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Logistics service sharing in cross-border e-commerce

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A B S T R A C T

While the demand for cross-border e-commerce has grown rapidly, challenges have emerged for both retailers and consumers participating in this global market. Retailers have been struggling with high logistics costs to fulfill cross-border demand, while the lack of trust in foreign retailers is a major issue for consumers. In this paper, we study a cross-border collaboration scheme between a domestic and a foreign retailer to mitigate these challenges. This entails a co-opetition framework where the domestic retailer performs the last-mile delivery of the foreign retailer's orders in exchange for a logistics service fee. We model demand via a Multinomial Logit (MNL) choice model where the consumers are trust- and price-sensitive. We compare the market outcomes of the two retailers in "pre-collaboration" and "post-collaboration" settings. We find that there exist win-win outcomes where both retailers benefit from collaboration under realistic settings. We also show that a cooperative mechanism can lead to higher profits for both retailers compared to the non-cooperative mechanism for setting the logistics service fee, if the contract terms are decided carefully.

1. Introduction

The widespread adoption of Internet shopping, accelerated by the COVID-19 pandemic, encouraged many retailers to extend their online businesses and offer their products to consumers in foreign countries. Data show that cross-border e-commerce constituted 22% of the total online sales worldwide in 2022, compared to 15% in 2016 (Statista, 2022).

Despite the rise in sales, both retailers and consumers continue to face issues in cross-border e-commerce. For retailers, cross-border delivery operations remain to be a big challenge due to high costs (Wang et al., 2021). As DHL (2015) highlights, this is because "customs regulations and processes worldwide were designed for large-scale, repetitive industrial shipments, not for the small, unique orders that form the bulk of e-commerce transactions". (European Commission, 2016) estimates that retailers may pay up to five times higher delivery costs for cross-border shipments compared to domestic deliveries of similar distance. In addition to the challenges experienced by retailers, cross-border e-commerce raises a concern for consumers as well when they look for a product on foreign websites. European Commission (2016) states that lack of trust is a major issue when consumers are buying from foreign websites. The market research agency (GfK, 2015) echoes the same finding: "Trust issues are important in preventing people from buying abroad, mostly for tangible goods". While there are several factors that contribute to this distrust, such as differences in language, culture (Cui et al., 2020) and legal systems (Steenkamp and Geyskens, 2006; GfK, 2015) highlights that "barriers for cross-border online purchasing are mostly centered on delivery conditions, since physical distance plays a more important role in this case". Hence, even for the same product (with the same brand, model, and price), foreign websites may be less attractive to consumers than their domestic counterparts due to the trust issues arising from potential delivery problems.

In this paper, our goal is to investigate whether a supply chain collaboration mechanism can alleviate the aforementioned challenges and ensure profitability in cross-border e-commerce. Industry research highlights that many e-commerce retailers look internationally for new growth markets to raise their profits (Visa, 2019). However, to do so, they need to adopt strategies that overcome the aforementioned challenges. In this paper, we study whether and when a supply chain collaboration strategy can help retailers to achieve this. While there are several empirical works in the literature studying the challenges in cross-border e-commerce (see, for example, Wang et al., 2017; Kim et al., 2017; Cui et al., 2020; Mou et al., 2020), there are currently no works studying potential supply chain solutions that help retailers overcome these challenges. Hence, our paper sheds light into the settings under which supply chain collaboration can be a solution to ensure profitability in cross-border e-commerce, aiding retailers in decision-making.

Industry practices show that such collaborations with local retailers can help mitigate delivery problems in cross-border e-commerce. In domestic settings, a variety of these partnerships has developed to

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improve the logistics operations via collaboration between (potentially competing) retailers. For example, in Germany, while the retailers Kohl's and Amazon compete for the same market across a variety of product groups, they also collaborate such that the consumers can pick up, return and exchange their Amazon purchases in more than 1,150 Kohl's stores for free (Kohl's, 2019). Similarly, in the UK, eBay collaborates with the competitors Next and Sainsbury's such that these two retailers offer order collection points in their stores to enable consumers to pick up their eBay orders (Sainsbury's, 2016). Another interesting collaboration arises in the UK between two grocery retailers, Waitrose and Ocado, where the latter retailer has been providing home delivery services to Waitrose for nearly 20 years. Ocado has recently started the same collaboration with the retailer M&S (The Guardian, 2019).

Most recently, a cross-border collaboration has emerged between Shopify and the Chinese e-commerce giant JD. The partnership greatly simplifies the cross-border logistics processes for Shopify's US-based sellers that ship goods to Chinese consumers. For instance, the partnership allows these US-based sellers to ship the items in bulk to JD's warehouse, which are then delivered to consumers via JD's extensive logistics network in China. As such, costs and operational challenges (e.g., regarding customs processes) are greatly simplified, alleviating the retailers' cross-border logistics challenges (Design1st, 2022). Undoubtedly, serving consumers in collaboration with a well-established Chinese e-commerce retailer also enables Chinese consumers to build trust in US-based foreign retailers by alleviating logistics-related concerns.

Motivated by these partnerships as management cases implemented in practice, we study a stylized setting where two e-commerce retailers, located in different countries, collaborate on logistics. Specifically, this horizontal collaboration entails a foreign retailer collaborating with a domestic retailer such that the domestic retailer provides last-mile delivery services for the orders placed at the foreign retailer in exchange for a fee (similar to the case of JD and Shopify's US-based retailers).

This collaboration can have several advantages for both foreign and domestic retailers. Firstly, the (European Commission, 2016) emphasizes that in cross-border e-commerce, "E-retailers sending bulk shipments were able to save at least 18% per parcel compared to smaller e-retailers who paid the 'single piece' price". Hence, by shipping consumer orders in bulk to the domestic retailer for last-mile delivery to the consumers, the foreign retailer could cut down on the logistics costs by circumventing the costly customs procedures for single-piece cross-border shipments. Secondly, due to the fragmented delivery services across the EU, retailers experience problems with liability and responsibility during delivery (European Commission, 2016). As Kim et al. (2008) and Giuffrida et al. (2021) state, this leads to distrust in foreign websites regardless of the make of the product. Collaboration with a domestic retailer can induce trust in the foreign websites, as it can give consumers a sense of security as a result of their familiarity with the domestic partner (as in the case between JD's Chinese consumers and Shopify's US-based foreign retailers). Lastly, the domestic retailer can also benefit from this partnership by receiving a fee for the logistics services provided to the foreign retailer. As such, this logistics service fee can help the domestic retailer raise additional revenue, which can translate to higher profits.

Note, however, that despite the potential benefits, the decision to collaborate or not is not an easy task. This is because both retailers operate in the same market, and compete for the same consumers to generate sales. Hence, they are competing retailers that collaborate at the same time, engaging in a "co-opetition". The profitability of this co-opetition hinges on how the implemented collaboration mechanism affects the prices and market shares for the two competing retailers. In this setting, our goal is to address the following questions:

1. How does the logistics service sharing affect the retailers' profits?
2. Under which settings is cross-border co-opetition a "win-win" strategy for both retailers?
3. How does co-opetition affect the consumers?
4. How does a cooperative vs. non-cooperative mechanism for setting the logistics service fee affect the win-win settings for collaboration?

To address these research questions, we adopt a game theoretic framework and study two settings: *(i)* pre-collaboration (competition) setting, and *(ii)* post-collaboration (co-opetition) setting. By comparing the outcomes of the two settings, we identify the conditions under which, the collaboration is a win-win strategy for both retailers. In the former (competition) setting, the two retailers engage in a simple price competition game to sell to price- and trust-sensitive consumers whose demand is modeled via the Multinomial Logit (MNL) choice model. Applying the same demand function, the latter (co-opetition) setting is modeled as a two-stage game, which is solved via backward induction. In the second stage, a price competition game is solved and equilibrium prices are determined for a given logistics service fee. In the first stage, the optimal logistics service fee is determined. At this step, we first study a non-cooperative mechanism for setting the logistics service fee where the domestic retailer determines the optimal service fee by maximizing his own profit. Then, we study an alternative contract that employs a cooperative mechanism for setting the logistics service fee, where the optimal service fee is determined by maximizing the sum of both retailers' profits. Then, the foreign retailer gives part of her surplus gained out of collaboration to the domestic retailer as a fixed payment.

Our analysis reveals that the impact of logistics service sharing on retailers' profits crucially depends on the interplay between the logistics service fee and consumers' trust in the foreign retailer. Our results show that, to ensure profitability in collaboration, the domestic retailer should charge the foreign retailer a higher fee when the trust in the foreign retailer is high. On the bright side, with high trust from the consumers, the foreign retailer would be able to withstand this fee (due to an increase in demand) and still be profitable. As a result, we show that there exists a range for the logistics service fee, which leads to a win-win outcome for both retailers even when a non-cooperative mechanism is adopted for setting the logistics service fee, and we observe that this range gets wider as the consumer trust in the foreign retailer increases. More interestingly, we show that within this range, the consumers can also benefit from collaboration. This occurs when the logistics service fee is set at the lower end of this win-win range for the logistics service fee. Hence, we show that there exist settings where both retailers as well as consumers benefit from this collaboration, leading to win-win-win outcomes (when the logistics fee is at a moderate level). Lastly, we show that a cooperative mechanism can lead to higher profits for both retailers compared to the non-cooperative mechanism for setting the logistics service fee if the contract terms are decided carefully.

Many retailers look beyond the national borders to capture new markets in sales to raise profits. A survey conducted by Visa (2019) finds that "An overwhelming majority (88%) of executives believe that having an international presence will be essential for their company's success in the next five years". However, Visa (2019) also highlights that, in doing so, the largest hurdle is still logistics, leading to potential trust issues in capturing demand. Hence, retailers are still looking for the right strategies to overcome these challenges to generate profits in cross-border e-commerce. So far, the research on cross-border e-commerce has mainly focused on understanding the inhibiting factors to cross-border e-commerce (see Wang et al., 2017; Kim et al., 2017; Cui et al., 2020; Mou et al., 2020). However, we are not aware of any work focusing on potential supply chain solutions to achieve profitability given these factors. Our work addresses precisely this problem and shows that "win-win" outcomes can be achieved by adopting a collaboration scheme in cross-border e-commerce, aiding retailers in decision-making.

The broader impacts of our study relate to the efforts taken by governments to facilitate cross-border e-commerce. For example, the European Commission (EC) strives to create a Single Digital Market in Europe (European Commission, 2019). Despite the lack of physical borders in Europe, the e-commerce market is still fragmented due to the aforementioned factors; hence, consumers confine themselves mostly to national borders. The EC has taken some policy measures (such as simplifying the tax rules and standardizing parcels) to facilitate cross-border e-commerce. We contribute to these ongoing efforts by studying a supply chain mechanism as another potential solution that retailers can implement as a complementary strategy. While our work is stylized, it shows promise that a successful implementation of policy measures along with supply chain strategies, as proposed in our study, has the potential to increase cross-border e-commerce success in the long run, helping consumers and retailers to access wider markets.

The remainder of this paper is organized as follows. In Section 2, we review the relevant literature and discuss our contributions to each line of research. We present our model and analytical results in Section 3. In Section 4, we study the win-win settings for collaboration under a non-cooperative mechanism for setting the logistics service fee. Then, we compare the outcomes with those under a cooperative mechanism in Section 5. Finally, in Section 6, we conclude our study with the implications of our findings and future research directions.

2. Related literature

Our research is relevant to two streams of literature: *(i)* research on co-opetition, and *(ii)* research on logistics service sharing in e-commerce.

Co-opetition occurs when firms cooperate with their competitors (Brandenburger and Nalebuff, 1996). Co-opetition has been studied in a variety of supply chain settings, including manufacturing capacity sharing (Wu et al., 2014; Guo and Wu, 2018; Cao et al., 2023a), airlines' code-sharing (Hu et al., 2013; Qin et al., 2020b), information and technology sharing (Jiang and Hao, 2014; Wu et al., 2019; Li et al., 2021b,a; Hafezi et al., 2023; Liu et al., 2023a), and service sharing in retail (Yuan et al., 2021). Very recently, Katsaliaki et al. (2023) provided a comprehensive review on supply chain co-opetition. Co-opetition studies usually adopt a two-stage game-theoretic framework, which is solved via backward induction. In this setup, competition is formulated by a non-cooperative game in the second stage, combined with another cooperative or non-cooperative scheme for collaboration in the first stage. We rely on co-opetition studies from a methodological perspective. From that view, the studies that are most similar to our work include (Roma and Perrone, 2016), Li et al. (2021a), and Hafezi et al. (2023). Similar to our work, these studies solve a price competition game in the second stage. Then, in the first stage, they consider different decisions pertaining to collaboration, such as joint expenditure in research and development (R&D) investments in Roma and Perrone (2016), reduction in R&D costs in Li et al. (2021a), and innovation sharing in Hafezi et al. (2023). In the first stage, while (Roma and Perrone, 2016) use a cooperative mechanism, Li et al. (2021a) use a non-cooperative mechanism, and Hafezi et al. (2023) use both a cooperative and non-cooperative mechanism. Methodologically, we follow a similar approach to these studies, while the novelty lies in the problem context we analyze. We are not aware of other co-opetition studies that focus on cross-border e-commerce. This makes our demand model, decision variables, and research questions specific to this novel application area.

From an application perspective, our work is relevant to the research on logistics service sharing in e-commerce. The first line of research in this area is related to dual-channel supply chains (where a manufacturer sells to the end consumers both via a retailer and through his own direct e-commerce channel). In this setting, a vertical collaboration happens within a supply chain where the retailer owns a superior logistics service and shares it with the manufacturer in exchange for a logistics service fee (see, e.g., Wang et al., 2022). He et al. (2020) study this setting, and show that logistics service sharing always increases the direct-channel price, but the retailer's price may increase or decrease depending on the logistics service fee. A shortcoming of this work lies in studying a single strategy (logistics service sharing by the retailer) under a single contracting mechanism (linear transfer payment). To address this shortcoming, He et al. (2022) compare the performance of the supply chain players under different strategies, i.e., the logistics service is provided by a third-party logistics (3PL) providers (outsourcing), by the retailer (complete service sharing), or by both (partial service sharing) under different contracting mechanisms (revenue-sharing and linear transfer payment). While these works offer valuable contributions to the logistics service-sharing literature, they all focus on vertical supply chains. Our setting entails two online retailers that compete and collaborate horizontally (under different contracting mechanisms). This requires a different modeling framework (i.e., the Stackelberg framework implemented in the aforementioned works does not apply) and provides different insights. This aspect makes our paper more relevant to the second line of research in logistics sharing in e-commerce, which is in the context of online platforms, as we elaborate below.

The online platform serves three purposes in the studies pertaining to logistics service sharing (see, e.g., Li and Li, 2023; Liu et al., 2023a,b; Li et al., 2024; Cao et al., 2023b). First, it provides a platform through which multiple sellers can sell their goods. Next, it can provide logistics services to the sellers on the platform. Finally, it may sell its own products, which are substitutes for the goods sold by the sellers on the platform. One of the most relevant works in this domain includes (Qin et al., 2020a), who design a two-stage non-cooperative game to study a seller's decision to receive the logistics service from the platform or from a 3PL. Similar to our study, in the first stage, the platform optimizes the logistics service fee that it charges the seller, and then in the second stage, the platform and the seller enter a price game. They show that a win-win outcome can be achieved when the 3PL's logistics service level and the market potential are in the middle range. In another study, Lai et al. (2022) study a similar problem setting between a platform and its sellers, but in addition, they investigate how the platform's supplier might also gain from the downstream co-opetition. These studies contribute to the literature by analyzing pricing decisions in logistics service sharing. However, contextually, they study domestic settings. As a result, the model formulation, as well as the parameters in focus, are tailored to this setting. Adding to the literature, we focus on aspects that are unique to cross-border settings. For example, we employ a general demand function, which takes into account consumer trust in retailers, as this is an important aspect in a cross-border setting. In addition, different from the above studies, we focus on the collaboration between two horizontally competing firms rather than a setting where one of the firms (i.e., platform) is an enabler of the other (i.e., platform seller). This distinction leads to two key innovations in our model. First, our unique setting eliminates channel conflict, a common issue in platform co-opetition (Ryan et al., 2012). Second, in contrast to platform-seller logistics sharing, where the platform typically holds a dominant role, our horizontal co-opetition framework features no predefined dominance, allowing for broader practical applications. This opens the door to different contracting mechanisms than that are implemented in the aforementioned studies. To that end, we study two contracting mechanisms that can be adopted in our setting: a non-cooperative and a cooperative contracting mechanism. Our results show that the cooperative option might be more beneficial for both retailers, contributing to the findings of the aforementioned studies, which did not examine this option.

3. Model

We consider a market with two online retailers, namely, a domestic retailer and a foreign retailer who are selling substitutable products (e.g., with the same functionality, brand/quality level, etc.).

We use the MNL choice model to derive the demand for each retailer in this setting. The MNL model belongs to the family of random utility-based choice models. The model was initially formalized by the economist (McFadden, 1974), and since then, it has been widely used to realistically model demand in the Operations Management and Marketing studies both for theoretical and empirical research (Besbes and Sauré, 2016; Schuur et al., 2021; Li and Webster, 2024). It also lays the foundation for other choice models (e.g., Mixed Multinomial or Multivariate Logit choice models, see Aksoy-Pierson et al., 2013; Mutlu et al., 2023).

In the MNL model, it is assumed that there is a population of consumers, and a set of alternatives which the consumers can choose from. Based on the consumers' choices, demand is derived for different alternatives (see Talluri and Van Ryzin (2006) for the theory of choice models). Consumers make their choices based on the "utility" that they derive from each alternative. A strength of the MNL model is that it takes into account the idiosyncratic differences between consumers. That is, not all consumers are the same. Hence, even for the same alternative, different consumers can derive different utilities. In other words, consumer utilities are random.

Following the MNL model, in our problem setting, the consumers have three options to choose from when they are making their purchasing decision: purchasing from the domestic retailer, purchasing from the foreign retailer, or not purchasing at all (denoted by subindices d, f, and 0, respectively). The MNL model assumes that a consumer associates a "valuation" with each alternative (i.e., a willingness to pay, representing the value derived from each option). This valuation has a deterministic component and a stochastic component. The former represents the mean valuation across the consumer population, while the latter captures the randomness in consumer valuation as individuals may differ in their valuation. The final "utility" (i.e., "benefit") that a random consumer derives from each alternative equals their valuation less the price that they need to pay. Below, we introduce the utility u_i that a random consumer derives from each option $i \in \{d, f, 0\}$:

$$u_d = v - p_d + \xi_d, \quad u_f = \underline{\theta} v - p_f + \xi_f, \quad \text{and} \quad u_0 = v_0 + \xi_0.$$

In this MNL utility formulation, the parameter v denotes the consumers' mean valuation of the product when purchased at the domestic retailer while the random variable ξ_d captures the stochasticity in consumer valuation of this option. Consumers also need to pay a price p_d when purchasing at the domestic retailer; hence, the final utility that a random consumer derives from this option is: $u_d = v - p_d + \xi_d$.

(European Commission, 2016) and GfK (2015) show that lack of trust is a major issue when consumers consider buying from foreign retailers. Similarly, Ramkumar and Jin (2019), Giuffrida et al. (2021), Cui et al. (2020) confirm that consumers might not trust domestic and foreign websites equally. As a result, these trust issues may lower the utility of the product if it is obtained at the foreign retailer, hurting the consumers' purchase intentions. To capture this effect, we denote the consumers' mean valuation of the product when purchased at the foreign retailer by $\underline{\theta} v$, where $\underline{\theta} \in [0, 1]$ represents the reduced degree of trust with respect to the foreign retailer (see Chiang et al. (2003) for a similar formulation). The stochasticity in consumer valuation of this option is represented by the random variable ξ_f. Consumers also need to pay the price p_f at the foreign retailer; hence, the final utility that a random consumer derives from this option is $u_f = \underline{\theta} v - p_f + \xi_f$.

Finally, following the convention in the literature, the utility that a random consumer derives from the no-purchase option is $u_0 = v_0 + \xi_0$, where $v_0 = 0$ represents the consumers' mean valuation of not purchasing a product at all while the term ξ_0 represents the stochastic term associated with this option. Following the convention in the literature (Hanson and Martin, 1996; Besbes and Sauré, 2016; Bernstein and Federgruen, 2004), it is assumed that the random variables ξ_d, ξ_f, ξ_0 are i.i.d standard Gumbel distributed.

The MNL model derives the demand for each option within a utility maximization framework. That is, a random consumer chooses the option $i \in \{d, f, 0\}$ only if the utility derived from this option is greater than the utility derived from the other two options. Hence, the portion of consumers who choose option d is given by $q_d \equiv Pr(u_d > \max(u_f, u_0))$. Similarly, we have $q_f \equiv Pr(u_f > \max(u_d, u_0))$ and $q_0 \equiv Pr(u_0 > \max(u_d, u_f))$. With the above assumptions on the distribution of random variables, the following standard form can be derived for $q_i, i \in \{d, f, 0\}$ (see also (Hanson and Martin, 1996; Bernstein and Federgruen, 2004; Talluri and Van Ryzin, 2006; Besbes and Sauré, 2016) for this standard form):

$$q_d = \frac{e^{v-p_d}}{1 + e^{v-p_d} + e^{\underline{\theta} v - p_f}}, \quad q_f = \frac{e^{\underline{\theta} v - p_f}}{1 + e^{v-p_d} + e^{\underline{\theta} v - p_f}},$$
$$\text{and} \quad q_0 = \frac{1}{1 + e^{v-p_d} + e^{\underline{\theta} v - p_f}}. \tag{1}$$

In Fig. 1, we illustrate the decision-making process of a random consumer.

Given the market shares $q_i, i \in \{d, f, 0\}$, in Eq. (1), we first analyze the retailers' decision-making problem in the pre-collaboration setting. In Table 1, we summarize the main notation used throughout the paper.

3.1. Pre-collaboration (competition) setting

In the pre-collaboration setting, the domestic and the foreign retailers are simply competitors for the market share. That is, they are competing for the same consumers such that they can raise their profits. Hence, this benchmark setting entails a simultaneous duopoly price game, where each competing retailer aims to maximize their own profit by adjusting their prices. The profit function of retailer $i \in \{d, f\}$ is defined as follows:

$$\Pi_i = (p_i - c_i) q_i, \tag{2}$$

where $c_i, i \in \{d, f\}$, denotes the unit delivery cost incurred per sale by retailer i. The profit of retailer i is simply the market share (q_i) multiplied by the net profit margin earned on a sale ($p_i - c_i$). (Note that any procurement costs from the suppliers can easily be embedded in c_i as well, and this would not lead to any changes in our formulation or results.)

Given the profit functions in Eq. (2), the retailers engage in a duopoly price competition to maximize their profits. We start with the following result.

Proposition 1 (*Milgrom and Roberts, 1990*). *There exists a unique Nash equilibrium for the pre-collaboration price game.*

(Milgrom and Roberts, 1990) show that the simultaneous duopoly price game with an MNL demand model is a supermodular game with a unique Nash equilibrium. The equilibrium prices in this setting can be easily derived by using the best response functions, denoted by $p_i^*(p_j), i \in \{d, f\}, i \neq j$, in Lemma 1 via a simple iterative algorithm (Bernstein and Federgruen, 2004). (To improve the exposition of the paper, we relegate the proofs of all technical results to the Appendix A.)

Lemma 1. *The retailers' best response functions in the pre-collaboration price game are:*

$$p_d^*(p_f) = 1 + c_d + W\left(\frac{e^{v-1-c_d}}{1 + e^{\underline{\theta} v - p_f}}\right), \quad \text{and} \quad p_f^*(p_d) = 1 + c_f + W\left(\frac{e^{\underline{\theta} v - 1 - c_f}}{1 + e^{v-p_d}}\right),$$

where $W(x)$ denotes the Lambert W function[1].

Proposition 1 and Lemma 1 are general and hold in any parameter setting without restriction. In practice though, the observed values are more specific. Particularly, the (European Commission, 2016) highlights that cross-border deliveries are much costlier compared to domestic deliveries due to how the customs procedures are designed,

[1] Lambert W function is the inverse of function $x = ye^y$. We refer to Corless et al. (1996) for an in-depth discussion.

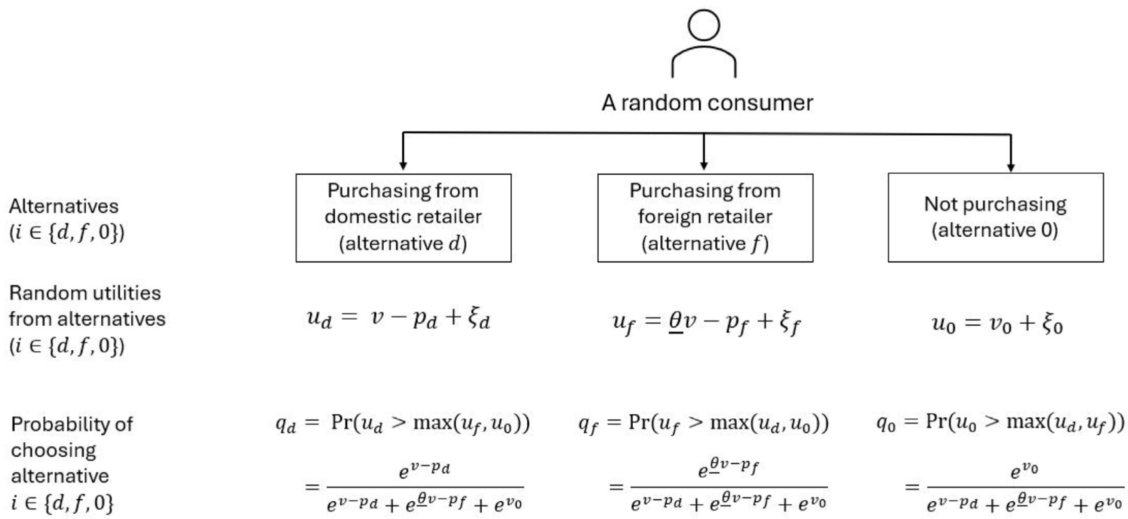


Fig. 1. Alternatives, utilities, and choice probabilities for a random consumer within an MNL framework.

Table 1
Main notation.

<u>Parameters</u>	
v	Consumers' mean valuation of the product when purchased at the domestic retailer
v_0	Consumers' mean valuation of the no-purchase option
$\underline{\theta}$	Consumer's reduced degree of trust with respect to purchasing at the foreign retailer
c_i	Unit delivery cost incurred per sale by retailer $i \in \{d, f\}$
c_o	Per unit cost of bulk shipping from foreign to domestic retailer in the post-collaboration setting
<u>Random variables</u>	
ξ_i	Random variable capturing the stochasticity in consumer valuation of alternative $i \in \{d, f, 0\}$
<u>Intermediate variables</u>	
u_i	Utility that a random consumer derives from alternative $i \in \{d, f, 0\}$
q_i	Portion of consumer who choose alternative $i \in \{d, f, 0\}$
Π_i	Profit of retailer $i \in \{d, f\}$
CS	Consumer surplus
<u>Decision variables</u>	
p_i	Price charged by retailer $i \in \{d, f\}$
w	Logistics service fee charged per unit by domestic to foreign retailer in the post-collaboration setting

i.e., $c_f > c_d$. In addition, the consumers might suffer from trust issues when they are buying from foreign retailers due to potential delivery problems, lowering the utility that they obtain when they purchase from foreign retailers even at the same price point of the domestic retailer, i.e., $\underline{\theta} \in [0, 1)$. The best response functions in Lemma 1 enable us to capture these two types of asymmetries that foreign retailers might suffer from when they are selling cross-border. While the former is an operational challenge that leads to lower profit margin $(p_i - c_i)$ for the foreign retailer at the same price point of the domestic retailer, the latter is a demand-side challenge that leads to lower market share (q_i) for the foreign retailer even when the same price is adopted by both retailers (see Eq. (2)).

In the following, we study a collaboration mechanism between the two retailers such that these challenges can be overcome for the foreign retailer by also making the domestic retailer better off.

3.2. Post-collaboration (co-opetition) setting

In this section, we examine the setting where the foreign and the domestic retailers collaborate for logistics besides competing for the market share. Specifically, inspired by the collaboration between JD and Shopify, we study the collaboration scheme where the domestic retailer provides last-mile logistics services to deliver the orders placed at the foreign retailer in exchange for a fee.

This collaboration can have several advantages both for the foreign retailer and the domestic retailer. Firstly, the (European Commission, 2016) emphasizes that in cross-border e-commerce, retailers can save on logistics costs via bulk shipping rather than individual parcel shipping due to how the customs procedures are designed. Hence, by shipping consumer orders in bulk to the domestic retailer for last-mile delivery to the consumers, the foreign retailer could cut down on the logistics costs by circumventing the costly customs procedures for single-piece cross-border shipments. Secondly, market research agency (GfK, 2015) highlights that lack of trust is a major issue when consumers buy from foreign retailers due to potential delivery concerns. Collaboration with a domestic retailer can induce trust in the foreign retailer, as it can give consumers a sense of security as a result of their familiarity with the domestic retailer. Lastly, the domestic retailer can also benefit from this partnership by receiving a commission fee for the logistics services provided to the foreign retailer. As such, the domestic retailer can raise additional revenue through this service, which can translate to higher profits.

We start by formulating the domestic and foreign retailers' market shares (q_d and q_f, respectively) as well as the share of customers who choose the no-purchase option (q_0) in the post-collaboration setting by using an MNL formulation (similar to the pre-collaboration setting):

$$q_d = \frac{e^{v-p_d}}{1 + e^{v-p_d} + e^{\theta v - p_f}}, \quad q_f = \frac{e^{\theta v-p_f}}{1 + e^{v-p_d} + e^{\theta v - p_f}}, \quad \text{and} \quad q_0 = \frac{1}{1 + e^{v-p_d} + e^{\theta v - p_f}}, \tag{3}$$

where $\theta \geq \underline{\theta}$ represents consumers' (potentially) improved level of trust in the foreign retailer due to collaboration with a domestic partner. In this setting, the profit function of each retailer is formulated as follows:

$$\Pi_d = (p_d - c_d)q_d + (w - c_d)q_f, \quad \text{and} \quad \Pi_f = (p_f - w - c_o)q_f, \tag{4}$$

where c_o is the per unit cost incurred by the foreign retailer for sending her orders to the domestic retailer in bulk for subsequent last-mile delivery to the consumers. In line with the (European Commission, 2016), we assume that $c_o < c_f$, i.e., the foreign retailer's cross-border logistics cost per parcel is lower via bulk shipping to the domestic retailer rather than single item shipping to each individual consumer. Then, however, the foreign retailer also pays a logistics service fee w to the domestic retailer for providing last-mile delivery to the consumer per parcel. That is, the profit of the foreign retailer equals her market share (q_f) multiplied by the profit margin per sale, which is the sales price less the total logistics cost ($p_f - w - c_o$).

The domestic retailer's total profit, on the other hand, depends not only on his own market share (q_d) and profit margin ($p_d - c_d$), but also on the competitor's market share (q_f) and the additional margin that he obtains on each sale made by the foreign retailer ($w - c_d$), i.e., the domestic retailer obtains a logistics service fee w from the foreign retailer for providing last-mile delivery services and incurs cost of c_d for this service.

We study this co-opetition problem as a two-stage game where the domestic retailer sets the optimal logistics service fee by maximizing his own profit in the first stage, and then, given this fee, the retailers engage in a simultaneous price game in the second stage.

3.2.1. Second stage problem: price game

Using backward induction, we first solve the second stage problem where we determine the equilibrium prices for a given w (see Lemma 2 in Appendix A for the precise formulations of the best response functions). We start with the following result. In the remainder of the paper, we denote the retailers' best response functions for a given w by $p_i^*(p_j; w), i \in \{d, f\}, i \neq j$.

Proposition 2. *The retailers' best response functions in the post-collaboration second stage price game behave as follows:*

1. *The foreign retailer's best response function increases in the domestic retailer price.*
2. *There exists a threshold $w^T \geq c_d$ such that the domestic retailer's best response function increases in the foreign retailer's price for $w \leq w^T$ and decreases otherwise.*

Proposition 2 states that the foreign retailer's best response function is increasing in the domestic retailer's price (i.e., ${}^{dp_f^*(p_d;w)}/_{dp_d} \geq 0, \forall w \geq c_d$). This is intuitive since an increase in the competitor's price would raise the foreign retailer's demand. As a result, he can afford to charge consumers a higher price. Surprisingly though, the behavior of the domestic retailer's best response function is not straightforward: it is increasing in the foreign retailer's price if the logistics service fee is kept sufficiently low, but it is decreasing otherwise.

The intuition for the above result is as follows. In general, all else kept the same, an increase in the foreign retailer's price would lead to an increase in the domestic retailer's demand (q_d) while it leads to a decrease in her own demand (q_f). Note in Eq. (4) that the domestic retailer's profit function depends on both of these demand amounts with a profit margin of $p_d - c_d$ on the former (due to the domestic retailer's own product sales) and $w - c_d$ on the latter (due to the logistics service sharing). Hence, if the latter margin is small, i.e., w is small, then a drop in q_f and an increase in q_d would lead to a mild drop in the profit gained due to logistics service sharing with a high increase in the profit gained due to the domestic retailer's own product sales. As this would lead to higher profits overall, the domestic retailer can afford to charge customers a higher price as the competitor's price increases (${}^{dp_d^*(p_f;w)}/_{dp_f} \geq 0$). However, if w is large, then a drop in q_f and an increase in q_d would lead to a big loss in the profit gained due to logistics service sharing with a mild increase in the profit gained due to the domestic retailer's own product sales. As this would lead to lower profits overall, the domestic retailer would need to lower its own price in response to a higher competitor price (${}^{dp_d^*(p_f;w)}/_{dp_f} < 0$). Relying on Lemma 2, we derive the following results on the equilibrium outcomes (denoted by superscript °).

Proposition 3. *There exists a unique Nash equilibrium for the post-collaboration second stage price game, and the following equations hold at equilibrium: $\Pi_f^\circ(w) = p_f^\circ(w) - w - c_o - 1$ and $\Pi_d^\circ(w) = p_d^\circ(w) - c_d - 1$.*

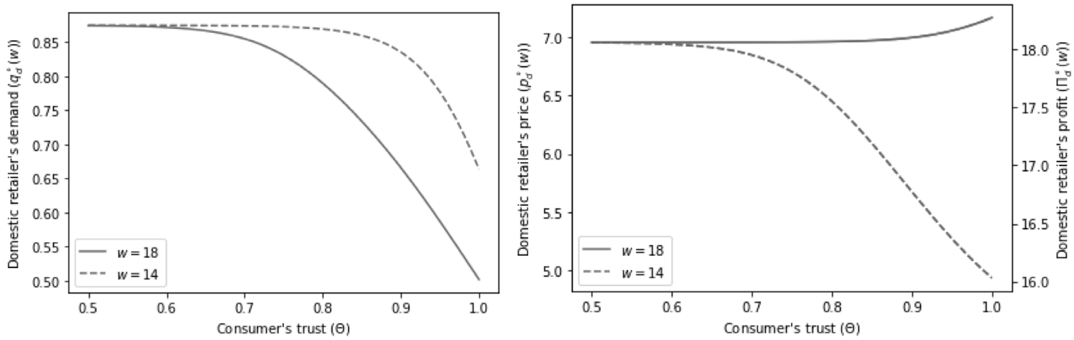
Proposition 3 enables us to study the characteristics of the equilibrium outcomes (i.e., prices, market share, profits, and consumer surplus) based on the changes in different problem parameters. Our first result pertains to the impact of consumers' trust in the foreign retailer (θ) on the equilibrium outcomes, as we formalize below.

Proposition 4. *All else kept the same, the foreign retailer's second stage equilibrium price, market share, and profit are increasing in consumers' trust.*

Proposition 4 indicates that if the consumers trust the foreign retailer more (i.e., higher θ), then the retailer can afford to charge consumers higher while also obtaining higher market share and profit, for a given logistics service fee. This is intuitive as a higher level of trust in the foreign retailer naturally raises the marginal utility obtained from purchasing at the foreign retailer. This translates to higher demand for the foreign retailer, which enables him to charge a higher price for the product. Consequently, a higher price and market share together lead to a higher profit. Empirical evidence supporting this result can be found in Deloitte (2023), which shows that highly trusted companies show significantly higher profitability, with some achieving up to a 400% increase in market value. Additionally, 88% of customers who have high trust in a retailer are likely to return to the retailer for future purchases, demonstrating the strong positive link between consumer trust and a retailer's market share, pricing power, and overall profitability.

The level of trust in the foreign retailer (θ) affects the domestic retailer's equilibrium price and profit in a non-straightforward way due to the logistics service sharing. Fig. 2(a) shows that as the consumers' trust in the foreign retailer increases, the domestic retailer's demand decreases as expected (due to more consumers shopping at the foreign retailer, see Proposition 4, as supported by empirical evidence). Interestingly though, Fig. 2(b) shows that the domestic retailer's price and profit may behave differently: we observe that they decrease in θ when w is sufficiently small but increase in θ otherwise. This can be explained by the structure of the domestic retailer's profit function. The domestic retailer generates revenue via two streams of demand: its own demand (q_d) and the demand of the foreign retailer (q_f), see Eq. (4). Higher trust in the foreign retailer lowers q_d (which is multiplied by the profit margin $p_d - c_d$) while it raises q_f (which is multiplied by the profit margin $w - c_d$). As a result, if w is small, then the gains due to an increase in the foreign retailer's demand q_f would be overcome by the profit loss due to the decrease in the domestic retailer's own demand q_d. As this would lead to a lower profit overall, the domestic retailer would need to lower its equilibrium price, leading to lower profits. However, if w is large, then the profit gains due to higher q_f would dominate the losses due to a reduction in the domestic retailer's own demand. As this would lead to higher profit overall, the domestic retailer can afford to raise its equilibrium price and obtain higher profits.

Our analyses highlight the importance of consumers' trust on the equilibrium outcomes of the two retailers; however, they also reveal that the impact of consumers' trust depends on the value of the logistics service fee w. Thus next, we focus on the behavior of the equilibrium outcomes in the first-stage variable w, i.e., logistics service fee.



(a) Domestic retailer's demand **(b)** Domestic retailer's price and profit

Fig. 2. The effect of θ on the domestic retailer's equilibrium outcomes ($c_o = 3$, $c_d = 10$, $v = 20$).

Proposition 5. *The post-collaboration second stage price game equilibrium outcomes behave as follows with respect to the first-stage variable w:*

1. *The foreign retailer's equilibrium price increases in w while her equilibrium demand and profit decrease in w.*
2. *There exists a threshold $\hat{w}$ such that the domestic retailer's equilibrium price and profit increase in w for $w \leq \hat{w}$ and decrease otherwise. Further, as the value of w goes to infinity, the domestic retailer's equilibrium price approaches a fixed value larger than $1 + c_d$.*
3. *The consumer surplus decreases in w for $w \leq \hat{w}$.*

Proposition 5.1 indicates that the foreign retailer's equilibrium price is increasing in the logistics service fee w (i.e., ${dp_f^\circ(w)}/{dw} \geq 0$). This is intuitive as a higher service fee implies a higher cost for the foreign retailer, which forces her to raise the price. This, in turn, leads to a reduction in sales and profit (i.e., ${dq_f^\circ(w)}/{dw}; {d\Pi_f^\circ(w)}/{dw} \leq 0$). Proposition 5.2 shows the effect of these changes on the domestic retailer. A higher price at the foreign retailer due to a higher logistics service fee w is beneficial for the domestic retailer in terms of market share, as it captures some of the demand lost by the foreign retailer. This enables the retailer to charge a higher price while earning more profits initially (i.e., ${dp_d^\circ(w)}/{dw}; {d\Pi_d^\circ(w)}/{dw} \geq 0$ when $w \leq \hat{w}$). Surprisingly though, this behavior reverses as the service fee w keeps increasing. That is, the equilibrium price and profit start declining even though the domestic retailer earns more per unit delivered for the foreign retailer (i.e., ${dp_d^\circ(w)}/{dw}; {d\Pi_d^\circ(w)}/{dw} < 0$ when $w > \hat{w}$). The reasoning is that the decline in the foreign retailer's sales due to the high service fee starts damaging the domestic retailer's revenue through his collaboration with the foreign retailer (see Eq. (4)). To compensate for the loss, the domestic retailer lowers his price, and though this does not help with the declining profit, it reduces the pace of reduction. Proposition 5.3 highlights the implications of the retailers' equilibrium prices for the consumers. Specifically, it is shown that the consumer surplus at equilibrium is decreasing in w for $w \leq \hat{w}$. This is intuitive as higher prices lower the utility that the consumers obtain from purchasing an item, which lowers consumer surplus. These findings are consistent with the empirical evidence showing that rising logistics costs impact all stakeholders in the e-commerce ecosystem, including service providers, sellers, and consumers (ParcelPlanet, 2022). During the COVID-19 pandemic between 2020 and 2022, logistics providers and platforms offering fulfillment services (such as Amazon) raised logistics fees by as much as 30% (SupplyChainDive, 2023). This surge in service fees created significant challenges for small and medium-sized online sellers. In response to these increases, many sellers initially raised prices for consumers, leading to a reduction in sales volumes and customer satisfaction. This mirrors the dynamics described in Proposition 5, where higher logistics fees force sellers to increase prices, negatively affecting both sales and profit.

We next study the first stage problem, and derive the optimal logistics fee (w).

3.2.2. First stage problem: logistics fee optimization

In the first stage of the game, the domestic retailer sets the logistics service fee w to maximize his own profit (i.e., the domestic retailer adopts a non-cooperative mechanism to set the logistics service fee). That is, the domestic retailer solves the following problem to determine the logistics service fee that he charges the foreign retailer:

$$\max_{w} \quad \Pi_d^\circ(w). \tag{5}$$

Proposition 5.2 highlights that the domestic retailer would set the logistics service at $\hat{w}$ to maximize his own profit. We formally express this result in the following corollary.

Corollary 1. *$\hat{w}$ is the unique maximizer of $\Pi_d^\circ(w)$.*

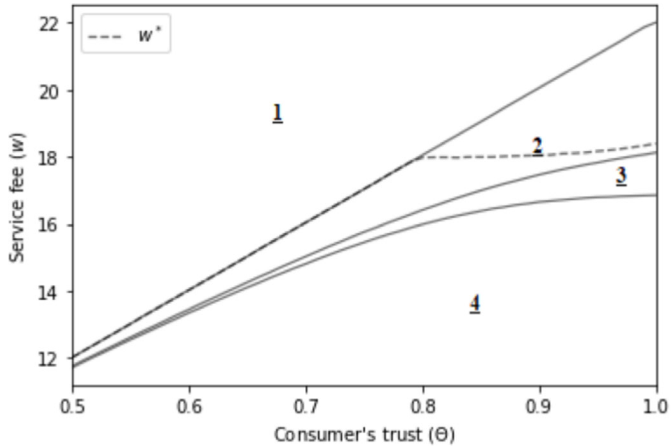
Corollary 1 proves that there is a unique logistics service fee, $\hat{w}$, that maximizes the domestic retailer's profit in the post-collaboration (co-opetition) setting. However, this unique maximizer does not guarantee a higher profit than that obtained in the pre-collaboration (competition) setting for either of the retailers. In the next section, we study under which settings of w a win-win outcome is achievable for the retailers and also the consumers via collaboration.

4. When is collaboration beneficial?

In the following, we denote, for a given w, retailer i's post-collaboration price game equilibrium profit as $\Pi_i^{\circ a}(w)$. Similarly, the pre-collaboration game equilibrium profit is denoted as $\Pi_i^{\circ b}$ (Note the absence of argument w, as this setting entails a simple price competition game, rather than a two-stage game with logistics fee w optimization, see Section 3.1). Then, the difference between post- and pre-collaboration price game equilibrium profits for a given w is denoted as $\Delta\Pi_i^\circ(w) \equiv \Pi_i^{\circ a}(w) - \Pi_i^{\circ b}, i \in \{d, f\}$. In Proposition 6, we show that this difference is positive for both retailers under realistic settings.

Proposition 6. *When $\theta = \underline{\theta}$ and $c_d + c_o < c_f$, there exists a logistics service fee $c_d < \underline{w} \leq c_f - c_o$ such that for $w \in [\underline{w}, c_f - c_o]$, the collaboration benefits both retailers.*

Proposition 6 shows that even if collaboration does not lead to any changes in consumers' trust in the foreign retailer (i.e., $\theta = \underline{\theta}$), a win-win outcome can be achieved via collaboration. That is, as long as the total cost incurred for the delivery of foreign retailer's orders in the post-collaboration setting (which includes the cost of bulk shipping to the domestic retailer plus the cost of last-mile delivery by the domestic retailer, i.e., $c_o + c_d$) is less than the cross-border delivery cost that the foreign retailer incurs without any collaboration (i.e., c_f), both retailers can be better off via collaboration for a range of w. Note that this condition is realistic, as (European Commission, 2016) emphasizes that



1	$\Delta\Pi_d^\circ > 0$	$\Delta\Pi_f^\circ < 0$	$\Delta CS^\circ < 0$
2	$\Delta\Pi_d^\circ > 0$	$\Delta\Pi_f^\circ > 0$	$\Delta CS^\circ < 0$
3	$\Delta\Pi_d^\circ > 0$	$\Delta\Pi_f^\circ > 0$	$\Delta CS^\circ > 0$
4	$\Delta\Pi_d^\circ < 0$	$\Delta\Pi_f^\circ > 0$	$\Delta CS^\circ > 0$

Fig. 3. Comparison of retailers' pre- and post-collaboration profits and consumer surplus at different levels of w and θ ($c_f = 15$, $c_o = 3$, $c_d = 10$, $\underline{\theta} = 0.5$, $v = 20$).

retailers can save up to 18% in the cross-border delivery cost per parcel when shipped in bulk rather than as a single piece.

As Proposition 6 states, in this post-collaboration setting, a logistics service fee of $w \le c_f - c_o$ is beneficial for the foreign retailer because it leads to a reduction in the delivery cost to the end customer (which equals c_f in pre-collaboration vs. $w + c_o$ in post-collaboration). On the other hand, if the service fee is larger than c_d, collaboration creates an additional benefit for the domestic retailer (compare again Eqs. (2) and (4)), which makes him better off by collaboration.

In Fig. 3, we demonstrate how the post-collaboration profit of each retailer, as well as consumer welfare, vary with the logistics service fee and the improved trust level in the foreign retailer for a realistic setting. Region 4 indicates that when the logistics service fee w is low, it is beneficial for the foreign retailer but not for the domestic retailer, as expected. Further, the foreign retailer can afford to pay slightly higher w and still benefit from the collaboration if the consumers' trust in the foreign retailer is more elevated with collaboration (higher θ). In contrast, Region 1 indicates that if the logistics service fee is too high, then the foreign retailer would not benefit from the collaboration.

Regions 2 and 3 constitute the only settings where both retailers benefit from and, hence, participate in collaboration in this example. These regions indicate the setting where the logistics service fee w is set at a moderate level. As expected, the range of w that enables this win-win outcome for the retailers gets wider at more elevated trust levels in the foreign retailer (i.e., the range is the smallest when $\theta = \underline{\theta}$, whose existence is proven in Proposition 6, and grows larger as θ rises). In Region 3, consumers also benefit from collaboration, and a win-win-win outcome occurs for both retailers and consumers. This is in line with the findings of Forbes (2023), which states that doing business with highly trusted firms helps companies to grow and improve profits. In Appendix B, we present the results of our detailed numerical study, which shows the robustness of our findings with respect to the existence of win-win settings for the retailers (see Table B.1).

Note, however, that w is a decision variable that is set by the domestic retailer to maximize his own profit. Corollary 1 proves that he needs to offer the foreign retailer a logistics service of $\hat{w}$ to maximize his profit. Importantly, $\hat{w}$ does not guarantee higher profits for either of the retailers after collaboration. That is, $\hat{w}$ need not lie in Regions 2 and 3.

The dashed line in Fig. 3 indicates, for each θ, the logistics service fee w that maximizes the domestic retailer's profit with the constraint that both retailers are better off with (or indifferent about) collaboration, i.e.,

$$w^* = \operatorname*{argmax}_{w} \Pi_d^{\circ a}(w) \quad s.t. \quad \Delta\Pi_i^\circ(w) \ge 0, \quad \forall i \in \{d, f\}. \tag{6}$$

Hence, the dashed line indicates the logistics service fee w^* that the domestic retailer needs to implement to achieve the highest potential growth in his own profit with collaboration while not making the foreign retailer worse off (i.e., equal or even higher profits in post- vs. pre-collaboration settings for both retailers such that they both participate in a collaboration).

Fig. 3 shows that with high consumer trust in the foreign retailer ($\theta > 0.8$), the logistics service fee that maximizes the domestic retailer's profit also leads to higher profits for both retailers in the example studied, i.e., $w^* = \hat{w}$, which lies in Region 2 where $\Delta\Pi_i^\circ > 0, i \in \{d, f\}$. Hence, in this example, the domestic retailer can implement $w^* = \hat{w}$, which would maximize his own post-collaboration profit and also improve both retailers' profits. If the consumer trust in the foreign retailer is lower, however ($\theta \le 0.8$), implementing $\hat{w}$ (which would lie in Region 1) would make the foreign retailer worse off with collaboration. Therefore, the domestic retailer has to implement a lower w that would still improve his profit after collaboration while not making the foreign retailer worse off. This is achieved by implementing a logistics service fee $w^* < \hat{w}$ that is at the boundary between Regions 1 and 2. In this setting, the domestic retailer is still better off with collaboration, and the foreign retailer is indifferent to collaboration (i.e., $\Delta\Pi_d^\circ > 0$ and $\Delta\Pi_f^\circ = 0$). With such a set-up, collaboration would bring benefit to the domestic retailer, while not hurting the foreign retailer.

5. Alternative contracting mechanism

In this section, we analyze a cooperative scheme as an alternative contracting mechanism to set the logistics service fee w. We show that this cooperative scheme can lead to a better post-collaboration outcome for both retailers.

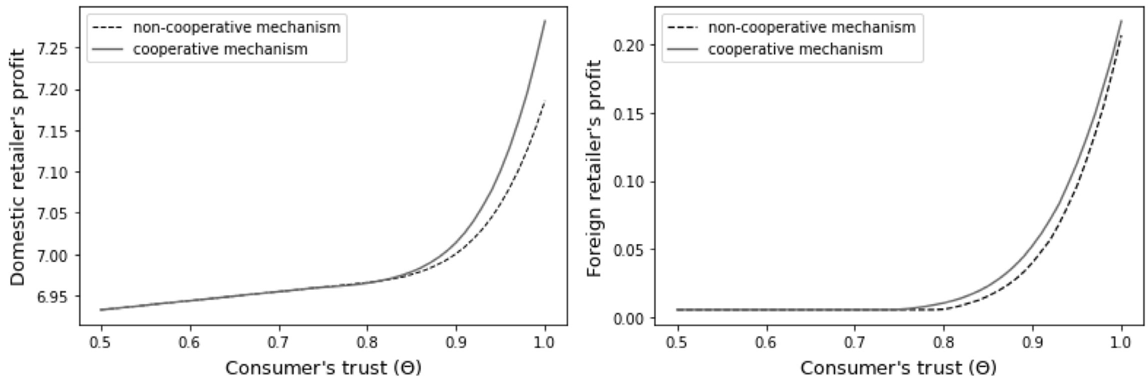
Under the cooperative scheme, the domestic retailer determines the optimal logistics service fee w by maximizing the total profit of both retailers with the constraint that they are better off after collaboration. Then, however, the foreign retailer shares a portion of his profit surplus with the domestic retailer. As a result, the fee structure is a two-part tariff which includes: a per-unit payment w and a fixed payment. Consequently, the first stage problem of optimizing the logistics fee within this cooperative mechanism can be formulated as follows:

$$\max_{w} \quad \Pi_d^{\circ a}(w) + \Pi_f^{\circ a}(w) \quad s.t. \quad \Delta\Pi_i^\circ(w) \ge 0, \quad \forall i \in \{d, f\}. \tag{7}$$

We denote the solution to the above problem by w^{**}. Then, the profit surplus gained by the foreign retailer via collaborating with this contract compared to the pre-collaboration setting is:

$$\Delta\Pi_f^\circ(w^{**}) \equiv \Pi_f^{\circ a}(w^{**}) - \Pi_f^{\circ b}. \tag{8}$$

Lastly, part of this profit surplus is shared with the domestic retailer. We denote this amount by $F(w^{**}) \equiv \lambda\Delta\Pi_f^\circ(w^{**})$, where λ ranges



(a) Domestic retailer's profit at equilibrium prices **(b)** Foreign retailer's profit at equilibrium prices

Fig. 4. Performance of two contracting mechanisms for each retailer across θ ($c_f = 15$, $c_o = 3$, $c_d = 10$, $\underline{\theta} = 0.5$, $v = 20$).

between 0 and 1. Hence, the final profit that each retailer obtains is the following:

$$\Pi_d^* = \Pi_d^{oa}(w^{**}) + F(w^{**}) \quad \text{and} \quad \Pi_f^* = \Pi_f^{oa}(w^{**}) - F(w^{**}). \tag{9}$$

Our numerical experiments show that there exists a feasible range of λ where the cooperative mechanism provides greater benefits to both retailers than the non-cooperative one, especially when consumers' trust in foreign retailers improves through retailer collaboration ($\theta \gg \underline{\theta}$). For instance, Fig. 4 compares the two contracting mechanisms' performances when $\lambda = 0.5$ (i.e., the foreign retailer gives half of her surplus profit to the rival). The figure shows that the cooperative scheme outperforms the non-cooperative one, particularly when θ is relatively high. The reasoning is that when the domestic retailer maximizes the total profit rather than his own profit when setting the logistics service fee, he implements a lower w, as shown in Proposition 7 below. Due to this lower fee, the foreign retailer's profit substantially increases. If this additional surplus is shared reasonably between the two retailers, both benefit more from the cooperative mechanism.

Proposition 7. *w^{**} is a unique solution and $w^{**} \leq w^*$.*

Lastly, we show that the cooperative contracting mechanism always benefits the customers more than the non-cooperative mechanism.

Corollary 2. *The consumer surplus at w^{**} is always greater than the consumer surplus at w^*.*

Corollary 2 indicates that customers reap greater benefits from the retailers' collaboration via cooperative than non-cooperative contracting mechanism. This is due to the fact that a lower logistics service fee results in lower equilibrium prices, ultimately benefiting the consumers. Therefore, the cooperative contracting mechanism could enable all players to benefit from collaboration. This finding aligns with the findings in existing literature in other areas of supply chain collaboration, where cooperative contracts consistently outperform non-cooperative alternatives if the terms are chosen correctly (Mortimer, 2002; Zhang and Frazier, 2011; Hernandez-Martinez et al., 2021). It is particularly relevant in the e-commerce industry, where empirical evidence shows that customers are highly sensitive to online prices (Minderest, 2021). Therefore, any initiative that reduces costs and in turn, prices, such as a cooperative contracting mechanism, holds even greater value for consumers.

The next section provides a summary of our findings, discusses relevant managerial insights, and outlines the limitations of our research.

6. Conclusion

While the demand for cross-border e-commerce has grown rapidly, both retailers and consumers have been facing challenges in cross-border e-commerce. Retailers have been struggling with high logistics costs to fulfill cross-border demand, while they also suffer from consumers' lack of trust in foreign retailers. In local settings, different collaboration schemes have been implemented between competing retailers to address similar logistics issues. Inspired by these practices, in this paper we study a horizontal collaboration scheme to mitigate the logistics challenges in a cross-border setting. This entails a coopetition framework where demand is modeled via an MNL choice model incorporating trust- and price-sensitive consumers. We compare the market outcomes of the two retailers in "pre-collaboration" and "post-collaboration" settings. We find that there exist win-win outcomes where both retailers benefit from collaboration under realistic settings. We also show that a cooperative mechanism can lead to higher profits for the two retailers and their consumers compared to the non-cooperative mechanism for setting the logistics service fee if the contract terms are decided carefully.

Our work leads to several managerial insights. First, logistics service sharing can benefit both retailers when the service fee is at a moderate level. In the partnership example of JD and Shopify, if the logistics service fee that is charged by JD to a Shopify seller is too high, it may deter the seller from participating in the collaboration. Conversely, if it is too low, it might not cover JD's operational costs or adequately reflect the value of the service provided, potentially diminishing JD's profitability, leading to a failed collaboration. Second, this collaboration not only holds advantages for retailers but also extends significant benefits to consumers. For example, via the aforementioned partnership, the US-based sellers can access a wider range of customers, while customers also access a wider range of sellers, improving competitiveness. Third, the collaboration may increase the consumers' trust in foreign retailers. This could be beneficial for both retailers, motivating joint investment in trust-increasing initiatives. For example, a joint JD-Shopify marketing campaign can increase customer trust by publicly highlighting the partnership and emphasizing the benefits and reduced risks associated with the delivery process. Finally, if the foreign retailer would not like to engage in logistics service sharing, the domestic retailer can provide certain preferential treatments (e.g., using a cooperative contracting mechanism) to encourage the foreign retailer to do so. This might benefit both partners.

We conclude this paper by pointing out some limitations of our model and potential directions for future research. First, we assume the growth of consumers' trust in foreign retailers through collaboration as an exogenous parameter. It could be interesting to examine where this factor is defined as a function of retailers' marketing strategies, e.g., advertising effort which has an impact on demand (see Pappas (2016) and Mutlu and Bish (2019)). We leave it to future research to explore potential new insights in this direction. Second, we have assumed only two retailers in the market. In practice, many foreign and domestic competing retailers can sell substitutable products in the same online market. We expect that choosing a partner from a group of competitors will impact their strategic choices. Incorporating the possibility of a coalition among multiple players into our model framework may generate new and interesting insights and deserves a separate study. Finally, our model assumes that the information regarding the parameters is complete. However, factors such as hidden market information, unobservable logistics service costs, and consumers' trust can influence the retailers' strategic choices. Asymmetric information issues are beyond the scope of this paper but deserve their own theoretical study in future research.

CRediT authorship contribution statement

Zohreh Khooban: Writing – review & editing, Writing – original draft, Visualization, Validation, Resources, Methodology, Formal analysis, Data curation, Conceptualization. **Nevin Mutlu:** Writing – review & editing, Supervision, Project administration, Methodology, Funding acquisition, Conceptualization. **Ton de Kok:** Writing – review & editing, Supervision, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A

Proof of Lemma 1. Π_i is continuous and differentiable unimodal in p_i. We derive the best response function $p_i^*(p_j)$ (for $i,j \in \{d,f\}$) using the first order condition (FOC) through solving $\frac{\partial \pi_i}{\partial p_i} = 0$, where we use Eq. (2). For simplicity, we present $p_i^*(p_j)$ for $i,j \in \{d,f\}$ by p_i^*. To calculate $\frac{\partial \Pi_i}{\partial p_i}$, we need first to obtain $\frac{\partial q_i}{\partial p_i}$, but to avoid involving the complexity of MNL demand functions as it is in Eq. (1), we use below the closed-form demand functions following a simple calculus.

$$\frac{\partial q_i}{\partial p_i} = -q_i(1-q_i), \quad \frac{\partial q_j}{\partial p_i} = q_i q_j,\ i \neq j, i,j \in \{d,f\} \tag{10}$$

Substituting $\frac{\partial q_i}{\partial p_i}$ and $\frac{\partial q_j}{\partial p_i}$ from Eq. (10) in $\frac{\partial \Pi_i}{\partial p_i}$, we use FOC to derive the best response functions:

$$\frac{\partial \Pi_i}{\partial p_i} = 0 \Rightarrow q_i + (p_i - c_i)(-q_i(1-q_i)) = 0 \Rightarrow \begin{cases} q_i = 0 \\ \text{or} \\ 1-(p_i-c_i)(1-q_i) = 0. \end{cases}$$

The solution to $q_i = 0$ above is $p_i^* = \infty$, which is not applicable; therefore, the only answer to $\frac{\partial \Pi_i}{\partial p_i} = 0$ is the one by the second equation above, which is:

$$p_i^* = c_i + \frac{1}{1-q_i}.$$

The left-hand side is strictly increasing in p_i, starting at zero for $p_i = 0$, and the right-hand side is strictly decreasing in p_i, starting at a positive value for $p_i = 0$. Thus the two lines on the left side and right side cross each other only once. This implies that Π_i is unimodal in p_i with a single maximum, and p_i^* is the unique best response function of retailer i. By changing the demand function back to the MNL form in Eq. (1), we can derive p_d^* and p_f^* as in Eqs. (11) below:

$$p_d^* = 1 + c_d + \frac{e^{v-p_d^*}}{1+e^{\theta v - p_f}},\ p_f^* = 1 + c_f + \frac{e^{\theta v - p_f^*}}{1+e^{v-p_d}}. \tag{11}$$

To have p_i^* as a function of p_j for $i,j \in \{d,f\}$, we need to deal with p_i^* in the right-hand-side in Eqs. (11) above. To that end, we use the following property of Lambert W function (see Corless et al., 1996, for more details):

$$\text{If } X = A + Be^{CX} \Rightarrow X = A - \frac{1}{C} W\left(-BCe^{AC}\right). \tag{12}$$

If for the domestic retailer, we set $X = p_d^*, A = 1 + c_d, B = \frac{e^{v}}{1+e^{\theta v - p_f}}$, and $C = -1$, and for the foreign retailer we set $X = p_f^*, A = 1 + c_f, B = \frac{e^{\theta v}}{1+e^{v-p_d}}$, and $C = -1$, we can re-wright the best response functions in Eqs. (11) as below:

$$p_d^* = 1 + c_d + W\left(\frac{e^{v-1-c_d}}{1+e^{\theta v - p_f}}\right),\ p_f^* = 1 + c_f + W\left(\frac{e^{\theta v - 1 - c_f}}{1+e^{v-p_d}}\right). \quad \square$$

Lemma 2. *The retailers' best response functions in the post-collaboration second stage price game are:*

$$p_d^*(p_f; w) = 1 + c_d + \frac{(w-c_d)e^{\theta v - p_f}}{1+e^{\theta v - p_f}} + W\left(\frac{e^{v-1-c_d-\frac{(w-c_d)e^{\theta v - p_f}}{1+e^{\theta v - p_f}}}}{1+e^{\theta v - p_f}}\right), \quad \textit{and}$$

$$p_f^*(p_d; w) = 1 + w + c_o + W\left(\frac{e^{\theta v - 1 - w - c_o}}{1+e^{v-p_d}}\right).$$

Proof of Lemma 2. We follow the same steps as in the proof of Lemma 1, while using the post-collaboration profit functions given by Eq. (4). As Π_i is differentiable in p_i, for $i \in \{d,f\}$, FOC is sufficient for optimality. We derive p_i^* as the solution of $\frac{\partial \Pi_i}{\partial p_i} = 0$ where we use Eq. (10) for $\frac{\partial q_i}{\partial p_i}$. Thus, for the domestic retailer, we have:

$$\frac{\partial \Pi_d}{\partial p_d} = 0 \Rightarrow q_d + (p_d - c_d)(-q_d(1-q_d)) + (w-c_d)q_f q_d = 0 \Rightarrow p_d^* = c_d + \frac{(w-c_d)q_f + 1}{1-q_d}.$$

For the foreign retailer, we have:

$$\frac{\partial \Pi_f}{\partial p_f} = 0 \Rightarrow q_f + (p_f - w - c_o)(-q_f(1-q_f)) = 0 \Rightarrow p_f^* = w + c_o + \frac{1}{1-q_f}.$$

By changing the demand function back to the MNL form in Eq. (1), we can derive p_d^* and p_f^* as in Eqs. (13) below:

$$p_d^* = 1 + c_d + \frac{e^{v-p_d^*} + (w-c_d)e^{\theta v - p_f}}{1+e^{\theta v - p_f}},\ p_f^* = 1 + w + c_o + \frac{e^{\theta v - p_f^*}}{1+e^{v-p_d}}. \tag{13}$$

For both cases, the left-hand side is strictly increasing in p_i, starting at zero for $p_i = 0$, and the right-hand side is strictly decreasing in p_i, starting at a positive value for $p_i = 0$. Thus the two lines on the left side and right side cross each other only once. Thus, Π_i is unimodal in p_i and p_i^* is the unique best response function of retailer i.

To derive p_i^* as the function of p_j (for $i,j \in \{d,f\}$), we follow the same steps as we did in Lemma 1 for the pre-collaboration setting. We apply the properties of Lambert W function as in (12), while in the case of the domestic retailer, we set $X = p_d^*, A = 1 + c_d + \frac{(w-c_d)e^{\theta v - p_f}}{1+e^{\theta v - p_f}}, B = \frac{e^{v}}{1+e^{\theta v - p_f}}$, and $C = -1$ and in the case of the foreign retailer, we set $X = p_f^*, A = 1 + w + c_o, B = \frac{e^{\theta v}}{1+e^{v-p_d}}$, and $C = -1$. Thus we have:

$$p_d^* = 1 + c_d + \frac{(w-c_d)e^{\theta v - p_f}}{1+e^{\theta v - p_f}} + W\left(\frac{e^{v-1-c_d-\frac{(w-c_d)e^{\theta v - p_f}}{1+e^{\theta v - p_f}}}}{1+e^{\theta v - p_f}}\right),$$

$$p_f^* = 1 + w + c_o + W\left(\frac{e^{\theta v - 1 - w - c_o}}{1+e^{v-p_d}}\right). \quad \square$$

Proof of Proposition 2. Part1. To show that $\frac{\partial p_f^*}{\partial p_d} \geq 0$, we use the intermediate form of p_f^* as presented in (13), thus:

$$\frac{\partial p_f^*}{\partial p_d} = \frac{\partial(1 + w + c_o + \frac{e^{\theta v - p_f^*}}{1+e^{v-p_d}})}{\partial p_d} = \frac{\partial(\frac{e^{\theta v - p_f^*}}{1+e^{v-p_d}})}{\partial p_d}.$$

Using implicit differentiation, we have

$$\frac{\partial p_f^*}{\partial p_d} = \frac{(\frac{\partial e^{\theta v - p_f^*}}{\partial p_f^*}\frac{\partial p_f^*}{\partial p_d})(1+e^{v-p_d}) - \frac{\partial(1+e^{v-p_d})}{\partial p_d}e^{\theta v - p_f^*}}{(1+e^{v-p_d})^2}.$$

After some algebra, this expression can be rewritten as

$$\frac{\partial p_f^*}{\partial p_d} = \frac{e^{v-p_d}e^{\theta v - p_f^*}}{(1+e^{v-p_d})(1+e^{v-p_d}+e^{\theta v - p_f^*})}. \tag{14}$$

We see above in Eq. (14) that all the terms in the numerator and denominator are non-negative which means that $\frac{\partial p_f^*}{\partial p_d} \geq 0$.

Part2. As for $\frac{\partial p_d^*}{\partial p_f}$, we have:

$$\frac{\partial p_d^*}{\partial p_f} = \frac{\partial\left(1 + c_d + \frac{e^{v-p_d^*}+(w-c_d)e^{\theta v - p_f}}{1+e^{\theta v - p_f}}\right)}{\partial p_f} = \frac{\partial\left(\frac{e^{v-p_d^*}+(w-c_d)e^{\theta v - p_f}}{1+e^{\theta v - p_f}}\right)}{\partial p_f}.$$

Using implicit differentiation, we have

$$\frac{\partial p_d^*}{\partial p_f} = \frac{\left(\frac{\partial(e^{v-p_d^*})}{\partial p_d^*}\frac{\partial p_d^*}{\partial p_f} + (w-c_d)\frac{\partial(e^{\theta v - p_f})}{\partial p_f}\right)(1+e^{\theta v - p_f})}{(1+e^{\theta v - p_f})^2} - \frac{\frac{\partial(1+e^{\theta v - p_f})}{\partial p_f}\left(e^{v-p_d^*}+(w-c_d)e^{\theta v - p_f}\right)}{(1+e^{\theta v - p_f})^2},$$

which can be rewritten as

$$\frac{\partial p_d^*}{\partial p_f} = \frac{e^{\theta v - p_f}\left(e^{v-p_d^*} - w + c_d\right)}{(1+e^{\theta v - p_f})(1+e^{v-p_d^*}+e^{\theta v - p_f})}. \tag{15}$$

As shown in Eq. (15), the sign of $\frac{\partial p_d^*}{\partial p_f}$ depends on the sign of $\left(e^{v-p_d^*} - w + c_d\right)$. Following a simple calculus by deriving $\frac{\partial p_d^*}{\partial w}$ in Eq. (13), it is easy to show that $(e^{v-p_d^*} - w + c_d)$ is a convex function of w; as such, when w is small, $\frac{\partial p_d^*}{\partial p_f} \geq 0$, while it becomes negative for enough large w. Therefore, there is a unique solution to $e^{v-p_d^*} - w + c_d = 0$, denoted as w^T, and $\frac{\partial p_d^*}{\partial p_f}$ is positive for $w \leq w^T$, and negative otherwise. □

Proof of Proposition 3. Here we first show the existence of the Nash equilibrium and then prove its uniqueness. Vives (1999) states that "*In any game, if the strategy sets are nonempty convex and compact subsets of Euclidean space, and the payoff to one player is continuous in the actions of all other players and quasi-concave in its own price, then there is at least one Nash equilibrium*". In our setting, the prices (strategy sets) are continuous variables, convex and compact subsets with predefined boundaries (we assume that $0 \leq p_i \leq p_{\max}$), and the profit function of each retailer is a continuous and twice differentiable function in both prices. Therefore, we only need to check for the quasi-concavity of each retailer's profit in their own price to prove the existence of Nash equilibrium. To that end, following (Osborne, 2016), we use Lemma 3 below to show the quasi-concavity of the profit functions.

Lemma 3. *A function $f(x)$; $x \in \{I\}$ is quasi-concave if and only if one of the following conditions holds:*

- *f is non-decreasing*
- *f is non-increasing*
- *There exist a number x^* such that f is nondecreasing on $\{x \in I : x \leq x^*\}$ and non-increasing on $\{x \in I : x \geq x^*\}$.*

Proof of Lemma 3. Lemma 2 shows that the profit functions satisfy the last condition in Lemma 3. Therefore both profit functions are quasi-concave in their prices and we can conclude that the price game has at least one Nash equilibrium. □

Now, in the following step, we need to prove the uniqueness of equilibrium solutions. By proving the quasi-concavity of profit functions, we show that there is at least one intersection for the two best response functions, while we can prove the uniqueness of Nash equilibrium by showing that the best response functions p_d^* and p_f^* only meet each other once. Below, we show that the slope of each best response function to the competitor's price is always less than 1. This indicates that the two response functions diverge after the first intersection, so there is no possibility to meet again after the first crossing. Mathematically, we can fulfill this condition by showing that $\frac{\partial p_f^*}{\partial p_d} \leq 1$ and $\frac{\partial p_d^*}{\partial p_f} \leq 1$ always hold.

From (14), we have the following equation, with the numerator clearly smaller than the denominator, thus:

$$\frac{\partial p_f^*}{\partial p_d} = \frac{e^{v-p_d}e^{\theta v - p_f^*}}{(1+e^{v-p_d})(1+e^{v-p_d}+e^{\theta v - p_f^*})} < 1.$$

From (15), we have the following equation:

$$\frac{\partial p_d^*}{\partial p_f} = \frac{e^{\theta v - p_f}\left(e^{v-p_d^*} - w + c_d\right)}{(1+e^{\theta v - p_f})(1+e^{v-p_d^*}+e^{\theta v - p_f})}.$$

Considering the assumption of $w \geq c_d$, one can simply show that $\frac{\partial p_d^*}{\partial p_f} < 1$. Showing that both $\frac{\partial p_f^*}{\partial p_d} < 1$ and $\frac{\partial p_d^*}{\partial p_f} < 1$ hold, we conclude that the price game has a unique Nash equilibrium.

For the second part of the proposition, using the definition of the foreign retailer's profit function in Eq. (4), we have:

$$\Pi_f^\circ = (p_f^\circ - w - c_o)q_f^\circ.$$

We know that at equilibrium, $\frac{\partial \Pi_f^\circ}{\partial p_f^\circ} = 0$ holds. Using Eqs. (4) and (10) we find the following implications,

$$\frac{\partial \Pi_f^\circ}{\partial p_f^\circ} = q_f^\circ + (p_f^\circ - w - c_o)\frac{\partial q_f^\circ}{\partial p_f^\circ} = 0 \Rightarrow q_f^\circ\left(1 - (p_f^\circ - w - c_o)(1-q_f^\circ)\right) = 0 \Rightarrow$$

$$(p_f^\circ - w - c_o)(1-q_f^\circ) = 1 \Rightarrow p_f^\circ - w - c_o - \Pi_f^\circ = 1. \tag{16}$$

We follow the same steps as above for the domestic retailer. First, by using the definition of the domestic retailer's profit function, we have:

$$\Pi_d^\circ = (p_d^\circ - c_d)q_d^\circ + (w-c_d)q_f^\circ \Rightarrow \frac{\partial \Pi_d^\circ}{\partial p_d^\circ} = q_d^\circ + (p_d^\circ - c_d)\frac{\partial q_d^\circ}{\partial p_d^\circ} + (w-c_d)\frac{\partial q_f^\circ}{\partial p_d^\circ}.$$

We know that in equilibrium situation $\frac{\partial \Pi_d^\circ}{\partial p_d^\circ} = 0$. Using again Eqs. (4) and (10), we obtain

$$\frac{\partial \Pi_d^\circ}{\partial p_d^\circ} = 0 \Rightarrow q_d^\circ\left(1 - (p_d^\circ - c_d)(1-q_d^\circ) + (w-c_d)q_f^\circ\right) = 0 \Rightarrow$$

$$p_d^\circ - c_d - \Pi_d^\circ = 1 \quad \square \tag{17}$$

Proof of Proposition 4. We first derive $\frac{dp_d^\circ}{d\theta}$ and $\frac{dp_f^\circ}{d\theta}$ by taking derivative of Eqs. (13) with respect to θ, and then substitute the former in the latter. After some algebra, this yields.

$$\frac{dp_f^\circ}{d\theta} = \frac{ve^{\theta v - p_f^\circ}(1+e^{v-p_d^\circ})(1+e^{\theta v - p_f^\circ})(1+e^{v-p_d^\circ}+e^{\theta v - p_f^\circ}) + (w-c_d)ve^{\theta v - p_f^\circ} - ve^{\theta v - p_f^\circ}e^{v-p_d^\circ}}{(1+e^{v-p_d^\circ})(1+e^{\theta v - p_f^\circ})(1+e^{v-p_d^\circ}+e^{\theta v - p_f^\circ})^2 + (w-c_d)e^{\theta v - p_f^\circ}v - e^{\theta v - p_f^\circ}e^{v-p_d^\circ}} \geq 0 \tag{18}$$

We use Eq. (16) and Inequality (18) to show that $\frac{dq_f^\circ}{d\theta}$ and $\frac{d\Pi_f^\circ}{d\theta}$ are non-negative:

$$(p_f^\circ - w - c_o)(1-q_f^\circ) = 1 \Rightarrow (1-q_f^\circ)\frac{dp_f^\circ}{d\theta} - \frac{dq_f^\circ}{d\theta}(p_f^\circ - w) = 0 \Rightarrow \frac{dq_f^\circ}{d\theta} = \frac{(1-q_f^\circ)}{(p_f^\circ - w)}\frac{dp_f^\circ}{d\theta} \geq 0,$$

$$\frac{dp_f^\circ}{dw} = \frac{(1+e^{\upsilon-p_d^\circ})^2 + \left(\frac{e^{\theta\upsilon-p_f^\circ}(1+e^{\theta\upsilon-p_f^\circ}) + \frac{dp_f^\circ}{dw}e^{\theta\upsilon-p_f^\circ}(e^{\upsilon-p_d^\circ}-w+c_d)}{(1+e^{\theta\upsilon-p_f^\circ})(1+e^{\theta\upsilon-p_f^\circ}+e^{\upsilon-p_d^\circ})}\right)e^{\theta\upsilon-p_f^\circ}e^{\upsilon-p_d^\circ}}{(1+e^{\upsilon-p_d^\circ})(1+e^{\theta\upsilon-p_f^\circ}+e^{\upsilon-p_d^\circ})} \Rightarrow$$

$$0 \le \frac{dp_f^\circ}{dw} = \frac{(1+e^{\upsilon-p_d^\circ})^2(1+e^{\theta\upsilon-p_f^\circ})(1+e^{\theta\upsilon-p_f^\circ}+e^{\upsilon-p_d^\circ}) + e^{2(\theta\upsilon-p_f^\circ)}e^{\upsilon-p_d^\circ}(1+e^{\theta\upsilon-p_f^\circ})}{(1+e^{\upsilon-p_d^\circ})(1+e^{\theta\upsilon-p_f^\circ}+e^{\upsilon-p_d^\circ})^2(1+e^{\theta\upsilon-p_f^\circ}) - e^{2(\theta\upsilon-p_f^\circ)}e^{2(\upsilon-p_d^\circ)} + e^{2(\theta\upsilon-p_f^\circ)}e^{\upsilon-p_d^\circ}(w-c_d)} \le 1. \tag{21}$$

Box I.

$$p_f^\circ - w - c_o - \Pi_f^\circ = 1 \Rightarrow \frac{dp_f^\circ}{d\theta} - 1 - \frac{d\Pi_f^\circ}{d\theta} = 0 \Rightarrow \frac{d\Pi_f^\circ}{d\theta} = \frac{dp_f^\circ}{d\theta} \ge 0. \quad \square$$

Proof of Proposition 5. Part 1. By taking derivative of Eqs. (13) with respect to w and applying the implicit differentiation technique, we have:

$$\frac{dp_f^\circ}{dw} = \frac{(1+e^{\upsilon-p_d^\circ})^2 + \frac{dp_d^\circ}{dw}e^{\theta\upsilon-p_f^\circ}e^{\upsilon-p_d^\circ}}{(1+e^{\upsilon-p_d^\circ})(1+e^{\theta\upsilon-p_f^\circ}+e^{\upsilon-p_d^\circ})}, \tag{19}$$

$$\frac{dp_d^\circ}{dw} = \frac{e^{\theta\upsilon-p_f^\circ}(1+e^{\theta\upsilon-p_f^\circ}) + \frac{dp_f^\circ}{dw}e^{\theta\upsilon-p_f^\circ}\left(e^{\upsilon-p_d^\circ}-w+c_d\right)}{(1+e^{\theta\upsilon-p_f^\circ})(1+e^{\theta\upsilon-p_f^\circ}+e^{\upsilon-p_d^\circ})}. \tag{20}$$

By substituting (20) in (19), we have Eq. (21) (given in Box I).

As it is evident in Eq. (21), the numerator is positive. With simple calculus, we can show that the denominator is also positive (the negative term will cancel out after opening up the multiplied parentheses), with a value larger than the numerator. Therefore, $\frac{\partial p_f^\circ}{\partial w}$ is a positive value between zero and one.

For checking the behaviors of the foreign retailer's demand and profit with respect to w, we use the relationships in Eq. (16). By taking derivative of both sides in Eqs. (16) with respect to w, we have:

$$(1-q_f^\circ)(\frac{dp_f^\circ}{dw}-1) - \frac{dq_f^\circ}{dw}(p_f^\circ - w - c_o) = 0 \Rightarrow \frac{dq_f^\circ}{dw} = \frac{(1-q_f^\circ)}{(p_f^\circ - w - c_o)}(\frac{dp_f^\circ}{dw}-1),$$

$$\frac{dp_f^\circ}{dw} - 1 - \frac{d\Pi_f^\circ}{dw} = 0 \Rightarrow \frac{d\Pi_f^\circ}{dw} = \frac{dp_f^\circ}{dw} - 1.$$

Since we know from above that $0 \le \frac{dp_f^\circ}{dw} \le 1$, we conclude that $\frac{dq_f^\circ}{dw} \le 0$ and $\frac{d\Pi_f^\circ}{dw} \le 0$; therefore the foreign retailer's equilibrium price behaves opposite to her demand and profit with respect to w at equilibrium.

Part 2. Using the chain rule for differentiation, we can derive $\frac{dp_d^\circ}{dw}$ as below:

$$\frac{dp_d^\circ}{dw} = \frac{\partial p_d^\circ}{\partial w} + \frac{\partial p_d^\circ}{\partial p_f^\circ}.\frac{dp_f^\circ}{dw}. \tag{22}$$

The first term is the partial derivative with respect to w (assuming p_f as a fixed value) which is equal to q_f°. We also know from part 1 that $\frac{dp_f^\circ}{dw}$ is always non-negative in w; thus, the behavior of $\frac{dp_d^\circ}{dw}$ only depends on the behavior of $\frac{\partial p_d^\circ}{\partial p_f^\circ}$ that is analogous to $\frac{\partial p_d^*}{\partial p_f}$, which based on our finding in Proposition 2, is positive for $w \le w^T$ and negative otherwise. Equivalently, there is another threshold ($\hat{w}$), where $\frac{dp_d^\circ}{dw}$ is positive for $w \le \hat{w}$ and negative for $w \ge \hat{w}$. We can show that this threshold $\hat{w}$ exists; because when w is in its minimum value ($w = c_d$), $\frac{dp_d^\circ}{dw} \ge 0$. On the other hand, when $w \to \infty$, $\frac{dp_d^\circ}{dw}$ converges to zero; therefore, $\hat{w}$ as the solution to $\frac{dp_d^\circ}{dw} = 0$ exists somewhere before $w = \infty$.

For checking the behaviors of the domestic retailer's profit with respect to w, we use the relationships in Eq. (17). By taking derivative of both sides of (17) with respect to w we have:

$$\frac{dp_d^\circ}{dw} - \frac{d\Pi_d^\circ}{dw} = 0 \Rightarrow \frac{d\Pi_d^\circ}{dw} = \frac{dp_d^\circ}{dw}.$$

Therefore, we showed that the equilibrium price and profit of the domestic retailer behave similarly with respect to the change in the service fee.

As the final step in this part, we show below the asymptotic behavior of p_d° when $w \to \infty$. We first formulate p_d° using the domestic retailer's best response function in Lemma 2, and then apply the limit rules on it:

$$\lim_{w\to\infty} p_d^\circ = \lim_{w\to\infty} 1 + c_d + \frac{(w-c_d)e^{\theta\upsilon-p_f^\circ}}{1+e^{\theta\upsilon-p_f^\circ}} + W\left(\frac{e^{\upsilon-1-c_d-\frac{(w-c_d)e^{\theta\upsilon-p_f^\circ}}{1+e^{\theta\upsilon-p_f^\circ}}}}{1+e^{\theta\upsilon-p_f^\circ}}\right) \Rightarrow$$

$$\lim_{w\to\infty} p_d^\circ = 1 + c_d + \lim_{x\to\infty}\left(\frac{(w-c_d)e^{\theta\upsilon-p_f^\circ}}{1+e^{\theta\upsilon-p_f^\circ}}\right) + \lim_{w\to\infty} W\left(\frac{e^{\upsilon-1-c_d-\frac{(w-c_d)e^{\theta\upsilon-p_f^\circ}}{1+e^{\theta\upsilon-p_f^\circ}}}}{1+e^{\theta\upsilon-p_f^\circ}}\right).$$

We know from Part 1 that $\frac{\partial p_f^\circ}{\partial w} \ge 0$; thus if $w \to \infty$, we have $p_f^\circ \to \infty$ and as a result, $\Rightarrow e^{\theta\upsilon-p_f^\circ} \to 0$. Thus we have:

$$\lim_{w\to\infty} p_d^\circ = 1+c_d+\frac{\lim_{w\to\infty}(w-c_d)e^{\theta\upsilon-p_f^\circ}}{1}+W\left(\frac{e^{\upsilon-1-c_d-\frac{\lim_{w\to\infty}(w-c_d)e^{\theta\upsilon-p_f^\circ}}{1}}}{1}\right). \tag{23}$$

As it is shown in (23), when $w \to \infty$, limits contain multiplication of zero and infinity ($\infty \times 0$). In this situation, the output of the limit can be any value between and including zero and infinity. To find the exact values for the limits, we use L'Hospital's rule: $\lim_{x\to\infty}\frac{f(x)}{g(x)} = \lim_{x\to\infty}\frac{f'(x)}{g'(x)}$ (Taylor, 1952), where in our setting, $x = w$, $f(x) = (w - c_d)$ and $g(x) = e^{p_f^\circ-\theta\upsilon}$. Therefore we have:

$$\lim_{w\to\infty}(w-c_d)e^{\theta\upsilon-p_f^\circ} = \lim_{w\to\infty}\frac{(w-c_d)}{e^{p_f^\circ-\theta\upsilon}} = \lim_{w\to\infty}\frac{1}{\frac{dp_f^\circ}{dw}.e^{p_f^\circ-\theta\upsilon}} = 0. \tag{24}$$

By substituting (24) in (23), we derive a constant value for p_d° when $w \to \infty$, as shown in (25). Therefore, for enough large value of w, p_d° converges to a constant positive value larger than c_d as follows:

$$\lim_{w\to\infty} p_d^\circ = 1 + c_d + W\left(e^{\upsilon-1-c_d}\right) \ge 1. \tag{25}$$

Part 3. based on the MNL demands in Eq. (1), the consumer surplus (CS) is defined as follows: $CS = \ln(1+e^{\upsilon-p_d}+e^{\theta\upsilon-p_f})$ (De Jong et al., 2007). By this definition, consumer surplus is decreasing in retailers' prices. Thus, since we know from the first two part of Proposition 5 that $\frac{dp_f^\circ}{dw} \ge 0$, and $\frac{dp_d^\circ}{dw} \ge$ for $w \le \hat{w}$, the consumer surplus is decreasing in w for $w \le \hat{w}$. $\square$

Proof of Proposition 6. We keep all the parameters of the model before and after collaboration the same. If the domestic retailer offers the logistics service fee equal to the last-mile delivery cost of the foreign retailer in the pre-collaboration setting ($w = c_f - c_o$), the profit function of the foreign retailer before and after the collaboration are identical for any set of prices p ($\Pi_f^a(p) = \Pi_f^a(p)|_{w=c_f-c_o}$). However, for the domestic retailer, the additional term ($(w-c_d)q_f$) in his post-collaboration profit function brings him higher profit for any set of price p ($\Pi_d^b(p) < \Pi_d^a(p)|_{w=c_f-c_o}$). Thus the best response of the domestic retailer is higher after collaboration because of the more profitability (increasing the domestic retailer's profit aligns with increasing his equilibrium price, as

Table B.1
Robustness check of post-collaboration win-win possibility ($\theta = 0.8$).

	c_d		c_f		v		c_o	p_d°	p_f°	w^*	$\Delta\Pi_d^\circ(w^*)$	$\Delta\Pi_f^\circ(w^*)$
Low	5		20		20		3	17.55	20.95	16.95	≥0	≥0
Moderate	10		20		20		3	18.05	21.63	17.63	≥0	≥0
High	15		20		20		3	18.92	22.71	18.71	≥0	≥0
	10	Low	10		20		3	17.9	17.13	13.1	≥0	≥0
	10	Moderate	20		20		3	18.05	21.63	17.63	≥0	≥0
	10	High	40		20		3	18.06	22	18	≥0	≥0
	10		20	Low	10		3	11.27	14.92	10.92	≥0	≥0
	10		20	Moderate	20		3	18.05	21.63	17.63	≥0	≥0
	10		20	High	30		3	27.21	30.18	26.18	≥0	≥0
	10		20		20	Low	0	18.05	18.98	17.98	≥0	≥0
	10		20		20	Moderate	3	18.05	21.63	17.63	≥0	≥0
	10		20		20	High	6	18.05	23.54	16.54	≥0	≥0

proved in Proposition 5. part 2). A higher price by the domestic retailer, in turn, causes the foreign retailer's best response to increases (Using Proposition 2), which brings her a higher equilibrium price and profit compared to the pre-collaboration situation (Using Proposition 5.part 1). Therefore, when $w = c_f - c_o$, both retailers are better off by collaboration ($\Delta\Pi_d^\circ > 0$ and $\Delta\Pi_f^\circ > 0$).

On the other hand, when $w = c_d$, we have $\Pi_d^b(p) = \Pi_d^a(p)|_{w=c_d}$, while if $w = c_d < c_f - c_o$, $\Pi_f^b(p) < \Pi_f^a(p)|_{w=c_d}$. Thus, based on what we discussed above, the foreign retailer chooses a lower best response after collaboration ($p_f^{\circ b} > p_f^{\circ a}$), which leads to higher profit compared to pre-collaboration setting ($\Pi_f^{\circ b} < \Pi_f^{\circ a}|_{w=c_d}$). From Proposition 2, we know that the domestic retailer decreases his price as the best response to the foreign retailer's price fall, which itself results in lower profit for him at equilibrium compared to the pre-collaboration setting ($p_d^{\circ b} > p_d^{\circ a}$) according to the Propositions 5. Thus, $\Delta\Pi_d^\circ|_{w=c_d} < 0$ but $\Delta\Pi_d^\circ|_{w=c_f-c_o} > 0$. Since $\Pi_{d,a}^\circ$ is continuous in w, there is a subset for w in $c_d < w \le c_f - c_o$ that $\Pi_d^{\circ b} < \Pi_d^{\circ a}$ and $\Pi_f^{\circ b} < \Pi_f^{\circ a}$, so both retailers better off after collaboration. ☐

Proof of Proposition 7. We proved in Proposition 5 that $\Pi_f^{\circ a}$ is decreasing and $\Pi_d^{\circ a}$ is quasi-concave in w. As a result, $\Pi_f^{\circ a} + \Pi_d^{\circ a}$ is quasi-concave in w (Bhatia, 2013) and has a unique maximum point. Adding a decreasing function to a quasi-concave function shifts its maximum point to the left, which leads to $w^{**} \le w^*$. ☐

Proof of Corollary 2. We know from Proposition 5.part 3 that at the equilibrium prices, the consumer surplus is decreasing in w for $w \le \hat{w}$. Since we proved in Proposition 7, that $w^{**} \le w^*$, thus, $CS^\circ(w^{**}) > CS^\circ(w^*)$. ☐

Appendix B

See Table B.1.

Data availability

No data was used for the research described in the article.

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