“Product + logistics” bundling sale and co-delivery in cross-border e-commerce

Baozhuang Niu1 · Jingmai Wang1 · Carman K. M. Lee2 · Lei Chen1

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Abstract
When customers purchase products via cross-border e-commerce, they care about both the product quality and the logistics service quality. Actually, retailers are selling “product + logistics” to customers, although their contracted logistics service provider (LSP) might not be preferred by customers. In practice, it is observed that a retailer selling high-quality products tends to contract with multiple LSPs to ensure higher customer volumes and the overall high quality of “product + logistics”. However, interestingly, we find that the LSP’s profits might be negatively affected by serving two competing retailers, and preferences of the LSP and the retailer selling high-quality products through logistical cooperation result in two “prisoner’s dilemma” regions. We also identify the size of the system’s profit pie and the allocation rules among the competing LSPs and retailers. We show that it is possible to observe competing retailers’ co-delivery, which benefits both the LSP and the retailer selling high-quality products.

Keywords Cross-border e-commerce · Logistics service · Customer utility · Prisoner’s dilemma

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1 Introduction

In recent years, cross-border e-commerce (CBEC) has witnessed tremendous growth. The global e-commerce market is expected to grow rapidly, and Asia Pacific (APAC), Western Europe and North America are recognized as the top three contributors (Business Wire 2018, Technavio 2018). Taking China as an example, iiMedia Research reported that the total transaction volume of China’s CBEC in 2017 reached RMB 7.6 trillion. Nielsen’s online shopper trend study showed that the proportion of customers who had recently made a CBEC purchase reached 67% in 2017 compared to 34% in 2015.

In CBEC, customers have shifted from buying standalone physical products to buying bundles of physical products and related services. Logistics service has been a critical service for e-commerce. Kaola.com has received many complaints regarding logistics service for reasons such as product loss and damage, incorrect order fulfillment, slow delivery, and so on. Products sold via Kaola.com are believed to be of high quality and trustworthy with strict product quality control. However, its contract LSP, Sinotrans Limited, was not preferred by some customers. In many countries/regions, Sinotrans’s logistics network is insufficient and only comprises a global market share of 1.0%, while DHL occupies the largest market share of 4.1%. Actually, a recent study by Temando of 214 retailers and 1000 U.S. customers showed that many shipping services are not what customers want and expect. Customers want to have more LSP options and are willing to pay more for these options [State of Shipping in Commerce 2016 (US)]. Therefore, to improve the overall quality of the “product + logistics” that are offered via Kaola.com, the e-retailer has contracted with SF Express to satisfy customers’ personalized LSP requirements. Similarly, the available LSPs on Amazon include UPS, FedEx, USPS, and SF Express. However, it is interesting to observe that some retailers use sole LSP. For example, Shanshui Leather, which sells products via Amazon Global Selling, has Amazon (FBA) Logistics as its sole contracted LSP, and Shanshui’s sales have increased by 200% since 2016. Another example is that the Walmart Global store on

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JD Worldwide has JD Logistics as a sole contracted LSP. Bloomberg reports that Walmart’s sales can reach more than 90% of China’s customers through collaboration.\(^\text{10}\)

The above illustrations epitomize two strategies in practice. If a retailer selling high-quality products contracts with two competing LSPs, we refer to it as the retailer’s *dual-LSP strategy (DS)*. In parallel, if an LSP serves two competing retailers, we refer to it as *co-delivery* service. Intuitively, a retailer adopting the *DS* benefits from LSPs’ price wars because they compete for the retailer’s order allocation. The retailer with the adoption of *DS* also benefits from customers’ preferences for its “product + logistics” because customers purchase high-quality products and use their preferred LSP. In contrast, some retailers use the *sole-LSP strategy (SS)*. The benefits of the *SS* include maintaining stable, long-term cooperation with an LSP and more effective supervision. Therefore, it can be a strategic decision for a cross-border retailer to select the *DS* or the *SS* to improve the overall customer perception. Our research questions arise. Why would a retailer selling high-quality products choose the *sole-LSP strategy* when customers’ preferences over LSPs are heterogeneous? Is there an underlying negative impact when a retailer chooses the *dual-LSP strategy*? If the *DS* is adopted, will the LSP also benefit, and hence, will a win–win situation result for both the LSP offering *co-delivery service* and the retailer selling high-quality products?

We build a stylized model with two competing retailers and two competing LSPs. To facilitate our demonstration, we use the Hotelling model as our theoretical framework. One retailer chooses the *SS*, while the other retailer selling high-quality products has the option of the *DS* or the *SS*. We make this assumption because the retailer selling high-quality products usually has an ever-increasing customer base, which can ensure more volumes for its LSPs (later, we show that the retailer selling low-quality products has no incentives to contract with multiple LSPs). Clearly, if the *DS* is chosen, then the LSP offers *co-delivery service*. The two competing retailers actually cooperate by sharing a common LSP.

Our findings are summarized as follows. First, our findings suggest that the adoption of the DS versus the SS is significantly impacted by the product’s differentiation based on two items: (1) Product quality; (2) Customer’s perception and recognition degree of logistics service when she finds ideal logistics service is absent. We also examine the LSP’s incentives to offer *co-delivery service* of two competing retailers. Contrary to conventional wisdom, we show that the LSP only prefers to cooperate with retailers via *co-delivery* when the product’s differentiation based on quality is in a moderate range. That is, when retailers’ products are very different or very similar, the LSP should work with a single retailer to avoid a logistics price war, although serving two retailers increases the demand. Interestingly, we identify two regions where the “prisoner’s dilemma” occurs, which is the main contribution of this paper. That is, the total profits are increased because of the LSP’s *co-delivery*, but the LSP and the retailer have a conflict of interest because of profit allocation.

and channel power issues. The dilemma is not intuitive and is important for managers to know about because it is a complex situation to deal with.

The rest of this paper is organized as follows. In Sect. 2, we review the related literature. In Sect. 3, we present the settings of the base model. The equilibriums of the base model and the dual-LSP model are summarized in Sect. 4. In Sect. 5, we examine the profits from different customer groups and the profit shares of the retailer selling high-quality products and the LSP offering co-delivery service. We find the conditions in which they have the incentive to cooperate with each other. We discuss the generalizability of our results and conclude this paper in Sect. 6.

2 Literature review

Online product’s quality is not the only factor that affects customers’ purchasing decisions. To attract more customers, e-commerce companies also provide a variety of services. Our study focuses on the impact of the service on e-retailers’ profits and is closely related to the literature on “online product + service” sales issues. A great number of these studies examine return services. Lantz and Hjort [16] study the impact of free delivery and free returns on e-customers’ purchasing choices. Geng et al. [10] calculate the optimal insurance price and return-freight insurance compensation for insurance companies. Chen and Chen [6] suggest how a retailer should define their return policies for both online and offline channels. There is also a large body of literature that considers information services. Xiao and Benbasat [31] suggest that product-related deceptive information often misleads customers, and they study how deception in e-commerce happens and how to fight online deception. Peng et al. [21] study female customers’ purchasing behaviors when they use a fashion shopping guide website. Dahana et al. [8] study customers’ showroom behavior (comparing prices by searching for information online) and examine the impacts of several variables on showroom probability. Our paper differs from the abovementioned literature by incorporating the following features in e-commerce. First, we study “product + logistics service”, which is a common practice in e-commerce. Customers have preferences over both products and logistics services. This introduces the corresponding disutility due to the mismatch between a customer’s ideal product or logistics service and the one she intends to buy. Our work is among the earliest studies investigating “product + logistics” in e-commerce where customers’ mismatch between ideal product and logistics service is characterized. Second, researchers tend to characterize customers’ tastes and preferences by the mismatch cost regarding the overall product or the core product [1, 35]. Similarly, our study addresses a customer’s choice by investigating customer’s perception and recognition degree of logistics service when she finds ideal logistics service is absent. We compare the customer’s utility changes and the corresponding demand reallocation. Second, we formulate the bundling operations in e-commerce, and find that a logistics service provider that contracts with a retailer selling high-quality products dedicatedly enjoys the spillover benefits from product advantage. These are all new and interesting contributions to the literature in e-commerce.
To help e-retailers deal with logistics problems, auction-based logistics procurement is widely studied in previous literature. Gujo and Schwind [12] study a combinatorial auction that addresses bundling and pricing problems of transportation contracts. Such combinatorial auctions are considered in a lot of other studies because they allow for the capture of synergies between shipment requests through bundled bids. However, to mitigate the computational burden of combinatorial auctions, many recent works have studied double-auction mechanisms. Huang and Xu [13] develop three multi-unit trade reduction mechanisms for logistics procurement in bilateral exchange e-marketplaces. Xu et al. [33] consider procurement auctions with ex-post cooperation among capacity-constrained bidders. Nevertheless, this stream of literature rests on an assumption of fees being charged to the e-retailer rather than the customer, which may not correspond to widely spread practices in e-commerce. Since the logistics fee is a challenge for many e-retailers, especially in the toy and drug industry [3], charging customers logistics fees is a measure to cover the expenses. Michalak et al. [18] find that the delivery cost can be cut down by as much as 10–20% via a combined delivery service of customers. Lim et al. [17] calculate the exact delivery cost with the consideration of destination and delivery speed. Yao and Zhang [34] study how to design a shipping price scheme to help e-retailers maximize profits strategically. Cao et al. [4] investigate the potential benefit of an “online-to-store” channel considering the costs and delays of delivery. Along with these early studies, the logistics fee is charged directly to customers in our work.

Most of the above studies stand in the e-retailers’ position, but the logistics service provider (LSP) also plays an important role. The LSP’s decision affects the whole business. So there is a stream of literature investigating logistics collaboration, which is also our research emphasis. Stank and Daugherty [28] study the cooperative relationship formation between manufacturers and third-party logistics firms in various operating and strategic environments. Song and Regan [26] find that auctions can be used to form a collaborative network in the trucking industry. Jin and Wu [14] construct an auction mechanism that induces the suppliers’ cooperation and profit maximization. Wang and Sang [29] develop an e-commerce-based 3PL system with the collaboration of multiple agents to realize win–win situations between the customer and the logistics service vendor. Özener and Ergun [19] devise cost-allocation mechanisms in the setting of a collaborative logistics network. Based on noncooperative game-theoretic models, Özener et al. [20] design lane-exchange mechanisms that facilitate carrier collaboration and costs savings by assuming that each carrier pursues the maximization of their individual benefits. More recently, Song et al. [25] propose a coordination mechanism that uses modified quantity discount contracts between an online retailer and an LSP in a decentralized supply chain. Although logistics collaboration issues have been well studied in other settings, it has not been integrated as the service in question when retailers make strategic decisions regarding the selection of LSPs. Our study aims to fill the gap between the analysis of the incentives of the LSP and the retailer in a competitive environment. We thus study the LSPs’ logistics price war and the retailers’ product price war, which may provide managerial insights regarding collaboration space and competition strategies.
Our work is also related to the literature on the unbundling of product and logistics. A subset of literature focuses on the partitioned pricing problem where separate prices are charged for components in the bundle. Chakravarti et al. [5] claim that partitioned pricing enables customers to assess the value of each component unambiguously. From the behavioral perspective, Greenleaf et al. [11] investigate how partitioned pricing influence customers’ purchasing decisions. Song and Li [24] further study the service unbundling issue where the seller should charge a full price dynamically or unbundle the add-on service in a stochastic demand and capacitated setting. Another literature stream is related to logistics sharing. By introducing competition among LSPs, Song et al. [27] find that the overall performance of the global supply chain is enhanced. Based on a customer survey, Xing et al. [32] suggest that e-retailers should weigh both the advantages and risks carefully regarding how to choose LSPs. Lai et al. [15] investigate the motivation of Amazon to provide logistics services to its competing retailers. Differently, our study characterizes the unbundling in a competitive environment where one retailer unbundles the logistics service (e.g., contracts with two competing LSPs) while the other retailer contracts a sole LSP. Once unbundled, customers can select the desired logistics service according to their preferences. Table 1 summarizes the main features of related literature and our contributions.

3 Model settings and assumptions

There are four participants in our model: two competing retailers $R_i$, where $i \in \{A, B\}$, and two LSPs $L_j$, where $j \in \{A, B\}$. We consider two models to reflect the relationships between retailers and LSPs. First is the base model, where customers purchase an imported product from a retailer $R_i$ and obtain logistics service from an LSP $L_j$ (see Fig. 1b for an illustration). Thus, it is a bundled model where $R_i$ and $L_j$ are bundled, which means the service bundled with the product is the logistics service. Second is the dual-LSP model, where the high-quality retailer $R_B$ also cooperates with the rival’s bundled LSP $L_A$. That is, customers who purchase an imported product from $R_B$ can choose whichever of the two LSPs that provides the better fit, while customers who purchase from $R_A$ obtain logistics service from $L_A$ only (see Fig. 1d for a graphical illustration). These two models are referred to as B and D, respectively. Specifically, in each model, the four participants make their decisions simultaneously and pursue the maximization of their profits.

Customers purchase the product that is sold by either of the two retailers, pay for the “product + logistics”, and then wait for the product to arrive. That is, each product consists of two modules: a product online with standalone value, and a logistics service module that has no value without the product. Following previous studies [4, 17, 18, 34], we assume that the logistics fee is charged directly to customers. We use the Hotelling framework to capture customers’ preferences via the mismatch cost. $R_A$ and $R_B$ are respectively located at 0 and 1 on a line of length 1. A continuum of customers of measure 1 is uniformly distributed along the line. A customer’s location represents her ideal product. If a product or service does not perfectly match the customer’s tastes and preferences, she incurs a mismatch cost, which increases with the distance between her location and the product she intends to buy. Customer
utility is the combination of the customer’s standalone value of the product minus the price, tax and disutility from the mismatch between a customer’s ideal product or service and the given product (According to the tax rules in China, a customer who buys an imported product should pay the tariff, import value-added tax (VAT) and consumption tax (CT) on top of the dutiable value. We use \( r \) to stands for CBEC comprehensive tax rate.). Similar to Adner et al. [1], a customer’s unit mismatch cost for the entire “product + service” is denoted by \( m \), which consists of the unit logistics mismatch cost, \( m\theta \), where \( \theta \in (0, 1) \), and the unit product mismatch cost, \( m(1 - \theta) \); that is, \( m = m\theta + m(1 - \theta) \). It means that \( \theta \) stands for the ratio of logistics service mismatch cost to the overall mismatch cost. In other words, \( \theta \) indicates

Table 1  Summary of the main features of abovementioned works and what our contribution is

<table>
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<th></th>
<th>Cooperation</th>
<th>Logistics procurement</th>
<th>Product + service</th>
<th>Competition</th>
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<td>Lantz and Hjort [16]</td>
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<td>Song and Li [24]</td>
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customer’s perception and recognition degree of logistics service when she finds ideal logistics service is absent. If $\theta$ is high, customers’ preference for logistics service plays an important role in customers’ purchasing decisions.

$v_i (i \in \{A, B\})$ is the standalone value that customers derive from product $i$. As discussed earlier in the Introduction, Kaola.com (i.e., $R_B$) has thorough quality controls. We assume $v_{RB} > v_{RA}$ and denote the product’s differentiation based on quality as $\Delta$; thus, $\Delta = v_{RB} - v_{RA} > 0$. We assume that $\Delta$ is not too large to ensure $R_A$ has a positive market share. Customers compare the two retailers and choose the one that offers greater utility. Table 2 summarizes the notations used in the model.

### 4 Analysis of base model and dual-LSP model

#### 4.1 The base model

In the base model, the utility $U_{ij} (i \in \{A, B\}, j \in \{A, B\})$ for a customer that is located at $x$ can be formulated as

\[ U_{AA}^B = v_{RA} - (p_A + t_A)(1 + r) - m \]  
\[ U_{BB}^B = v_{RA} + \Delta - (p_B + t_B)(1 + r) - m(1 - x) \]  

\[ 11 \text{ Technically, this assumption requires } \Delta \in (0, 3m, 3\theta m). \text{ That is, } \Delta \in 3m - 3\theta m. \]
“Product + logistics” bundling sale and co-delivery in…

Table 2 Summary of notations

<table>
<thead>
<tr>
<th>Notation</th>
<th>Definition</th>
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<tbody>
<tr>
<td>$U_{ij}$</td>
<td>The utility of customers who purchase products from $R_i$ and logistics services from $L_j$</td>
</tr>
<tr>
<td>$v_{RA}$</td>
<td>Customer’s standalone value of the product from $R_A$</td>
</tr>
<tr>
<td>$\Delta$</td>
<td>$R_B$’s product advantage based on quality over $R_A$</td>
</tr>
<tr>
<td>$p_i$</td>
<td>Product price charged by retailer $i$</td>
</tr>
<tr>
<td>$t_j$</td>
<td>Logistics fee charged by LSP $j$</td>
</tr>
<tr>
<td>$m$</td>
<td>Customer’s unit mismatch cost for the entire “product + service”</td>
</tr>
<tr>
<td>$\theta$</td>
<td>The ratio of logistics service mismatch cost to the overall mismatch cost</td>
</tr>
<tr>
<td>$x$</td>
<td>The distance from a customer to $R_i/L_A$, $x \sim U[0, 1]$</td>
</tr>
<tr>
<td>$r$</td>
<td>CBEC comprehensive tax rate</td>
</tr>
<tr>
<td>$\pi$</td>
<td>Participant’s profits</td>
</tr>
<tr>
<td>$\pi_{ij}$</td>
<td>Profits from customer group $ij$</td>
</tr>
<tr>
<td>$q_{ij}$</td>
<td>Quantity demanded by customers who purchase products from $R_i$ and logistics services from $L_j$</td>
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</table>

Table 3 Outcomes in the base model

<table>
<thead>
<tr>
<th></th>
<th>Product prices</th>
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<tbody>
<tr>
<td>$p^B_B$</td>
<td>$\frac{5m-\Delta}{5(1+r)}$</td>
</tr>
<tr>
<td>$p^A_A$</td>
<td>$\frac{5m+\Delta}{5(1+r)}$</td>
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<table>
<thead>
<tr>
<th></th>
<th>Logistics fees</th>
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<tbody>
<tr>
<td>$t^A_A$</td>
<td>$\frac{5m-\Delta}{5(1+r)}$</td>
</tr>
<tr>
<td>$t^B_B$</td>
<td>$\frac{5m+\Delta}{5(1+r)}$</td>
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<table>
<thead>
<tr>
<th></th>
<th>Quantities Demanded</th>
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<tbody>
<tr>
<td>$q^A_AA$</td>
<td>$\frac{1}{2} - \frac{\Delta}{10m}$</td>
</tr>
<tr>
<td>$q^B_BB$</td>
<td>$\frac{1}{2} + \frac{\Delta}{10m}$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Retailers’ profits</th>
</tr>
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<tbody>
<tr>
<td>$\pi^B_{RA}$</td>
<td>$\frac{(5m-\Delta)^2}{50m(1+r)}$</td>
</tr>
<tr>
<td>$\pi^B_{RB}$</td>
<td>$\frac{(5m+\Delta)^2}{50m(1+r)}$</td>
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<table>
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<tr>
<th></th>
<th>LSPs’ profits</th>
</tr>
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<tbody>
<tr>
<td>$\pi^B_{LA}$</td>
<td>$\frac{(5m-\Delta)^2}{50m(1+r)}$</td>
</tr>
<tr>
<td>$\pi^B_{LB}$</td>
<td>$\frac{(5m+\Delta)^2}{50m(1+r)}$</td>
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</table>

The profit functions of the four participants are

\[ \pi^B_{RA} = p_A q_{AA} \] (3)

\[ \pi^B_{LA} = t_A q_{AA} \] (4)

\[ \pi^B_{RB} = p_B q_{BB} \] (5)

\[ \pi^B_{LB} = t_B q_{BB} \] (6)

Solving the first-order conditions for the four profit-maximizing participants yields the equilibrium product prices, logistics fees, quantities demanded, and participants’ profits (see Table 3).

Two observations related to the equilibrium are worth highlighting. First, note that $p^B_B > p^B_A$, $q^B_BB > \frac{1}{2}$, $q^B_AA$, and $\pi^B_{RB} > \pi^B_{RA}$. This result is expected because $v_{RB} > v_{RA}$. That is, $R_B$’s product is more attractive than those of $R_A$, and thus, $R_B$ can charge a higher price and acquire a larger market share. $R_B$ consequently earns more
profits than $R_A$. Second, $t^B_B > t^B_A$ and $\pi^B_L > \pi^B_A$. The reason is that $L_B$, as a free rider, enjoys the spillover benefits from $R_B$’s product advantage. This makes $L_B$ have a profit advantage over $L_A$.

### 4.2 The dual-LSP model

When $R_B$ contracts with $L_A$ and $L_B$, the utility $U_{ij} (i \in \{A, B\}, j \in \{A, B\})$ for a customer located at $x$ can be formulated as

\[
U^{D}_{AA} = v_{R_A} - (p_A + t_A)(1 + r) - m
\]

\[
U^{D}_{BA} = v_{R_A} + \Delta - (p_B + t_A)(1 + r) - m\theta x - m(1 - \theta)(1 - x)
\]

\[
U^{D}_{BB} = v_{R_A} + \Delta - (p_B + t_B)(1 + r) - m(1 - x)
\]

The profit functions of the four participants are

\[\pi^D_{R_A} = p_A q_{AA}\]

\[\pi^D_{L_A} = t_A (q_{AA} + q_{BA})\]

\[\pi^D_{R_B} = p_B (q_{BA} + q_{BB})\]

\[\pi^D_{L_B} = t_B q_{BB}\]

Solving the first-order conditions for the four profit-maximizing participants yields the equilibrium product prices, logistics fees, quantities demanded, and participants’ profits (see Table 4).

Similar to the base model, we have $p^D_B > p^D_A$, $q^D_{BB} + q^D_{BA} > \frac{1}{2} > q^D_{AA}$ and $\pi^D_B > \pi^D_A$. As in the standard setup, by letting $U^B_{AA} = U^B_{BB}$, we define the indifferent customer’s location for the entire “product+logistics” as $x_1$, that is, whose net utility is equal when she chooses the combination of $R_A$’s product and $L_A$’s logistics service or the

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<td><strong>Product prices</strong></td>
<td>$p^D_A = \frac{3m(1-\theta)+\Delta}{3(1+r)}$</td>
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<td><strong>Logistics fees</strong></td>
<td>$t^D_A = \frac{m\theta}{1+r}$</td>
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<td><strong>Retailers’ profits</strong></td>
<td>$\pi^D_{R_A} = \frac{[\Delta - 3m(1-\theta)]^2}{18m(1-\theta)(1+r)}$</td>
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combination of $R_B$’s product and $L_B$’s logistics service. Similarly, the indifferent customer with respect to products is located at $x_2 < \frac{1}{2}$ by letting $U_{AA}^D = U_{BA}^D$. The indifferent customer with respect to logistics services is located at $x_3 = \frac{1}{2}$ by letting $U_{BB}^D = U_{BA}^D$. Hence, $t_i^D = t_B^D$ and $\pi_i^D = \pi_L^D$. Logistics dual sourcing enables customers to obtain the product and logistics service they need in an ideal way.

5 Comparison

Comparing the equilibriums in the two models, we first have the following lemma that compares the product prices, logistics fees and quantities demanded.

Lemma 1

(a) For any $\theta \in (0, 1)$ and $\Delta \in (0, \hat{\Delta})$, we have $t_i^D < t_i^B (i \in \{A, B\}), p_A^D < p_B^B$, and $p_B^D > p_B^B$ if and only if $\theta \in \left(0, \frac{2}{7}\right)$ and $\Delta \in \left(\frac{15\theta - 2}{2}, \hat{\Delta}\right)$.

(b) For any $\theta \in (0, 1)$ and $\Delta \in (0, \hat{\Delta})$, we have $q_{RA}^D < q_{RA}^B, q_{RB}^D > q_{RB}^B, q_{LA}^D > q_{LA}^B$, and $q_{LB}^D < q_{LB}^B$.

(c) For any $\theta \in (0, 1)$ and $\Delta \in (0, \hat{\Delta})$, we have

(i) $\frac{\partial(p_A^D - p_B^B)}{\partial \theta} < 0, \frac{\partial(p_A^D - p_B^B)}{\partial \theta} < 0, \frac{\partial(p_A^D - p_B^B)}{\partial \theta} > 0, \text{and} \frac{\partial(p_A^D - p_B^B)}{\partial \theta} > 0$; and

(ii) $\frac{\partial(p_A^D - p_B^D)}{\partial \Delta} < 0, \frac{\partial(p_A^D - p_B^D)}{\partial \Delta} > 0, \frac{\partial(p_A^D - p_B^D)}{\partial \Delta} > 0, \text{and} \frac{\partial(p_A^D - p_B^D)}{\partial \Delta} < 0$

Once $R_B$ adopts the DS and contracts with $L_A$ and $L_B$, it induces a price war between the two LSPs. This lowers prices for their “product + logistics” sets. However, when $R_B$’s logistics mismatch is small and its product advantage is significant, $R_B$ may still charge a higher price.

In the base model, the customers in $[x_2, x_1]$ purchase from $R_A$ because they prefer $L_A$’s logistics service even though they prefer $R_B$’s product. The customers in $[x_1, x_3]$ purchase from $R_B$ because of its product advantage, although they prefer the logistics service of $L_A$. Actually, in the base model, all potential customers in $[x_2, x_3]$ might derive more utility from the combination of $R_B$’s product and $L_A$’s logistics service, thus making it possible for them to transfer. On the left side of $x_1$ customers’ preference for logistics service dominates product advantage and on the right side is the opposite. In the dual-LSP model, customers are divided into three segments: customer group AA, customer group BA and customer group BB. The customers in $[x_2, x_1]$ prefer the combination of $R_B$’s product and $L_A$’s logistics service, because $R_B$’s product advantage is strong enough to dominate a customer’s preference for logistics service without bundling constraint. The customers in $[x_1, x_3]$ prefer the combination of $R_B$’s product and $L_A$’s logistics service, because customers who purchase $R_B$’s product can choose whichever of the two LSPs they prefer without bundling constraint (see Fig. 2 for an illustration).
We define two effects in the dual-LSP model to name our observations for short: the price-war effect and the unbundled effect.

**Price-war effect:** The unit product mismatch cost is measured by \( m(1 - \theta) \), and the unit logistics service mismatch cost is measured by \( m \). As \( \theta \) increases, customers’ preference for logistics service plays a more important role in customers’ purchasing decisions. That is, from a customer’s perspective, logistics service differentiation is more significant. Therefore, logistics services’ price competition is eased, which benefits LSPs in the dual-LSP model. In contrast, products’ price competition is intensified as \( \theta \) increases, which negatively affects retailers in the dual-LSP model. We define this effect because we have the mathematical results shown in Lemma 1(c)(i).

**Unbundled effect:** Compared with the base model, \( L_B \) cannot enjoy \( R_B \)’s product advantage to charge a higher logistics fee, because customers are free to choose whichever of the two LSPs’ services they prefer without bundling constraint. As \( \Delta \) increases, more customers in \([x_2, x_1]\) will transfer from group AA to group BA in the dual-LSP model. As a result, both \( L_A \) and \( R_B \) can charge higher prices because of the increase of the added potential demand (group BA). Therefore, it benefits \( R_B \) and \( L_A \), but negatively affects \( R_A \) and \( L_B \). We define this effect because we have the mathematical results shown in Lemma 1(c)(ii).

In the dual-LSP model, \( R_B \) makes profits from customer group BA and customer group BB. The next lemma compares the customer groups’ marginal profit and the share of \( R_B \) in each model.
Lemma 2

(a) For any $\theta \in (0, 1)$ and $\Delta \in (0, \bar{\Delta})$, we have $p_B^D + \bar{r}_i^D < p_B^B + \bar{r}_i^B$ and
\[
\frac{\partial((p_B^D + \bar{r}_i^D) - (p_B^B + \bar{r}_i^B))}{\partial \Delta} < 0 \quad (i \in \{A, B\}).
\]

(b) $\frac{p_B^D}{p_B^B + \bar{r}_B^D} > \frac{p_B^B}{p_B^D + \bar{r}_B^B} (i \in \{A, B\})$ if and only if either of these two conditions is satisfied:

(i) $\theta \in \left(0, \frac{1}{2}\right)$ and $\Delta \in (0, \bar{\Delta})$, or

(ii) $\theta \in \left(\frac{1}{2}, \frac{2}{3}\right)$ and $\Delta \in (3m(-1 + 2\theta), \bar{\Delta})$.

(c) For any $\theta \in (0, 1)$ and $\Delta \in (0, \bar{\Delta})$, we have $\frac{\partial\left(p_B^D + \bar{r}_i^D\right)}{\partial \Delta} < 0$ and $\frac{\partial\left(p_B^B + \bar{r}_B^B\right)}{\partial \Delta} > 0$ \((i \in \{A, B\})\).

We find that the competition of “product + logistics” is intensified, and it leads to system inefficiency. Once unbundled, customers transfer between products easier, which enhances customers’ power. In the base model, $R_B$ charges higher prices due to their product advantage, and $L_B$ enjoys the spillover benefits from $R_B$’s product advantage because of the bundle sale. However, in the dual-LSP model, two LSPs suffer from a price war, and $L_B$ loses the free-rider benefits.

Although marginal profit from customer group BA or customer group BB is lowered, $R_B$ may still benefit by gaining a large share. From our earlier discussions in Lemma 1(c), the price-war effect benefits LSPs but negatively affects retailers as $\theta$ increases. The unbundled effect significantly benefits $R_B$ as $\Delta$ increases. Therefore, $R_B$ earns a high share of marginal profit when $\theta$ is small [see Lemma 2(b)(i)] or when $\theta$ and $\Delta$ are relatively large [see Lemma 2(b)(ii)].

We next examine the total profit pie from $R_B$’s customer groups and the conditions under which $R_B$ can earn a larger share of the pie. A somewhat counterintuitive finding comes from the following proposition, which shows that profits in the dual-LSP model are even worse.

Proposition 1

(a) $\pi_{BA}^D + \pi_{BB}^D < \pi_{BB}^B$ for any $\theta \in (0, 1)$ and $\Delta \in (0, \bar{\Delta})$.

(b) $\frac{\pi_{BA}^D}{\pi_{BA}^D + \pi_{BB}^D} > \frac{\pi_{BB}^B}{\pi_{BB}^B}$ if and only if either of these two conditions is satisfied:

(i) $\theta \in \left(0, \frac{1}{2}\right)$ and $\Delta \in (0, \bar{\Delta})$, or

(ii) $\theta \in \left(\frac{1}{2}, \frac{2}{3}\right)$ and $\Delta \in (3m(-1 + 2\theta), \bar{\Delta})$.

Contrary to conventional wisdom, Proposition 1 indicates that the dual-LSP strategy always leads to a smaller total profit pie from $R_B$’s customer groups. Essentially, this is because the rate of decline in marginal profit is faster than the rate of transfer...
from $R_A$ to $R_B$. Since the two LSPs charge the same logistics fees, marginal profit of group $BA$ equal to those of group $BB$. Thus, $R_B$’s share of the total profit pie is the same as its share of marginal profit. Similar to Lemma 2(b), when $\theta$ is small or when $\theta$ and $\Delta$ are relatively large, $R_B$ can acquire a larger share of the total profit pie.

In the dual-LSP model, $L_A$ makes profits from customer group $AA$ and customer group $BA$. $L_A$ offers co-delivery service to two competing retailers and has to balance its profits from two groups. The next lemma compares the customer group’s marginal profit and the proportion of $L_A$ in each model.

**Lemma 3** For any $\theta \in (0, 1)$ and $\Delta \in (0, \bar{\Delta})$, we have

(a) $\frac{\partial (\pi_{AA}^D)}{\partial \theta} > 0$ and $\frac{\partial (\pi_{BA}^D)}{\partial \theta} > 0$;

(b) $\frac{\partial ((p_{AA}^D + p_{BA}^D) - (p_{AA}^D + p_{BA}^D))}{\partial \Delta} > 0$ (i $\in \{A, B\}$); and

(c) $\frac{\partial (\pi_{AA}^D - \pi_{BA}^D)}{\partial \theta} > 0$, $\frac{\partial (\pi_{BA}^D - \pi_{BA}^D)}{\partial \theta} > 0$, $\frac{\partial (\pi_{BA}^D - \pi_{BA}^D)}{\partial \Delta} > 0$, and $\frac{\partial (\pi_{BA}^D - \pi_{BA}^D)}{\partial \Delta} < 0$.

In the dual-LSP model, $L_A$ offers co-delivery service to two competing retailers and some customers prefer products from $R_B$ over $R_A$ due to product advantage. We use $\frac{\pi_{BA}^D}{\pi_{AA}^D}$ to characterize the transfer effect, which increases in both the ratio of logistics service mismatch cost to the overall mismatch cost and product advantage.

The price-war effect benefits the LSPs but negatively affects the retailers as $\theta$ increases. Therefore, $L_A$ gains a larger share of marginal profit. As $\Delta$ increases, the unbundled effect benefits $L_A$, but negatively affects $R_A$, and thus, $L_A$ gains a larger share of marginal profit from group $AA$. However, $L_A$ gains a smaller share of marginal profit from group $BA$.

We next examine the total profit pie from $L_A$’s customer groups and the conditions under which $L_A$ can earn a larger share of the pie.

**Proposition 2**

(a) $\pi_{AA}^D + \pi_{BA}^D > \pi_{AA}^B$ if and only if $\theta \in \left(0, \frac{49 + 5\sqrt{217}}{36}\right)$ and $\Delta \in \left(\frac{15m}{(1-\theta)(7 + \sqrt{(1-\theta)(177 + 23\theta)})}, \bar{\Delta}\right)$.

(b) $\frac{\pi_{BA}^D}{\pi_{AA}^D + \pi_{BA}^D} > \frac{\pi_{BA}^B}{\pi_{AA}^D}$ if and only if either of these three conditions is satisfied:

(i) $\theta \in \left(\frac{7}{15}, \frac{1}{2}\right)$ and $\Delta \in \left(\frac{3m}{4(1-\theta)(7 + \sqrt{(1-\theta)(177 + 23\theta)})}, \frac{3m}{4(1-\theta)(7 + \sqrt{(1-\theta)(177 + 23\theta)})}\right)$;

(ii) $\theta \in \left(\frac{1}{2}, \frac{2}{3}\right)$ and $\Delta \in \left(0, \frac{3m}{4(1-\theta)(7 + \sqrt{(1-\theta)(177 + 23\theta)})}\right)$; or

(iii) $\theta \in \left(\frac{2}{3}, 1\right)$ and $\Delta \in (0, \bar{\Delta})$.  

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Proposition 2 indicates that the total profit pie of $L_A$ is larger when $\Delta$ is large and $\theta$ is small. Clearly, more customers transfer from group AA to group BA when $\Delta$ is sufficiently large.

As $\theta$ increases, the price-war effect benefits LSPs but negatively affects the retailers, which helps $L_A$ to gain a larger share of the total profit pie. In particular, we find that when $\theta \in \left(\frac{7}{15}, \frac{1}{2}\right)$, $L_A$’s preference could switch twice from the base model to the dual-LSP model and back to the base model as $\Delta$ increases. The reasons are as follows. From our earlier discussions in Lemma 3(c) that, in the dual-LSP model, $L_A$’s share of marginal profit from group AA increases in $\Delta$, while that from group BA decreases in $\Delta$. On the one hand, the transfer effect indicates more customers transferring from group AA to group BA, which has a higher marginal profit as $\Delta$ increases. On the other hand, $L_A$ gains a smaller share in group BA as $\Delta$ increases. When $\Delta$ is small, marginal profit is higher in the base model, and the unbundled benefits in the dual-LSP model are not significant. Thus, $L_A$ prefers the base model. When $\Delta$ is relatively large, marginal profit in group BA is sufficiently large to offset the loss of a lower share in group BA. Therefore, $L_A$ prefers the dual-LSP model. When $\Delta$ is sufficiently large, the transfer effect leads to the negative effect that there are more customers in group BA, whereas $L_A$ gains a smaller share. Thus, $L_A$ will still prefer the base model.

We next examine the conditions under which $R_B$ and $L_A$ have incentives to cooperate with each other.

**Corollary 1**

(a) $\pi^D_{R_B} > \pi^B_{R_B}$ if and only if $\theta \in \left(0, \frac{-26+10\sqrt{10}}{9}\right)$ and $\Delta \in \left(\frac{15m}{16+9\theta}, \tilde{\Delta}\right)$.

(b) $\pi^D_{L_A} > \pi^B_{L_A}$ if and only if $\theta \in \left(\frac{4}{9}, 1\right)$ and $\Delta \in \left(5m\left(1 - \sqrt{\theta}\right), \tilde{\Delta}\right)$.

Corollary 1 suggests that both the base model and the dual-LSP model can be viable for retailers and LSPs. This result is consistent with our observations in practice. For example, it is widely known that fengqu.com is welcomed by customers due to its incomparable convenience, which is supported by its bundled logistics (i.e., SF Express). However, SF Express also serves the competing rival of fengqu.com and offers co-delivery service. We find that the retailer has a stronger motivation to choose the dual-LSP model than LSPs. As we will see in Fig. 6, cooperation between $R_B$ and $L_A$ may lead to a larger profit pie, and they should focus on how to divide the profit pie.

Figure 6a is the combination of Figs. 3 and 5a. According to Proposition 1(a), the total profits from $R_B$ cooperating with its contracted LSP/LSPs are always smaller in the dual-LSP model than in the base model. Only if $R_B$ can enjoy a larger share of the smaller total profit pie (which we called a small pie) will she choose the dual-LSP model. In both regions ① and ②, $R_B$ achieves a larger share of the total profits in the dual-LSP model than in the base model. In region ①, the
share is extremely large in the dual-LSP model (compared with the base model), which results in $R_B$ preferring the dual-LSP model over the base model. Meanwhile, in region ①, the share is not sufficiently large, which results in $R_B$ still preferring the base model. In contrast, in region ③, $R_B$ achieves a smaller share of the total profits in the dual-LSP model than in the base model. There is no doubt that $R_B$ prefers the base model in this region.

Figure 6b is the combination of Figs. 4a, b and 5b. According to Proposition 5 (a), in regions ②, ③, and ⑥, the total profits from $R_B$ cooperating with its contracted LSP/LSPs are always smaller in the dual-LSP model than in the base model, which is similar to Fig. 6a. In contrast, in regions ①, ④, and ⑤, the total profits from $R_B$ cooperating with its contracted LSP/LSPs are always larger in the dual-LSP model than in the base model. In region ①, $R_B$ achieves an extremely small share of the total profits in the dual-LSP model (compared with the base model), which results in $R_B$ preferring the base model over the dual-LSP model. In region ④, $R_B$ also achieves a small share, but it is not that small, which results in $R_B$ preferring the dual-LSP model over the base model. In region ⑥, $R_B$ enjoys both a larger share of the total profits and large total profits. Undoubtedly, she prefers the dual-LSP model.

$R_B$ and $L_A$ cooperate with each other when they both benefit in the dual-LSP model (i.e., region ③ in Fig. 7), where $R_B$ gains a large share of a small pie, while $L_A$ gains a small share of a large pie.

Otherwise, there exist two “prisoner’s dilemmas” (i.e., regions ① and ② in Fig. 8). That is, $R_B$ and $L_A$ choose noncooperation although their profit pie is larger under cooperation. As shown in region ①, $R_B$ benefits in the dual-LSP model, but $L_A$
"Product + logistics" bundling sale and co-delivery in…

However, the total profit pie is larger if they cooperate. Similarly, in region $\textcircled{2}$, $L_A$ benefits in the *dual-LSP model*, but $R_B$ benefits in the *base model*. This motivates them to design a subsidy scheme so that they benefit

![Diagram](image)

**Fig. 4** a The total profit pie of $L_A$ in the two models. b $L_A$’s share of the total profit pie in the two models
from a large profit pie in a win–win situation. One possible way to break this *prisoner’s dilemma* is to design agreements in which the revenues can be fairly allocated. For example, in region $\Box$, $R_B$ can provide $L_A$ a subsidy, which is denoted as $F$. This results in a win–win situation for them. However, how to determine $F$ is beyond the scope of this paper. New analytical models considering this are worth investigating, where new optimization techniques are required. We leave it as future research.

**Fig. 5** a Profits of $R_B$ in the two models. b Profits of $L_A$ in the two models
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Fig. 6  a Profits division of $R_B$ in the two models. b Profits division of $L_A$ in the two models

Fig. 7  Cooperation region between $R_B$ and $L_A$
6 Conclusion

Observing that logistics plays an increasingly important role in CBEC, we study the high-quality retailer’s logistics sourcing decisions. We investigate the impacts of several key drivers that have not been well studied in the existing literature. First, as the ratio of logistics service mismatch cost to the overall mismatch cost increases, the price-war effect leads to an eased logistics price war but an intensified product price war. Second, we find that in the base model, the retailer has to share its product advantage with the corresponding LSP. Therefore, the unbundled effect benefits the high-quality retailer but negatively affects the bundled LSP in the dual-LSP model. Lastly, we find that the LSP’s preferences over the two models may switch twice from the base model to the dual-LSP model and back to the base model because of the transfer effect.

Our work can be useful for managers in the cross-border e-commerce industry when they make strategic decisions regarding the selection of logistics service providers (LSPs). The logistics dual sourcing strategy allows customers to purchase an imported product in an ideal way, which significantly benefits customers. In this paper, we examine the total profit pie and the shares of the high-quality retailer and the bundled LSP to find the conditions under which they have incentives to cooperate with each other. We find that there are two noncooperation regions, although their profit pie is larger under cooperation. To the best of our knowledge, few existing logistics studies have investigated prisoner’s dilemma situations.

Two recent works that are closely related are Shang and Liu [23] and Wang et al. [30]. We find that Shang and Liu [23] study firms’ competition by considering the promised delivery time, which is a quality measure of logistics service. Different from their prisoner’s dilemma due to overinvestment issues in quality improvement, we contribute by identifying the prisoner’s dilemma when the retailer and the LSP decide whether to cooperate in co-delivery service. We focus on the logistics variety issues, rather than logistics service quality issues, when the retailer sells “product+logistics” to customers. Wang et al. [30] find a lose-lose situation when inland shipping companies canvass

![Prisoner's dilemma graph](image-url)
for cargo and a price negotiation agent is hired. Different from their work, downstream retailers canvass for cargo in our work, but they have the options to find multiple upstream LSPs to offer differentiated logistics services to customers. We characterize the incentive alignment opportunities between the LSP offering co-delivery service and the retailer selling high-quality products. The prisoner’s dilemma in our work is at the strategic collaboration level while theirs is at the complementary level, which is the main contribution of this paper. To expand the cooperation in the dual-LSP model, the beneficiary is suggested to provide their partner with a proper subsidy scheme.

We incorporate some new features in e-commerce, which constitutes another contribution of this paper. First, service bundled with the product is a common practice in e-commerce. Customers have preferences over both products and logistics services. This introduces the corresponding disutility due to the mismatch between a customer’s ideal product or logistics service and the one she intends to buy. Our work is among the earliest studies investigating “product + logistics” in e-commerce where customers’ mismatch between ideal product and logistics service is characterized. Second, we formulate the bundling operations in e-commerce, and find that a logistics service provider that contracts with a retailer selling high-quality products dedicatedly enjoys the spillover benefits from product advantage. These are all new and interesting contributions to the literature in e-commerce.

We also note a few limitations in this paper. First, we use the Hotelling model to facilitate our analysis. However, the market may not be fully covered. That is, new customers may enter, and the total demand can be larger, although a Hotelling model cannot include this. Second, in this study, we find that the prisoner’s dilemma requires more complex collaboration. To solve the prisoner’s dilemma situations, the retailer selling high-quality products and its dedicated carrier might benefit from agreements in which revenues can be fairly allocated. New analytical models considering revenue-transfer mechanisms are worth investigating, where new optimization techniques are required. We leave these items for future research.

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Appendix

Proof of Lemma 1

(a) Comparing the logistics fees and product prices in the two models, we have

\[ t_D^A - t_B^A = \frac{m\theta}{1+r} - \frac{5m-\Delta}{5(1+r)} = \frac{\Delta + 5m(\theta-1)}{5(1+r)}. \]

Note that \(0 < \Delta < 3m(1-\theta),\)

\[ t_D^A - t_B^A < \frac{2m(\theta-1)}{5(1+r)} < 0. \]
\[
\begin{align*}
    t_B^D - t_B^B &= \frac{m\theta}{1 + r} - \frac{5m + \Delta}{5(1 + r)} = -\frac{\Delta + 5m(\theta - 1)}{5(1 + r)} < 0 \\
p_A^D - p_A^B &= \frac{3m(1 - \theta) - \Delta}{3(1 + r)} - \frac{5m - \Delta}{5(1 + r)} = -\frac{2\Delta - 15m\theta}{15(1 + r)} < 0 \\
p_B^D - p_B^B &= \frac{3m(1 - \theta) + \Delta}{3(1 + r)} - \frac{5m + \Delta}{5(1 + r)} = \frac{2\Delta - 15m\theta}{15(1 + r)}.
\end{align*}
\]

Calculating \(2\Delta - 15m\theta = 0\), we have \(\Delta_1 = \frac{15m\theta}{2}\). Then we show that, \(p_B^D > p_B^B\) if \(\Delta > \Delta_1\); \(p_B^D < p_B^B\) otherwise.

(b) Comparing the demand of four participants in the two models, we have the demand of \(R_A, q_{AA}^D - q_{AA}^B = \left(\frac{1}{2} - \frac{\Delta}{6m(1 - \theta)}\right) - \left(\frac{1}{2} - \frac{\Delta}{10m}\right) = \frac{\Delta(3\theta + 2)}{30m(\theta - 1)} < 0\) the demand of \(R_B, q_{BA}^D + q_{BB}^D - q_{BB}^B = \left(\frac{\Delta}{6m(1 - \theta)} + \frac{1}{2}\right) - \left(\frac{1}{2} + \frac{\Delta}{10m}\right) = -\frac{\Delta(3\theta + 2)}{30m(\theta - 1)} > 0\) the demand of \(L_A, q_{BA}^D + q_{AA}^D - q_{AA}^B = \left(\frac{\Delta}{6m(1 - \theta)} + \frac{1}{2}\right) - \left(\frac{1}{2} - \frac{\Delta}{10m}\right) = \frac{\Delta}{10m} > 0\) the demand of \(L_B, q_{BB}^D - q_{BB}^B = \frac{1}{2} - \left(\frac{1}{2} + \frac{\Delta}{10m}\right) = -\frac{\Delta}{10m} < 0\).

(c) Conducting a sensitivity analysis of price difference with respect to \(\theta\) and \(\Delta\), we have

\[
\begin{align*}
    \frac{\partial (p_A^D - p_A^B)}{\partial \theta} &= -\frac{m}{1 + r} < 0, & \frac{\partial (p_A^D - p_A^B)}{\partial \Delta} &= -\frac{2}{15(1 + r)} < 0 \\
    \frac{\partial (p_B^D - p_B^B)}{\partial \theta} &= -\frac{m}{1 + r} < 0, & \frac{\partial (p_B^D - p_B^B)}{\partial \Delta} &= \frac{2}{15(1 + r)} > 0 \\
    \frac{\partial (t_A^D - t_A^B)}{\partial \theta} &= \frac{m}{1 + r} > 0, & \frac{\partial (t_A^D - t_A^B)}{\partial \Delta} &= \frac{1}{5(1 + r)} > 0 \\
    \frac{\partial (t_B^D - t_B^B)}{\partial \theta} &= \frac{m}{1 + r} > 0, & \frac{\partial (t_B^D - t_B^B)}{\partial \Delta} &= -\frac{1}{5(1 + r)} < 0.
\end{align*}
\]

**Proof of Lemma 2** In the dual-LSP model, \(R_B\) makes profits from customer group BA and customer group BB. While in the base model, \(R_B\) makes profits from customer group BB.

(a) Comparing the customer groups’ marginal profit and conducting a sensitivity analysis with respect to \(\Delta\), we have
(b) Comparing the proportion of $R_B$ in the customer groups’ marginal profit, we have

$$\frac{p_B^D + t_i^D}{p_B^B + t_i^B} - \frac{p_B^B}{p_B^D + t_i^D} = \frac{\Delta + 15m}{15(1 + r)} < 0$$

$$\frac{\partial}{\partial \Delta} \left[ \frac{p_B^D + t_i^D}{p_B^B + t_i^B} - \frac{p_B^B}{p_B^D + t_i^D} \right] = \frac{-1}{15(1 + r)} < 0$$

(c) Conducting a sensitivity analysis of the difference between $p_B$’s proportion with respect to $\theta$ and $\Delta$, we have

$$\frac{\partial}{\partial \theta} \left( \frac{p_B^D}{p_B^D + t_i^D} - \frac{p_B^B}{p_B^D + t_i^D} \right) = -\frac{3m}{3m + \Delta} < 0$$

$$\frac{\partial}{\partial \Delta} \left( \frac{p_B^D}{p_B^D + t_i^D} - \frac{p_B^B}{p_B^D + t_i^D} \right) = \frac{3m\theta}{(3m + \Delta)^2} > 0$$

**Proof of Proposition 1** We next examine the total profit pie of $R_B$’s customer groups and the conditions under which $R_B$ can earn a larger share of the pie.

(a) Comparing the total profit pie of $R_B$’s customer groups in the two models, we have

$$\pi_{BA}^D + \pi_{BB}^D - \pi_{BB}^B = \left( \pi_{RB}^D + \pi_{LB}^D + t_i^D q_{BA}^D \right) - \left( \pi_{RB}^B + \pi_{LB}^B \right)$$

$$= \left( \frac{[\Delta + 3m(1 - \theta)]^2}{18m(1 - \theta)(1 + r)} + \frac{m\theta}{2(1 + r)} + \frac{m\theta}{1 + r} \cdot \frac{\Delta}{6m(1 - \theta}) \right)$$

$$- \left( \frac{(5m + \Delta)^2}{50m(1 + r)} + \frac{(5m + \Delta)^2}{50m(1 + r)} \right)$$

$$= \frac{225m^2(-1 + \theta) + 15m\Delta(-2 + 7\theta) + \Delta^2(7 + 18\theta)}{450m(1 + r)(1 - \theta)} < 0$$

for $0 < \theta < 1$ and $0 < \Delta < 3m - 3m\theta$
(b) Comparing the proportion of $R_B$ in the total profit pie of $R_B$’s customer groups, we have

$$\frac{x^D_{RB}}{x^D_{AA} + x^D_{RB}} - \frac{x^B_{RB}}{x^B_{BB}} = \frac{1}{2} - \frac{3m\theta}{3m + \Delta}$$

\[
\begin{cases}
> 0, & \text{if } \theta \in \left(0, \frac{1}{3}\right) \text{ and } \Delta \in (0, \bar{\Delta}) \\
< 0, & \text{otherwise}
\end{cases}
\]

**Proof of Lemma 3**

(a) We use $q^D_{RA}$ to characterize the transfer effect in the dual-LSP model. Conducting a sensitivity analysis of the transfer effect with respect to $\theta$ and $\Delta$, we have

$$\frac{\partial}{\partial \theta} \left( \frac{\Delta}{3m(1-\theta) - \Delta} \right) = \frac{3m\Delta}{[3m(1-\theta) - \Delta]^2} > 0$$

$$\frac{\partial}{\partial \Delta} \left( \frac{3m(1-\theta)}{[3m(1-\theta) - \Delta]^2} \right) > 0$$

(b) In the dual-LSP model, $L_A$ makes profits from customer group AA and customer group BA. While in the base model, $L_A$ makes profits from customer group AA. Comparing the customer groups’ marginal profit and conducting a sensitivity analysis with respect to $\theta$ and $\Delta$, we have

$$\frac{\partial}{\partial \Delta} \left[ (p^D_A + t^D_A) - (p^B_A + t^B_A) \right] = \frac{\partial}{\partial \Delta} \left[ -15m + \Delta \right] = \frac{1}{15(1 + r)} > 0$$

$$\frac{\partial}{\partial \Delta} \left[ (p^B_A + t^B_A) - (p^A_A + t^A_A) \right] = \frac{\partial}{\partial \Delta} \left[ -15m + 11\Delta \right] = \frac{11}{15(1 + r)} > 0$$

(c) Conducting a sensitivity analysis of the difference between $t_A$’s proportion with respect to $\theta$ and $\Delta$, we have
"Product + logistics" bundling sale and co-delivery in…

We next examine the total profit pie of $L_A$’s customer groups and the conditions under which $L_A$ can earn a larger share of the pie.

(a) Comparing the total profit pie of $L_A$’s customer groups in the two models, we have

$$
\frac{\partial}{\partial \theta} \left( \frac{p_B^A - p_B^{D_A}}{p_B^{D_A} + p_B^B} \right) = \frac{3m}{3m - \Delta} > 0
$$

$$
\frac{\partial}{\partial \Delta} \left( \frac{p_B^A - p_B^{D_A}}{p_B^{D_A} + p_B^B} \right) = \frac{3m}{(3m - \Delta)^2} > 0
$$

$$
\frac{\partial}{\partial \Delta} \left( \frac{p_B^A - p_B^{D_A}}{p_B^{D_A} + p_B^B} \right) = \frac{3m}{(3m + \Delta)^2} < 0
$$

**Proof of Proposition 2** We next examine the total profit pie of $L_A$’s customer groups and the conditions under which $L_A$ can earn a larger share of the pie.

(a) Comparing the total profit pie of $L_A$’s customer groups in the two models, we have

$$
\pi^D_{AA} + \pi^D_{RA} - \pi^B_{AA} = \left( \pi^D_{RA} + \pi^D_{LA} + p_B^D q_B^D \right) - \left( \pi^B_{RA} + \pi^B_{LA} \right)
$$

$$
= \frac{-225m^2(-1 + \theta) + 105m\Delta(-1 + \theta) - 2\Delta^2(16 + 9\theta)}{450m(1 + r)(-1 + \theta)}
$$

$$
\begin{cases}
> 0, & \text{if } \theta \in \left(0, \frac{-49 + 5\sqrt{217}}{36}\right) \quad \text{and} \quad \Delta \in \left(\frac{15m[-7(1-\theta)+\sqrt{17}\tau(177+23\theta)]}{4(16+9\theta)}, \Delta\right) \\
< 0, & \text{otherwise}
\end{cases}
$$

(b) Comparing the proportion of $L_A$ in the total profit pie of $L_A$’s customer groups, we have

$$
\frac{\pi^D_{LA}}{\pi^D_{AA} + \pi^D_{RA}} - \frac{\pi^B_{LA}}{\pi^B_{AA}} = \frac{2\Delta^2 + 3m\Delta(-1 + \theta) + 9m^2(-1 + \theta)(-1 + 2\theta)}{2(-2\Delta^2 + 9m^2(-1 + \theta) - 3m\Delta(-1 + \theta))}
$$

$$
\begin{cases}
> 0, & \text{if } \theta \in \left(\frac{7}{15}, \frac{1}{2}\right) \quad \text{and} \quad \Delta \in \left(\frac{3m[1(1-\theta)\sqrt{1(1-\theta)-7+15\theta}]}{4}, \frac{3m[1(1-\theta)+\sqrt{1(1-\theta)(7+15\theta)}]}{4}\right);
\\
\theta \in \left(\frac{1}{2}, \frac{2}{3}\right) \quad \text{and} \quad \Delta \in \left(0, \frac{3m[1(1-\theta)+\sqrt{1(1-\theta)(7+15\theta)}]}{4}\right);
\\
\theta \in \left(\frac{2}{3}, 1\right) \quad \text{and} \quad \Delta \in (0, \Delta) \\
< 0, & \text{otherwise}
\end{cases}
$$
Proof of Corollary 1 We next examine the conditions under which $R_B$ and $L_A$ have incentives to cooperate with each other.

(a) Comparing the profits of $R_B$ in the two models, we have

$$\pi_D^{RB} - \pi_B^{RB} = \frac{-60m\Delta(-1 + \theta) + 225m^2(-1 + \theta)\theta + \Delta^2(16 + 9\theta)}{450m(1 + r)(-1 + \theta)}\begin{cases} > 0, & \text{if } \theta \in \left(0, \frac{-26+10\sqrt{10}}{9}\right) \text{ and } \Delta \in \left(\frac{15m[-2(1-\theta)+(2+3\theta)\sqrt{1-\theta}]}{16+9\theta}, \bar{\Delta}\right) \\
< 0, & \text{otherwise} \end{cases}$$

(b) Comparing the profits of $L_A$ in the two models, we have

$$\begin{cases} > 0, & \text{if } \theta \in \left(\frac{4}{9}, 1\right) \text{ and } \Delta \in \left(5m\left(1 - \sqrt{\theta}\right), \bar{\Delta}\right) \\
< 0, & \text{otherwise} \end{cases}$$

References


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