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Research Article

Considering the Sales Method and Logistics Service Strategy, Which Operating Mode Is the Best under Different Power Structures?

Yanan Zhao and Wei Jia

School of Economics and Management, Liaoning Petrochemical University, Fushun, China

Correspondence should be addressed to Yanan Zhao; zhao3226870051@163.com

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When merchants enter hybrid e-commerce platforms (such as JD.com and Amazon), they will face issues such as which sales methods to choose and whether to use platform logistics under different power structures. Different sales methods and logistics service strategies have resulted in three operating modes: (a) resale mode, marked as *A*, (b) agency + no-platform logistics, marked as *B*, and (c) agency + platform logistics, marked as *C*. This paper constructs an analysis framework composed of an e-commerce platform and a merchant to explore the optimal operating mode. The game models of the three modes are first constructed, and then, the equilibrium results are compared and analysed. Based on the results of comparative analysis and considering the dynamic game between the e-commerce platform and the merchant regarding sales methods and logistics service strategies, the optimal operating mode is determined. The results show that when the platform has absolute power, mode *C* is optimal for it. When the logistics service sensitivity coefficient and market size are both large, the best for the merchant with absolute power is mode *B*. In addition, if neither of them has absolute power, only when the merchant first decides the logistics service strategy, then the platform decides the sales method; the best for both parties is mode *B*; otherwise, the best is mode *A*. This research has generated new insights and has practical management significance, which can provide guidance for merchant and platform decision-making.

1. Introduction

1.1. Background and Motivation. The choice of the sales method is one of the most important decisions in the supply chain based on the Internet platform [1]. Merchants and e-commerce platforms widely use two different sales methods: agency sales and resale [2, 3]. In the agency method, manufacturers sell products to end consumers through online platforms and pay a certain percentage of commission to the platform for each transaction. In the resale method, the platform is an online retailer, ordering products from upstream manufacturers and then selling them to final consumers. These two sales methods are widely used on many platforms. For example, JD uses the resale method when cooperating with brands such as Huawei and Coach and uses the agency method when cooperating with brands such as LILANZ and Sephora.

Nowadays, the important role of logistics service in e-commerce has been widely recognized by practitioners and scholars [4]. Many large-scale e-commerce platforms recognize the importance of logistics service to their businesses, so they have established their own logistics systems to provide consumers with excellent logistics service. Amazon and JD are two typical representatives of such e-commerce giants. JD is famous mainly because of its fast delivery service for retail business [4, 5]. In recent years, logistics resource sharing has become more and more popular in the e-commerce market [6]. For example, JD has been sharing its superior logistics resources with merchants opening stores on its platform since 2016. Without JD's logistics resource sharing, merchants have no choice but to use the service of other third-party logistics (3PL) companies (such as ZTO and YTO Express). With the sharing of logistics

resources, merchants can choose to purchase and use JD's high-quality logistics service. Chinese consumers generally believe that JD's logistics service is superior to almost all third-party logistics service [4, 7]. However, under the agency sales method, some merchants use JD logistics (such as Sephora), while others use other third-party logistics (such as LILANZ).

In the cooperation between the merchant and the platform, the firm in a monopoly position can completely decide which sales method to use and whether to use platform logistics. When no firm is in a monopoly position, the merchant or the platform can only decide one of two strategies. For well-known big brands, such as Xiaomi and Dell, they have a monopoly position in cooperation with JD; while for some small brands, JD has a monopoly position. For some medium-sized enterprises, they are evenly matched in the negotiations with JD. Therefore, there will be a game about sales methods and logistics service strategies. These different power structures will cause supply chain members to make different decisions.

Based on the above discussion, it can be seen that when merchants are preparing to rely on hybrid e-commerce platforms for product sales, they will face the problem of which sales methods to use and whether to use platform logistics. Due to the different power structures of platforms and merchants, the complexity of the problem is increased.

1.2. Research Questions and Major Findings. Considering the different combinations of sales methods and logistics service strategies, three operating modes are proposed, namely, resale mode, agency + no-platform logistics mode, and agency + platform logistics mode. Motivated by the discussion above, this paper mainly answers the following questions:

(1) What is the performance of product price, sales volume, and corporate profit under different operating modes?

(2) Considering different power structures, which is the best operating mode for the merchant and the platform?

To solve the above questions, we construct an analytical framework that includes a merchant and an e-commerce platform. First, we obtain the equilibrium results under each operating mode; then, according to the equilibrium results, we determine the best operating mode for the merchant and platform under different power structures. The major findings we obtain are as follows.

First, we compare the retailer price and sales volume of the products under the three modes. The results show that the retail price is closely related to market size and logistics service sensitivity coefficient (LSSC) under the three modes. Specifically, except when the LSSC and market size are small, the retail price is the highest under the mode B; in other cases, the retail price is the largest under the mode A. In addition, only when the LSSC is small and the market size is large, the retail price is the lowest under the mode B. In other cases, mode C generates the lowest retail price. Interestingly, the relationship between product sales volume under the three modes is only related to market size. When the market size is sufficiently large, the sales volume in mode B is the largest, but smallest in the mode A.

Second, by comparing the profit of the platform and the merchant under the three modes, it is found that in the B mode, the platform profit is the smallest. However, in the C mode, the platform has the highest profit. For the merchant, the relationship of revenue in the three modes is closely related to LSSC and market size. When the LSSC and the market size are both large, the profit of the merchant under mode B is the largest while the smallest under mode C.

Finally, we determine the best mode according to the strategic interaction between the platform and the merchant on the sales method and the logistics service strategy under different power structures. When the platform has absolute power, the C mode is the best for it. When the LSSC and market size are both large, the B mode is the best for the merchant if it has absolute power. In addition, if neither of them has absolute power, we find that only when the merchant first decides whether to use platform logistics, then the platform decides which sales method to use; the best mode for them is mode B; otherwise, the best mode is mode A.

1.3. Contribution Statements and Organization. The innovations and main contributions of this paper are as follows:

(1) According to different combinations of sales methods and logistics service strategies, three operating modes are proposed

(2) Using game theory and optimization algorithms, the equilibrium results in each mode are obtained and a comparative analysis is carried out

(3) According to the different power structures of the platform and the merchant regarding sales methods and logistics service strategies, the optimal operation mode is determined

Our research generates new insights and management implications and provides guidance for merchants and platforms to make decisions. The rest of this paper is organized as follows. In Section 2, we review the relevant literature. Model construction and solution are placed in Section 3 and Section 4, respectively. In Section 5, we make a comparative analysis of the equilibrium results under the three operating modes. Section 6 presents the optimal operating mode for the firm. In Section 7, we conclude the paper. To improve the readability of the paper, all technical proofs are given in the appendix.

2. Literature Review

Our research is related to online sales methods, platform logistics resource sharing, and supply chain operation decision under different power structures. Below, we will review these three aspects of the literature and locate the research contribution of this paper.

2.1. Online Sales Methods. With the prosperity of online retailing, there has been a lot of research on online sales methods. Online sales methods refer to the agency method and the resale method. For example, Jiang et al. [8] study how product demand characteristics affect the choice of platform sales methods. Kwark et al. [9] study how the accuracy of online product reviews will affect online retailers' strategic choices between two different sales methods. Mantin et al. [10] point out that e-retailers have improved their position in negotiations with manufacturers by introducing agency sales. Abhishek et al. [11] discuss when e-commerce platforms should use agency methods instead of resale methods. Chen et al. [12] analyze the influence of customer loyalty on the choice of sales methods. Zennyo [13] study the sales method selection strategy between the e-commerce platform and two suppliers with different market potentials. Considering the disadvantages of upstream manufacturers' online sales in terms of sales efficiency and demand information, Yan et al. [14] examine whether agency sales should be introduced. Li et al. [15] use a panel vector autoregressive model to study the influence of agency methods on resale methods in hybrid e-commerce platforms. Liu et al. [1] explore the influence of data-driven marketing and market size on the choice of e-commerce platform sales methods. Zhang and Zhang [16] investigate the demand information sharing strategies between e-commerce retailers and suppliers who may establish physical channels under two sales methods. Chen et al. [17] study the issue of whether a manufacturer chooses an agency method or a resale method when cooperating with e-commerce platforms to sell promotional products. Xu et al. [18] study the channel addition problem of manufacturers who use agency or resale methods to sell products through online platforms, in which manufacturers are regulated by carbon cap-and-trade policy. Pu et al. [19] discuss the marketing and pricing strategies of online channels under different offline channel power structures in which the manufacturer sells the product through the offline retailer and the e-retailer, and the manufacturer cooperates with the e-retailer through resale or agency sales. Based on the environmental and economic perspectives, Zhang and Hou [20] investigate the issue of the sales method used by the manufacturer and the e-retailer for cooperation under the e-retailer's own brand. Chen et al. [21] study the online channel introduction strategy of manufacturers. They find that the agency sales method is better than the resale method. Similarly, under the condition that manufacturers have independent offline sales channels, Pu et al. [22] explore three online channel introduction strategies of manufacturers, namely, direct sales, agency sales, and resale. Yang et al. [23] study the sales methods' selection and information-sharing strategies of e-commerce platforms under uncertain demand. Considering the background of an e-commerce platform and manufacturer-selling alternative products, Li et al. [24] explore logistics service strategies under different sales methods.

Except [24], the above literature focuses on the research on the choice of sales methods for merchants in online retail. Although Li et al. [24] consider logistics service strategies, they mainly investigate the impact of logistics service sensitivity on corporate decision-making and profits. However, this paper considers different combinations of sales methods and logistics service strategies and proposes three operating modes, focusing on the optimal operating mode for the platform or merchant.

2.2. E-Commerce Platform Logistics Resource Sharing. At present, the sharing of logistics resources on e-commerce platforms has attracted the attention of many scholars. He et al. [25] and Niu et al. [26] consider two competitive e-commerce platforms, one of which has advanced logistics service. The author studies whether the weaker party in logistics service should use the logistics service of the superior party. Qin et al. [27] study an e-commerce platform and a retailer who sells products on this e-commerce platform, between which they sell alternative products. The author discusses the impact of platform logistics resource sharing on enterprise-related decisions and profits. He et al. [6] study the logistics resource sharing and the resulting competition issues in the dual-channel e-commerce supply chain composed of a manufacturer and an e-commerce platform. In this study, the manufacturer opens the online direct sales channel and at the same time wholesales their products to the e-commerce platform for resale. However, these literatures only examine the issue of e-commerce platform logistics resource sharing, but do not consider the selection of sales methods. Different from the above research, Qin et al. [28] study the interaction between sales methods and logistics service strategies, focusing on the situation under which the highest service level and market equilibrium mode are available. Cao et al. [29] explore whether offline retailers should access e-commerce platforms and, if they do, whether to use platform logistics or third-party logistics.

This paper also studies the logistics resource sharing strategy of the e-commerce platform. The most similar research to our study is Qin et al. [28], but our research is different from it in three points. First, we assume that when merchants do not use platform logistics, they use other third-party logistics, while Qin et al. [28] consider that merchants provide logistics themselves. Second, we take the platform logistics service level as an exogenous variable and focus on the impact of the platform logistics service level on related decision-making; however, Qin et al. [28] regard the logistics service level as an endogenous variable, which is very different from the equilibrium result we obtained. Finally, we determine the equilibrium mode under different power structures, while Qin et al. [28] only determine the situation when the platform is the dominant player.

2.3. Supply Chain under Different Power Structures. Different power structures will lead to different decisions. Many scholars have conducted research on supply chain operation decision-making issues under different power structures. For example, Pan et al. [30] compare revenue-sharing contracts and wholesale price contracts under different power structures. The author's purpose is to reveal

whether it is advantageous for manufacturers to use revenue-sharing contracts. Wu et al. [31] investigate the pricing decisions in a noncooperative supply chain consisting of two retailers and a public supplier. The authors analyze the horizontal competition between retailers and the vertical competition between suppliers and retailers under different power structures. Gao et al. [32] study the influence of different power structures on closed-loop supply chain decision-making. They focus on revealing what kind of power structure is optimal for the enterprise and propose a corresponding coordination contract. Luo et al. [33] study a supply chain consisting of a retailer and two brand manufacturers. The author focuses on the influence of different power structures on the pricing decisions of manufacturers and retailers. Luo et al. [34] investigate the impact of consumer valuation and different power structures on retailer product selection and pricing strategies. Li et al. [35] investigate the impact of government subsidy programs and channel power structure on the level of innovation in the supply chain. The author finds that, for a given channel power structure, consumer subsidies are more effective than producer subsidies in promoting innovative investment. Jin et al. [36] explore the impact of different power structures on the pricing and coordination of reverse supply chains with online and offline dual recycling channels. Hu et al. [37] study the issue of whether online retailers integrate logistics enterprises under different power structures.

The different power structures proposed in the above literature mainly refer to two companies with equal power or one company as the leader. However, our research is different from them. The different power structure in this paper refers to a certain enterprise monopoly or a certain enterprise dominance. We first obtain the equilibrium results under each operating mode according to the agreed decision sequence. Then, according to the equilibrium results, the strategic interaction between sales methods and logistics service is considered under different power structures to determine the optimal operation method for the enterprise, which is essentially different from the above research.

2.4. Summary. Through the review of the above literature, we find that this paper is the first study to determine the optimal operating mode considering the dynamic game about online sales methods and logistics service strategies between e-commerce platforms and merchants under different power structures. In order to clarify the literature positioning of this paper, we give Table 1, which shows the similarities and differences between this paper and most related studies. We classify the topics into three aspects: sales methods, logistics service, and different power structures. The previous literature has examined some topics individually, but our paper examines all these topics and they are important to the field.

3. Model

This paper studies the operating mode selection strategy between an e-commerce platform and a brand merchant. There are two sales methods to choose for the platform and the merchant: the agency method and the resale method. In the resale method, the merchant wholesales their products to the e-commerce platform, which then sells them to consumers. In the agency method, the merchant set up shop on the e-commerce platform and sells their products to consumers, while the e-commerce platform takes commission. Here, we assume that the e-commerce platform has a strong logistics system. In the resale method, the platform uses its own logistics resources; while in the agency method, the merchant can choose whether to use the logistics resources of the platform. For example, JD is not only an e-commerce platform but also an e-commerce retailer. At the same time, it has a strong logistics service system, JD Logistics. Currently, JD has fully opened its logistics service to third-party sellers. Table 2 summarizes the notation used in this paper.

We consider the following three operating modes:

(1) Resale mode (denoted by symbol A): in this mode, the merchant determines the product wholesale price w, and the platform determines the retail price p and uses their own logistics service. Following He et al. [6], Niu et al. [26], and Qin et al. [27, 28], we assume that the demand function under this mode is

$$Q^A = a - p + ks, \tag{1}$$

where a is the potential market size and s is the logistics service level of the platform, which can be seen as the shortening time of the delivery lead time when using platform logistics compared with other third-party logistics. k is the sensitivity coefficient of logistics service level to demand. Here, we assume that the production cost of the product is zero, which does not affect the relevant conclusions of this paper. Therefore, the profit functions of the platform and the merchant are, respectively,

$$\pi_1^A = (p - w)Q^A, \tag{2}$$

$$\pi_2^A = wQ^A. \tag{3}$$

(2) Agency + no-platform logistics mode (denoted by symbol B): in this mode, since the merchant uses other third-party logistics, the service level of other third-party logistics is far lower than that of platform logistics, so it is assumed that the service level of other third-party logistics is zero. Therefore, the demand function in this mode is

$$Q^B = a - p. \tag{4}$$

Table 1: Differences between this paper and relevant studies.

Paper	Sales methods	Logistics service	Different power structures
[1, 17, 20, 23]	√		
[6, 25–27, 29]		√	
[24, 28]	√	√	
This paper	√	√	√

Table 2: Notations.

Symbols	Definition
s	Service level of e-commerce platform logistics
k	Logistics service sensitivity coefficient
r	Commission rate
a	Market size
c	Third-party logistics unit price
Q^i	Demand function, $i \in \{A, B, C\}$
π_1^i $i \in \{A, B, C\}$	E-commerce platform profit function,
π_2^i	Brand merchant profit function, $i \in \{A, B, C\}$
Decision variables	
p	Retail price
w	Wholesale price
l	Platform unit logistics price

In this mode, it is assumed that the unit logistics price of the third-party logistics enterprise is c. Therefore, the profit functions of the platform and the merchant are, respectively,

$$\pi_1^B = rpQ^B, \tag{5}$$

$$\pi_2^B = [(1-r)p - c]Q^B. \tag{6}$$

(3) Agency + platform logistics mode (denoted by symbol$_C$): therefore, the demand function in this mode is

$$Q^C = a - p + ks. \tag{7}$$

We do not consider the unit logistics cost of the platform here. Assuming that the unit logistics price of the platform is $_l$, then the profit functions of the platform and the merchant are, respectively,

$$\pi_1^C = rpQ^C + lQ^C, \tag{8}$$

$$\pi_2^C = [(1-r)p - l]Q^C. \tag{9}$$

According to the commission rate of Tmall and JD, it is assumed here that $r \in [0, 0.2]$. At the same time, in order to ensure that product demand in each mode is not negative, we assume that market size a is large enough. Figure 1 shows the supply chain structure under the three modes.

4. Equilibrium Analysis

In mode A, the merchant first decides the wholesale price, and then, the platform decides the retail price. By backward induction, Lemma 1 is obtained.

Lemma 1. *In mode A, the optimal price, sales volume, and profit are as follows:*

$$\begin{aligned} w^{A*} &= \frac{a+ks}{2}, \\ p^{A*} &= \frac{3(a+ks)}{4}, \\ Q^{A*} &= \frac{a+ks}{4}, \\ \pi_1^{A*} &= \left(\frac{a+ks}{4}\right)^2, \\ \pi_2^{A*} &= \frac{(a+ks)^2}{8}. \end{aligned} \tag{10}$$

According to Lemma 1, under mode A, the increase of product market size and consumers' sensitivity to the logistics service level will lead to the increase of product wholesale price and the corresponding retail price. Moreover, product sales volume will also increase, which will lead to increased profits for both the platform and the merchant.

In mode B, the merchant decides the retail price on the premise of a certain commission rate and Lemma 2 is obtained.

Lemma 2. *In mode B, the optimal price, sales volume, and profit are as follows:*

$$\begin{aligned} p^{B*} &= \frac{a+c-ar}{2(a-r)}, \\ Q^{B*} &= \frac{c-a+ar}{2r-2}, \\ \pi_1^{B*} &= \frac{r(a+c-ar)^2}{4(r-1)^2}, \\ \pi_2^{B*} &= \frac{(c-a+ar)^2}{4(1-r)}. \end{aligned} \tag{11}$$

Lemma 2 shows that, in mode B, when the third-party logistics price increases, the retail price of the product will increase, but the sales volume will decrease, which will lead to the decrease of the platform and merchants' profits. Moreover, it can be found that the platform commission rate has no influence on the retail price and sales volume of products, but only affects the corporate profit.

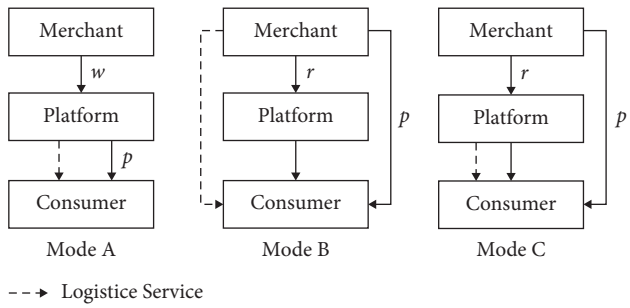

Figure 1: Supply chain structure under three modes.

In mode C, on the premise of a certain commission rate, the platform first decides the unit logistics price, and then, the merchant decides the retail price. Lemma 3 is obtained by backward induction.

Lemma 3. *In mode C, the optimal price, sales volume, and profit are as follows:*

$$\begin{aligned} p^{C*} &= \frac{(2r-3)(a+ks)}{2r-4}, \\ l^{C*} &= \frac{a-2ar+ks+ar^2+kr^2s-2krs}{2-r}, \\ Q^{C*} &= \frac{a+ks}{4-2r}, \\ \pi_1^{C*} &= \frac{(a+ks)^2}{8-4r}, \\ \pi_2^{C*} &= \frac{(1-r)(a+ks)^2}{4(r-2)^2}. \end{aligned} \tag{12}$$

From Lemma 3, we find a very interesting phenomenon, that is, in mode C, when the platform commission rate increases, the retail price of the product decreases ($\partial p^{C*}/\partial r < 0$). In addition, the logistics price of the platform is reduced ($\partial l^{C*}/\partial r < 0$), but the product sales volume is increased ($\partial Q^{C*}/\partial r < 0$).

5. Comparative Analysis

Proposition 1. *The retail price under the three modes satisfies the relationship:*

(i) When $k < k_1$,
If $a < a_1$, then $p^{B*} > p^{A*} > p^{C*}$.
If $a_1 < a < a_2$, then $p^{A*} > p^{B*} > p^{C*}$.
If $a > a_2$, then $p^{A*} > p^{C*} > p^{B*}$.

(ii) When $k_1 < k < k_2$,
If $a > a_2$, then $p^{A*} > p^{C*} > p^{B*}$.
If $a < a_2$, then $p^{A*} > p^{B*} > p^{C*}$.

(iii) If $k > k_2$, then $p^{A*} > p^{B*} > p^{C*}$, where $k_1 = 2c/3s(1-r)$ and $k_2 = c(2-r)/s(2r-3)(r-1)$:

$$\begin{aligned} a_1 &= \frac{2c-3ks+3krs}{1-r}, \\ a_2 &= \frac{c(2-r)+ks\left(5r-2r^2-3\right)}{(r-1)^2}. \end{aligned} \tag{13}$$

Proposition 1 shows the relationship between the retail prices under three modes. According to Proposition 1 (i), when the LSSC and the market size are both small, the retail price under mode C is the minimum and the retail price under mode B is the largest. If the market size is medium, the retail price under mode C is still the smallest, but under mode A, the retail price is the largest. If the market size is large, the retail price under mode k is still the highest, while that under mode B is the lowest.

Proposition 1 (ii) shows that when the LSSC is at a medium level, the relationship between retail prices in the three modes is only related to parameter a_2. Specifically, when the market size is less than a_2, the retail price in mode A is the highest, while that in mode C is the lowest. When the market size is larger than a_2, the retail price is still the highest under mode A, but lowest under mode B.

According to Proposition 1 (iii), the relationship of retail price under the three modes is only related to the LSSC. When this coefficient is large, the retail price under mode A is the largest, but smallest under mode C.

To sum up, it can be found that there are two thresholds for market size, a_1 and a_2. No matter how the LSSC changes, if the market size is larger than a_1, the retail price under mode A is the largest. If the market size is less than a_2, the retail price in mode C is the minimum. Only when consumers are very sensitive to logistics service, the relationship between retail prices under the three modes is not affected by market size.

Figure 2 depicts the conclusion of Proposition 1. Figure 2 clearly shows the influence of market size on retail price in three modes under different values of ($k = 5$, $s = 1$, $r = 0.05$, $c = 5$).With the expansion of the market size, the retail prices under the three modes gradually increase. In addition, the retail price under mode ($k = 5$, $s = 1$, $r = 0.05$, $c = 5$) is always higher than that under mode ($k = 5$, $s = 1$, $r = 0.05$, $c = 5$), and the change rate of retail price with respect to market size is almost the same under the two modes. However, when the market size is large, the retail price under mode ($k = 5$, $s = 1$, $r = 0.05$, $c = 5$) is significantly lower than that under mode ($k = 5$, $s = 1$, $r = 0.05$, $c = 5$) and ($k = 5$, $s = 1$, $r = 0.05$, $c = 5$). This also

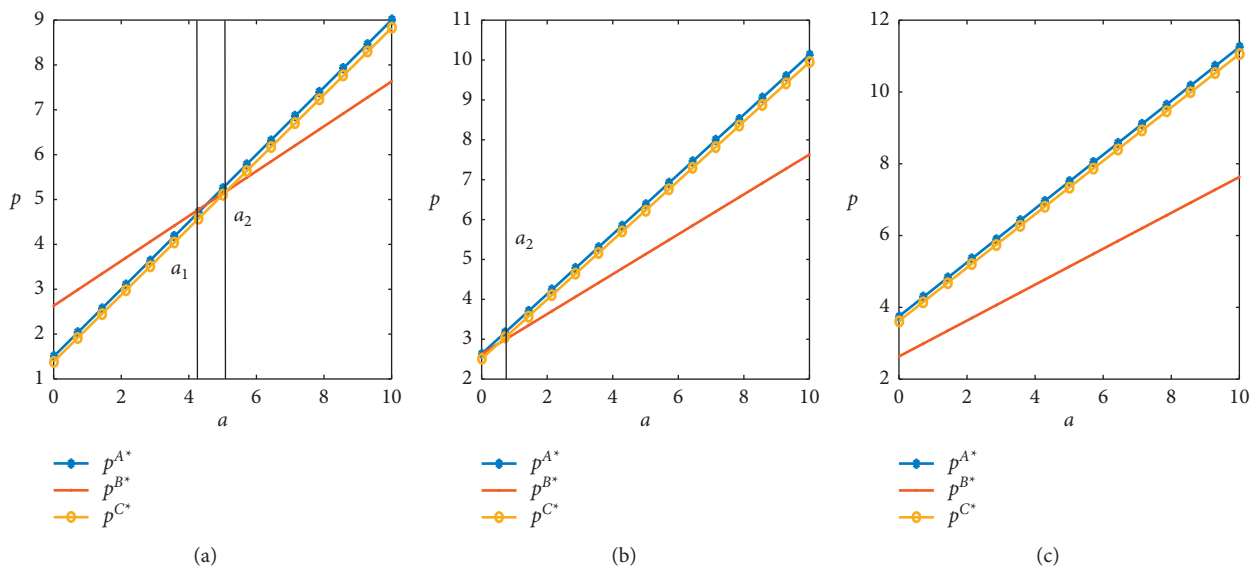

Figure 2: The effect of market size on retail price under different k conditions ($s = 1$, $r = 0.05$, $c = 5$). (a) $k < k_1$ ($k = 2$). (b) $k_1 < k < k_2$ ($k = 3.51$). (c) $k > k_2$ ($k = 4$).

indicates that when the product market size is large, mode ($k = 5$, $s = 1$, $r = 0.05$, $c = 5$) can bring more benefits to consumers.

Proposition 2. *The sales volume under the three modes satisfies the following relationship:*

If $a < a_3$, then $Q^{C*} > Q^{A*} > Q^{B*}$

If $a_3 < a < a_4$, then $Q^{C*} > Q^{B*} > Q^{A*}$

If $a > a_4$, then $Q^{B*} > Q^{C*} > Q^{A*}$

where $a_3 = 2c + ks - krs/1 - r$ and $a_4 = 2c - cr + ks - krs/(r - 1)^2$.

Proposition 2 presents the comparison results of sales volume under three modes. The results show that the relationship between the sales volume under the three modes is only related to the market size. Specifically, when the market size is small, the sales volume under mode ($k = 5, s = 1, r = 0.05, c = 5$) is the largest while that under mode ($k = 5, s = 1, r = 0.05, c = 5$) is the smallest. When the market size is at a medium level, the sales volume under mode ($k = 5, s = 1, r = 0.05, c = 5$) is still the largest, and the sales volume under mode ($k = 5, s = 1, r = 0.05, c = 5$) is the smallest. However, when the market size is large, the sales volume of mode ($k = 5, s = 1, r = 0.05, c = 5$) is the largest, while that of mode ($k = 5, s = 1, r = 0.05, c = 5$) is still the smallest. At this point, it can be found that the market size has a threshold of ($k = 5$, $s = 1$, $r = 0.05$, $c = 5$).When the market size is smaller than ($k = 5, s = 1, r = 0.05, c = 5$), the sales volume under mode ($k = 5$, $s = 1$, $r = 0.05$, $c = 5$) is the largest. When the market size is larger than ($k = 5, s = 1, r = 0.05, c = 5$), mode ($k = 5$, $s = 1$, $r = 0.05$, $c = 5$) has the highest sales volume. This also indicates that the sales volume under the agency method is greater than the sales volume under the resale method.

Figure 3 depicts the effect of market size on sales volume. Obviously, with the expansion of the market size, the sales volume of the products under the three modes gradually increases. When the market size is large, the sales volume under mode $a_9 = (2c - ks)(1 - r) + (c + ks - krs)\sqrt{2(1 - r)}/2r^2 - 3r + 1$ is significantly higher than that under mode $a_9 = (2c - ks)(1 - r) + (c + ks - krs)\sqrt{2(1 - r)}/2r^2 - 3r + 1$ and $a_9 = (2c - ks)(1 - r) + (c + ks - krs)\sqrt{2(1 - r)}/2r^2 - 3r + 1$. This is related to the lower retail price when the market size is larger under mode $a_9 = (2c - ks)(1 - r) + (c + ks - krs)\sqrt{2(1 - r)}/2r^2 - 3r + 1$.

Proposition 3. *The optimal logistics price of the platform meets the following relationship with relevant parameters:*

$$\begin{aligned} \frac{\partial l^{C*}}{\partial a} &> 0, \\ \frac{\partial l^{C*}}{\partial r} &< 0, \\ \frac{\partial l^{C*}}{\partial k} &> 0, \\ \frac{\partial l^{C*}}{\partial s} &> 0. \end{aligned} \tag{14}$$

Proposition 3 shows the influence of relevant parameters on the optimal logistics price of the platform. The results show that when the market size, LSSC, and logistics service level increase, the corresponding platform logistics service price will also increase. Interestingly, when the platform commission rate increases, the platform logistics service price will decrease. The underlying reason is that the platform wants to retain merchants and cannot increase the commission rate and logistics service price simultaneously.

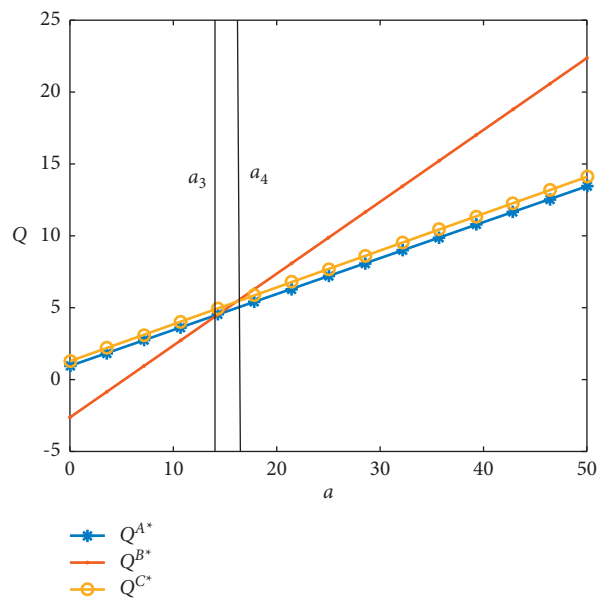

Figure 3: The impact of market size on sales volume ($k = 5$, $s = 1$, $r = 0.05$, $c = 5$).

Proposition 4. *Platform profit under three modes satisfy the relationship* $\pi_1^{B*} < \pi_1^{A*} < \pi_1^{C*}$.

Proposition 4 reveals the comparative results for the profit of platform under three modes. For the platform, mode B is the least profitable because the platform under this mode only has commission income. Platform revenue under mode A is at a medium level, while platform revenue under mode C is the largest. In mode C, the platform has not only the commission income but also the logistics service income, so the profit is the largest. In other words, the platform tends to allow merchants to set up shop on its platform, while merchants use the platform logistics.

Proposition 5. *The merchant's profit under three modes satisfies the following relationship:*

(i) When $k < k_5$,

If $0 < a < a_{10}$, *then* $\pi_2^{B*} > \pi_2^{A*} > \pi_2^{C*}$;

If $a_{10} < a < a_{12}$, *then* $\pi_2^{A*} > \pi_2^{B*} > \pi_2^{C*}$;

If $a_{11} < a < a_{12}$, *then* $\pi_2^{A*} > \pi_2^{C*} > \pi_2^{B*}$;

If $a_{11} < a < a_9$, *then* $\pi_2^{A*} > \pi_2^{B*} > \pi_2^{C*}$;

If $a > a_9$, *then* $\pi_2^{B*} > \pi_2^{A*} > \pi_2^{C*}$.

(ii) When $k_5 < k < k_6$,

If $0 < a < a_{12}$, *then* $\pi_2^{B*} > \pi_2^{A*} > \pi_2^{C*}$;

If $a_{12} < a < a_{11}$, *then* $\pi_2^{A*} > \pi_2^{C*} > \pi_2^{B*}$;

If $a_{11} < a < a_9$, *then* $\pi_2^{A*} > \pi_2^{B*} > \pi_2^{C*}$;

If $a > a_9$, *then* $\pi_2^{B*} > \pi_2^{A*} > \pi_2^{C*}$.

(iii) When $k > k_6$,

If $0 < a < a_{12}$, *then* $\pi_2^{A*} > \pi_2^{B*} > \pi_2^{C*}$;

If $a_{11} < a < a_9$, *then* $\pi_2^{A*} > \pi_2^{B*} > \pi_2^{C*}$;

If $a > a_9$, *then* $\pi_2^{B*} > \pi_2^{A*} > \pi_2^{C*}$.

where

$$
\begin{aligned}
k_5 &= \frac{(2r - 2 + \sqrt{2(1-r)})c}{(s - rs)(1 - \sqrt{2(1-r)})},\\
k_6 &= \frac{(2-r)c}{(1-r)s},\\
a_9 &= \frac{2c - 2cr + ks - krs + \sqrt{2}c\sqrt{1-r} + \sqrt{2}ks\sqrt{1-r} - \sqrt{2}krs\sqrt{1-r}}{2r^2 - 3r + 1},\\
a_{10} &= \frac{2cr - 2c - ks + krs + \sqrt{2}c\sqrt{1-r} + \sqrt{2}ks\sqrt{1-r} - \sqrt{2}krs\sqrt{1-r}}{2r^2 - 3r + 1},\\
a_{11} &= \frac{2c - cr + ks - krs}{r^2 - 2r + 1},\\
a_{12} &= \frac{2c - cr - ks + krs}{r^2 - 4r + 3}.
\end{aligned}
\tag{15}
$$

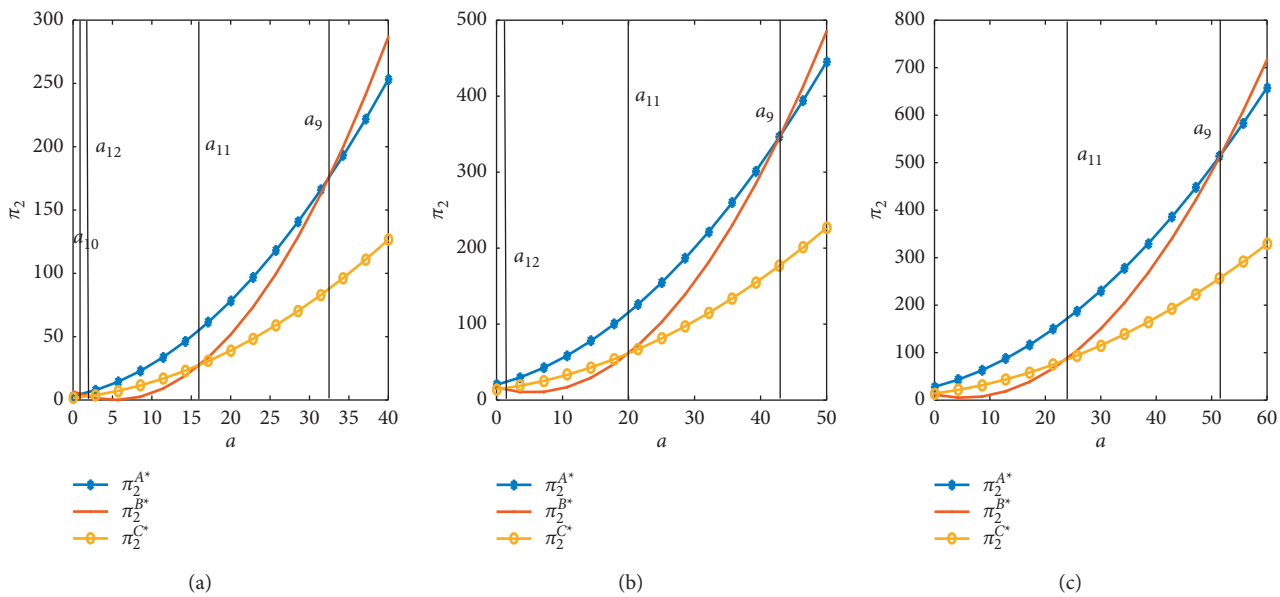

Figure 4: The influence of market size on merchants' profits under different k conditions $(s = 1, r = 0.05, c = 5)$. (a) $k < k_5\,(k = 7)$. (b) $k_5 < k < k_6\,(k = 9)$. (c) $k > k_2\,(k = 12)$.

Proposition 5 reveals the relationship between the merchant profits under the three modes. As can be seen from Proposition 5 (i), when the LSSC is small, with the increase of market size, the mode generating maximum merchant profit starts from $B \longrightarrow A \longrightarrow B$, while the mode generating minimum merchant profit starts from $C \longrightarrow B \longrightarrow C$. In other words, if consumers are not sensitive to logistics service, merchants prefer mode B when the market size is small or large. In most cases, the merchant has the smallest profit in mode C. Therefore, mode C is the merchant's most secondary choice.

Proposition 5 (ii) shows that when the LSSC is at a medium level, with the increase of the market size, the mode generating the largest merchant profit changes from A to B, while the mode generating the smallest merchant profit still changes from $C \longrightarrow B \longrightarrow C$. As can be seen from Proposition 5 (iii), when the LSSC is large, with the increase of market size, the mode that generates the largest merchant profit changes from A to B, and the mode that generates the smallest merchant profit changes from B to C.

To sum up, no matter how sensitive consumers are to logistics service and how the market size changes, merchants only generate maximum benefits in modes A and B. In some cases, merchants generate minimal revenue under mode B, but in most cases, merchants generate minimal revenue under mode C.Therefore, the optimal mode for the merchant is A or B.

Figure 4 depicts the impact of market size on merchants' profits under different values of k. Obviously, with the increase of market size, the merchant's profit in the three modes gradually increases, and the growth rate also increases gradually. In addition, when k is small, the merchant's profit in mode B reaches the maximum under a small market size. However, when k is large, the merchant can obtain the optimal profit under mode B only when the market size is large. This indicates that no matter how the sensitivity coefficient of logistics service changes, when the market size is large, merchants prefer mode B.

6. Best Mode Analysis

According to the above analysis, if the platform or the merchant has absolute power to completely decide operating mode, then the platform will choose mode C, i.e., agency + platform logistics mode, while the merchant will choose mode A or B, i.e., resale mode or agency + no-platform logistics mode.

However, in practice, it is more common for platforms and merchants to have no absolute power. They cannot decide the sales method and logistics service strategy at the same time. The following paper considers the dynamic game between the platform and the merchant and analyzes it in two cases. Considering that online shopping consumers are sensitive to logistics service and the online sales market size increases year by year [24–29], only $k > k_6$ and $a > a_9$ are analysed here. This time there is $\pi_2^{B*} > \pi_2^{A*} > \pi_2^{C*}$.

6.1. The Platform Decides the Sales Method and the Merchant Decides the Logistics Service Strategy. If the platform first determines the sales method, then the merchant determines the logistics service strategy; the game structure is shown in Figure 5(a). According to the backward induction method, the merchant's decision is considered first. Because $\pi_2^{B*} > \pi_2^{C*}$, the merchant will choose not to use platform logistics. For the platform, $\pi_1^{A*} > \pi_1^{B*}$, so the platform will choose the resale method, i.e., the best is mode A.

If the merchant first decides the logistics service strategy, then the platform decides the sales method; the game structure is shown in Figure 5(b). According to the backward

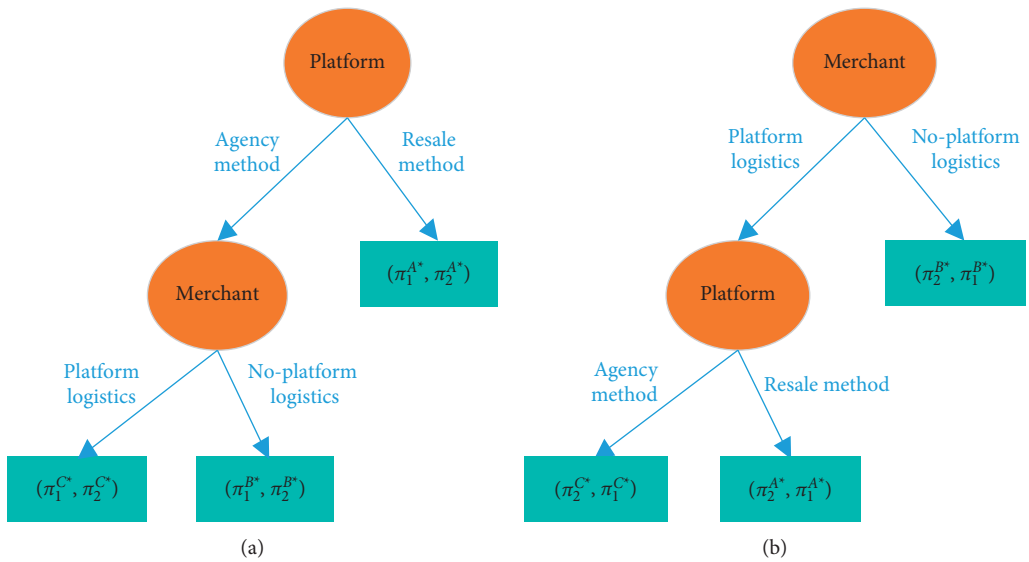

Figure 5: The game structure in which the platform decides the sales method and the merchant decides the logistics service strategy.

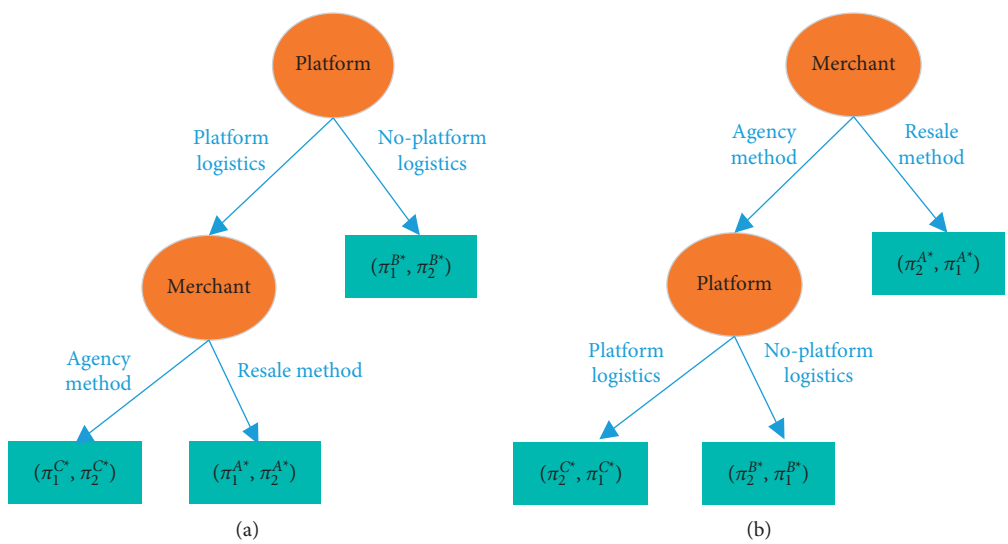

Figure 6: The game structure in which the platform decides the logistics service strategy and the merchant decides the sales method.

induction method, the platform decision is considered first. Because $\pi_1^{C*} > \pi_1^{A*}$, the platform chooses the resale method. For the merchant, $\pi_2^{B*} > \pi_2^{C*}$, so they will choose not to use platform logistics. Therefore, the best is the mode B.

6.2. The Platform Decides the Logistics Service Strategy and the Merchant Decides the Sales Method. If the platform first determines the logistics service strategy, then the merchant determines the sales method; the game structure is shown in Figure 6(a). According to the backward induction method, the merchant's decision is considered first. Because $\pi_2^{A*} > \pi_2^{C*}$, the merchant will choose the resale method. For the platform, $\pi_1^{A*} > \pi_1^{B*}$, so the platform will let the merchant use the platform logistics. Therefore, the best is mode A.

If the merchant first determines the sales method, then the platform logistics service strategy; the game structure is shown in Figure 6(b). According to the backward induction method, the platform decision is considered first. Because $\pi_1^{C*} > \pi_1^{B*}$, the platform will let the merchant use the platform logistics. For the merchant, $\pi_2^{A*} > \pi_2^{C*}$, so the merchant will choose the resale method. Therefore, the best is mode A.

7. Conclusion

7.1. Summary of Findings. In the era of e-commerce, platforms and merchants are faced with the question of which sales methods to use and whether to use platform logistics. Based on this, we propose three operating modes, namely, mode A, B, and C. This paper constructs an analytical

framework that includes an e-commerce platform and a merchant and mainly discusses the optimal operating mode for the firms under different power structures.

Our main findings have three aspects. First, we compare the retailer price and sales volume of the products under the three modes. The results show that the retail price is closely related to market size and the LSSC. Specifically, except when the LSSC and market size are small, the retail price is the highest under the mode B; in other cases, the retail price is the largest under the mode A. In addition, only when the LSSC is small and the market size is large, the retail price is the lowest under the mode B. In other cases, mode C generates the lowest retail price. Interestingly, the relationship between product sales volume under the three modes is only related to market size. When the market size is sufficiently large, the sales volume in mode B is the largest, but smallest in the mode A.

Second, by comparing the profit of the platform and the merchant under the three modes, it is found that, in the B mode, the platform profit is the smallest. However, in mode C, the platform has the highest profit. For the merchant, the relationship of revenue in the three modes is closely related to LSSC and market size. When the LSSC and the market size are both large, the profit of the merchant under mode B is the largest while the smallest under mode C.

Finally, we determine the best mode according to the strategic interaction between the platform and the merchant on the sales method and the logistics service strategy under different power structures. When the platform has absolute power, the C mode is the best for it. When the LSSC and market size are both large, the B mode is the best for the merchant if it has absolute power. In addition, if neither of them has absolute power, we find that only when the merchant first decides whether to use platform logistics, then the platform decides which sales method to use; the best mode for them is mode B; otherwise, the best mode is mode A.

7.2. Managerial Implications. Based on the conclusions of this paper, we further propose the following management implications, which will help to develop action plans for different stakeholders and participants.

For merchants, if they are in a dominant position in the supply chain, they can use the agency method and do not use platform logistics. For the platforms, if they are in a dominant position, they should make the merchant use the agent sales method and force the merchant to use the platform logistics. If neither of them has absolute power, they can only decide part of the sales and logistics service methods. If the merchant can first choose whether to use platform logistics, then the platform determines the sales method; the best decision for the platform and the merchant is to choose the agency method, but not to use the platform logistics. Otherwise, they should choose the resale method.

7.3. Future Studies. In practice, many merchants have used both agency and resale methods to sell products on the e-commerce platform. How does using both modes to sell products on the same platform affect the merchant and the platform? When using both models, does the platform have an incentive to share its logistics resources? The research on these questions will get very interesting conclusions, which is worth further exploration.

Appendix

Proof of Lemma 1. From $\partial\pi_1^A/\partial p^2 = -2 < 0$, we know that π_1^A is concave in p. Let $\partial\pi_1^A/\partial p = 0$; we get the response function of the platform $p(w) = a + w + ks/2$. Substituting $g_3(a) = (2r-1)a^2 + (4c - 4cr + 2ks)a + (2c^2r - 2c^2 + k^2s^2)$ into π_2^A, we obtain $\partial^2\pi_2^A/\partial w^2 = -1 < 0$ and know that π_2^A is concave in $g_3(a) = (2r-1)a^2 + (4c - 4cr + 2ks)a + (2c^2r - 2c^2 + k^2s^2)$. Let $\partial\pi_2^A/\partial w = 0$; we get the optimal wholesale price $w^{A*} = a + ks/2$. Thus, we obtain $p^{A*}, \pi_1^{B*}, \pi_2^{B*}$. □

Proof of Lemma 2. From $\partial^2\pi_2^B/\partial p^2 = 2(r-1) < 0$, we know that π_2^B is concave in p. Let $\partial\pi_2^B/\partial p = 0$, we obtain the optimal retail price $p^{B*} = a + c - ar/2(1-r)$. So, we get π_1^{B*}, π_2^{B*}. □

Proof of Lemma 3. From $\partial^2\pi_2^C/\partial p^2 = 2(r-1) < 0$, we know that π_2^C is concave in p. Let $\partial\pi_2^C/\partial p = 0$; we get the response function of the merchant $p(l) = a + w + ks/2$. Substituting $g_3(a) = (2r-1)a^2 + (4c - 4cr + 2ks)a + (2c^2r - 2c^2 + k^2s^2)$ into π_1^C, we obtain $\partial^2\pi_1^C/\partial l^2 = r - 2/2(r-1)^2 < 0$ and know that π_1^C is concave in l. Let $\partial\pi_1^C/\partial l = 0$; we get the optimal wholesale price:

$$l^{C*} = \frac{a - 2ar + ks + ar^2 + kr^2s - 2krs}{2-r}. \tag{16}$$

Thus, we obtain $p^{C*}, \pi_1^{C*}, \pi_2^{C*}$. □

Proof of Proposition 1

(i) We first compare p^{A*} and p^{B*}.

From $p^{A*} - p^{B*} = 2c - a + ar - 3ks + 3krs/4(r-1) = 0$, we get $a_1 = 2c - 3ks + 3krs/1 - r$. If $k > 2c/3s(1-r) = k_1$, then $a_1 < 0$; thus, we can yield that $p^{A*} > p^{B*}$ is always satisfied.

When $k < k_1$, if $a > a_1$, then $p^{A*} > p^{B*}$, vice versa.

(ii) We next compare p^{C*} and p^{B*}. From $p^{A*} - p^{B*} = 2c - a + ar - 3ks + 3krs/4(r-1) = 0$ $p^{B*} - p^{C*} = a - 2c - 2ar + cr + 3ks + ar^2 + 2kr^2s - 5krs/2(2-r)(r-1) = 0$, we get $a_2 = c(2-r) + ks(5r - 2r^2 - 3)/(r-1)^2$. If $k > c(2-r)/s(2r-3)(r-1) = k_2$, then $a_2 < 0$; we can yield that $p^{B*} < p^{C*}$ is always satisfied. When $k < k_2$, if $a > a_2$, then $p^{B*} < p^{C*}$, vice versa.

(iii) We finally compare p^{A*} and p^{C*}.

From $p^{A*} - p^{C*} = r(a + ks)/4(2-r) > 0$, we know $p^{A*} > p^{C*}$.

As $k_1 - k_2 = cr/3s(1-r)(2r-3) < 0$, we obtain $k_1 < k_2$.

If $k < k_1$, both a_1 and a_2 are greater than zero. Since $a_1 - a_2 = -r(c - ks + krs)/(r-1)^2$ and $k_1 < c/s(1-r)$, we can yield $a_1 < a_2$.

To summarize, we derive the results shown in Proposition 1. □

Proof of Proposition 2

(i) We first compare Q^{A*} and Q^{B*}.

From $Q^{A*} - Q^{B*} = 2c - a + ar + ks - krs/4(1-r) = 0$, we get $a_3 = 2c + ks - krs/1 - r$. If $a > a_3$, then $Q^{A*} < Q^{B*}$, vice versa.

(ii) We next compare Q^{B*} and Q^{C*}.

From $Q^{B*} - Q^{C*} = a - 2c - 2ar + cr - ks + ar^2 + krs/2(r-2)(r-1) = 0$, we get $a_4 = 2c - cr + ks - krs/(r-1)^2$. If $a > a_4$, then $Q^{B*} > Q^{C*}$, vice versa.

(iii) We finally compare Q^{A*} and Q^{C*}.

From $Q^{A*} - Q^{C*} = r(a + ks)/4(r-2) < 0$, we know $Q^{A*} < Q^{C*}$.

Since $a_3 - a_4 = r(c + ks - krs)/-(1-r)^2 < 0$, thus $a_3 < a_4$.

To summarize, we derive the results shown in Proposition 2. □

Proof of Proposition 3

$$\begin{aligned}
\frac{\partial l^{C*}}{\partial a} &= \frac{(r-1)^2}{2-r} > 0,\\
\frac{\partial l^{C*}}{\partial r} &= \frac{(1-r)(r-3)(a+ks)}{(r-2)^2} < 0,\\
\frac{\partial l^{C*}}{\partial k} &= \frac{(1-r)^2 s}{2-r} > 0,\\
\frac{\partial l^{C*}}{\partial s} &= \frac{(1-r)^2 k}{2-r} > 0.
\end{aligned} \tag{17}$$

□

Proof of Proposition 4

(i) We first compare π_1^{A*} and π_1^{B*}.

$\pi_1^{A*} - \pi_1^{B*} = g_1(a)/-16(r-1)^2$, where $g_1(a) = (4r-1)(r-1)^2 a^2 + 2ks(r-1)^2 a - k^2 s^2 (r-1)^2 - 4c^2 r$.

Thus, $g_1(a)$ is a quadratic function with respect to a and its opening is upward. The discriminant of $g_1(a)$ with respect to the heel is $\Delta_1 = 16r(r-1)^2(4c^2 r - c^2 + k^2 r^2 s^2 - 2k^2 r s^2 + k^2 s^2)$. Let $k_3 = c\sqrt{1-4r}/s(1-r)$; if $k < k_3$, then $\Delta_1 < 0$; we can infer that $g_1(a) < 0$ is always satisfied. Thus, we obtain $\pi_1^{A*} > \pi_1^{B*}$.

If $k > k_3$, then $\Delta_1 > 0$. Thus, we get that the two real roots of $g_1(a) = 0$ are

$$\begin{aligned}
a_5 &= \frac{-ks + krs + 2\sqrt{r\left(4c^2 r - c^2 + k^2 r^2 s^2 - 2k^2 r s^2 + k^2 s^2\right)}}{4r^2 - 5r + 1},\\
a_6 &= \frac{-ks + krs - 2\sqrt{r\left(4c^2 r - c^2 + k^2 r^2 s^2 - 2k^2 r s^2 + k^2 s^2\right)}}{4r^2 - 5r + 1}.
\end{aligned} \tag{18}$$

Obviously, $a_6 < 0$. Since $g_1(0) = -k^2 s^2 (r-1)^2 - 4c^2 r < 0$, we know $a_5 < 0$. So, if $a > 0$, then $g_1(a) < 0$. To sum up, $\pi_1^{A*} > \pi_1^{B*}$.

(ii) We next compare π_1^{C*} and π_1^{B*}.

$\pi_1^{B*} - \pi_1^{C*} = g_2(a)/4(r-2)(r-1)^2$, where $g_2(a) = (r-1)^4 a^2 + 2ks(r-1)^2 a + k^2 s^2 (r-1)^2 + c^2 r(2-r)$. Thus, $g_1(a)$ is a quadratic function with respect to a, and its opening is upward. The discriminant of $g_1(a)$ with respect to the heel is $\Delta_2 = 4r(r-1)^4(r-2)(c-ks)(c+ks)$.

Let $k_4 = c/s$; if $k < k_4$, then $\Delta_2 < 0$; we can infer that $g_2(a) > 0$ is always satisfied. Thus, we obtain $\pi_1^{B*} < \pi_1^{C*}$.

If $k > k_4$, then $\Delta_2 > 0$. Thus, we get that the two real roots of $g_2(a) = 0$ are

$$\begin{aligned}
a_7 &= \frac{\sqrt{r(r-2)(c+ks)(c-ks)} - ks}{r^2 - 2r + 1},\\
a_8 &= \frac{-\sqrt{r(r-2)(c+ks)(c-ks)} - ks}{r^2 - 2r + 1}.
\end{aligned} \tag{19}$$

Obviously, $a_8 < 0$. Since $g_2(0) = k^2 s^2 (r-1)^2 + c^2 r(2-r) > 0$, we know $a_7 < 0$. So, if $a > 0$, then $g_2(a) > 0$. To sum up, $\pi_1^{B*} < \pi_1^{C*}$.

(iii) We finally compare π_1^{A*} and π_1^{A*}.

From $\pi_1^{A*} - \pi_1^{C*} = (a + ks)^2 (r+2)/16(r-2) < 0$, we know $\pi_1^{A*} < \pi_1^{C*}$.

To summarize, we derive the results shown in Proposition 4. □

Proof of Proposition 5

(i) We first compare π_2^{A*} and π_2^{B*}.

$$\pi_2^{A*} - \pi_2^{B*} = \frac{g_3(a)}{8(r-1)}, \tag{20}$$

where $g_3(a) = (2r^2 - 3r + 1)a^2 + (4cr - 4c - 2ks + 2krs)a + 2c^2 - k^2 s^2 + k^2 r s^2$.

Thus, $g_3(a)$ is a quadratic function with respect to a, and its opening is upward. The discriminant of $g_3(a)$ with respect to the heel is $\Delta_3 = 8(1-r)(c + ks - krs)^2 > 0$. So, we get that the two real roots of $g_3(a) = 0$ are

$$a_9 = \frac{2c - 2cr + ks - krs + (c + ks - ksr)\sqrt{2(1-r)}}{2r^2 - 3r + 1},$$

$$a_{10} = \frac{2c - 2cr + ks - krs - (c + ks - ksr)\sqrt{2(1-r)}}{2r^2 - 3r + 1}. \tag{21}$$

Obviously, $a_9 > 0$. Let $k_5 = (2r - 2 + \sqrt{2(1-r)})c/(s - rs)(1 - \sqrt{2(1-r)})$, and if $k > k_5$, then $a_{10} < 0$. Thus, if $0 < a < a_9$, then $g_3(a) < 0 \Longrightarrow \pi_2^{A*} > \pi_2^{B*}$; if $a > a_9$, then $g_3(a) > 0 \Longrightarrow \pi_2^{A*} < \pi_2^{B*}$.

If $k < k_5$, then $a_{10} > 0$. Thus if $0 < a < a_{10}$ or $a > a_9$, then $g_3(a) > 0 \Longrightarrow \pi_2^{A*} < \pi_2^{B*}$; if $a_{10} < a < a_9$, then $g_3(a) < 0 \Longrightarrow \pi_2^{A*} > \pi_2^{B*}$.

(ii) We next compare π_2^{C*} and π_2^{B*}:

$$\pi_2^{B*} - \pi_2^{C*} = \frac{g_4(a)}{4(r-2)^2(1-r)}, \tag{22}$$

where $g_4(a) = [(r^2 - 2r + 1)a + (cr - 2c - ks + krs)][(r^2 - 4r + 3)a + (cr - 2c + ks - krs)]$the two real roots of $g_4(a) = 0$ are

$$a_{11} = \frac{2c - cr + ks - krs}{r^2 - 2r + 1},$$

$$a_{12} = \frac{2c - cr - ks + krs}{r^2 - 4r + 3}. \tag{23}$$

Let $k_6 = (2 - r)c/(1 - r)s$, and if $k > k_6$, then $a_{12} < 0$. Thus, if $0 < a < a_{11}$, then $g_4(a) < 0 \Longrightarrow \pi_2^{B*} < \pi_2^{C*}$; if $a > a_{11}$, then $g_4(a) < 0 \Longrightarrow \pi_2^{B*} < \pi_2^{C*}$.

If $k < k_6$, then $a_{12} > 0$. Thus, if $0 < a < a_{12}$ and $a > a_{11}$, then $g_4(a) > 0 \Longrightarrow \pi_2^{B*} > \pi_2^{C*}$; if

$$a_{12} < a < a_{11}, \text{then, } g_4(a) < 0 \Longrightarrow \pi_2^{B*} < \pi_2^{C*}. \tag{24}$$

(iii) We finally compare π_2^{A*} and π_2^{C*}.

From $\pi_2^{A*} - \pi_2^{C*} = (a + ks)^2(r^2 - 2r + 2)/8(r - 2)^2 > 0$, we know $\pi_2^{A*} > \pi_2^{C*}$. $k_5 - k_6 = \sqrt{2}c/2sf(r)$, where $f(r) = (r - 3)\sqrt{2(1-r)} - 3r + 4/(\sqrt{2}/2 - \sqrt{1-r})(1-r)$. We can infer that $f(r) < 0$ by numerical simulation, i.e., $k_5 < k_6$. We can infer $a_9 > a_{11} > a_{12} > a_{10}$ by the similar method.

To summarize, we derive the results shown in Proposition 5. □

Data Availability

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

Conflicts of Interest

The authors declare no conflicts of interest.

Acknowledgments

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