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Research on Logistics Cooperation Strategy of the Retailer and the Platform Based on Paid Membership System

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Abstract: E-commerce platforms have widely embraced the paid membership system as a sustainable and effective customer management method to increase repurchase rates and offer value-added services to loyal consumers. As a common means of member benefits and a crucial link for interaction with direct consumers, logistics service is related to the platform's sustainable operation. In this context, this paper studies retailers' and e-commerce platforms' cooperation strategies regarding logistics services under paid membership systems, and analyzes the impact of paid membership system on optimal outcomes. The results indicate that, in the case of the basic-service contract, sales profits decrease but membership fees increase as membership service quality increases. In accordance with the terms of the full-service contract, the platform would lower the commission fee and membership fee as the membership service quality improves. The retailer and the platform tend to sign basic-service contracts when the third-party logistics fee is low-cost, since there is a win–win interval. We also extend the logistics plan to include self-delivery and switch to centralized decision making, and we find that the basic-service contract's win–win interval persisted. Our results reveal the fundamental connection between paid membership systems and logistics cooperation strategy, serving as a theoretical guide for the decision makers.

Keywords: paid membership system; cooperation strategy; logistics service sharing; e-commerce platform

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1. Introduction

The rapid rise in omnichannel retailing in recent years has further contributed to the growth of the consumption experience and revenue of e-commerce platforms. Amazon served as the biggest internet retailer in the US; its net sales reached USD 524 billion in 2022 [1]. Most of online shopping platforms' revenue is derived from advertising revenue and membership fees [2]. Amazon launched its Prime membership service in 2005. In 2022, Amazon's subscription service revenue exceeded USD 35 billion [3]. With the improvement of income levels and the upgrading of consumption, consumers are more lined up to pay the annual membership fee so as to access premium services. Once a consumer pays the membership fee, due to the existence of the sunk cost effect [4,5], it means that the consumer will make at least one purchase during the membership period. And now, the majority of e-commerce platforms have a premium membership structure in place, such as Tmall and Sam's Club. The e-commerce platform's membership system connects various services, including free shipping, preferential after-sales service on this platform, and VIP service on some video websites and music platforms (e.g., JD, Tmall), and it brings in a large stream of consumers and a constant income for the membership period [6]. Alibaba launched its 88VIP card in 2018. According to statistics data from Tmall, the category numbers of 88VIP members are six times those of ordinary consumers, and members' consumption has grown by over 40% compared to the previous year in the Tmall double 11 [7].

The continuous and constant consumption of members undoubtedly is greatly attractive for e-commerce platforms. Recruiting new retailers and improving service quality are key to improving the retention rate of members [8,9]. To carry out full-service cooperation with the retailer, platforms provide one-stop logistics services to ensure the timeliness of product distribution. Amazon launched Amazon logistics services Fulfillment By Amazon (FBA) and Fulfilment By Merchant (FBM) for retailers. The retailers joining the FBA service can integrate their goods into Amazon's logistics system and enjoy services such as arrival of goods every other day and exclusive customer service to optimize the logistics costs [10]. Based on the user volume of the platform, the new entrant could easily start their retail business. However, they need to meet certain inventory, packaging, and quality conditions to join the FBA. For retailers, they can obtain flow support and save storage or distribution costs based on FBA, but they may lose the control of commodity distribution. Through FBM, retailers deliver goods to consumers by themselves, and Amazon only provides a sales marketplace [11]. If self-delivery is adopted, retailers can fully control all details of the goods from delivery to receipt, but timeliness may not be guaranteed.

Under this circumstance, if retailers need to sell products on the e-commerce platform, they need to consider their own capital, the product type, the cooperation cost, and the service quality of the platform, and choose a cooperation mode. For e-commerce platforms, signing different cooperation contracts with retailers means different operating costs, and they also need to consider their own profits. It is ambiguous which cooperation mode is better for retailers when faced with a platform which has a certain number of paying members.

This study aims to explore the following questions:

(1) Whether to cooperate with the e-commerce platform in logistics services?
(2) How does membership service affect the decision of the platform and the retailer?
(3) For the whole market, what would be a balanced cooperation strategy with a win–win outcome?

To analyze the above questions, this study develops an analytical model including one e-commerce platform, one retailer, and one third-party logistics service (TPLS) provider. The e-commerce platform offers marketplace and logistics services to the retailer, and the retailer sells products on the platform. The e-commerce platform implements a paid membership system, and consumers can choose whether to join members based on their consumption habits, including purchase frequency, brand preference, etc. Under the existing cooperation system, the retailer needs to consider the cooperation mode with the platform: (1) basic-service contract: the platform only serves as a marketplace, and the retailer finds logistics service providers by himself to distribute the products; (2) full-service contract: the retailer sells products on the platform and relies on the platform's logistics system. The platform is in charge of all the distribution, from wrapping to last-mile delivery. We first assume that the retailer and platform choose one of the contracts and then discover the optimal decision. Secondly, we consider the impact of a paid membership system on the optimal decision. Furthermore, we analyze whether there is a balanced strategy that enables the platform and the retailer to obtain a win–win result. Finally, we extend the retailer's logistics strategy to self-delivery and centralized decision, then discuss the win–win outcome and compare the optimal results.

Compared with the prior research, this paper discusses the cooperation contract selection mechanism for the platform and retailer based on a paid membership system. We study how the retailer chooses the optimal cooperation contract, especially when the platform implements a paid membership system. We noticed that Niu et al. [12] and Qin et al. [13] studied the different choices of logistics cooperation models between retailers and e-commerce platforms, but they did not take the consumer membership system into account. A paid membership system is one of the most efficient strategies to guarantee the platform's constant operation. Moreover, the platform affects the retailer's choice through the paid membership system, including the number of members and the service quality.

Our findings are summarized as follows. First, we develop a game model to analyze the logistics strategies of retailers and platforms based on a paid membership system. We indicate that when the retailer signs the basic-service contract, with the improvement of the membership service quality, the sales profit of the products and the commission fee decrease, but the membership fee increases. When the retailer signs the full-service contract, the single logistics fee and membership fee fall as the quality of service improves. The consumer type has the same effect on the retailer and the platform's optimal decision. Under two cooperation contracts, the percentage of high-demand consumers results in an increase in the membership fee and commission fee. Under the basic-service contract, the type of consumer has no bearing on the sales price.

Second, the basic-service contract results in win–win results for both parties. When there is a low TPLS fee, both the retailer and the platform prefer to simply cooperate with each other. When the TPLS fee is rather high, the platform always chooses the basic-service contract, but the retailer favors the full-service contract. Third, if the retailer chooses self-delivery, when the membership service quality of the platform is in the middle range, the basic-service contract benefits both sides.

The structure of this paper is organized as follows: Section 2 is a brief literature review. Section 3 introduces the model's structure. Section 4 provides the optimal results and describes the analysis. Section 5 details the win–win situation. The win–win situation is extended to the case with self-delivery and a centralized decision in Section 6. The summary and directions for future studies are provided in Section 7. Proofs are presented in Appendix A.

2. Literature Review

For the research on the impact of the membership service, this paper has two relevant research streams: the first is to discuss the impact of price discrimination on supply chain members; the second stream deals with the relationship between the platform and other supply chain members.

Membership pricing systems, as a manifestation of price discrimination [14] on video websites [15], has been studied extensively for e-commerce platforms [16,17] and other consumer entertainment channels. Price discrimination increases consumer engagement and thus stimulates consumption [18]. It is especially true that paid membership is an effective mechanism to bring in a constant sales revenue for sellers [17] and to increase the degree of customer loyalty [19]. Moreover, it can help to distinguish the different types of consumers through membership price, so as to provide the best-matching commodity and service for different consumers. It is also a known method of precision marketing [15].

At present, the related studies on price discrimination in retailing mainly discuss the effects of different price discrimination strategies on supply chain members. Zhang et al. [20] compared the choices between a long-term strategy and a short-term strategy and between a uniform pricing strategy and a discriminatory pricing strategy in the bilateral market. They found that discriminatory pricing is more conducive to the platform, but it has an adverse impact on consumer utility and social welfare. Tang et al. [21] examined the optimal pricing strategy between pricing discrimination and quality differentiation. Based on the research of enterprises in large-scale advertising and price decision making, Esteves et al. [22] suggested that targeted advertising of price discrimination could improve the profits of enterprises, and the total social welfare would be better, but the impact on consumers is controversial. Many price discrimination strategies have been introduced in previous research. Kung et al. [23] discussed that warehouse clubs compete with the physical retail market by using three strategies: membership-based pricing, transaction-based pricing, and cross-subsidization. They showed that, when there is no discount factor and the order frequency of consumers is less price-sensitive, the three discriminatory pricing strategies are equivalent, while for impatient platforms and price-sensitive consumers, the membership-based pricing strategy is better. Leng et al. [24] examined the impact of discriminatory pricing strategies based on joint pricing and contingent free-shipping on consumers' purchasing behavior in a duopoly market; contingent free-shipping is more effective for consumers with high demand for the orders. Discriminatory pricing based on the number of transactions and transaction costs is more common in financial markets [25]. Wang et al. [26] studied the application of a price discrimination strategy based on a minimum sales quota in crowdfunding projects. Dan et al. [27], based on the green preferences of consumers, discussed different price discrimination strategies. Tan et al. [14] demonstrated two shipping policies and found that, if faster shipping is employed, membership fee shipping leads to a higher profit for e-retailers. We follow this stream to discuss the impact of threshold-based membership pricing on consumers and supply chain members based on the different demands of consumers.

The second stream of literature involves the impact of the platform's relationships with other supply chain members on decision making [28–30]. The development of the sharing economy has stimulated the emergence of sharing platforms [31], which is an important channel to connect consumers with suppliers. When a sharing platform first emerges, sellers may choose to enter the product market offered by the platform's owner [32]. With the expansion of platform capital and market power, the platform is not satisfied with only serving as an intermediary marketplace, but also wants to expand product sales to carve up the market [33], which makes the cooperative relationship gradually change into a competitive relationship [34,35], as well as an encroachment [36]. The competition–cooperation relationship is more common in the process of change [37,38], which means cooperation in common interests and competition in private interests [39]. Even competing stores collaborate with each other on returns [40] and recycling [41]. Furthermore, after comparing competition and cooperation, both market participants need to consider the competitive intensity and the depth of cooperation. Chen et al. [37] established an analytical model to discuss the impacts of competitive and cooperative intensity on the optimal strategies of enterprises in the market.

The relationship between the platform and other supply chain members affects the platform's decision on whether to provide shared services [42]. Those manufacturers with large market power and sufficient funds can choose their way to participate in the market competition, i.e., choose to build their own sharing platform or join a third-party sharing platform. Zhang et al. [43] started from consumers' purchases and lease choices between two periods, and showed that when the consumer's inconvenience cost is small and marginal cost is significant, the manufacturer chooses to build its own lease platform. In addition, the selection of the sharing model is also influenced by the proportion of consumers leasing the manufacturer's products. As the proportion rises, the manufacturer tends to join the sharing lease platform. Compared with the previous agent model, self-built sharing platforms can sell products to consumers directly and increase the methods of participating in the market competition [13]. He et al. [44] considered logistics resource sharing between competing companies. Furthermore, the platform could influence the decisions of other members whose market power is relatively weak. Niu et al. [45] studied the strategy of retailers joining the logistics sharing alliance based on promised delivery time from the perspective of the retailers. Niu et al. [12] also explored profitability and sustainability from the perspectives of retailers to study the strategic choices of restaurant delivery services between self-logistics and platform logistics. They found that, when market potential is low, platform logistics is a more favorable option for the retailer, and in their study, the retailer was a restaurant. We obtained different results from the perspective of the single logistics fee and membership service quality. When the logistics fee is higher, platform logistics are better than third-party logistics. When considering the membership service quality, it may be better to choose self-delivery logistics when the single logistics fee is small. Qin et al. [13] studied the strategic choices of whether two parties provide shared services and whether to join the shared services from both platform and retailer perspectives.

Differently from their works, this study focuses on the cooperative relationship between the sharing platform and the retailer and explores the optimal decision among the different cooperation contracts. For the platform, this is when to provide sharing logistics services. For the retailer, this is whether to adopt the platform's sharing logistics. In summary, the differences between our paper and closely related studies are presented in Table 1.

Table 1. Comparison between this study and closely related studies.

	Niu et al. [12]	Qin et al. [13]	Choi et al. [46]	Kung et al. [23]	This Study
E-commerce platform with logistic service	√	√	√	×	√
Cooperative relationship	√	√	√	√	√
Membership mechanism	×	×	×	√	√

3. Model

3.1. Model Framework

Problem description. The supply chain consists of one retailer, one e-commerce platform, and one third-party logistics service (TPLS) provider. We analyzed the consumers' membership choice and the cooperative relationship between the retailer and e-commerce platform and evaluated their cooperative strategies based on consumers' utility and their profits.

For the retailer, there are two cooperation contracts with different cooperation depths:

(1) Basic-service contract: The platform only provides a marketplace [47–49], which means the retailer sells products on the platform by paying a commission fee. The platform is only used as an intermediary between the retailer and consumers. A TPLS needs to be selected that is in charge of picking up, packaging, and terminal distribution.

(2) Full-service contract: The platform not only serves as an intermediary, but also provides one-stop logistics services, including picking up, packaging, and terminal distribution, for an online retailer. And the retailer is also required to pay a commission fee.

For consumers, we assume that the platform provides a paid membership system for logistics services. If consumers become members of the platform, they are required to pay a membership fee in advance. During the membership period, they can purchase products on the platform and enjoy free distribution of logistics services and other additional benefits. If consumers do not join the platform's membership system, they can also purchase goods from retailers on the platform, but they have to pay a certain logistics fee each time they make a purchase. These membership systems have been widely adopted in practice, such as Amazon Prime and JD Plus. JD Plus members receive free shipping coupons every month, and Amazon Prime members can enjoy free shipping and two-day delivery services for most products. In addition, we assume that the content of the two contracts and the approximate range of commissions are used as public information before the decision is made, and the specific commission amount needs to be determined by the platform. Amazon charges sellers 8–15% commission depending on the category of goods, while JD's commission is between 2% and 10%.

Demand. Consumers have different purchase frequencies for commodities. Referring to the setting of the classification on consumers' demand in Tan et al. [14], Dan et al. [27], and Sun et al. [50], and considering the heterogeneity of consumer demand, we divide consumers into high-demand consumers h and low-demand consumers l. More specifically, for ease of calculation, we assume that the high-demand consumer purchases two units at a proportion of α in the membership period, and the low-demand consumer consumes one unit at a ratio of 1-α in a membership period. This can also be regarded as the demand of high-demand consumers being two times that of low-demand consumers (The authors also calculated that when the high-demand consumers purchase n units, low-demand consumers purchase one unit. It was found that most of the propositions of this study still hold; thus, for the sake of calculation simplicity, we assume two times).

The total marker demand is normalized to 1. The perceived value of a unit of goods is $v \sim U$ [0,1]. For the consumer with high demand, if he/she becomes a member of the platform, the membership service utility of purchasing goods on the platform within the membership period is $U_m^h = 2v - 2p_0 - d$. Otherwise, the service utility within the same period is $U_n^h = 2\theta v - 2p_0 - 2s$. The notations are shown in Table 2.

Table 2. Summary of symbols.

Symbol	Descriptions
Index	
$i = 1, 2$	1 for the basic service and 2 for the full service
$j = r, p$	r for the retailer, p for the platform
Variable	
$v \sim U\,[0,1]$	Consumers' perceived value
p_0	The unit sales price
w	The unit wholesale price
p_i	The net sales profit for i contract
d_i	Membership fee of unit period for i contract
s	Unit product logistics fee of TPLS
k	Unit product logistics fee of platform
b_i	Commission fee of retailer for i contract
θ	Membership service quality parameter
α	Proportion of high-demand consumer
π_{ji}	Profit of j for i contract

In this study, θ represents the membership service quality parameters, which reflect the additional benefits service difference between members and non-members, except for logistics services, during the whole shopping process. It can measure the effectiveness of membership services ($0 < \theta < 1$). The smaller the θ, the greater the service quality difference between members and non-members. Conversely, the larger the θ, the more similar the quality of service between members and non-members. When θ is close to 1, it indicates that there is only a difference in whether members and non-members need to pay for logistics services. In practice, membership service quality is one of the most crucial factors in platform operation [2,17,51]. Improving the shopping experience on the platform and expanding the additional services are two main modes of enhancing the membership service quality for the platform. For example, as Prime members, consumers receive free shipping and price discounts on Amazon's platform. As 88VIP, in addition to enjoying price discounts for specific commodities on Tmall, members can also receive additional services of other cooperative platforms, which are not available for non-members.

We treat the cost of the platform to provide the additional benefit system as a one-time fixed cost, which is omitted in the profit function. Based on Tan et al. [14], we assume that the storage cost is high for the high-demand consumers who join the membership. To avoid paying the storage cost, they choose to purchase the products two times. For the high-demand consumers who do not join the membership program, the cost of goods storage is higher than the cost of single logistics, and they will also choose to purchase goods two times. s is the logistics fee paid by non-members for each purchase. We assume that the logistics fee paid by non-members is equal to the actual logistics cost, that is, neither the retailer nor the platform makes profits from logistics, but from sales prices and membership fees. d is the membership fee paid by members within a membership period, and p_0 is the unit sales price. Similarly, the membership service utility obtained by low-demand consumers to purchase the product is $U_m^l = v - p_0 - d$, and the service utility obtained by not joining members is $U_n^l = \theta v - p_0 - s$.

When $U_m^h \geq U_n^h$, that is, $v \geq \frac{d-2s}{2(1-\theta)}$, the high-demand consumers choose to join the platform membership. When $U_m^h < U_n^h$, the high-demand consumers do not join the platform membership. Similarly, it can be determined that when $U_m^l \geq U_n^l$, that is, $v \geq \frac{d-s}{1-\theta}$, low-demand consumers choose to join the platform membership. When $U_m^l < U_n^l$, low-demand consumers do not join the platform membership.

Based on the service utility of members and non-members, we can determine the number of members and non-members for high-demand and low-demand consumers (see Table 3). The number of members comes from the number of high-demand members and low-demand members—in other words, from two parts: $(1 - \frac{d-s}{1-\theta})$ is the portion of members who would choose to join regardless of the type of consumer. $(\alpha(\frac{d-s}{1-\theta} - \frac{d-2s}{2(1-\theta)}))$ is the difference between the high demand and low demand. Similarly, the number of non-members is the difference between the total consumers of the platform and the number of members.

Table 3. The numbers of members and non-members.

Types	Total Demand	High-Demand	Low-Demand
Members	$q_m = \alpha(\frac{d-s}{1-\theta} - \frac{d-2s}{2(1-\theta)}) + 1 - \frac{d-s}{1-\theta}$	$q_m^h = \alpha(1 - \frac{d-2s}{2(1-\theta)})$	$q_m^l = (1-\alpha)(1 - \frac{d-s}{1-\theta})$
Non-members	$q_n = (1-\alpha)(\frac{d-s}{1-\theta} - \frac{d-2s}{2(1-\theta)}) + \frac{d-2s}{2(1-\theta)} - \frac{p_0+s}{\theta}$	$q_n^h = \alpha(\frac{d-2s}{2(1-\theta)} - \frac{p_0+s}{\theta})$	$q_n^l = (1-\alpha)(\frac{d-s}{1-\theta} - \frac{p_0+s}{\theta})$

3.2. Timeline

The retailer first decides the cooperation mode with the platform, i.e., signing the full-service contract or the basic-service contract. If the retailer joins the basic-service contract with the platform, the platform decides the commission fee b and the membership fee d within a member period, and then the retailer decides the sales price p_0 of each product. Finally, consumers decide whether to join the platform membership and pay the membership fee. If the consumer does not join the membership, the logistics fee is paid for each purchase of the product. If the retailer joins the full-service contract with the platform, the platform first decides the commission fee b, the membership fee d, and the single logistics fee k that the non-member needs to pay, while the retailer decides the sales price p_0 and consumers decide whether to join the platform membership or not, and then make purchase decisions. Figure 1 gives the decision structure under two cooperation contracts.

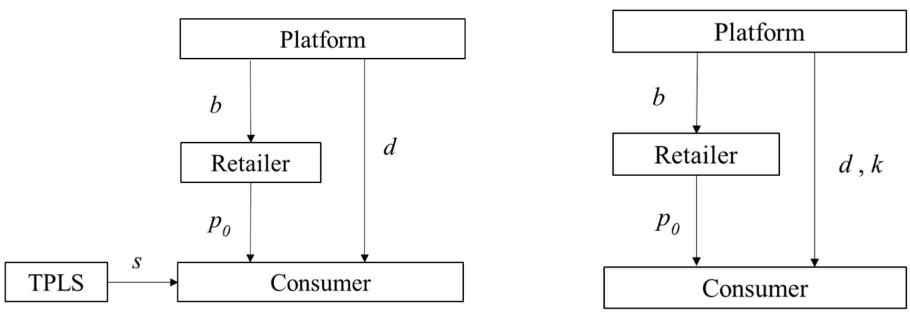


Figure 1. Decision structure.

4. Results and Analysis

In this section, according to the basic assumptions of the model, we discuss the optimal decisions of the retailer and the platform under two cooperation contracts, respectively.

4.1. Basic-Service Contract

If the online retailer signs the basic-service contract with the platform, the platform acts as an intermediary sales platform. The retailer has to pay the unit transaction fee b to the platform. The TPLS provides logistics services to the retailer. The unit logistics fee is exogenous, given as s. The retailer's profit is derived from the net sales profit of high-demand and low-demand consumers. Since the logistics costs of non-members are offset by the logistics fees of consumers, retailers only need to pay the logistics costs of members. The retailer's profit function is:

$$\pi_{r1} = (q_m^h + q_n^h)2(p_0 - w) + (q_m^l + q_n^l)(p_0 - w) - b(q_m^h + q_n^h + q_m^l + q_n^l) - 2sq_m^h - sq_m^l \quad (1)$$

For simplicity, we use p to represent the unit net sales profit, which means $p = p_0 - w$. w is the unit wholesale price, given as exogenous. In the following section, we take the unit net sales profit as the decision variable to observe the retailer's decision regarding commodity price. If $p > 0$, the retailer can profit from the sale of goods; if $p < 0$, the retailer is selling at a loss. The retailer's profit function can be written as:

$$\pi_{r1} = (q_m^h + q_n^h)2p + (q_m^l + q_n^l)p - b(q_m^h + q_n^h + q_m^l + q_n^l) - 2sq_m^h - sq_m^l \quad (2)$$

While the platform's profit comes from the retailer's transaction fee and the consumer's membership fee, the platform's profit function is:

$$\pi_{p1} = (q_m^l + q_m^h)\, d + b\,(q_m^h + q_n^h + q_m^l + q_n^l) \quad (3)$$

The equilibrium solution can be obtained by introducing the demands of consumers into the profit function and using backward induction.

Lemma 1. *When $\theta > s$, the retailer's optimal unit sales profit is $p_1^* = \frac{3}{4}(\theta - s)$, the platform's optimal commission fee is $b_1^* = \frac{1}{2}(1+\alpha)(\theta - s)$, and the optimal membership fee is $d_1^* = \frac{1-\theta+s}{2-\alpha}$.*

From Lemma 1, we know that when the retailer signs the basic-service contract with the platform, the retailer only needs to decide the net sales profit of the product. The optimal net profit of the product is irrelevant to the type of consumer, but is related to the TPLS fee and the service quality of the platform. No matter how the heterogeneous demand ratio of consumers changes, the optimal sales profit of the retailer remains the same. Furthermore, the decision variables of the platform are related to the types of consumers, platform services, and logistics fees.

Lemma 2. *The retailer's profit:*

$$\pi_{r1}^* = \frac{\theta^2(2-\alpha)(\alpha+1)(1-\theta) - 2s\theta(9\alpha(1-\alpha)+10)(1-\theta) + s^2(2(1-9\theta)+\alpha(1-\alpha)(1-17\theta))}{16(2-\alpha)(1-\theta)\theta},$$

and the platform's profit:

$$\pi_{p1}^* = \frac{2s\theta(1-\theta)\left(\alpha^2+2-\alpha\right) - \theta(1-\theta)\left(\theta\left(\alpha^2+2-\alpha\right)-4\right) + s^2(\alpha(1-\alpha)(1-\theta)+2(1+\theta))}{8\theta(2-\alpha)(1-\theta).}$$

According to Lemma 2, although consumer heterogeneity has nothing to do with the sales price, profit is affected by heterogeneity. This impact is reflected in the commission fee retailers pay to the platform.

In order to explain the key factors that affect the decisions regarding cooperation contracts, we analyze the impact of the platform's membership service quality on the optimal results, then discuss the effect of the consumer type on the decision making.

Proposition 1. *Under the basic-service contract, the impact of the membership service quality on the optimal results is:*

(a) $\frac{\partial p_1^*}{\partial \theta} > 0$, $\frac{\partial b_1^*}{\partial \theta} > 0$, $\frac{\partial d_1^*}{\partial \theta} < 0$.

(b) *If* $0 < \theta < \sqrt{2} - 1$, *then* $\frac{\partial \pi_{p1}^*}{\partial \theta} < 0$. *If* $0 < s < s^*$, *there is* $\frac{\partial \pi_{r1}^*}{\partial \theta} > 0$. *If* $s > s^*$, *then* $\frac{\partial \pi_{r1}^*}{\partial \theta} < 0$.

The quality of the membership service determines the platform members' consumption experience. From the previous analysis, we can see that the quality of the membership service affects the consumers' utility and, thus, affects the consumers' choice to become members, which further affects the platform's and retailer's decision making. Proposition 1(a) shows that when the basic-service contract is signed, the retailer's net sales profit and the platform's commission fee increase in the membership service quality parameter. A large θ means a slight difference in the services experienced between members and non-members, that is, low service quality. The larger θ is, the higher the net sales profit and commission fee become. When it is close to 1, all consumers receive almost the same consumption experience. The only difference is whether to pay for logistics fees. At that time, the total market demand increases. Due to the market power of the platform, retailers raise net sales profits and the platform increases commission fees to obtain more profit. The smaller θ is, the higher the quality of membership services becomes. Moreover, the higher the platform's membership service quality, the higher the membership fee.

Proposition 1(b) indicates that the relationship between the platform's membership service quality and the retailer's profit is affected by the TPLS fee. When the TPLS fee is significant, the retailer's profit decreases in the membership service quality parameter. When the TPLS fee is small, the retailer's profit increases in the membership service quality parameter. The larger the θ, the lower the membership service quality, and the higher the retailer's profit. When the TPLS fee is low, the member logistics fee that the retailer needs to pay is lower, and the corresponding optimal profit is higher.

Figure 2 illustrates the impact of membership service quality parameters on the platform and the retailer's profit under the basic-service contract. We can see that if θ is relatively low, the three lines almost coincide, which means that consumer type (α) has little impact on the retailer's profit (see Figure 2). When θ is relatively small, it means that the platform's membership service quality is relatively high and more consumers would be attracted by this paid membership system; then, the number of members is relatively high and the consumer type cannot affect the retailer's profit. This can be also seen in Figure 3a, Figure 4a, and Figure 5a. When θ is relatively low, the curve of profits with consumer type is smooth. For the platform (see Figure 2b), profit decreases in the membership service quality parameter under the basic-service contract. The lower the θ, the higher the membership service quality and the lower the platform's profit. The parameters are assigned according to the model assumptions: $s = 0.004$, $\alpha = 0.65$, $\theta = 0.1$. The sensitivity analyses in the following sections are based on this assignment.

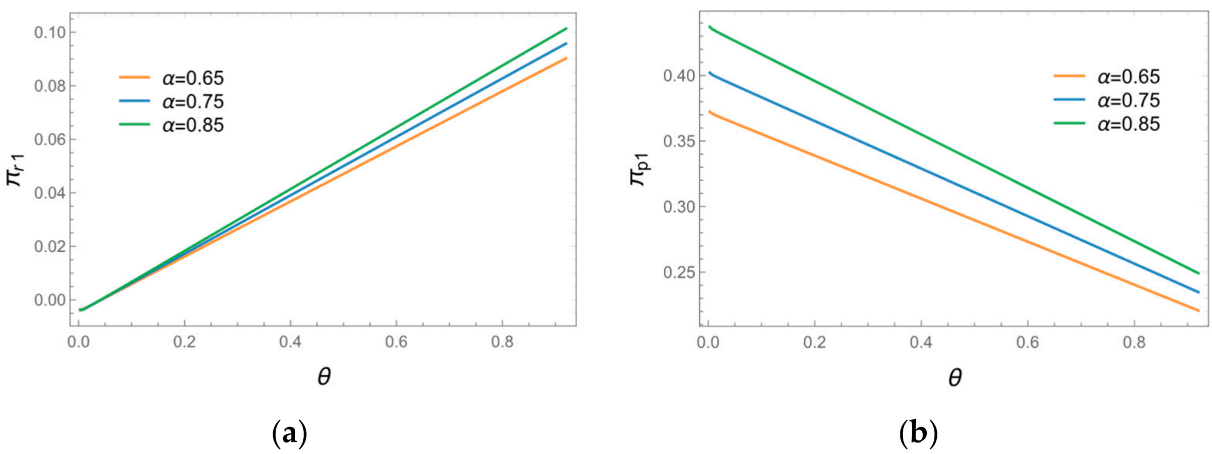
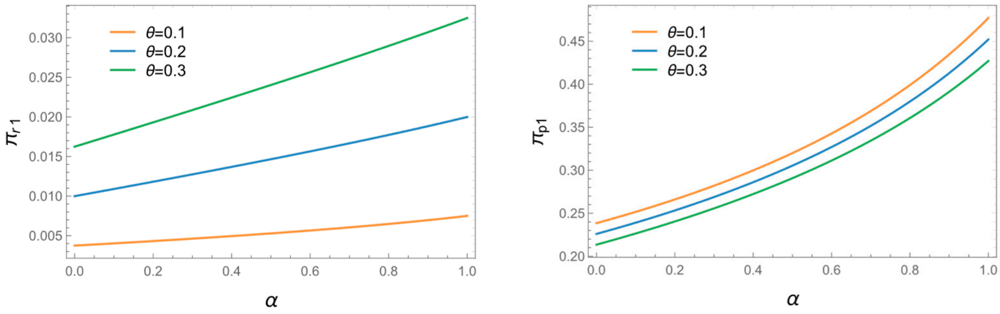
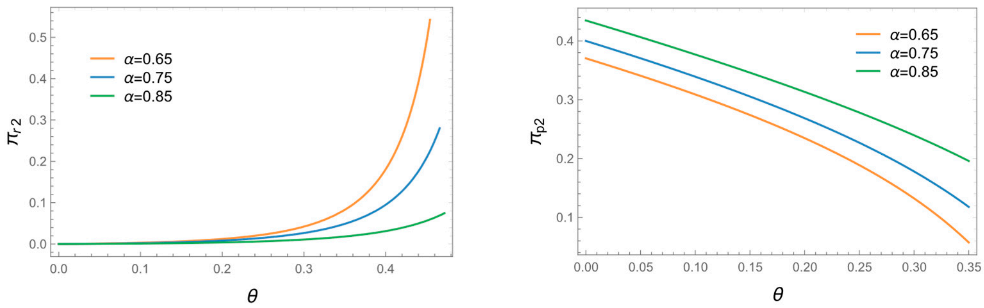


Figure 2. Impact of membership service quality on retailer's profit (**a**) and platform's profit (**b**) under the basic-service contract.



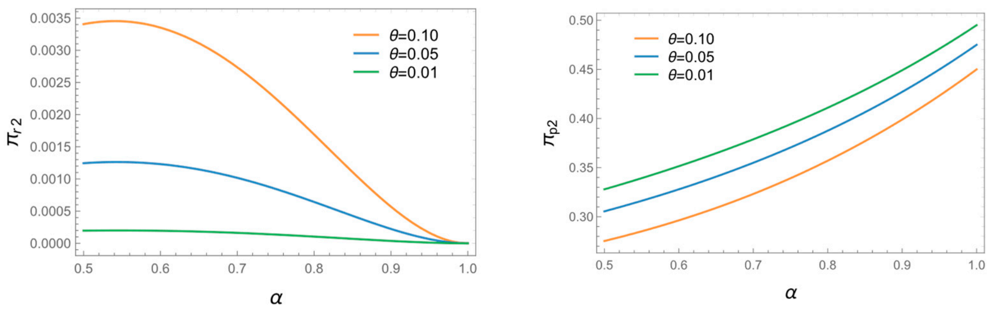
(**a**) (**b**)

Figure 3. Impact of consumer type on retailer's profit (**a**) and platform's profit (**b**) under the basic-service contract.



(**a**) (**b**)

Figure 4. Impact of membership service quality on retailer's profit (**a**) and platform's profit (**b**) under the full-service contract.



(**a**) (**b**)

Figure 5. Impact of consumer type on retailer's profit (**a**) and platform's profit (**b**) under the full-service contract.

The consumer type determines the number of consumer demands. Referring to Tan et al. [14], we divided consumers into high-demand and low-demand consumers. It is easy to realize that, under the same circumstances, a total market demand with a high proportion of high-demand consumers is correspondingly larger than that of a market with a high proportion of low-demand consumers, thus affecting the decisions of market participants. Here, we analyze the impact of consumer types on decision making.

Proposition 2. Under the basic-service contract, the impact of the consumer type on the optimal results is:

(a) $\frac{\partial b_1^*}{\partial \alpha} > 0, \frac{\partial d_1^*}{\partial \alpha} > 0;$

(b) *If* $s < s_1$*and* $\theta < \theta_1$, *then* $\frac{\partial \pi_{r1}^*}{\partial \alpha} > 0, \frac{\partial \pi_{p1}^*}{\partial \alpha} > 0.$

Proposition 2(*a*) suggests that, when the retailer and the platform sign the basic-service contract, the commission fee increases with the proportion of high-demand consumers. The higher the proportion of high-demand consumers, the higher the commission fee and membership fee. When the proportion of high-demand consumers rises, the market demand increases, and the sales volume of retailers correspondingly increases under the same condition. As a nibbler of the sales volume of retailers, the platform has the incentive to further increase the commission fee and membership fee to offset the member logistics cost growth caused by the increase in the proportion of high-demand consumers.

Proposition 2(*b*) implies that, when TPLS fee is relatively low and membership service quality is relatively high, the retailer's profit rises with the increase in the proportion of high-demand consumers. The number of members increases as the demand rises, and the retailer's sales increase more than the members' logistics cost to be paid, thus resulting in a growth in profit. As depicted in Figure 3, the profits of both sides increase with the growth of the proportion of high consumers under the basic-service contract.

4.2. Full-Service Contract

Now, if the retailer signs the full-service contract, the platform integrates the retailer's warehouse into the platform's warehousing system, providing the retailer with a one-stop logistics service including picking, packaging, and terminal distribution. The retailer's profit is derived from the net sales profit of high-demand consumers and low-demand consumers. As we assumed before, the logistics fee is the same as the actual logistics cost. The retailer's profit function is:

$$\pi_{r2} = (q_m^h + q_n^h)2(p_0 - w) + (q_m^l + q_n^l)(p_0 - w) - b(q_m^h + q_n^h + q_m^l + q_n^l) \tag{4}$$

As we mentioned in Section 4.1, we use p to represent the unit net sales profit as a decision variable, and the retailer's profit can be rewritten as:

$$\pi_{r2} = (q_m^h + q_n^h)2p + (q_m^l + q_n^l)p - b(q_m^h + q_n^h + q_m^l + q_n^l) \tag{5}$$

The platform's profit is derived from the retailer's commission fee, the membership fee, and the logistics fee caused by the members. The platform's profit function is:

$$\pi_{p2} = (q_m^l + q_m^h)\, d + b\, (q_m^h + q_n^h + q_m^l + q_n^l) - 2\, k\, q_m^h - k\, q_m^l \tag{6}$$

By inputting different numbers of consumer types into the profit function, the backward induction is used to obtain the equilibrium solution.

Lemma 3. *When $\theta < \theta_2$, the retailer's optimal unit sales profit are $p_2^* = -3\alpha\theta(1-\alpha)(1+\theta)M_1$, the platform's optimal commission fee is $b_2^* = -2\alpha\theta\left(1-\alpha^2\right)(1+\theta)M_1$, the optimal membership fee is $d_2^* = (1+\alpha)\left(1-\theta^2\right)M_1$, and the optimal unit logistics fee is $k^* = \theta(\theta-1)\left(5\alpha^2 - 2 - 5\alpha\right)M_1$.*

When the retailer and the platform sign the full-service contract, the optimal decision variables of the retailer and the platform are all related to the types of consumers and the membership service quality. However, because the logistics fee becomes the decision variable of the platform in the full-service contract, there is no logistics fee in the members' optimal solution. Furthermore, we need to assume that $\theta < \theta_2 = \frac{(2-\alpha)(1+\alpha)}{2+9\alpha(1-\alpha)}$, which means the service quality gap between members and non-members should not be too small, and consumers can perceive the benefits of membership. This assumption is quite universal in reality; 88VIP of Tmall provides members with a 5% discount on some products and offers membership cards and coupons for other platforms, saving up to RMB 2000 per year [52].

Lemma 4. *The retailer's profit is $\pi_{r2}^* = \theta\alpha^2 M_1^2(1+\alpha)(1-\alpha)^2(1+\theta)^2$ and the platform's profit is $\pi_{p2}^* = \frac{M_1}{2}\left(\alpha + (1-\theta)^2 + 2\theta\alpha^3(3-2\theta) - \alpha\theta(8-5\theta)\right)$.*

Lemmas 3 and 4 also present that, when the retailer decides to join the full-service system of the platform, the retailer cannot make profits from the sale of goods (i.e., $p_2^* < 0$); it sells at a loss. Meanwhile, the platform subsidizes $|b_2^*|(b_2^* < 0)$ commission to the retailer to make up for the loss. The retailer can make profits from the platform's commission subsidies (i.e., $\pi_{r2}^* > 0$), which the platform covers by charging a membership fee (i.e., $\pi_{p2}^* > 0$).

Proposition 3. Under the full-service contract, the impact of the membership service quality on the optimal results is:

(a) $\frac{\partial|p_2^*|}{\partial\theta} > 0$, $\frac{\partial|b_2^*|}{\partial\theta} > 0$, $\frac{\partial k^*}{\partial\theta} > 0$, $\frac{\partial d_2^*}{\partial\theta} > 0$.

(b) $\frac{\partial\pi_{r2}^*}{\partial\theta} > 0$, $\frac{\partial\pi_{p2}^*}{\partial\theta} < 0$.

When the retailer and the platform sign the full-service contract, the retailer is selling at a loss. The larger the membership service quality parameter, the more the retailer loses, and the more subsidies the platform offers. However, the membership fee within the membership period and the platform logistics fee increase in the membership service quality parameter. When θ decreases, that is, with the increase in membership service quality, the gap in consumption experience between members and non-members becomes larger and the sales price and commission fee of the retailer increase, but the membership fee and the logistics fee decrease.

Focusing on consumers, we find that, compared with the basic-service contract, higher membership service quality means lower membership fees and logistics fees under the full-service contract, which is consistent with Xu et al. [53]. This is because, when the retailer chooses the full-service contract, the platform is responsible for logistics. As the membership service quality improves, the platform increases the commission fee, and the retailer increases prices to offset the lower logistics fee and membership fee.

Proposition 3(*b*) shows that the retailer's profit increases in the membership service quality parameter, but the platform's profit decreases. When θ decreases, the membership service quality increases, and the impact on the platform's profit is always more significant (see Figure 4). The reduction in the retailer's profit derived from the commission fee is greater than the increase in profit due to the increase in sales price, so the retailer's total profit decreases, while that of the platform increases. Meanwhile, the increase in the commission fee raises the platform's total profit due to the increase in the quality of membership services and the membership fee. In the transaction process with the platform, the retailer is always in a relatively weak position.

Proposition 4. *Under the full-service contract, the impact of the consumer type on the optimal results is:*

(a) *If* $0 < \theta < \frac{1}{9}$*and* $\alpha > \frac{1}{2}$, *then* $\frac{\partial|p_2^*|}{\partial\alpha} < 0$, $\frac{\partial d_2^*}{\partial\alpha} > 0$, $\frac{\partial k^*}{\partial\alpha} < 0$, $\frac{\partial|b_2^*|}{\partial\alpha} < 0$.

(b) *If* $\alpha > \frac{1}{2}$*and* $0 < \theta < \frac{1}{9}$, *then* $\frac{\partial\pi_{r2}^*}{\partial\alpha} < 0$, $\frac{\partial\pi_{p2}^*}{\partial\alpha} > 0$.

Proposition 4(*a*) declares that, when the proportion of high-demand consumers is relatively high and the membership service quality parameter is relatively small, the membership fee increases with the proportion of high-demand consumers. In contrast, the logistics fee, platform subsidy, and retailer loss degree decrease with the proportion of high-demand consumers. When the proportion of high consumers and the platform's membership service quality in the existing market are relatively high, if more consumers become high-demand consumers at this time, the platform has the motivation to increase the membership fee and decrease the subsidy to increase profit, as well as to reduce the logistics fee to keep attracting low-demand consumers. With fewer subsidies, the retailer reduces the extent to which they sell at a loss, which means raising prices to offset the profits.

Proposition 4(b) shows that, under the full-service contract, when the proportion of high-demand consumers is relatively small and the membership service quality is relatively high, the retailer's profit falls with the increase in the proportion of high-demand consumers. However, the platform's profit increases with the increase in the proportion of high consumers. The number of members increases as the demand rises, so the membership income grows and results in profit improvement. The same characteristics can be found in the basic-service contract, indicating that the impact of consumer types on profit is the same in the two contracts, which is opposite to the different impacts of membership service quality parameters in the two contracts. Figure 5 illustrates the impact of consumer types on the profits of both sides under the full-service contract. Furthermore, as Section 4.1 mentioned, when θ is relatively low, the impact of the consumer type on retailer's profit is weak, as represented by the orange line in Figure 3a and the green line in Figure 5a.

5. Win–Win Range

As can be seen from the previous discussion, both the membership service quality and the consumer types have a certain impact on the choice of platform and retailer. Is there a balanced choice between two contracts, so that both the platform and the retailer prefer the same cooperation contract?

For participants, the choice between the basic-service contract and the full-service contract needs to be decided according to their profits. The profit gap of the retailer and platform between the two cooperation contracts is recorded as:

$$\Delta\pi_r = \pi_{r1} - \pi_{r2} \tag{7}$$

$$\Delta\pi_p = \pi_{p1} - \pi_{p2} \tag{8}$$

Lemma 5. *For the retailer, when* $0 < \theta < \frac{1}{9}$*, if* $0 < s < s_1^*$*, then the retailer chooses the basic-service contract. If* $s > s_1^*$*, then the retailer selects the full-service contract. For the platform, it always prefers the basic-service contract. Therefore, there is an interval* $(0, s_1^*)$ *which makes the basic-service contract become the win–win situation.*

Lemma 5 demonstrates that, for the retailer, the TPLS fee is one of the key factors that affect the retailer's contract choice. When the TPLS fee is lower than s_1^*, the retailer tends to outsource the logistics to TPLS. When the scale effect of the TPLS reduces and the logistics fee increases, full-service cooperation with the platform becomes a better option. However, for the platform, whatever the TPLS fee is, it does not influence the platform's logistics choice. Thus, the competition between the platform and the third party in the retailer's logistics service does not affect the platform's decision making, and the platform always tends to choose the basic-service contract. At this time, the increased consumer demands brought by the full-service contract and the control over the retailer's pricing do not bring additional profits to the platform. Generally speaking, when $s \in (0, s_1^*)$, the retailer and the platform both choose the basic-service contract. The profit is greater than that if they choose the full-service contract, and the equilibrium at this time is that both parties select the basic-service contract. The numerical simulation result is shown in Figure 6.

As shown in Figure 6, when $0 < s < s_1^*$, the margin of difference between the platform and the retailer is greater than 0, and the profit from the basic-service contract is greater than the profit from the full-service contract. When $s > s_1^*$, if the TPLS fee is relatively high, the retailer's profit from the full-service contract is higher than the profit from the basic-service contract, and the platform's profit is also higher. Therefore, we obtain a win–win interval between the retailer and the platform $s \in (0, s_1^*)$. Cooperation can promote profit growth, but a deeper cooperative mode cannot make market participants more profitable at the same time. On the contrary, as a retailer who has direct contact with consumers, when choosing logistics cooperation, more attention is still paid to the impact of logistics fees on profit, and the one with a lower logistics fee is preferred.

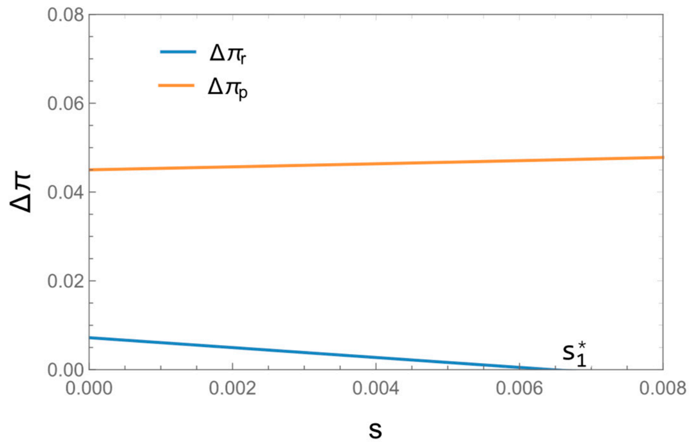


Figure 6. Equilibrium interval.

6. Extended Model

In this section, we expand the base model to change the logistics mode and decision-making method and study whether the conclusions are stable. Further, we have some interesting ideas.

6.1. Self-Delivery

We observe that e-retailers often face the choice between outsourcing logistics and self-support logistics, such as FBA or FBM. In the previous section, we analyzed two outsourcing logistics modes (TPLS and platform logistics service). Now, we turn to discuss the equilibrium mode by considering self-delivery. That is, when the platform signs the basic-service contract with the retailer, the retailer is likely to use its own logistics rather than a TPLS.

It can be seen from the analysis of the win–win interval (Section 5) that the logistics fee is a vital factor that affects the decision making of the e-commerce platform and the retailer. In the previous section, we assumed that if the logistics fee were exogenous, the retailer would choose TPLS when signing the basic-service contract with the platform. In this section, we assume that the retailer chooses to undertake logistics by himself (self-delivery) when signing the basic-service contract, and then analyze whether the win–win interval still exists.

When s is endogenous, there is no change in the profit function form of the retailer and the platform under the basic-service contract, but the retailer needs to make decisions regarding the logistics fee.

The retailer's profit function is:

$$\pi'_{r1} = (q^h_m + q^h_n)2p' + (q^l_m + q^l_n)p' - b'(q^h_m + q^h_n + q^l_m + q^l_n) - 2s'q^h_m - s'q^l_m \tag{9}$$

The platform's profit function is:

$$\pi'_{p1} = (q^l_m + q^h_m)d' + b'(q^h_m + q^h_n + q^l_m + q^l_n) \tag{10}$$

We obtain the optimal solution by using backward induction in this case, and the solution form is given in Table 4. We need to indicate that $\theta > \frac{1}{3}$ is a prerequisite for Table 4. This means that only when the membership service quality of the platform is relatively low is the retailer likely to choose self-delivery, with the maximum profit.

Table 4. The optimal solution of self-delivery.

Variable	Basic-Service Contract
p'^*	$\frac{M_2}{4}\left(2(1-2\theta-5\theta^2)+\alpha(1-\alpha)(1-6\theta-7\theta^2)\right)$
b'^*	$\frac{(1+\alpha)(1+\theta)}{4}$
d'^*	$M_2(1+\alpha)(1-\theta)(1-2\theta)$
s'^*	$\frac{M_2}{4}(1-\theta)(10\theta-2-\alpha(1-\alpha)(1-11\theta))$
${\pi'_{r1}}^*$	$\frac{M_2^2 M_4(1+\alpha)}{16}$
${\pi'_{p1}}^*$	$\frac{M_2}{8}\left(\alpha^3(1+\theta)^2+\alpha\left(1-10\theta+\theta^2\right)+2\left(1-4\theta+\theta^2\right)\right)$

Proposition 5. *For self-delivery under the basic-service contract:* $p'^* > 0,\ b'^* > 0$.

From Proposition 5, we know that, similarly to third-party logistics, if the retailer selects self-delivery under the basic-service contract, the retailer profits from sales of goods and pays a platform commission fee at the same time.

We still use $\Delta\pi'_r$ and $\Delta\pi'_p$ to represent the margin difference between the two contracts when the retailer chooses self-delivery.

Lemma 6. *Win–Win situation.*
If $\theta < \theta_1$ *or* $\theta_1 < \theta < \theta_3$*, then* $\Delta\pi'_r > 0$*. If* $\theta_3 < \theta < \theta_2$*, then* $\Delta\pi'_r < 0$*.*
If $\theta_1 < \theta < \theta_2$*, then* $\Delta\pi'_p > 0$*. If* $\theta < \theta_1$*, then* $\Delta\pi'_p < 0$*.*
When $\theta \in (\theta_1, \theta_3)$*, the basic-service contract is the win–win situation.*

Lemma 6 shows that when $\theta < \theta_1$ or $\theta_1 < \theta < \theta_3(\theta_3 < \theta < \theta_2)$, if the retailer chooses the basic-service contract, the retailer's profit is higher (lower) than that if they chose the full-service contract. When $\theta_1 < \theta < \theta_2(\theta < \theta_1)$, the e-commerce platform benefits from the basic-service contract (full-service contract). Then, we can determine that when $\theta \in (\theta_1, \theta_3)$, both the retailer and the platform choose the basic-service contract to obtain a higher profit. As we can see in Figure 7, within a range of θ_1 to θ_3, the margin of difference between the retailer and the platform when they opt for the basic-service contract is greater than zero, which means that when $\theta \in (\theta_1, \theta_3)$, it is a win–win result for both sides, and our main result in Lemma 5 qualitatively holds.

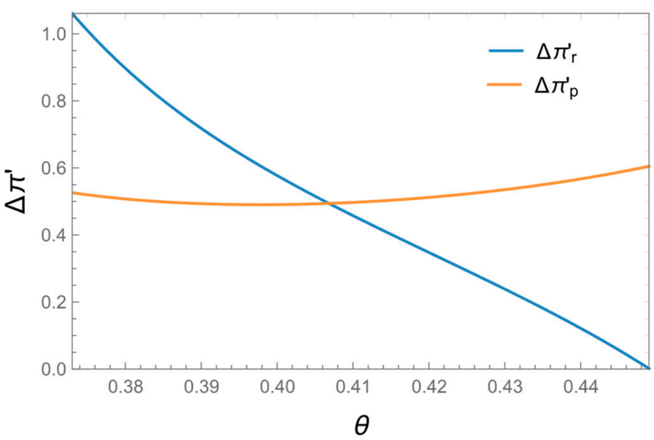


Figure 7. Margin of difference under self-delivery.

Lemma 6 indicates that when the membership service quality is high, which means a small θ, the retailer would like to be in charge of its own delivery to make a higher profit. Under the basic-service contract, a small θ leads to a high sales profit (i.e., $\frac{\partial p'^*}{\partial \theta} < 0$), where the retailer realizes higher profit levels. Once the membership service quality falls, which means $\theta > \theta_3$, as the number of members increases, more member logistics costs need to be paid (i.e., $\frac{\partial s'^*}{\partial \theta} > 0$), and the full-service contract would be a better choice. As for the platform, according to Proposition 4(b), with the improvement in the membership service quality (i.e., smaller θ), the profit of the platform with the full-service contract increases, while the profit of the platform with the basic-service contract decreases. When the membership service quality is relatively high (i.e., $\theta < \theta_1$), the profit of the full-service contract is higher than the basic one, making the full-service contract a better choice.

6.2. Centralized Decision

In this section, we solve the optimal result of centralized decision and maximize the benefits from global consideration to verify whether there is a double marginal effect.

The assumptions and cooperation mode of the model remain unchanged, but there are differences in the decision sequence. Firstly, the platform and the retailer decide to choose one contract to sign. With the basic-service contract, the platform and the retailer jointly decide the membership fee d_{c1} and net sales profit p_{c1}. The unit logistics fee is exogenous given as s. With the full-service contract, the platform and the retailer jointly decide the membership fee d_{c2}, net sales profit p_{c2}, and single logistics fee s_c. Finally, consumers decide whether to become members and make purchase decisions.

The profit function in the centralized decision becomes: $(i = 1, 2)$

$$\pi_{ci} = (q_m^h + q_n^h)2p_{ci} + (q_m^l + q_n^l)p_{ci} + (q_m^l + q_m^h)d_{ci} - 2s_c q_m^h - s_c q_m^l \tag{11}$$

We solve the optimal solution with backward induction.

Lemma 7. *For the basic-service contract, the optimal unit net sales profit is* $p_{c1} = \frac{\theta - s}{2}$, *the optimal membership fee is* $d_{c1} = \frac{1-\theta+2s}{2-\alpha}$, *and the optimal profit is*

$$\pi_{c1} = \frac{\left(2s\theta(1-\theta)\left(\left(3\alpha^2 - 3\alpha - 2\right) + \left(2\theta + \alpha\theta^2(1-\alpha)\right)\right) + s^2/M_3\right)}{4\theta(2-\alpha)(1-\theta)}.$$

For the full-service contract, the optimal unit net sales profit is $p_{c2} = -\frac{\alpha\theta(1-\alpha)(1+\theta)}{M_2+4\theta}$, *the optimal membership fee is* $d_{c2} = M_3(1-\theta^2)(1+\alpha)$, *the optimal unit logistic fee is* $s_c = \theta M_3(1-\theta)(2+3\alpha(1-\alpha))$, *and the profit is* $\pi_{c2} = \frac{M_3}{2}\left(\alpha + (1-\theta)^2 + \theta\alpha\left(2\alpha^2 - 3\right)(2-\theta)\right)$.

Then, we compared the previous optimal outcomes with the optimal outcomes of a centralized decision.

Proposition 6. *Comparison of net sales profit and membership fee between decentralized and centralized decision:* $p_{c1} < p_1^*$, $|p_{c2}| < |p_2^*|$, $d_{c1} > d_1^*$, $d_{c2} < d_2^*$.

Under the basic-service contract, the net sales profit with a centralized decision is lower, but the membership fee is higher, and consumer surplus and social welfare are always higher than the basic model. We know that there is a double marginal effect in the basic-service contract. For the full-service contract, the sales loss and membership fee with the centralized decision are lower.

7. Conclusions

As a sales strategy of personalized pricing, paid membership systems are widely used in the existing online shopping platforms. The cooperation between platforms and retailers has becoming an inevitable trend. We put forward an analysis framework for the logistics cooperation model between the retailer and the platform under the paid membership system and discuss the equilibrium cooperation mode. The following subsections present the key findings and management implications of our study and indicate the limitations and directions for future research.

7.1. Key Findings

First, we find that under two cooperation contracts, the impacts of membership service quality on the platform and the retailer's optimal decision are completely opposite. A deeper cooperation level results in a higher commission subsidy and a higher sales profit loss under the full-service contract. An increase in high-demand consumers leads to a higher commission fee and a higher membership fee for the basic-service contract. The proportion of high-demand consumers has a positive superposition effect on the platform's profits.

Second, when the logistics fee of the TPLS is relatively low, the full-service contract cannot bring more profits to the retailer and the platform, while outsourcing logistics reduces the logistics fee. The basic-service contract enables them to obtain a win–win result. When the TPLS fee is relatively significant, the retailer prefers the full-service contract, but the platform always chooses the basic-service contract.

Third, if the retailer chooses self-delivery under the basic-service contract, we also show that when the membership service quality is within a certain range, there still exists a win–win interval which makes the basic-service contract benefit both sides. Compared with the full-service contract, the basic-service contract can mitigate the impact of the platform's profit reduction due to the lower membership service quality.

7.2. Managerial Implications

This study analyzes the relationship between the paid membership system and the logistics cooperation strategy, which serves as a theoretical framework for platforms and retailers making operational decisions.

First, we provide management information regarding the implementation of the full-service strategy. For the retailer, he/she will lose a portion of sales profit and overcontrol of commodity logistics if he/she integrates the inventories into the platform's full-service system. However, the platform will offer commission subsidies, which allows the retailer to remain lucrative. For the platform, the paid membership system brings stable membership consumption. But the platform must offer more than commission subsidies under the full-service contract. It also needs to lower membership fees and enhance membership service quality to boost the repurchase rate and encourage retailers to sign up for the paid membership program. For example, Tmall offers a commission subsidy of up to 160% for retailers who join the affiliate program.

Second, a deeper cooperation level does not always translate into a more profitable logistics cooperation plan. Although the full-service contract enhances consumers' perceived value for retailers, in cases of relatively high TPLS fees, both the platform and the retailer prefer the basic-service contract due to considerations of membership service quality and logistics costs, ensuring their profitability.

Finally, there is inspiration to improve the membership service quality. As detailed in Section 6.1, by redirecting the competition of logistics services from external to internal, we indicate that membership service quality is a determinant factor in logistics strategies. Notably, achieving a moderate level of membership service quality is essential to ensuring mutually beneficial outcomes for both the platform and the retailer.

7.3. Limitations and Future Research

In addition, we need to point out limitations and future research directions. First, in practice, it is common for multiple retailers to sell complementary or substitute products on the platform. If these relationships between retailers are considered in this model, richer results may be obtained. Second, we assume that the platform acts as a marketplace and provides logistics services, but in the research of Qin et al. [13] and Zhang et al. [43], the platform sometimes sold products to compete with retailers. In fact, JD Self-operation and Tmall Supermarket are embodiments of the platform's participation in retailer competition. If the competitive relationship between the platform and the retailer were also considered in the game model based on member pricing, the model would be more complicated, and the results may be more realistic and interesting. Third, in this study, we consider that consumers pay the membership fee in advance for the period of time and then enjoy the membership's preferential measures. There are still more types of discriminatory pricing. In the future, we can also refer to the study of Kung et al. [23] and incorporate more discriminatory pricing strategies into the model to further discuss the cooperation contract between the retailer and the platform. Finally, when making decisions in the actual world, we must take into account more complicated circumstances and limitations in addition to the previously mentioned factors, which will significantly raise the complexity of our model. To enhance the model's applicability and timeliness, we can experiment with more research techniques in the future, such as agent-based simulation and empirical analysis.

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Appendix A

Proof of Lemma 1. According to backward induction, first, we consider the optimal net sales profit of the retailer. We have $\frac{\partial^2 \pi_{r1}}{\partial p^2} < 0$, which indicates that there exists a unique optimal solution. Then, we use the first-order condition to obtain the p reaction function with respect to b and d, which is $p_1^* = \frac{1}{2}\left(\theta - s + \frac{b}{1+\alpha}\right)$. Second, we consider the profit of the platform. The Hessian matrix of the platform's profit is negatively definite. From the first-order condition, we obtain the optimal commission fee $b_1^* = \frac{1}{2}(1+\alpha)(\theta - s)$, the optimal membership fee $d_1^* = \frac{1-\theta+s}{2-\alpha}$, and the optimal price $p_1^* = \frac{3}{4}(\theta - s)$. In a general way, we have $\theta - s > 0$. □

Proof of Lemma 3. By using the same method, we can obtain $\frac{\partial^2 \pi_{r2}}{\partial p^2} < 0$. Then, by solving the first-order condition, we obtain the reaction function $p_2^* = \frac{b-k-k\alpha+\theta+\alpha\theta}{2(1+\alpha)}$. For the platform, when $\theta < \frac{(2-\alpha)(1+\alpha)}{2+9\alpha(1-\alpha)}$, the Hessian matrix is negatively definite, and the platform's profit has a unique maximum solution. Therefore, we have $b_2^* = -\frac{2\alpha\theta\left(1-\alpha^2\right)(1+\theta)}{M_1}$, $d_2^* = \frac{(1+\alpha)\left(1-\theta^2\right)}{M_1}$, and $k^* = \frac{\left(5\alpha^2-2-5\alpha\right)(\theta-1)\theta}{M_1}$. Then, taking them into reaction function, we can obtain $p_2^* = -\frac{3\alpha\theta(1-\alpha)(1+\theta)}{M_1}$, where $M_1 = 1/(2(1-\theta) + \alpha(1-\alpha)(1-9\theta))$. □

Proof of Lemma 5.

$$\Delta\pi_r = \pi_{r1} - \pi_{r2}$$

$$= \frac{\begin{pmatrix} -2s\left(-10-9\alpha+9\alpha^2\right)(-1+\theta)\theta + \left(-2-\alpha+\alpha^2\right)(-1+\theta)\theta^2 + \\ s^2\left(2+\alpha-18\theta-17\alpha\theta+\alpha^2(-1+17\theta)\right) \end{pmatrix}}{16(-2+\alpha)(-1+\theta)\theta} - \frac{(-1+\alpha)^2\alpha^2(1+\alpha)\theta(1+\theta)^2}{M_1^2}$$

It is well known that $\Delta\pi_r^*$ is a quadratic function of s. When $\theta \neq \frac{(\alpha-2)(1+\alpha)}{9(\alpha-1)\alpha-2}$, we can solve the equation. We can obtain $\Delta\pi_r^* > 0$ if $0 < s < s_1^*$, and $\Delta\pi_r^* < 0$ if $s > s_1^*$.

$$s_1^* = \frac{(1-\theta)\theta(9\alpha^2 - 9\alpha - 10 - 8\sqrt{A} + 4\alpha\sqrt{A})}{(18\theta - 2 - \alpha(1-\alpha)(1-17\theta)),}$$

$$A = \frac{M_1^2}{(2-\alpha)^2}\left(\begin{array}{l} -4\alpha^7\left(6 - 103\theta + 341\theta^2\right) + \alpha^6\left(1 - 187\theta + 1202\theta^2\right) + \alpha^5\left(81 - 881\theta + 1168\theta^2\right) \\ +\alpha^4\left(-25 + 596\theta - 1527\theta^2\right) + \alpha^3\left(-113 + 757\theta - 484\theta^2\right) + \alpha^2\left(6 - 286\theta + 488\theta^2\right) \\ +4\alpha\left(17 - 77\theta + 44\theta^2\right) + 8\left(3 - 5\theta + 2\theta^2\right) \end{array}\right).$$

$$\Delta\pi_p^* = \pi_{p1} - \pi_{p2}$$

$$= \frac{\begin{array}{c} \theta^2 M_1\left(2 + 5\alpha - 5\alpha^2\right)^2(1-\theta)^2 - 2s\theta\left(2 - \alpha + \alpha^2\right)(1-\theta) \\ +s^2 M_1\left(\begin{array}{l} 4 - 4\theta^2 + 4\alpha\left(1 - 5\theta - 4\theta^2\right) - 2\alpha^3\left(1 - 10\theta + 9\theta^2\right) \\ +\alpha^4\left(1 - 10\theta + 9\theta^2\right) - \alpha^2\left(3 - 10\theta - 25\theta^2\right) \end{array}\right) \end{array}}{8\theta(2-\alpha)(1-\theta).}$$

We can prove that $\left(2 + 5\alpha - 5\alpha^2\right)^2(-1+\theta)^2\theta^2 > 0$. We have $2 - \alpha + \alpha^2 > 0$ and $\alpha^4 - 2\alpha^3 < 0$. When $0 < \theta < \frac{1}{9}$, we have $2 + \alpha - 2\theta - 9\alpha\theta + \alpha^2(-1 + 9\theta) > 0$, and the denominator is positive. Furthermore, $-1 + 5\theta + 4\theta^2 < 0$ if $0 < \theta < \frac{-5+\sqrt{41}}{8}$; $1 - 10\theta + 9\theta^2 > 0$ if $0 < \theta < \frac{1}{9}$; and $-3 + 10\theta + 25\theta^2 < 0$ if $0 < \theta < \frac{1}{5}$. And we change $4 - 4\theta^2 - 4\alpha\left(-1 + 5\theta + 4\theta^2\right) - 2\alpha^3\left(1 - 10\theta + 9\theta^2\right) + \alpha^4\left(1 - 10\theta + 9\theta^2\right) + \alpha^2\left(-3 + 10\theta + 25\theta^2\right)$ into $\left(2 + \alpha - \alpha^2 + 2\theta - \alpha\theta + \alpha^2\theta\right)\left(2 + \alpha - \alpha^2 - 2\theta - 9\alpha\theta + 9\alpha^2\theta\right)$. Then, we can obtain $2 + \alpha - \alpha^2 + 2\theta - \alpha\theta + \alpha^2\theta > 0$. Therefore, $\Delta\pi_p^* > 0$ if $0 < \theta < \frac{1}{9}$. Above all, we can obtain Lemma 5. □

Proof of Lemma 6.

$$\Delta\pi_r' = \pi_{r1}' - \pi_{r2}$$

$$= \frac{(1+\alpha)\left(\begin{array}{l} 4 - 36\theta + 92\theta^2 - 44\theta^3 - \alpha^3\left(6 - 82\theta + 298\theta^2 - 190\theta^3\right) \\ -\alpha^2\left(5 - 43\theta + 99\theta^2 - 45\theta^3\right) - 4\alpha\left(-2 + 21\theta - 62\theta^2 + 35\theta^3\right) \\ -\alpha^4\left(-3 + 41\theta - 149\theta^2 + 95\theta^3\right) \end{array}\right)}{16M_2^2} - \frac{(-1+\alpha)^2\alpha^2(1+\alpha)\theta(1+\theta)^2}{M_1^2},$$

$$\Delta\pi_p' = \pi_{p1}' - \pi_{p2}$$

$$= \frac{M_2}{8}\left(\alpha^3(1+\theta)^2 + \alpha\left(1 - 10\theta + \theta^2\right) + 2\left(1 - 4\theta + \theta^2\right)\right) - \frac{M_1}{2}\left((1-\theta)^2 + 2\alpha^3(3-2\theta)\theta + \alpha\left(1 - 8\theta + 5\theta^2\right)\right)$$

We need to indicate that $\theta_1 = \frac{\alpha^2-2-\alpha}{5\alpha^2-6-5\alpha}$, $\theta_2 = \frac{\alpha^2-\alpha-2}{9\alpha^2-9\alpha-2}$,

$$\theta_3 = \frac{f_1}{f_6} + \frac{1}{2}\sqrt{\frac{4f_1^2}{f_6^2} - \frac{4f_2}{3f_3} + \frac{16\sqrt[3]{\frac{1}{2}}f_4}{3f_3 z} + \frac{z}{3\sqrt[3]{\frac{1}{2}}f_6}} - \frac{1}{2}\sqrt{\frac{8f_1^2}{f_6^2} - \frac{8f_2}{3f_3} - \frac{16\sqrt[3]{\frac{1}{2}}f_4}{3f_6 z} - \frac{z}{3\sqrt[3]{\frac{1}{2}}f_6} + \frac{\frac{16f_1^3}{f_6^3} - \frac{8f_1 f_2}{f_6^2} + \frac{8f_5}{f_6}}{\sqrt{\frac{4f_1^2}{f_6^2} - \frac{4f_2}{3f_6} + \frac{16\sqrt[3]{\frac{1}{2}}f_4}{z} + \frac{z}{3\sqrt[3]{\frac{1}{2}}f_6}}}}$$

where

$$f_1 = 136 + 1260\alpha + 2190\alpha^2 - 3239\alpha^3 - 6272\alpha^4 + 5939\alpha^5 + 3905\alpha^6 - 5044\alpha^7 + 1261\alpha^8,$$
$$f_2 = 256 + 1496\alpha + 1468\alpha^2 - 3638\alpha^3 - 3331\alpha^4 + 4570\alpha^5 + 1160\alpha^6 - 2300\alpha^7 + 575\alpha^8,$$
$$f_3 = 176 + 2144\alpha + 7416\alpha^2 - 3400\alpha^3 - 29505\alpha^4 + 14780\alpha^5 + 32850\alpha^6 - 32380\alpha^7 + 8095\alpha^8,$$
$$f_4 = 2176 + 5440\alpha - 960\alpha^2 + 5664\alpha^3 - 10440\alpha^4 - 61500\alpha^5 + 97240\alpha^6 + 39352\alpha^7 - 171243\alpha^8$$
$$+104340\alpha^9 + 61236\alpha^{10} - 123096\alpha^{11} + 52730\alpha^{12} + 20720\alpha^{13} - 28380\alpha^{14} + 10168\alpha^{15} - 1271\alpha^{16},$$
$$f_5 = 40 + 164\alpha + 78\alpha^2 - 345\alpha^3 - 148\alpha^4 + 309\alpha^5 + 23\alpha^6 - 108\alpha^7 + 27\alpha^8,$$
$$f_6 = 176 + 2144\alpha + 7416\alpha^2 - 3400\alpha^3 - 29505\alpha^4 + 14780\alpha^5 + 32850\alpha^6 - 32380\alpha^7 + 8095\alpha^8,$$
$$f_7 = 16 + 48\alpha - 76\alpha^3 - 9\alpha^4 + 48\alpha^5 - 2\alpha^6 - 12\alpha^7 + 3\alpha^8,$$

$$f_8 = 34816 + 87040\alpha - 15360\alpha^2 + 90624\alpha^3 - 167040\alpha^4 - 984000\alpha^5 + 1555840\alpha^6 + 629632\alpha^7 - 2739888\alpha^8$$
$$+1669440\alpha^9 + 979776\alpha^{10} - 1969536\alpha^{11} + 843680\alpha^{12} + 331520\alpha^{13} - 454080\alpha^{14} + 162688\alpha^{15} - 20336\alpha^{16}$$
$$y = 16f_2^3 - 288f_1f_2f_5 + 432f_5^2f_6 + 432f_1^2f_7 - 144f_2f_6f_7,\ z = \left(y + \sqrt{y^2 - 4f_8^3}\right)^{\frac{1}{3}}.$$

Proof of the optimal solution of the basic-service contract when the retailer chooses self-delivery. When the retailer choose self-delivery, if they sign the basic-service contract, both of their profit functions are

$$\pi'_{r1} = (q_m^h + q_n^h)2p' + (q_m^l + q_n^l)p' - b'(q_m^h + q_n^h + q_m^l + q_n^l) - 2s'q_m^h - s'q_m^l$$
$$= \left(\alpha\left(1 - \frac{d'-2s'}{2(1-\theta)}\right) + \alpha\left(\frac{d'-2s'}{2(1-\theta)} - \frac{p'+s'}{\theta}\right)\right)2p' + \begin{pmatrix} (1-\alpha)\left(1 - \frac{d'-s'}{1-\theta}\right) \\ +(1-\alpha)\left(\frac{d'-s'}{1-\theta} - \frac{p'+s'}{\theta}\right) \end{pmatrix} p' - b'\left(1 - \frac{p'+s'}{\theta}\right)$$
$$-2s'\alpha\left(1 - \frac{d'-2s'}{2(1-\theta)}\right) - s'(1-\alpha)\left(1 - \frac{d'-s'}{1-\theta}\right),$$
$$\pi'_{p1} = (q_m^l + q_m^h)d' + b'(q_m^h + q_n^h + q_m^l + q_n^l) == \alpha\left(\frac{d'-s'}{1-\theta} - \frac{d'-2s'}{2(1-\theta)}\right) + 1 - \frac{d'-s'}{1-\theta})d' + b'\left(1 - \frac{p'+s'}{\theta}\right).$$

According to backwards induction, we can obtain the optimal solution as in Table 4, where

$$M_2 = 1/(2(1-3\theta) + \alpha(1-\alpha)(1-5\theta)),\ M_3 = 2(1-3\theta) + \alpha(1-\alpha)(1-5\theta) + 4\theta$$
$$M_4 = (4 - 36\theta + 92\theta^2 - 44\theta^3 + 4\alpha, (2 - 21\theta + 62\theta^2 - 35\theta^3) - \alpha^2(5 - 43\theta + 99\theta^2 - 45\theta^3)$$
$$-\alpha^3(6 - 82\theta + 298\theta^2 - 190\theta^3) + \alpha^4(3 - 41\theta + 149\theta^2 - 95\theta^3)).$$

□

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