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The optimal logistics service strategy choices between the platform and e-retailers

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Abstract: In the e-commerce market, the success of the hybrid online platform is well proven. The platform is not only an e-retailer but also provides online logistics services for other e-retailers in the platform. Logistics service is an indispensable link in e-commerce, and it also plays a vital role in promoting the online shopping. In our research, we analyze the impacts of logistics service sharing between the platform and the e-retailer and investigate the optimal strategy in two models. The study found that when the third-party logistics provider's logistics service level coordinates with logistics service fees and both are in the middle range, the platform and the e-retailer can achieve a logistics service sharing agreement, forming a win-win scenario. When the logistics service fee charged by the third-party logistics provider is too low, or the third-party logistics provider's logistics service is too high, both the platform and the e-retailer will choose the strategic mode of not sharing logistics service. Simultaneously, the third-party logistics provider's logistics service level promotes the logistics service level of the platform. Finally, numerical analysis is carried out to verify the equilibrium model and analyze the impacts of the equilibrium model's main parameters. Our study contributes to the growing body of research on the platform operation and provides management insights on firms' logistic service strategy choices.

Keywords: platform; e-commerce; logistics service; coopetition

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1 Introduction

With the development of mobile technology, online retailing has become more critical to people's daily lives. The total retail sales of consumer goods is \$ 6024.75 billion, a year-on-year decrease of 3.9% in 2020. Meanwhile, the online retail sales of physical goods is \$ 1499.95 billion, a year-on-year increase of 14.8% in 2020①. There are mainly two business mode in the online retail market. One is a pure platform, such as Taobao.com and Pinduoduo.com[1,2]; the other is a hybrid platform, such as JD.com, Suning.com, Amazon.cn[3,4]. In 2020, the revenue of JD.com logistics service increased by 47.2% year on year, and the revenue from external customers of JD.com logistics service accounted for 46.6%②. The survey data shows that the hybrid platform's transaction volume has accounted for more than 30% of the e-commerce sales in China③, and its scale is still expanding.

For the e-commerce industry, the logistics service becomes a critical factor in increasing the market demand[5-7]. The hybrid platforms such as JD.com, Suning.com, and Amazon.cn have established their own logistics and have a self-sufficient logistics service system to deliver products[2,8]. For the platforms, the self-running logistics service system achieves the improvement of logistics service efficiency and levels but usually leads to a capital shortage[9]. For the e-retailers, the third-party logistics service providers' (TPLs) poor service levels usually lead to no undesirable factors such as delivery delays, damaged goods, and poor service attitudes[10].

The TPLs' logistics service level is usually low.

① http://www.stats.gov.cn/tjsj/zxfb/202102/t20210227_1814154.html
② https://baijiahao.baidu.com/s?id=1698645787987107221&wfr=spider&for=pc
③ http://www.100ec.cn/detail-6559821.html

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However, the service level of platform's self-running logistics service system is high but needs a lot of financial supports. Under this circumstance, the e-commerce market has recently emerged a new trend of logistics service sharing; that is, the online platforms share self-operated logistics service systems with e-retailers in the marketplace. One example is from Amazon's logistics service which known as fulfillment by Amazon (FBA). Amazon shares its warehousing system and offers delivery services to e-retailers in its marketplace, and charges the corresponding service fee[11,12]. Moreover, JD. com also launched a logistics service sharing strategy to help retailers improve logistics efficiency, enhance consumer experience and improve customer satisfaction[4,13].

We think intuitively that logistics service sharing is a win-win strategy because it allows the platform to earn an extra logistics income and also improves the e-retailer's logistics service level. However, we note that this strategy will also affect the product sales competition between the platform and the e-retailers. Specifically, the platform is popular with consumers due to its high-quality logistics services. If the platform shares logistics service with e-retailers, the product sales revenue of the platform may decrease because it no longer has the advantage of high-quality logistics service. For e-retailers, the product sales revenue may increase but higher logistics service fees are possibly required.

Based on the analysis of the above phenomena, our study aims to discuss the following research questions: How does logistics service sharing affect the platforms and e-retailer's pricing and service decisions? Can the platform and the seller reach a logistics service sharing agreement? To solve above issues, we consider an online e-commerce service supply chain consisting of a platform, an e-retailer, and a third-party logistics provider (TPL). The platform acts as a e-retailer to sell products. The platform can also serve as a logistics service provider to provide logistics services for e-retailers, such as JD. com and Amazon. cn. The platform and the e-retailer sell the same types of products, forming competition in the end-consumer market. Moreover, the platform has a self-built logistics system, and the goods it sells are delivered to consumers through the platform's own logistics services. The e-retailer can choose the platform's logistics services or entrust other logistics companies to complete the order delivery. Our research discusses two alternative logistics service models: ① No sharing logistics service model (NL Model). The platform's logistics service only serves itself, and the e-retailer purchases logistics services from the TPL. ② Sharing logistics service model (UL Model). The platform shares its logistics service with the e-retailer; that is to say, the e-retailer purchases logistics services from the platform. Furthermore, our findings reveal some interesting insights.

Our analysis shows that logistics service sharing is mainly affected by the TPL's logistics service level and fees. When the TPL's logistics service level coordinates with logistics service fees and both are in the middle range, both the platform and the e-retailer will benefit from sharing logistics services, which can achieve a win-win situation. Second, when the TPL's single logistics service fee is high or the TPL's logistics service level is low, no sharing logistics service is optimal for the platform and e-retailers. Finally, as TPL's logistics service level increases, the platform's logistics service level will also increase, and the equilibrium model will evolve from no sharing logistics service to service sharing.

Our study mainly has three contributions as follows. Firstly, our research contributes to the competition and platform strategy literature and fills a significant gap in the literature stream about logistics service strategy for platform and e-retailer. This problem differs from conventional supply chain cooperation problems, our research explores how interaction of horizontal product retailing competition and vertical logistics service cooperation affects players' performance. Secondly, our study simultaneously determines the logistics service level and product retail price, which is unprecedented in previous studies. In the previous researches, the logistics service level is often regarded as an exogenous variable[14-17]. Thirdly, the notable results of our research are new and we conclude some new management insights. We find that the optimal strategy for both e-retailer and platform not only depends on the size of market potential[18,19], but also depends on the joint effect of external market characteristics. We conclude the optimal logistics service strategy for platform and e-retailer by examining the competition effect on two players' retail prices and individual and collective profits.

2 Literature review

In addition to the literature cited in the introduction, we draw on a rich body of studies on the e-commerce market and logistics service strategy. Specifically, there are three streams of research that closely relate to our work. The first stream focuses on coopetition research. The second stream is related to e-commerce platform business strategy. The last stream concentrates on service channel design.

Most previous researches concentrate on competition or cooperation, but little researches related to competition. Research on competition usually appeared in technological study and R&D. Gnyawali and Park[20] found that competition helps enterprises deal with significant technical challenges. It creates more profits for cooperative enterprises and promotes technological progress. In the research related to supply chain management, Wilhelm[21] took the automotive industry in Japan and Germany as the research object. He found that the fierce competition in the supply chain can be managed by actively establishing and maintaining competition. In terms of multichannel distribution, Yang et al[15] found that limited capacity may bring win-win-win results to suppliers, buyers, and consumers under the dual-channel strategy. Some studies also focused on the competition of strategic enterprise alliance[14], international trade, and marketing[22-24]. Previous research on competition primarily focuses on manufacturers and marketing, but few involving service supply chain strategy, especially in logistics services. We introduce competition into e-commerce services management and analyze the two modes of logistics service sharing and non-sharing to make the best strategic choices. It is different from the previous literature is that our study contributes the research on the logistics service supply chain's competition strategy, and analyze the influence of logistics service sharing mode on the product sales competition between the platform and the e-retailers.

In the study of platform strategy, Abhishek et al[25] found that if online channel sales negatively affect the supplier's traditional channel demand, the platform is more inclined to use the market pricing model. Qing et al[26] investigated the platform's business model and compared the platform performance under three strategies: the platform only as a e-retailer, or merely as a trading market, or using a mixed operation model. Other researches on e-commerce platform strategy involve the privacy and security study[27], the product information search and ranking study[28], and the discussion of online product sales reviews study[29]. Our research is very similar to the study[17], which explores the competition's optimal strategies between OEM and e-retailers. Our study emphasizes the choice of logistics strategies in the e-commerce market. He et al[16] examined that the manufacturer or e-retailer can provide the extended warranty service. The research found that no matter which party provides the extended warranty, the supply chain will obtain high profits, but customers' corresponding service quality is not necessarily maximized. However, these researches don't consider the impact of logistics services on operation decisions. Since logistics service is a very important link in e-commerce, the decision-making of platform logistics services will have an important impact on the revenue of platform and e-retailers. Our research focuses on the impact of platform logistics service sharing in the e-commerce market and the choice of equilibrium models between platforms and e-retailers. And then our research mainly analyzes the logistics service level and pricing in the platform operation decision.

Finally, our study is also related to the service channel design of the supply chain. Li et al[30] investigated four service channels' performance, including the manufacturer providing services, the e-retailer providing services, the manufacturer hiring the third-party to provide services, and the e-retailer hiring the third-party to provide services. In addition, some researchers have also studied service channel design issues that don't directly affect product demand. Hong et al[31] discussed how to choose the optimal reverse channel to collect second-hand products from customers. In the dual supply chain, Zhang[32] analyzed the difference between the manufacturer's service and the e-retailer's service under demand uncertainty. Zhang et al[33] studied the strategic decision-making about after-sales service and information sharing. Furthermore, some scholars also explored some new service modes of logistics service sharing in the competitive supply chain[13,34]. Different from the above studies, our research explores how the interaction of horizontal product retailing competition and vertical logistics service cooperation affects the platform's and e-retailer' performance. Most of the previous researches conducted research and analysis in a specific service model. However, the logistics service is rarely involved in the study of the e-commerce and platforms. Our study concentrates on the strategic impact of the logistics service on service strategy and pricing decisions of platforms and e-retailers to improve the research on platform logistics service decisions.

The studies closest to our study are those of Chen et al[17] and Niu et al[35]. Chen et al[17] adopted the Cournot competition model and also discussed the effects of cooperation and non-cooperation in product sales strategies. Different from their focus on two e-retailer in the e-commerce marketplace with the same or different service-investment efficiencies, our research concentrates on the relationship between platforms and e-retailers, and analyzes the effects of cooperation and non-cooperation in logistics service strategies. Niu et al[35] also employed the Cournot competition model to analyze the logistics service sharing strategies for two firms with guaranteeing customers a promised delivery time. The Reference [35] considered a promised delivery time for customers and examine how the promised delivery time for customer affects the two players' relationship and performances. Our research is different from it, we consider the case of logistics service sharing between platform and e-retailer and examine how logistics service sharing affects e-commerce marketplace competition and consequential firm decisions and performance. In our research, we examine the implications of logistics service sharing between platform and e-retailer when the platform not only offers marketplace services to e-retailers, but also competes with e-retailers in the retail market.

3 Model setup

We investigate an e-commerce service supply chain consisting of a platform, an e-retailer, and a third-party logistics provider. The platform in our study refers to hybrid online platforms such as JD. com, Suning. com, Amazon. cn, which sell products and have a self-built logistics system to provide logistics services. Online shopping services mentioned above include two parts: product sales and logistics services. In terms of product sales, platforms and the individual e-retailer sell the same types of product, forming competition in the end-consumer market. In terms of logistics services, platforms have self-built logistics systems. The product they sell is delivered to consumers through its own logistics services. The e-retailer can choose to adopt the logistics services offering by platforms or the TPLs. Therefore, there is a competition relationship between the platform and the e-retailer on the e-commerce market.

Table 1 summarizes the critical notation in our study. The decision variable $p_1^j(p_2^j)$, ω, and S_1^j reflect the platform and e-retailer's decision-making in the form of a competition relationship in e-commerce and logistics services. And other parameters are exogenous variables.

The decision sequence of events is as follows. Firstly, as the leader of the market, the platform decides whether or not to provide the e-retailer with its own logistics services. Then, the platform determines S_1^j and ω simultaneously. In the second stage, the e-retailer chooses whether to accept logistics services provided by the platform; otherwise, they still choose logistics services provided by the TPL. In the third stage, the platform and e-retailer decide the price of the product simultaneously. The decision sequence is shown in Figure 1.

Table 1. Notation of the model.

Parameters	α	E-retailer' market potential, $0<\alpha<1$
	β	The sensitivity of consumer on e-commerce logistics service, $0<\beta<1$
	φ	Percentage of commissions charged by platform to e-retailer, $0<\varphi<1$
	S_t	The service level of the third-party logistics provider, $0<S_t$
	f	Single commodity logistics service fee charged by the third-party logistics
	$D_1^j(D_2^j)$	The demand of the product on platform (e-retailer) in model $j, j=N, U$
	S_2^j	The logistics service level of the e-retailer in model $j, j=N, U$
	$\Pi_1^j(\Pi_2^j)$	Profit of platform (e-retailer) in model $j, j=N, U$
Decisions	$p_1^j(p_2^j)$	Price of the product on the platform (e-retailer) in model $j, j=N, U$
	ω	Single commodity logistics service fee charged by the platform
	S_1^j	The logistics service level of the platform in model $j, j=N, U$
Superscripts	N	No using logistics sharing strategy (NL)
	U	Using logistics sharing strategy (UL)

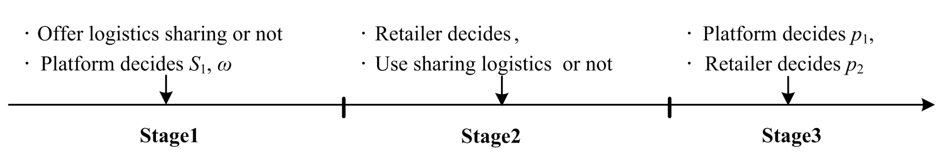

Figure 1. Parameter decision sequence.

We denote the demand for the product as D_i^j in model j, where the subscript $i \in \{1,2\}$ stands for the platform and e-retailer, and the subscript $j \in \{N,U\}$ stands for two logistics service strategies: No using logistics sharing strategy (NL model), Using logistics sharing strategy (UL model). We first discuss Model NL (subsection 4.1) and then Model NL (subsection 4.2). Now we discuss the critical assumptions in our study.

Assumption 3.1 Customers will perceive the difference in the level of logistics services when they are shopping online. The logistics service level will affect the market demand for online shopping products because it changes the customers' purchase behavior.

E-commerce and platform-related literature generally assume that the level of logistics services does not affect the market demand for products[36,37]. However, recent empirical studies have shown that the logistics service level is an essential factor affecting market demand and customer satisfaction and pointed out that logistics service is the foundation of the logistics system[38].

Assumption 3.2 The level of logistics services provided by the platform is higher than that offered by TPLs, that is $S_1^j > S_t$.

The platform's logistics have self-built warehouses and a series of supporting logistics infrastructure including transportation, warehousing, distribution, and after-sales service, efficiently managing and solving problems. Therefore, the platform's logistics service level is higher than TPLs[4,39].

Assumption 3.3 The capability of the platform's logistics service is not limited, the demand for the product is specific, and the market is perfectly competitive. The information between the platform and the e-retailer is entirely symmetrical, and there is no moral hazard between each other.

The researches on logistics services generally do not consider the situation of limited capacity, such as the References [40,41]. We assume that the platform's logistics service capacity is not limited. Moreover, similar to previous literature[15,42], we also assume that the demand is specific and the market is perfectly competitive.

Assumption 3.4 The cost of products sold online is standardized to zero to explore further the impact of logistics service level and product pricing in e-commerce.

Similar to traditional offline product sales channels, we standardize the sale cost of products to zero. We analyze the impact of logistics service costs on market demand and profits. This assumption about cost is quite common in the previous literature[41,43].

4 Models and analysis

This section we considers two models in the logistics service supply chain: no sharing logistics strategy model (NL model) and sharing logistics strategy model (UL model). Specifically, in the NL model, the e-retailer does not use the platform's logistics services. That is, the platform uses its own logistics service, and its logistics service level is S_1^N, while the e-retailer uses the logistics service provided by the TPLs, its logistics service level is S_t. And the single product logistics service fee charged is f. There is no cooperative relationship between the two on logistics services, and the sales of products form perfect competition in the end-consumer market. The product price of platforms and e-retailer is p_1^N and p_2^N. The platform charges commissions φ based on the sales of the e-retailer.

In the UL model, the e-retailer uses the platform's logistics services. At the meanwhile, the platform uses its own logistics services and provides logistics services for the e-retailer. The e-retailer and platform cooperate in logistics services but compete in end-of-products. The level of logistics services provided by the platform is S_1^U and the fee of logistics services from e-retailers charged by the platform is ω. The product price of the platform and e-retailer is p_1^U and p_1^U. The platform charges a commission φ based on the sales of the e-retailer. Therefore, the two have a competition relationship in e-commerce services. These two logistic modes are shown in Figures 2 and 3.

Consistent with previous studies[44,45], we assume that the e-retailer's market demand is a linear function of the price and logistics service level. The demand functions are as follows:

$$D_1^m = 1 - p_1^m + S_1^m - \beta \cdot S_2^m, m = \{U,N\} \quad (1)$$

$$D_2^m = \alpha - p_2^m + S_2^m - \beta \cdot S_1^m, m = \{U,N\} \quad (2)$$

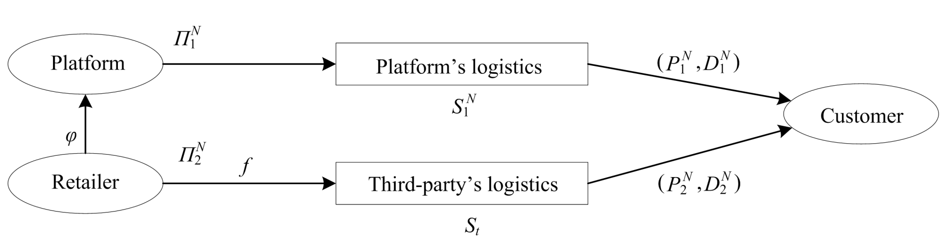

Figure 2. No using logistics sharing strategy (NL Model).

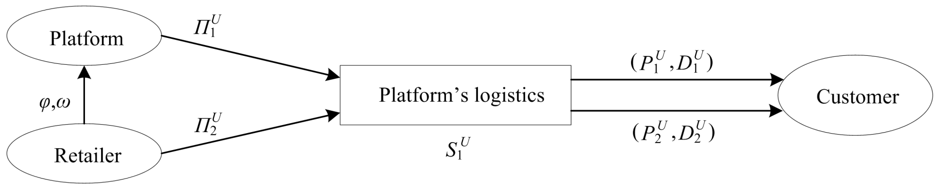

Figure 3. Using logistics sharing strategy (UL Model).

Equations (1) and (2) describe the impact of price and logistics service level on market demand. As a market leader, the platform has a larger market size than the e-retailer. Therefore, we suppose that the market size of the platform is 1, the market size of the e-retailer is α. This form of hypothesis has been adopted in many literature[46,47]. As a platform (e-retailer), its product retail price hurts its market demand. The logistics service level of the platform (e-retailer) has a positive impact on its demand. In contrast, the e-retailer's logistics service level (platform) as its opponent hurts the platform's demand (e-retailer).

4.1 Scenario 1: No sharing logistics strategy (NL)

To quantify the impact and economic benefits of the two logistics strategies for the platform and e-retailers, we start our research with no sharing logistics strategy. The market demand function of the platform and e-retailers can be expressed as follows:

$$D_1^N = 1 - p_1^N + S_1^N - \beta \cdot S_t \tag{3}$$

$$D_2^N = \alpha - p_2^N + S_t - \beta \cdot S_1^N \tag{4}$$

Assuming that the logistics cost of the platform is a quadratic function of its logistics service level, it expresses as $c_1 = \frac{1}{2}(S_1)^2$. This assumption is widely used in the literature on logistics service costs[9,17,45]. Then the profit function of the platform and e-retailer can be expressed as follows:

$$\Pi_1^N = p_1^N \cdot D_1^N + \varphi \cdot p_2^N \cdot D_2^N - \frac{1}{2}(S_1^N)^2 \tag{5}$$

$$\Pi_2^N = (1-\varphi) \cdot p_2^N \cdot D_2^N - f \cdot D_2^N \tag{6}$$

By deriving the profit function, we can obtain the price p_1^N and p_2^N of the platform and e-retailers, and the logistics service level of the platform S_1^N.

Proposition 4.1 Under the NL model, the optimal logistic service level, equilibrium prices, and player's profits are as follows:

$$S_1^{N*} = \frac{1-\alpha\beta\varphi+\beta(1+\varphi)S_t}{1-\beta^2\varphi},$$

$$p_1^{N*} = \frac{2-\beta(\alpha+\beta)\varphi-\beta(2+\varphi-\beta^2\varphi)S_t}{2(1-\beta^2\varphi)},$$

$$p_2^{N*} = \frac{(\alpha-\beta)(1-\varphi)+(1-\beta^2\varphi)f+(1+\beta^2)(1-\varphi)S_t}{2(1-\varphi)(1-\beta^2\varphi)},$$

$$\Pi_1^{N*} = \frac{(4-(\alpha^2-2\alpha\beta-\beta^2)(1-\varphi)^2-2\varphi+(1-\beta^2\varphi)f^2)\varphi}{2(1-\varphi)^2(1-\beta^2\varphi)} + \frac{4\beta-2(\alpha-\beta+\alpha\beta^2+\beta^3)\varphi S_t+(\beta^4\varphi-\varphi-2\beta^2(1+\varphi))^2}{2(1-\beta^2\varphi)},$$

$$\Pi_2^{N*} = \frac{(f-\alpha+\beta+(\alpha-\beta(1+f\beta))\varphi-(1+\beta^2)(1-\varphi)S_t)^2}{2(1-\varphi)(1-\beta^2\varphi)^2}.$$

In Proposition 4.1, it's worthy to note that if the TPL's logistics service level is too high (i.e., when $S_t > \overline{S_t} = \frac{1-\alpha\beta\varphi}{(1-\varphi)\beta+1-\beta^2\varphi}$), or the logistics service fee charged by the TPL is too high (i.e., when $f > \bar{f} = \frac{(1-\varphi)(\alpha-\beta+(1+\beta^2)S_t)}{1-\beta^2\varphi}$), the platform will exit the e-commerce market competition. So, in the rest of our study, we will focus on the conditions that the TPL's logistics service level is in a more reasonable range (i.e., when $0<S_t<\overline{S_t}$), and the TPL's logistics service fee is not too high (i.e., when $0<f<\bar{f}$). And the market potential of the e-retailer is reasonable high (i.e., when $0<\beta<\alpha<(1+\beta^2)S_t-\beta<1$), if not, the e-retailer will withdraw from the market.

Corollary 4.1 ① p_2^{N*} increase in S_t, but $S_1^{N*}(S_t)$ and p_1^{N*} decrease in S_t. ② If $0<S_t<S_t^k$, then Π_1^{N*} decrease in S_t, and if $\overline{S_t}>S_t>S_t^k$, Π_1^{N*} will increase in S_t. ③ Similar to Π_1^{N*}, if $0<S_t<S_t^l$, then Π_2^{N*} decrease in S_t, and if $\overline{S_t}>S_t>S_t^l$, Π_2^{N*} will increase in S_t.

Corollary 4.1 indicates that for the NL model, the TPL's logistics service S_t has a positive impact on the platform's logistics service level and hurts the platform's price of the product. It is not difficult to understand for us that product sales competition in the e-commerce market is a competition in logistics service quality. If the logistics service level of the competitor improves, it will reduce the demand for its own products. When the TPL's service quality improves, the platform will inevitably improve its own logistics service level and lower the price of products. The effect of TPL's logistics service on the optimal profit of platform and e-retailer is more complicated. This effect depends upon the relationship of S_t with a critical threshold S_t^k and S_t^l as shown in Corollary 4.1. This dependency exists because the platform has the advantage of a higher logistics service quality. A larger logistics service advantage can offset the platform's pressure to engage in fierce competition with its rival competitor. For instance, JD's self-operated stores are much more popular than other e-retailers on the platform. So JD.com is always in a favorable position in a product sales competition.

4.2 Scenario 2: Sharing logistics service strategy (UL)

In this scenario, the platform shares its own logistics services to the e-retailer, then $S_2^U = S_1^U$. Therefore, the market demand function of platforms and e-retailers can be expressed as follows:

$$D_1^U = 1 - p_1^U + (1-\beta)\cdot S_1^U \tag{7}$$

$$D_2^U = \alpha - p_2^U + (1-\beta)\cdot S_1^U \tag{8}$$

Since the platform provides logistics services for the e-retailer, the corresponding logistics fees ω must be charged. The profit function of platforms and e-retailers can be expressed as follows:

$$\Pi_1^U = p_1^U\cdot D_1^U + \varphi\cdot p_2^U\cdot D_2^U + \omega\cdot D_2^U - \frac{1}{2}(S_1^U)^2 \tag{9}$$

$$\Pi_2^U = (1-\varphi)\cdot p_2^U\cdot D_2^U - \omega\cdot D_2^N \tag{10}$$

By deriving the profit function, we can obtain the price p_1^U and p_2^U of the platform and e-retailers when the profit maximizes, and the logistics service level of the platform S_1^U and the logistics service fee of a single product charged by the platform ω.

Proposition 4.2 Under the UL model, the equilibrium logistics service fee, the optimal logistic service level, equilibrium prices, and player's profits are as follows:

$$\omega^* = \frac{((1-\beta)^2 + (1+(2-\beta)\beta)\alpha)(1-\varphi)^2}{1-\varphi+(2-\beta)(3-\varphi)\beta},$$

$$S_1^{U*} = \frac{(1-\beta)+(2+\alpha-\varphi)}{1-\varphi+(2-\beta)(3-\varphi)\beta},$$

$$p_1^{U*} = \frac{(1-\beta)^2(2+\alpha-\varphi)}{2(1-\varphi)+2(2-\beta)(3-\varphi)\beta} + \frac{1}{2},$$

$$p_2^{U*} = \frac{((1-\beta)^2 + (1+(2-\beta)\beta)\alpha)(3-2\varphi)}{2(1-\varphi)+2(2-\beta)(3-\varphi)\beta},$$

$$\Pi_1^{U*} = \frac{3+(2+\alpha)\alpha+2(\beta-\varphi)-2(2-\alpha)\alpha\beta-(1-\alpha)^2\beta^2}{4(1-\varphi)+4(2-\beta)(3-\varphi)\beta},$$

$$\Pi_2^{U*} = \frac{(\alpha+(1-\beta)^2+\alpha(2-\beta)\beta)^2(1-\varphi)}{4(1-\varphi+(2-\beta)(3-\varphi)\beta)^2}.$$

Similar to Proposition 4.1, if the TPL's logistics service level is too high (i.e., when $S_t > \overline{S_t} = \frac{1-\alpha\beta\varphi}{(1-\varphi)\beta+1-\beta^2\varphi}$) or the market potential of the e-retailer is too low (i.e., when $0<\alpha<\beta$), both the platform and the e-retailer will exit the e-commerce market competition. So, in the rest of our study, we will focus on the conditions that the TPL's logistics service level is in a more reasonable range (i.e., when $0<S_t<\overline{S_t}$), and the market potential of the e-retailer is reasonable high (i.e., when $0<\beta<\alpha<(1+\beta^2)S_t-\beta<1$).

Corollary 4.2 ① $\omega^*(\alpha)$, $S_1^{U*}(\alpha)$, p_1^{U*}, and p_2^{U*} all increase in α. ② If $0<\alpha<\alpha^0$, then Π_1^{U*} and Π_2^{U*} decreases in α, and if $\alpha^0<\alpha<1$, Π_1^{U*} and Π_2^{U*} will increase in α.

Corollary 4.2 indicates that the logistics service fee charged by platform and the platform's service quality are increasing functions of the e-retailer's market potential (α) for the UL model. Like the classic economic theory, as the e-retailer's potential market increases, the competition between the e-retailer and the platform will become more intense. Therefore, the platform must improve the service level, and the single logistics fees charged by the platform will also increase. The effect of the market potential of the e-retailer, and the optimal profit of the platform and thee-retailer is more complex. Depending upon the relationship between α and α^0. The platform's optimal profit can be a decreasing or increasing function of α because the high market potential will drive both prices of the platform and the e-retailer up. At the same time, the platform can set a higher logistics service price due to its possessing a greater quality of logistics service. It implies that the platform must consider the market competition factor when deciding the logistics service price. The revenue generated from logistics service must be incorporated by the platform in setting its optimal retail price.

5 Comparison analysis

In this section, we first compare the equilibrium prices of the platform and e-retailers under two models. Next, we analyze the logistics service level decision of the platform in two scenarios. Furthermore, we explore the platform and the e-retailer's optimal profits when sharing logistics services or not sharing. Then, we have the following propositions.

5.1 Comparison of equilibrium results

Proposition 5.1 ① If $0<S_t\leqslant S_t^{\,a}$, then $p_1^{U*}\leqslant p_1^{N*}$; If $\overline{S_t}>S_t>S_t^{\,a}$, then $p_1^{U*}>p_1^{N*}$. ② If $0<S_t\leqslant S_t^{\,b}$, then $p_2^{U*}\geqslant p_2^{N*}$; If $\overline{S_t}>S_t>S_t^{\,b}$, then $p_2^{U*}<p_2^{N*}$.

Proposition 5.1 implies that the logistics service sharing can drive up or down the prices of the platform and the e-retailer, which depends upon the differences in the TPL's logistics service quality (S_t). More specifically, the sharing logistics service leads to an increase of the optimal retail price of platform but a decrease of the e-retailer's optimal retail price with a large value of S_t. Therefore, customers benefit from buying the product at a lower price. With a small value of S_t, the effect of sharing logistics services on optimal retail prices is opposite to the above. It leads to a decrease in the platform's optimal retail price and an increase in the e-retailer's optimal retail price. It is also beneficial for customers.

Proposition 5.2 The platform's logistics service level is greatly affected by the TPL's logistics service level. If $0<S_t \leqslant S_t{}^r$, then $S_1^{U*} \leqslant S_1^{N*}$, and if $S_t{}^r<S_t<\overline{S_t}$, then $S_1^{U*}>S_1^{N*}$.

Proposition 5.2 suggests that the logistics service level of the TPL (S_t) has significant effects on the platform's logistics service level, and the impact is not monotonous. The platform's logistics service level increases with the increase of the TPL's and decreases with the decrease of the TPL's. Consistent with our intuition, when the TPL's logistics service is low, the platform's revenue from sharing the logistics service with the e-retailer mitigates the pressure of decreasing product demand from the intense market competition. The platform benefits from a low logistics service. However, The situation is opposite to the previous situation when the TPL's logistics services level is high. The platform must improve the level of logistics services to cope with more fierce logistics service competition. Our findings suggest that platform logistics and the TPLs complement each other and make progress together to continuously improve society's overall logistics service level. This relationship is similar to the logistics of JD with other logistics service providers, such as YTO Express, STO Express, and SF Express.

Proposition 5.3 ① If $0<f \leqslant f^c$ and $0<S_t \leqslant S_t{}^c$, then $\Pi_1^{U*} \geqslant \Pi_1^{N*}$; If $0<f \leqslant f^c$ and $\overline{S_t}>S_t>S_t{}^c$, then $\Pi_1^{U*}<\Pi_1^{N*}$. ②If $f^c<f<\bar{f}$ and $0<S_t \leqslant S_t{}^c$, then $\Pi_1^{U*} \leqslant \Pi_1^{N*}$; If $f^c<f<\bar{f}$ and $\overline{S_t}>S_t>S_t{}^c$, then $\Pi_1^{U*}>\Pi_1^{N*}$.

Proposition 5.3 illustrates that when both the TPLP's logistics service level and logistics service fee are relatively low or relatively high, sharing logistics services will benefit the platform. However, when the TPLP's logistics service level is not coordinated with the logistics service, sharing logistics services will hurt the platform. And the impact of sharing logistics service on the platform's profitability is not monotonous. On the one hand, when the platform shares its logistics service with the e-retailer, it will assuredly lose its competitive dominance in logistics service. On the other hand, the platform can earn more profit from sharing logistics services with the e-retailer. Therefore, the platform benefits from when the TPLP's logistics service level coordinates with the logistics service. Because the platform can influence the e-retailer's pricing decision by strategically transforming its logistics service fee ω. If the TPL has a high level of logistics service and charges low fees, sharing logistics service will only be detrimental for the platform. At this time, the platform can only encourage e-retailers to participate in sharing logistics services by reducing the price of logistics services. Still, the platform will reduce not only sales revenue but also logistics services revenue. Our research provides actionable management insights for e-commerce platforms, such as JD.com and Suning.com in China. If TPL's logistics service fee is not too high or too low, e-commerce platforms should share their logistics services with e-retailers.

Proposition 5.4 (① if $0<f \leqslant f^h$ and $0<S_t \leqslant S_t{}^h$, then $\Pi_2^{U*} \leqslant \Pi_2^{N*}$; If $0<f \leqslant f^h$ and $\overline{S_t}>S_t>S_t{}^h$, then $\Pi_2^{U*}>\Pi_2^{N*}$. ②If $f^h<f \leqslant \bar{f}$ and $0<S_t \leqslant S_t{}^g$, then $\Pi_2^{U*} \geqslant \Pi_2^{N*}$; If $f^h<f \leqslant \bar{f}$ and $\overline{S_t}>S_t>S_t{}^g$, then $\Pi_2^{U*}<\Pi_2^{N*}$.

Proposition 5.4 states that only if the TPL's logistics service level is low and the logistics service fee is high, or the TPL's logistics service level is high and logistics service fee is low, sharing logistics service will be beneficial for the e-retailer. Interestingly, the impact on the e-retailer's profit is completely different from the platform's. From the e-retailer's perspective, even if the sharing logistics service will improve its logistics service quality, it will limit its pricing flexibility and give the platform more pricing power. What's more, the lower the TPL's logistics service level is, the more the e-retailer will benefit from sharing logistics service. Simultaneously, the higher the TPL's logistics service fee is, the more the seller will benefit due to the limited pricing flexibility. Therefore, when the TPL's logistics service level is relatively low and the TPL's logistics service fee is high. The e-retailer is willing to share logistics services, and it will benefit from this situation. Our findings show that only when the TPLs with poor logistics service and charging a higher fee will the sellers have an incentive to purchase logistics services from the platform.

5.2 Logistic service strategy selection

In this subsection, we discuss the optimal logistics service strategy choices between platforms and e-retailers. From the above propositions, we know that the TPL's logistics service level and fees has essential impacts on the platform and e-retailer's equilibrium profits. In this section, we will use numerical analysis to show the impact on the UL model and NL model visually. Based on previous literature research[6,26], our research assumes $\alpha=0.5$, $\beta=0.5$, $\varphi=0.1$ in this section to investigate the impacts on the equilibrium strategy.

Proposition 5.5 We explore the effects of sharing logistics services on the maximum profits of the platform and the e-retailer.

(Ⅰ) If $\overline{S_t}>S_t \geqslant S_t{}^c$ and min $\{f^c, f^h\} \leqslant f<f^0$ there is a Pareto improvement when sharing logistics services.

(Ⅱ) In the Pareto improvement, if $\overline{S_t}>S_t \geqslant S_t{}^c$ and

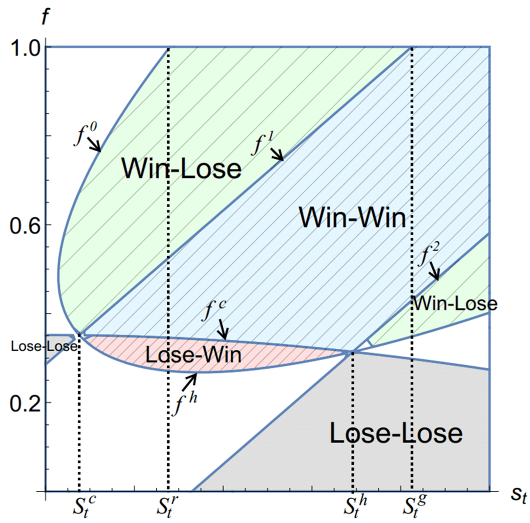

Figure 4. Equilibrium profit comparison.

$f^c \leqslant f < \max\{f^1, f^2\}$, then achieving a win-win situation. Otherwise, if $S_t^{\,h} > S_t > S_t^{\,c}$ and $f^h < f < f^c$, then $\Pi_1^{U*}(p_1^U) < \Pi_1^{N*}(p_1^N)$, and $\Pi_2^{U*}(p_2^U) > \Pi_2^{N*}(p_2^N)$; If $S_t^{\,g} > S_t > S_t^{\,c}$ and $f^0 < f < f^1$, *or* $\overline{S_t} > S_t > S_t^{\,c}$ and $f^h < f < f^2$ then $\Pi_1^{U*}(p_1^U) > \Pi_1^{N*}(p_1^N)$, $\Pi_2^{U*}(p_2^U) < \Pi_2^{N*}(p_2^N)$.

(Ⅲ) For the situation of win-win, $S_1^{U*} > S_1^{N*}$, $p_1^{U*} > p_1^{N*}$ and $p_2^{U*} < p_2^{N*}$.

Proposition 5.5 illustrates that whether sharing logistics service increases or decreases the platform's optimal profits compared with no sharing logistics service model is mainly decided by the TPL's logistics service level (S_t) and charged fees (f). It is divided into four decision regions showing in Figure 4. We now explain the relationship of parameters on each area in detail.

The blue region in Figure 4 suggests that the platform's optimal profits and the e-retailer under the UL model are greater than those under the NL model. This implies that the platform sharing logistics service with the e-retailer can lead to Pareto's optimal solution. Therefore, a cooperative relationship in logistics service will be embraced by both parties. From Proposition 5.1 and Proposition 5.2 above, we know that in the win-win region, the platform's logistics service level and price are higher than this under the NL model. At the same time, the e-retailer's retail price is lower than this under the UL model. Both the two results are beneficial to consumers. Therefore, we can conclude that sharing logistics services affects the e-commerce platforms, e-retailers, and consumers in this situation. And the optimal logistics service strategy choice between the platform and the e-retailer is the UL model.

The green region in Figure 4 suggests the platform will earn more profit in the UL model than the NL model, but the e-retailer will earn less profit in the UL model. And the total profit between the two is greater in the UL model than in the NL model ($\pi^U > \pi^N$). In this situation, the sharing logistics service hurts the e-retailer's profit. As a leader in the e-commerce market, only if the platform is willing to allocate a portion of the increased profit to the e-retailer by the profit distribution contract can the agreement of sharing logistics services be realized. The optimal logistics service strategy choices between the platform and the e-retailer are also the UL model.

The red region in Figure 4 suggests the e-retailer will earn more profit in the UL model than the NL model, but the sharing logistics service will hurt the platform, even though the total profit between the two is greater in the UL model than in the NL model ($\pi^U > \pi^N$). In this situation, the sharing logistics service hurts the platform's profit. Similar to the green region, Pareto improvement can only be realized by a further cooperation mechanism such as a profit-sharing contract. Then, the optimal logistics service strategy choices between the platform and the e-retailer are also the UL model.

The grey region in Figure 4 suggests that the NL model is the optimal strategy in this situation. More specifically, if the TPL's logistics service level is more than S_t^c and the TPL's logistics service fee is less than f^h, or the TPL's logistics service level is less than S_t^r and the TPL's logistics service fee is more than f^0 then $\pi^N > \pi^U$. There is no reality for the platform to share logistics services with the e-retailer in these two situations. The e-retailer will also not accept the sharing logistics service. Therefore, the UL model is infeasible. the optimal logistics service strategy choices between the platform and the e-retailer is the NL model.

Proposition 5.6 We conclude the optimal logistics service strategies of the platform and e-retailers as follows.

(Ⅰ) If $S_t^{\,c} \leqslant S_t < \overline{S_t}$ and $f^h < f < f^0$, UL mode is a better strategy for e-retailers. If $S_t^{\,c} \leqslant S_t < \overline{S_t}$ and $f > f^0$ or $f < f^h$, NL mode is a better strategy for e-retailers.

(Ⅱ) If $S_t^{\,c} \leqslant S_t < \overline{S_t}$ and $\min\{f^c, f^h\} \leqslant f$, UL mode is a better strategy for platforms. Otherwise, SL mode is a better strategy for the platform.

(Ⅲ) If $S_t^{\,c} \leqslant S_t < \overline{S_t}$ and $\max\{f^c, f^h\} \leqslant f < f^0$, UL mode is the best strategy for both e-retailers and platforms. If $S_t^{\,c} \leqslant S_t < \overline{S_t}$, and $f < \min\{f^c, f^h\}$ or $f > f^0$, NL mode is the best strategy for both e-retailers and platforms.

Proposition 5.6 illustrates that logistics service sharing can achieve equilibrium strategy choices on the condition that both the TPL's logistics service level (S_t) and charged fees (f) are moderate. Moreover,

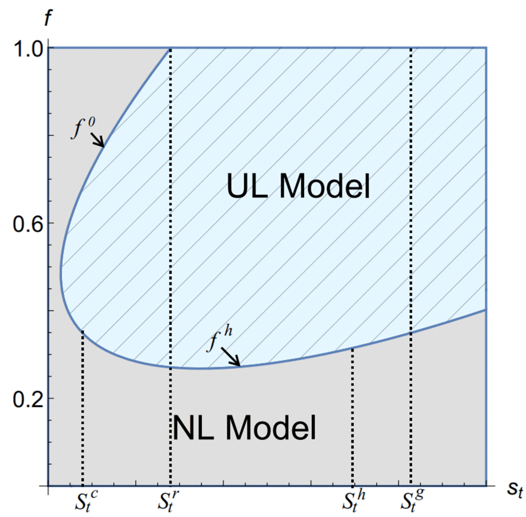

Figure 5. The selection of strategy model.

when both TPL's logistics services and charged fees are increased or decreased, the possibility of choosing UL mode will increase. For both e-retailers and platforms, when TPL's logistics services is moderate and logistics service fees charged by TPL is also moderate, UL mode is the best logistics service strategy for both players. Otherwise, NL mode is the best logistics service strategy for both players. For e-retailer, when TPL's logistics services is moderate and logistics service fees charged by TPL is smaller than the threshold value f^0, the UL mode is the best logistics service strategy. And when TPL's logistics services is moderate and logistics service fees charged by TPL is greater than the threshold value f^0, NL mode is the best logistics service strategy. For platform, when TPL's logistics services is moderate and logistics service fees charged by TPL is greater than the maximum of f^c and f^h, the UL mode is the best logistics service strategy. Otherwise, the UL mode is the best logistics service strategy. Moreover, the optimal logistics service strategy choices between the platform and the e-retailer are shown in Figure 5. The blue area represents the UL mode as the optimal choice of the logistics service strategy, and the gray area represents the NL mode as the optimal choice of the logistics service strategy.

6 Sensitivity analysis

We have analyzed the impacts of logistics service level of the TPL (S_t) the logistics service fee charged by the TPL (f) on the equilibrium price and profit profoundly by investigating the above equilibrium strategy. In this section, we will analyze the sensitivity of the other parameters, including the market potential of e-retailer (α), the commission rates charged by the platform (φ), and consumers' sensitivity to the level of logistics services (β).

According to the equilibrium solution $\omega^* = \dfrac{((1-\beta)^2+(1+(2-\beta)\beta)\alpha)(1-\varphi)^2}{1-\varphi+(2-\beta)(3-\varphi)\beta}$, we can obtain the influence of the parameters on the logistics service price in Figure 6.

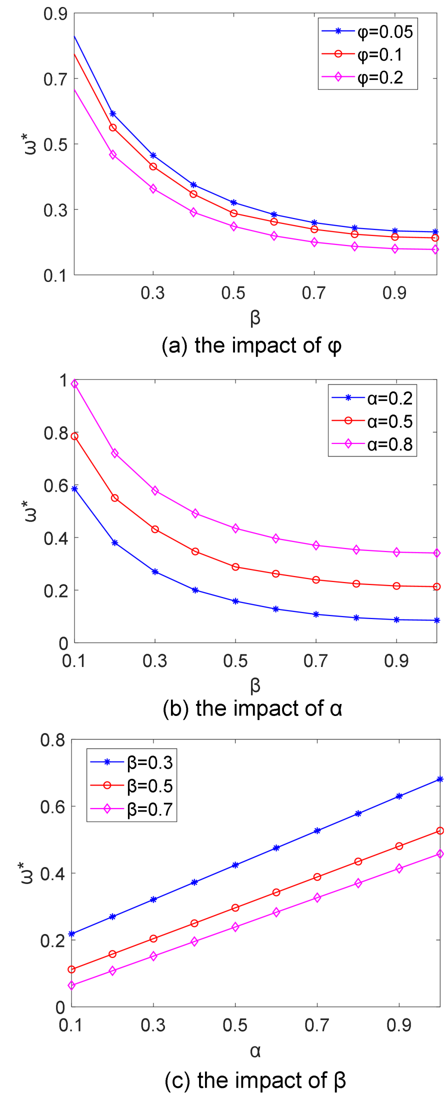

Figure 6. The impacts of parameters for ω^*.

From Figure 6 (a), we know that φ hurts ω^*, and the larger φ is, the greater the impact on ω^*. At the same time, as β increases, the slope of the curve gradually decreases, which indicates that the impacts on ω^* gradually decreases. The platform's profit mainly comes from three parts: sales of products, logistics service income, and platform commissions. The increase in platform commissions damages the profit of the e-retailer. The platform has to reduce the price of logistics services to attract more the e-retailer to use platform logistics service. The total profit of the platform doesn't decrease.

From Figure 6 (b), we know that α has a positive impact on ω^*, that is, as the market potential increases, the single logistics service fee charged by the platform will also increase. The more enormous the

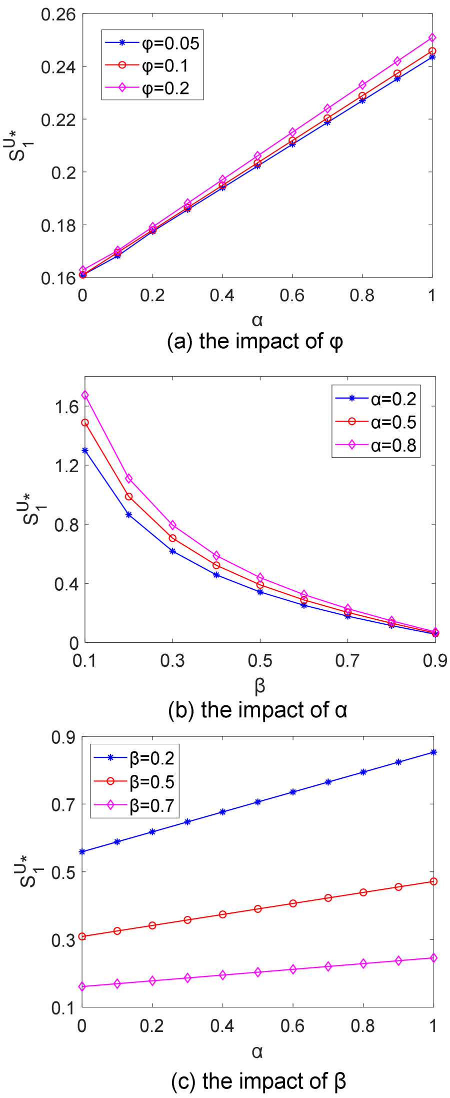

Figure 7. The impacts of parameters for S_1^{U*}.

market potential, the more intense competition between the e-retailer and the platform. Therefore, the platform must increase profits by increasing the price of logistics services.

We can see from Figure 6 (c) that β hurts ω^*, and the larger β has smaller impacts on ω^*. When the platform shares logistics services with e-retailers, the platform no longer has the advantage of high logistics service level. The larger consumer's sensitivity to the logistics service level, the small it has an impact on demand, and the lower price of logistics services on the platform.

According to the equilibrium solution $S_1^{U*} = \frac{(1-\beta)+(2+\alpha-\varphi)}{1-\varphi+(2-\beta)(3-\varphi)\beta}$, we obtain the influence of the parameters on the platform's logistics service level in Figure 7. We can know from Figure 7 (a) that the commission ratio φ has a positive effect on S_1^{U*}. But the effect is minimal. The higher the commission ratio φ charged by platform, the higher the level of logistics services S_1^{U*}. Because the commission income enables the platform to invest more funds in the construction of its logistics and promote the healthy development of logistics sharing with the e-retailer.

From Figure 7 (b), we can see that the market potential of thee-retailer α has a positive impact on S_1^{U*}, that is, as the potential scale α increases, the logistics service level of the platform S_1^{U*} will also improve. And when the sensitivity of consumers to the level of logistics services β is lower, the improvement of logistics service level is more excellent.

From Figure 7 (c), we can know that consumers' sensitivity to logistics service level β is negative to S_1^{U*}, which is consistent with the impact on the platform's logistics service price. Once the e-retailer chooses to use the platform's sharing logistics services, the platform no longer has an absolute advantage in the level of logistics services. Therefore, the platform won't increase the market demand by improving the logistics service level. If the platform improves the logistics service level, it will also increase the e-retailer's market demand. Simultaneously, the platform should continue to reduce the level of logistics services if customers' sensitivity to the level of logistics services is increasing. It is probably the reason why the platforms, such as JD. com, Suning. com, Amazon. cn, haven't released their own logistics service systems fully. If the logistics service level is reduced, a large number of customers will transfer to other platforms.

7 Conclusions

We consider an e-commerce service system composed of a platform, an e-retailer, and a third-party logistics provider. The platform not only sells products online but is also a logistics provider. The platform has its logistics network systems. And the platform's logistics service has the advantages of a fast speed and the excellent service quality. Platform's logistics network transports the products sold by platform and provides logistics services for the e-retailer's sales to obtain more profit. The logistics service e-retailer can be TPL or platform after he sells the product.

Our research contributes to the competition and platform strategy literature and fills a significant gap in literature stream about logistics service strategy for platform and e-retailer. Our study provides a broader set of decision outcomes that have not been reported by other studies concerning competition. By examining the competition effect on two player' retail prices and individual and collective profits, we find that the optimal strategy for both e-retailer and platform not only depends on the size of the market potential[18,19], but also depends on the joint effect of external market characteristics. We find that the TPL's logistics service level and the logistics service fee charged by the platform have significant impacts on the logistics service strategy between the platform and the e-retailer. Specifically, the platform will benefit from TPLP's logistics service level is coordinated with the logistics service. In contrast, the e-retailer will benefit from logistics service sharing when the TPL's logistics service level is low or the TPL's single logistics service fee is low. And there is a win-win situation that can achieve agreement of sharing logistics service when the TPL's logistics service levels and fees are in middle regions. According to the analysis of the equilibrium results, our research obtains some management applications. Specifically, our research finds three new management insights as follows.

Our findings provide executable managerial insights for the platforms and the e-retailers in the e-commerce market. First, the platform should share its logistics service with the e-retailer when the TPL's logistics service level is not too low, and the TPL's logistics service fee is not too high (i. e., when the platform does not have a great advantage in logistics service). Moreover, the improvement of TPL's logistics service will promote the platform's logistics service level and improve the overall logistics service level of society (i. e., The high level of TPL's will intensify competition between the platform and the e-retailer). Furthermore, suppose the e-retailer is not willing to engage in logistics service sharing. In that case, the platform can provide a certain discount (e. g., reducing the platform's logistics service price) to encourage the e-retailer to cooperate in logistics service.

Although our work helps understand how the platform and the e-retailer should determine the optimal retail price, the optimal logistics service price, and level of the platform, and choose optimal e-commerce marketing strategy between the UL model and the NL model. However, several possible extensions worth pursuing can further deepen our understanding of the logistics service strategy in the e-commerce market. First, our research assumes that the TPL's logistics service level is less than that of the platform. If considering that the TPL's logistics service level can be greater than that of the platform, more interesting results can be obtained. Second, we only consider the logistics service strategy of the platform and the e-retailer. The logistics service strategy of the TPLs in the e-commerce market is equally significant and worthy of future research. Finally, different types of e-retailers have different impacts on the logistics service strategies, such as fresh products, electronic products, and clothing. Exploring the optimal logistics service strategies that consider the characteristics of products value is also promising. Hence, a promising direction for future research is to collect real-world data and modify these analysis models in our study to guide further the practice of logistics service strategy in the e-commerce market.

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Conflict of interest

The authors declare no conflict of interest.

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平台与电子零售商的网购物流服务策略研究

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摘要: 在电子商务市场中,混合型电商平台已取得了较大成效.该平台不仅是一个电子零售商,还为平台上的其他电子零售商提供在线物流服务,而物流服务是电子商务中不可缺少的一个环节,对促进网上购物起着至关重要的作用.为此,分析了平台与电子零售商之间物流服务共享产生的影响,并研究了两种模型的最优策略选择.研究发现,当第三方物流提供商的物流服务水平与物流服务费用相协调,且两者处于中间区间时,平台与在线零售商可以达成物流服务共享协议,形成双赢的局面;当第三方物流服务商收取的物流服务费过低或第三方物流服务商提供的物流服务过高时,平台和电子零售商都将选择不共享物流的战略模式.除此之外,研究还发现,第三方物流提供商的物流服务水平的提高可以促进平台物流服务水平的提升.最后,通过数值分析对均衡模型进行了验证,并分析了主要参数对均衡模型的影响.本文的研究推动了平台运营策略研究的发展,并为企业物流服务战略选择提供了有效的管理启示.

关键词: 电商平台;电子商务;物流服务;竞争合作

Appendix

Proof of Proposition 4.1 According to Model (5) and Model (6), we obtain the second derivative of p_1^N and p_2^N, $\frac{\partial^2 \pi_1^N}{\partial^2 p_1^N}=-2<0$, $\frac{\partial^2 \pi_2^N}{\partial^2 p_2^N}=-2(1-\varphi)<0$, π_1^N, π_2^N is concave in p_1^N and p_2^N. Then we obtain the first derivative of p_1^N and p_2^N, $\frac{\partial \pi_1^N}{\partial p_1^N}=1-2p_1^N+S_1^N-\beta S_t$, $\frac{\partial \pi_2^N}{\partial p_2^N}=f+(1-\varphi)(\alpha-p_2^N-\beta S_1^N+S_t)$. Then, we solve the equations: $\frac{\partial \pi_1^N}{\partial p_1^N}=0$ and $\frac{\partial \pi_2^N}{\partial p_2^N}=0$. Then, $\widetilde{p_1^N}=\frac{1+S_1^N-\beta S_t}{2}$, $\widetilde{p_2^N}=\frac{f+(1-\varphi)(\alpha-\beta S_1^N+S_t)}{2(1-\varphi)}$. We substitute $\widetilde{p_1^N}$ into the π_1^N, we can obtain $\pi_1^N=\frac{-2\,S_1^{N2}+(1+S_1^N-\beta S_t)^2+\varphi((1-\varphi)(\beta S_1^N-S_t-\alpha)-f)((1-\varphi)(\beta S_1^N-S_t-\alpha)+f)}{4(1-\varphi)^2}$. And the second derivative of S_1^N is $\frac{\partial^2 \pi_1^N}{\partial^2 S_1^N}=-\frac{1-\beta^2\varphi}{2}<0$, π_1^N is concave in S_1^N. The first derivative of S_1^N is $\frac{\partial \pi_1^N}{\partial S_1^N}=\frac{1-\alpha\beta\varphi-(1-\beta^2\varphi)S_1^N-(1+\varphi)\beta S_t}{2}$. Then, we solve the equation $\frac{\partial \pi_1^N}{\partial S_1^N}=0$, then $S_1^{N*}=\frac{1-\alpha\beta\varphi+\beta(1+\varphi)S_t}{1-\beta^2\varphi}$. Substituting S_1^{N*} into the expression $\widetilde{p_1^N}$ and $\widetilde{p_2^N}$ and profit functions π_1^N and π_2^N, we have Proposition 4.1.

Proof of Corollary 4.1 $\frac{\partial p_2^N}{\partial S_t}=\frac{1+\beta^2}{2(1-\beta^2\varphi)}>0$, $\frac{\partial p_1^N}{\partial S_t}=-\frac{\beta(2-\beta^2\varphi+\varphi)}{2(1-\beta^2\varphi)}<0$, and $\frac{\partial S_1^N}{\partial S_t}=-\frac{\beta(1+\varphi)}{1-\beta^2\varphi}<0$. We obtain $\frac{\partial^2 \pi_1^N}{\partial^2 S_t}=\frac{(1-\beta^4)\varphi+2\beta^2(1+\varphi)}{2(1-\beta^2\varphi)}>0$, π_1^N is convex in S_t, then solve the equation $\frac{\partial \pi_1^N}{\partial S_t}=$

$\frac{\alpha\varphi-(2+\varphi-(\alpha+\beta)\varphi\beta)\beta+((1-\beta^4)\varphi+2\beta^2(1+\varphi))S_t}{2(1-\beta^2\varphi)}=0$, then $S_t=S_t^k=\frac{(2+(1-(\alpha+\beta)\beta)\varphi)\beta-\alpha\varphi}{(1-\beta^4)\varphi+2\beta^2(1+\varphi)}$. We obtain $\frac{\partial^2\pi_2^N}{\partial^2 S_t}=\frac{(1-\varphi)(1+\beta^2)^2}{2(1-\beta^2\varphi)^2}>0$, π_2^N is convex in S_t, then solve the equation $\frac{\partial\pi_2^N}{\partial S_t}=\frac{(1+\beta^2)(\alpha-f-\beta+(\beta(1+f\beta)-\alpha)\varphi+(1+\beta^2)(1-\varphi)S_t)}{2(1-\beta^2\varphi)^2}=0$, then $S_t=S_t^l=\frac{(1-\varphi)(\beta-\alpha)+(1-\beta^2\varphi)f}{(1+\beta^2)(1-\varphi)}$. Then we have Corollary 4.1.

Proof of Proposition 4.2 According to Model (9) and Model (10), we obtain the second derivative of p_1^U and p_2^U, $\frac{\partial^2\pi_1^U}{\partial^2 p_1^U}=-2<0$, $\frac{\partial^2\pi_2^U}{\partial^2 p_2^U}=-2(1-\varphi)<0$, π_1^U, π_2^U is concave in p_1^U and p_2^U. Then we obtain the first derivative of p_1^U and p_2^U, we can obtain that $\frac{\partial\pi_1^U}{\partial p_1^U}=1-2p_1^U+(1-\beta)S_1^U$, and $\frac{\partial\pi_2^U}{\partial p_2^U}=\omega+(1-\varphi)(\alpha-2p_2^U+(1-\beta)S_1^U)$. Then, we solve the equations: $\frac{\partial\pi_1^U}{\partial p_1^U}=0$ and $\frac{\partial\pi_2^U}{\partial p_2^U}=0$, obtain $\widetilde{p_1^U}=\frac{1+(1-\beta)S_1^U}{2}$, $\widetilde{p_2^U}=\frac{\omega+(1-\varphi)(\alpha+(1-\beta)S_1^U)}{2(1-\varphi)}$. We substitute $\widetilde{p_1^U}$ into π_1^U, we can obtain: $\pi_1^U=\frac{1+\alpha^2\varphi+2\alpha\omega+2(1-\beta)(1+\alpha\varphi+\omega)S_1^U-(1-\varphi+(2-\beta)\beta(1-\varphi))S_1^{U2}}{4}-\frac{(2-\varphi)\omega^2}{4(1-\varphi)^2}$. To get the optimal solution of S_1^U and ω, we first obtain the Hessian matrix of π_1^U as follows:

$$H=\begin{vmatrix} -\frac{1-\varphi+(2-\beta)\beta(1+\varphi)}{2} & \frac{1-\beta}{2} \\ \frac{1-\beta}{2} & -\frac{2-\varphi}{2(1-\varphi)^2}\end{vmatrix}>0.$$

And the second derivative of S_1^U and ω are all negative, $\frac{\partial^2\pi_1^U}{\partial^2 S_1^U}=-\frac{1-\varphi+(2-\beta)\beta(1+\varphi)}{2}<0$, $\frac{\partial^2\pi_1^U}{\partial^2\omega}=-\frac{2-\varphi}{2(1-\varphi)^2}<0$, π_1^U, π_2^U is concave in S_1^U and ω. We obtain $\frac{\partial\pi_1^U}{\partial S_1^U}=\frac{(1-\beta)(1+\alpha\varphi+\omega)-(1-\varphi+(2-\gamma)(1+\varphi)\gamma)S_1^U}{2}$, $\frac{\partial\pi_1^U}{\partial\omega}=\frac{1}{2}(\alpha-\frac{(2-\varphi)\omega}{(1-\varphi)^2}+(1-\beta)S_1^U)$. Then, we solve the equations: $\frac{\partial\pi_1^U}{\partial S_1^U}=0$ and $\frac{\partial\pi_1^U}{\partial\omega}=0$, the optimal platform's logistics service level and the optimal platform's single logistics service fee is $S_1^{U*}=\frac{(1-\beta)+(2+\alpha-\varphi)}{1-\varphi+(2-\beta)(3-\varphi)\beta}$, $\omega^*=\frac{((1-\beta)^2+(1+(2-\beta)\beta)\alpha)(1-\varphi)^2}{1-\varphi+(2-\beta)(3-\varphi)\beta}$. Substituting S_1^{U*} and ω^* into the expression $\widetilde{p_1^U}$ and $\widetilde{p_2^U}$ and profit functions π_1^U and π_2^U, we have Proposition 4.2.

Proof of Corollary 4.2 $\frac{\partial p_1^{U*}}{\partial\alpha}=\frac{(1-\beta)^2}{2(1-\varphi)+2(2-\beta)(3-\varphi)\beta}>0$, $\frac{\partial p_2^{U*}}{\partial\alpha}=\frac{(3-2\varphi)(1+(2-\beta)\beta)}{2(1-\varphi)+2(2-\beta)(3-\varphi)\beta}>0$, $\frac{\partial S_1^{U*}}{\partial\alpha}=\frac{1-\beta}{1-\varphi+(2-\beta)(3-\varphi)\beta}>0$ and $\frac{\partial\omega^*}{\partial\alpha}=\frac{(1+(2-\beta)\beta)(1-\varphi)^2}{1-\varphi+(2-\beta)(3-\varphi)\beta}>0$. We obtain $\frac{\partial^2\pi_1^U}{\partial^2\alpha}=\frac{1+(2-\beta)\beta}{2(1-\varphi)+2(2-\beta)(3-\varphi)\beta}>0$, $\frac{\partial^2\pi_2^U}{\partial^2\alpha}=\frac{(1-\varphi)(1+(2-\beta)\beta)^2}{2((1-\varphi)+(2-\beta)(3-\varphi)\beta)^2}>0$, π_1^U and π_2^U is all convex in α, then solve the equation $\frac{\partial\pi_1^U}{\partial\alpha}=\frac{\alpha+\alpha(2-\beta)\beta+(1-\beta)^2}{2(1-\varphi)+2(2-\beta)(3-\varphi)\beta}=0$, then $\alpha=\alpha^0=1-\frac{2}{1+(2-\beta)\beta}$, similar to π_1^U, solve $\frac{\partial\pi_2^U}{\partial\alpha}=\frac{\alpha+\alpha(2-\beta)\beta+(1-\beta)^2}{2(1-\varphi)+2(2-\beta)(3-\varphi)\beta}=0$, then $\alpha=\alpha^0$. And then we have Corollary 4.2.

Proof of Proposition 5.1 Solve $p_1^N-p_1^U=0$, we obtain $S_t=S_t^a=\frac{2(1-\beta^2\varphi)(\frac{2-\beta(\alpha+\beta)\varphi}{1-\beta^2\varphi}-\frac{(1-\beta)^2(2+\alpha-\varphi)}{1-\varphi+(2-\beta)(3-\varphi)\beta}-1)}{2\beta(2+\varphi-\beta^2\varphi)}$. And form Corollary 4.1, we know $\frac{\partial p_1^N}{\partial S_t}<0$, then when $0<S_t\leqslant S_t{}^a$, $p_1^{U*}\leqslant p_1^{N*}$; when $\overline{S_t}>S_t>S_t{}^a$, $p_1^{U*}>p_1^{N*}$. Solve $p_2^N-p_2^U=0$, we obtain $S_t=S_t^b=\frac{2(1-\varphi)(1-\beta^2\varphi)(\frac{\beta-\alpha}{2(1-\beta^2\varphi)}+\frac{(1-\beta)^2+\alpha(1+(2-\beta)\beta)(3-2\varphi)}{2(1-\varphi)+2(2-\beta)(3-\varphi)\beta}-\frac{f}{2(1-\varphi)})}{(1+\beta^2)(1-\varphi)}$. And form Corollary 4.1, we know

$\frac{\partial p_2^N}{\partial S_t}<0$, then when $0<S_t\leqslant S_t{}^b$, $p_2^{U*}\geqslant p_2^{N*}$; when $\overline{S_t}>S_t>S_t{}^b$, $p_2^{U*}<p_2^{N*}$.

Proof of Proposition 5.2 Solve $S_1^N-S_1^U=0$, we obtain $S_t=S_t^r=\frac{(1-\beta^2\varphi)\left(\frac{1-\beta\alpha\varphi}{1-\beta^2\varphi}-\frac{(1-\beta)(2+\alpha-\varphi)}{1-\varphi+(2-\beta)(3-\varphi)\beta}\right)}{\beta(1+\varphi)}$. And form Corollary 4.1, we know $\frac{\partial S_1^N}{\partial S_t}<0$, then when $0<S_t\leqslant S_t{}^r$, $S_1^{U*}\leqslant S_1^{N*}$, when $S_t{}^r<S_t<\overline{S_t}$, $S_1^{U*}>S_1^{N*}$.

Proof of Proposition 5.3 Let us set $a(S_t)=\Pi_1^N-\Pi_1^U$, solve $a(S_t)=0$, we obtain $S_t(f)=\frac{\sqrt{\varphi-(1-\varphi)\varphi((1-f^2)\varphi-(1-\varphi)(2+\alpha)\alpha)-(1-\varphi+(2-\beta)(3-\varphi)\beta)(1-\varphi^2)(1-\beta^2\varphi)}}{(1-\beta^4)\varphi+2\beta^2(1+\varphi)}$. $\frac{\partial^2 a(S_t)}{\partial^2 S_t}=\frac{(1-\beta^4)\varphi+2\beta^2(1+\varphi)}{2(1-\beta^2\varphi)}>0$, $a(S_t)$ is convex in S_t. Then let $\frac{\partial a(S_t)}{\partial S_t}=0$, we obtain $S_t=S_t^c=\frac{(2+(1-\beta(\alpha+\beta)\beta)\varphi)\beta-\alpha\varphi}{(1-\beta^4)\varphi+2\beta^2(1+\varphi)}$. Let $S_t(f)-S_t^c=0$, we obtain $f^c=\sqrt[\frac{1}{4}]{\frac{\varphi(1-\beta)(2+\alpha-\varphi)-2(1-\varphi)(1-\beta^2\varphi)}{(1-\varphi+(2-\beta)(3-\varphi)\beta)(1-\varphi^2)(1-\beta^2\varphi)+(1-\varphi^2)}}$. And $\frac{\partial^2 S_t(f)}{\partial^2 f}<0$, $S_t(f)$ is concave in f, then we have Proposition 5.3.

Proof of Proposition 5.4 Let us set $b(S_t)=\Pi_2^N-\Pi_2^U$, solve $b(S_t)=0$, we obtain $S_t^h=\frac{\frac{(1-\beta^2)f}{1-\varphi}-\frac{1+\beta(\varphi-3+\beta(\varphi-5+\beta(3+\varphi-\varphi\beta)))+\alpha(2-\varphi+\beta(8-2\varphi+\beta(\beta\varphi(\beta-2)-4)))}{1-\varphi+(2-\beta)(3-\varphi)\beta}}{1+\beta^2}$, and $S_t^g=\frac{\frac{(1-\beta^2)f}{1-\varphi}+\frac{1+\beta(\varphi-3+\beta(\varphi-5+\beta(3+\varphi-\varphi\beta)))+\alpha(2-\varphi+\beta(8-2\varphi+\beta(\beta\varphi(\beta-2)-4)))}{1-\varphi+(2-\beta)(3-\varphi)\beta}}{1+\beta^2}$. $\frac{\partial^2 b(S_t)}{\partial^2 S_t}=\frac{(1+\beta^2)^2(1-\varphi)}{2(1-\beta^2\varphi)^2}>0$, $b(S_t)$ is convex in S_t. Then let $S_t^g-\frac{\partial^2 b(S_t)}{\partial^2 S_t}=0$, we obtain $f^h=\frac{(1-\varphi)(1+(2\alpha(2-\beta)-1)\beta+(3\beta-7)\beta)+\alpha(1-\beta)(1+\beta)(1+(2-\beta)\beta)-\beta(1+\beta(3+(\beta-3)\beta))\varphi}{(1-\varphi+(2-\beta)(3-\varphi)\beta)(1-\beta^2\varphi)}$. And $\frac{\partial S_t^g(f)}{\partial f}=\frac{1-\beta^2\varphi}{(1+\beta^2)(1-\varphi)}>0$, $S_t^g(f)$ increases in f, then we have Proposition 5.4.

Proof of Proposition 5.5 We set $m(f)=\Pi_2^U-\Pi_2^N$, solve $m(f)=0$, we obtain $f^1=\frac{(1-\varphi)(\alpha(2-\varphi+\beta(8-2\varphi-\beta(4+(2-\beta)\beta\varphi)))+(1+\beta^2)((1-\varphi+(2-\beta)(3-\varphi)\beta))S_t)+(1-\varphi)(1+\beta(\varphi-3+\beta(\varphi-5+\beta(3+\varphi-\beta\varphi))))}{(1-\varphi+(2-\beta)(3-\varphi)\beta)(1-\beta^2\varphi)}$, and $f^2=\frac{(1-\varphi)(\beta+\beta^2(3-(3-\beta)\beta)+\alpha(\beta^2-1)(1+(2-\beta)\beta)\varphi)+(1-\varphi)(\beta(1+2\alpha(2-\beta))-1+\beta(3\beta-7))+(1-\varphi)((1+\beta^2)((1-\varphi+(2-\beta)(3-\varphi)\beta))S_t)}{(1-\varphi+(2-\beta)(3-\varphi)\beta)(1-\beta^2\varphi)}$. We set $n(f)=\Pi_1^U+\Pi_2^U-\Pi_1^N-\Pi_2^N$, solve $n(f)=0$, we obtain

$$f^0=\frac{\sqrt{(1-\varphi)^2+(1-\varphi)^2\alpha^2(1-\beta^2(1-\varphi)^2-2\beta^3\varphi+\beta^4\varphi+(\varphi-1)\varphi+2\beta(1-(2-\varphi)\varphi))(1+(2\alpha))+2(1-\varphi)^2\alpha^3((1+\beta)(\varphi+\beta-2+\beta(5-\beta+\beta^2)\varphi-(1+(2-\beta)\varphi^2))+(1-\varphi)^2((1-\varphi+(2-\beta)(3-\varphi)\beta S_t(4\beta-2(\alpha-\beta+\alpha\beta^2+\beta^3)\varphi)-((1-\beta^4)\varphi+2\beta^2(1+\varphi))S_t)}}{\sqrt{\varphi}}.$$

Then we have Proposition 5.5.

Proof of Proposition 5.6 Let $\Pi_1^{N*}-\Pi_1^{U*}=0$, and $\Pi_2^{N*}-\Pi_2^{U*}=0$, then we obtain $f^h=\frac{(1-\varphi)(1+(2\alpha(2-\beta)-1)\beta+(3\beta-7)\beta)+\alpha(1-\beta)(1+\beta)(1+(2-\beta)\beta)-\beta(1+\beta(3+(\beta-3)\beta))\varphi}{(1-\varphi+(2-\beta)(3-\varphi)\beta)(1-\beta^2\varphi)}$, and f^0, f^1, f^2 are shown as above. Proposition 5.6 is a summary of Proposition 5.5, so the detail proof of Proposition 5.6 is the same as Proposition 5.5.