq A_s c_s/2\,(c_o/c_s - \Delta)\}$.

(2) Similarly, the condition $F \leq F_o$ and $q_s = o$, $q_o > 0$ is equivalent to

$$\begin{cases} a - 2q_o - \rho c_o - \lambda c_o = 0, \\ a - (1+\gamma)q_o - \rho c_s - \lambda c_s \leq 0, \\ F - c_o q_o = 0. \end{cases} \tag{A.6}$$

Thus, we have $q_s^{BF} = 0$, $q_o^{BF} = F/c_o$ when $\{F \leq F_o\} \wedge \{(2/1 + \gamma - c_o/c_s)F \leq A_s c_o/1 + \gamma(\Delta - c_o/c_s)\}$.

(3) The condition $F \leq F_{so}$ and $q_s > 0$, $q_o > 0$ is equivalent to

$$\begin{cases} a - 2q_s - (1+\gamma)q_o - \rho c_s - \lambda c_s = 0, \\ a - 2q_o - (1+\gamma)q_s - \rho c_o - \lambda c_o = 0, \\ F - c_s q_s - c_o q_o = 0. \end{cases} \tag{A.7}$$

Thus, we have $q_s^{BF} = [2c_s - (1+\gamma)c_o]F - A_o c_s c_o + A_s c_o^2/2\,[c_s^2 + c_o^2 - (1+\gamma)c_s c_o]$, $q_o^{BF} = [2c_s - (1+\gamma)c_s]F - A_s c_s c_o + A_o c_s^2/2\,[c_s^2 + c_o^2 - (1+\gamma)c_s c_o]$ when $\{F \leq F_{so}\} \wedge \{(c_o/c_s - 1 + \gamma/2)F > A_s c_s/2\ (c_o/c_s - \Delta)\} \wedge \{(2/1 + \gamma - c_o/c_s)F > A_s c_o/1 + \gamma(\Delta - c_o/c_s)\}$. □

Proof of Proposition 4. The proof is straightforward, so it is omitted. □

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

Authors' Contributions

Both the authors contributed equally to this work.

Acknowledgments

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