Commission pricing strategy on online retail platforms: power and dependence in triad

Xu Chen[1*], Zheng Luo[1], Xiaojun Wang[2]

1. *School of Management and Economics, University of Electronic Science and Technology of China, Chengdu, 611731, P. R. China. E-mail: xchenxchen@263.net (Xu Chen); luozheng9026@gmail.com (Zheng Luo)*
2. *Department of Management, University of Bristol, Bristol, BS8 1TZ, UK. E-mail: xiaojun.wang@bristol.ac.uk*

Abstract: With the increasing popularity of online retailing, this research investigates the alternative online operation strategies regarding commission price when selling through online platforms. We exploit a triadic network setting that consists of one online platform firm and two competing vendors and examine the strategic choice of the involved parties to effectively compete in the marketplace. We develop game models for alternative commission pricing strategies and obtain the equilibrium solutions. Through a comparison of equilibrium solutions, our analysis reveals that alternative commission pricing strategies lead to different economic results for the online platform and the two vendors individually and collectively. While vendors can take necessary actions (e.g., an additional fee for an exclusive pricing right) to maximize their own benefit, competing vendors can also respond to their rival's strategic choice to minimize the negative impact of the deal reached by the other two parties. Our findings also suggest that the exclusive pricing right that the lead vendor tried to secure results in a higher commission fee paid to the online platform. Through modelling strategic behavior and consequential economic results in the setting of a triad network, our research also responds to the proposition that structural and behavioral approaches represent incommensurable ideas, and we show that a combined theoretical strategy appears well-adapted to the complex realities of interfirm networks.

Key words: Commission fee; pricing strategy; online retailing; game theory.

* *Corresponding author:* Xu Chen; E-mail: xchenxchen@263.net; Tel: +86 28 83206622

1 Introduction

The retail sector has been experiencing a significant consumer behavioral shift with the wide adoption of Internet technology and mobile devices in the last two decades. According to Statista (2018), retail e-commerce sales worldwide reached 2.3 trillion US dollars in 2017 and e-retail revenues are projected to increase to 4.88 trillion US dollars by 2021. As more consumers shop online, there have been several high-profile bankruptcies and store closures in recent years, including some biggest household names, such as Macy's and Sears in the United States (U.S.), and House of Fraser in the United Kingdom (UK). At the same time, when conventional offline retailers try to build their presence online, there are some greatly successful online platforms (e.g., Amazon.com, Taobao, and JD.com). Among them, Amazon, the online technology giant, reported record retail sales in 2017 amounting to full-year revenue of $177.9 billion driven by a surge in online shopping over the holiday season, which is an increase of nearly a third compared to 2016 (BBC, 2018). In China, led by marketplace firms such as Taobao and JD.com, online retail sales passed $1 trillion for the first time in 2017, an increase of 32% over the previous year (Lin, 2017; Lin and Abkowitz, 2017).

As a result, many vendors or bands move to online platforms such as Amazon.com or JD.com to become direct-to-consumer vendors (Gao et al., 2017; Luo et al, 2018). For instance, Amazon has over two million third-party vendors operating on its platform, and all vendors on Amazon.com have to pay a commission type "Referral Fee" for every item that sells through the platform. For Amazon, the income (e.g., commission fee) from 3rd party vendors is the second main revenue source after retail products it sells on its own. Therefore, from online platform firms' perspective, it is important to charge a good commission price to guarantee a crucial revenue source. From vendors' (e.g., vendors/brands) perspective, it is equally important since a high rate will increase operating costs and affect their profit margin. Practically, there are three possible commission pricing strategies for the online platform to adopt: (i) according to each vendor who sells common goods simultaneously to determine different commission prices; (ii) according to the lead vendor to decide the commission price and apply the same determined rate to other vendors; (iii) according to the follower vendors to decide the commission price and apply the same determined rate to other vendors, including the lead vendor. We take JD.com, one of the largest online e-commerce platform companies in China, as an example. According to the Open Platform Investment and Tariff Standard of JD.com, JD.com has two ways to determinate the commission fee. The first one is for a product category, JD.com sets a fixed commission price to all the vendors who want to sell product through the online platform. The second one is that JD.com sets different commission prices to different vendors based on each vendor's condition respectively. However, as far as we know, there are few studies that systematically examine the alternative commission pricing strategies. Only a similar problem with different pricing policies is examined by Chen et al. (2012). But their examination of different pricing strategies is in a setting of a two-echelon supply chain, which is different to the setting of online retail platform considered in this study. The above observations motivate us to investigate the following research questions:

- What is the best strategy for the online platform to determine commission price to vendors? Reciprocally, what are the best commission pricing strategies for vendors?
- How can the vendors respond to the online platform and their competitors' optimal commission pricing strategies to protect their own interests?
- How do these different commission pricing strategies affect the supply chain and consumers?

There is a growing stream of literature that discusses the importance of the strategy choices between online platform firms and vendors that focuses on the trade-offs between alternative options. Previous research addressing this general question has focused on channel competition and coordination (Cai, 2010; Ryan et al., 2012; Chen et al., 2017), online and offline channel integration (Gallino and Moreno, 2014; Cao and Li, 2015), channel structure and choice (Yoo and Lee, 2011; Chen, and Wang, 2015; Luo et al., 2017; Tian et al., 2018) and information asymmetry (Mukhopadhyay et al., 2008; Jiang et al., 2011; Chen et al., 2019b). Our focus is different, as the goal of this paper is to examine the differences of firms' choices among alternative commission pricing strategies when engaging online platform retailing operations. We exploit a triadic network setting that consists of one online platform firm and two competing vendors who sell through the online platform. We examine the strategic choice of effectively competing in the marketplace and find that vendors' optimal strategies evolve over time depending on a choice of rival vendors.

We summarize the key findings of our study as follows. First, our analysis reveals that alternative commission pricing strategies lead to different economic results for the online platform and the two vendors individually and collectively. While vendors can take necessary actions (e.g., an additional fee for an exclusive commission pricing right) to maximize their own benefit, competing firms can also respond to their rivals' strategic choices to minimize the negative impact of the deal reached between their rivals and the platform firm. The strategic behavior and consequential economic results captured in this study provide important managerial implications for firms operating in the online marketplace. Our findings also suggest that the exclusive commission pricing right that most industrial leaders try to secure does not necessarily result in a lower commission price paid to the online platform. Instead, it leads to a higher commission price, which enables them to gain benefits in the horizontal competition with rival firms. Although such an exclusive commission pricing strategy can deliver better economic performance for both the powerful vendor and the online platform, we will show in this paper that the better economic performance is not sustainable as the improved economic performance is at the expense of smaller vendors and consumers.

The remainder of this paper is organized as follows. First, we review the relevant literature and examine how our study relates to the existing literature. This is followed by a description of the model and equilibrium analysis in Section 3. Then, we examine the impact of alternative commission pricing strategies on the economic performance of the online platform and the two vendors and analyze vendors' battle for the exclusive commission pricing right in Sections 4 and 5, respectively. We highlight the change in the commission fee under different commission pricing strategies in Section 6. Finally, we conclude the paper with a summary of key insights and possible avenues for future extension.

2 Literature review

This study is closely related to the following two streams of literature: (i) online retailing e-commerce models, and (ii) online strategy regarding pricing and commission fees. Now, we discuss how our research relates to the literature in the above areas.

Online retailing through the e-marketplace has attracted extensive attention in recent years. One stream of relevant literature investigates the optimal choices among the different e-commerce models available to firms when engaging in online retailing. For instance, from the perspective of both marketplace firms and vendors, Ryan et al. (2012) analyzed the optimal decisions for both partners and characterized the equilibrium of the online marketplace system. Hagiu and Wright (2014) examined the fundamental trade-offs faced by an intermediary when choosing whether to operate as a marketplace or a reseller and found that the choice between the two modes is determined by the relevant important information that the intermediary or the independent suppliers have regarding the optimal tailoring of marketing activities for each specific product. Abhishek et al. (2015) investigated the channel structure choice between agency selling and reselling for online retailing. Here, the main difference between the two selling formats is that the retail prices are decided by the e-tailer in reselling, whereas in agency selling they are decided by the vendor and the e-tailer charges a commission fee for sales made through the channel, which is similar to the marketplace (e.g., Amazon). The findings of Abhishek et al. (2015) show that the preference between two channels depends on the negative or positive impact of the sales in the e-channel on the demand in the traditional channel, and this preference is mediated by competition between e-tailers. More recently, Tian et al. (2018) explored the strategic contractual choice between marketplace, reseller or hybrid (both marketplace and reseller operations) for online retailers. Their findings suggested that the selection of an optimal mode for the intermediary is moderated by the interaction of order fulfillment costs and upstream competition intensity.

With the increasing growth of online platforms, there is a growing body of literature on contractual design regarding pricing and commission fees in recent years. Inspired by Amazon's e-marketplace business model, Wang et al. (2004) studied consignment contracts with revenue sharing mechanisms by which marketplace firms (e.g., Amazon) collect commission fees when vendors' items are sold through the online platform. Mantin et al. (2014) investigated the strategic role of 3rd party marketplaces in online retailing. They found that the presence of 3rd party marketplaces can weaken the upstream monopolist's ability to extract profits from a downstream retailer. Furthermore, although consumers also benefit from this presence, this benefit diminishes as the retailer's power increases. Hao et al. (2017) investigated a mobile platform's in-app advertising contract under agency pricing for app sales, and their research findings indicated that the advertising revenue-sharing contract results in a higher app price. Tan and Carrillo (2017) analyzed the agency model, in which the publisher determines the retail price and the online platform collects a predetermined commission fee in the context of the digital goods industry. Their analysis found that the agency model, with price setting by the suppliers, performs better than the wholesale model because of a decreased level of double marginalization and an increased level of consumer surplus. More recently, Geng et al. (2018) investigated the interaction between a vendor's add-on strategy and an online platform's distraction contract choice. Their analysis results found that a higher commission rate does not always lead to greater profit for the platform under the agency contract. Our paper is different from the above studies in that we focus more on the interaction of different strategies in the contractual commission prices between the online platform and two vendors.

Our research is different from the abovementioned studies in that the question we address in this paper focuses on the impact of commission price strategies on the platform, vendors, and consumers, which has not been studied in the literature. Furthermore, we model the vendors' behavioral change in seeking for their own profit maximization, or alternatively minimizing the negative impact of the deal reached by the other two parties in a triadic network setting.

3 Model and equilibrium

This paper studies the management problem of commission pricing strategies in online platform selling. We consider a stylized supply chain that comprises two vendors and an online platform firm (To simplify, we use "V1" and "V2" to denote vendor 1 and vendor 2). Figure 1 provides the format of online platform selling in this paper. The online platform offers an e-marketplace through which vendors can sell products, and for each product that the vendors sell, the online platform will charge a predetermined commission fee, which is transferred between the vendors and the online platform. Unlike the traditional supply chain, in this online platform retailing format, the online platform is not a reseller; instead, it is similar to an agent and charges a certain agency fee (Wang et al., 2004; Hagiu and Wright, 2015). The product sale quantity and retail price are decided by the upstream vendors, not the downstream online platform.

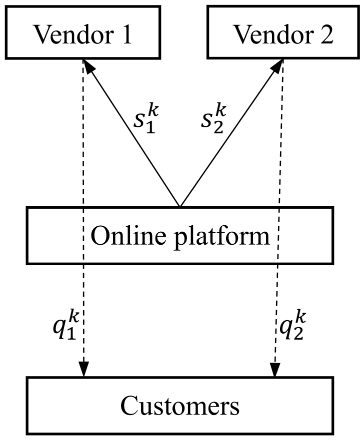

Figure 1. Online platform selling format

In this model, we assume that V1 and V2 sell perfectly substitutable products but hold different upper bounds of market prices, α_i, and unit selling costs, c_i (caused by different operating efficiency), which leads to different maximum marginal profits, δ_i, since $\delta_i = \alpha_i - c_i$. Without a loss of generality, V1 has a competitive advantage over V2 when assuming that the maximum marginal profit of V1 is higher than that of V2, namely $\delta_1 > \delta_2$. Please note that the upstream vendors can also be retailers who purchase products from a common manufacturer at the same wholesale price but with different unit operating costs. The online platform is a Stackelberg leader and has three alternative strategies of determining commission prices for V1 and V2. To make it clear, we use *Strategies A, B,* and *C* for the three alternative strategies:

Strategy A: The online platform decides the commission price of V1 only (the one with more competitive advantage), and charges V2 the same commission price as V1.

Strategy B: The online platform decides the commission price of V2 only (the one with less competitive advantage), and charges V1 the same commission price as V2.

Strategy C: The online platform makes commission price decision for both V1 and V2, and two different commission prices are decided discriminatingly for each vendor.

We denote the parameters and variables for model development by the notations shown in Table 1.

Table 1. Parameters and variables

Notation	Descriptions
α_i	Upper bound of market price for vendor i
c_i	Unit selling cost of vendor i
s_i^k	Commission price to vendor i under strategy k
q_i^k	Sale quantity of vendor i under strategy k
p_i^k	Retail price of vendor i under strategy k
β	Sensitivity of sale quantity to price
$\pi_i^k(\cdot)$	Vendor i's profit under strategy k
$\pi_O^k(\cdot)$	Online platform's profit under strategy k
$\pi_{SC}^k(\cdot)$	Entire supply chain's profit under strategy k
δ_i	Maximum marginal profit of vendor i, $\delta_i = \alpha_i - c_i$
ρ	Ratio of maximum marginal profit, $\rho = \delta_1/\delta_2 > 1$ since $\delta_1 > \delta_2$; to depict the gap of competitive advantage between V1 and V2

where $i = 1, 2$, and $k = A$ means *Strategy A*, $k = B$ means *Strategy B*, and $k = C$ means *Strategy C*.

The market demand is assumed to be deterministic and dependent on price. Since V1 and V2 sell perfectly substitutable products, then the sensitivity of sale quantity to price is the same. Therefore, to clearly show the substitutional relationship of products, we use an inverse demand function, which is expressed as

$$p_i^k = \alpha_i - \beta\left(q_i^k + q_j^k\right) \tag{1}$$

Where $i = 1, 2$ and $j = 3 - i$. Such demand functions have been commonly used in the economics and marketing literatures to capture competition between multiproduct retailers (Trivedi, 1998; Feng and Lu, 2012; Huang et al., 2013; Chen et al. 2019a).

For each sold product, the vendors should pay the online platform a commission fee, hence the vendors' profit function is

$$\pi_i(q_i) = \left(p_i^k - c_i - s_i^k\right)q_i^k \tag{2}$$

and the online platform's profit function is

$$\pi_O\left(s_i^k, s_j^k\right) = \sum_{i=1}^{2} s_i^k q_i^k \tag{3}$$

Moreover, the model and optimization are studied under the assumption of information symmetry. The online platform and both vendors know all the information about each other. And the vendors and the online platform are risk-neutral and each of them only cares about their own profit maximization. The next several subsections detail the game among the online platform, V1, and V2 under the different commission pricing strategies, and provide the optimal solutions to the commission price and sale quantity, as well as the retail prices and profits.

3.1 *Strategy A:* The online platform sets commission price for V1 only

When the online platform sets commission price to V1 only, V2 will not affect the determination of the commission price and just accepts the commission price decided by the online platform. Thus, the decision sequence of the vendors and the online platform is as follows. In the first-stage game, the online platform announces the commission price anticipating the optimal reaction of V1. In the second-stage game, given the commission price, V1 and V2 decide their optimal sale quantities simultaneously. In the third-stage game, the optimal commission price and the maximum profits of the online platform, V1, and V2 are obtained.

3.2 *Strategy B:* The online platform sets commission price for V2 only

Similar to *Strategy A*, when the online platform sets commission price for V2 only, V1 will not participate nor influence the determination of the commission price and will just accept the commission price decided by the online platform. Thus, the decision sequence of the vendors and the online platform is as follows. In the first-stage game, the online platform announces the commission price anticipating the optimal reaction of V2. In the second-stage game, given the commission price, V1 and V2 decide their optimal sale quantities simultaneously. In the third-stage game, the optimal commission price and the maximum profits of the online platform, V1, and V2 are obtained.

3.3 *Strategy C:* The online platform sets commission price for both V1 and V2

When the online platform sets commission price to both V1 and V2, different commission prices are set discriminatingly for V1 and V2 simultaneously. Thus, the decision sequence of the vendors and online platform is as follows. In the first-stage game, the online platform announces two different commission prices considering the reactions of V1 and V2. In the second-stage game, given the commission prices, V1 and V2 decide their optimal sale quantities simultaneously. In the third-stage game, the optimal commission prices and the maximum profits of the online platform, V1, and V2 are obtained.

3.4 Equilibrium solutions

Based on the game models for the three different commission pricing strategies, we can get the optimal solutions to the commission prices of the online platform and the sale quantities of both V1 and V2. The derivation of the equilibrium solutions is shown in the Appendix.

Lemma 1. ***For each commission pricing strategy, there exist unique optimal commission prices and sale quantities, as summarized in Table 2.***

Table 2. Equilibrium solutions

	Strategy A	*Strategy B*	*Strategy C*
s_1^k	$\frac{3\delta_1+2\delta_2}{9}$	$\frac{3\delta_2+2\delta_1}{9}$	$\frac{\delta_1}{2}$
s_2^k	$\frac{3\delta_1+2\delta_2}{9}$	$\frac{3\delta_2+2\delta_1}{9}$	$\frac{\delta_2}{2}$
q_1^k	$\frac{3\delta_1-2\delta_2}{6\beta}$	$\frac{4\delta_1-3\delta_2}{9\beta}$	$\frac{2\delta_1-\delta_2}{6\beta}$
q_2^k	$\frac{4\delta_2-3\delta_1}{9\beta}$	$\frac{3\delta_2-2\delta_1}{6\beta}$	$\frac{2\delta_2-\delta_1}{6\beta}$

Based on the equilibrium solutions of V1, V2, and online platform, we can get the retail prices and profits, which are shown in Table 3.

Table 3. Retail prices and profits

	Strategy A	*Strategy B*	*Strategy C*
p_1^k	$c_1+\frac{15\delta_1-2\delta_2}{18}$	$c_1+\frac{16\delta_1-3\delta_2}{18}$	$c_1+\frac{5\delta_1-\delta_2}{6}$
p_2^k	$c_2+\frac{16\delta_2-3\delta_1}{18}$	$c_2+\frac{15\delta_2-2\delta_1}{18}$	$c_2+\frac{5\delta_2-\delta_1}{6}$
π_1^k	$\frac{(3\delta_1-2\delta_2)^2}{36\beta}$	$\frac{(4\delta_1-3\delta_2)^2}{54\beta}$	$\frac{(2\delta_1-\delta_2)^2}{36\beta}$
π_2^k	$\frac{(3\delta_1-4\delta_2)^2}{54\beta}$	$\frac{(2\delta_1-3\delta_2)^2}{36\beta}$	$\frac{(\delta_1-2\delta_2)^2}{36\beta}$
π_O^k	$\frac{(3\delta_1+2\delta_2)^2}{162\beta}$	$\frac{(3\delta_2+2\delta_1)^2}{162\beta}$	$\frac{\delta_1^2+\delta_2^2-\delta_1\delta_2}{6\beta}$
π_{SC}^k	$\frac{153\delta_1^2-228\delta_1\delta_2+140\delta_2^2}{324\beta}$	$\frac{140\delta_1^2-228\delta_1\delta_2+153\delta_2^2}{324\beta}$	$\frac{11\delta_1^2-14\delta_1\delta_2+11\delta_2^2}{36\beta}$

Because of the nonnegativity of the sale quantity, retail price, and commission price under the three commission pricing strategies, the ratio of the maximum marginal of profit should satisfy $1 < \rho < \frac{4}{3}$. The following discussion is on the interval.

4 Analysis of commission pricing strategies on firms' performance

In this section, we analyze the optimal commission pricing strategy from the online platform's perspective. Since the online platform is a Stackelberg leader, it has the priority to choose a commission pricing strategy that brings it the most benefit. Through inputting the equilibrium solutions into the profit functions, we derive the following proposition.

Proposition 1. $\boldsymbol{\pi_O^C > \pi_O^A > \pi_O^B}$.

This proposition indicates that, when the online platform sets commission price to both V1 and V2, the maximum profit it can gain is more than that of the other two commission pricing strategies. That is, to get the most economic benefit, the online platform should set commission price to every single vendor according to each vendor's specific circumstance (e.g., cost information and profit margin). The online platform can maximize economic benefit with this discriminatory pricing method.

Next, we discuss the effect of different commission pricing strategies on the vendors' profits. The following corollary can be derived.

Corollary 1.

1) ***For V1, when*** $\boldsymbol{1 < \rho \le IP1}$***, then*** $\boldsymbol{\pi_1^A > \pi_1^C \ge \pi_1^B}$***; and when*** $\boldsymbol{IP1 < \rho < \frac{4}{3}}$***, then*** $\boldsymbol{\pi_1^A > \pi_1^B > \pi_1^C}$***, where*** $\boldsymbol{IP1 = \frac{9+\sqrt{6}}{10}}$.
2) ***For V2,*** $\boldsymbol{\pi_2^C > \pi_2^B > \pi_2^A}$.

It is clear that V1 produces the best economic performance when the online platform sets commission price to V1 only. However, the choice between the other two commission pricing strategies (set commission price to V2 only or to both V1 and V2) is dependent on how much competitive advantage V1 has over V2 (parameter ρ). When the competitive advantage is lower than $IP1$, the strategy of setting commission prices for both V1 and V2 is better than that of setting commission price for V2 only, and vice versa. However, V2 can gain the most profit when the online platform sets commission price to both V1 and V2. Interestingly, for V2, this commission pricing strategy leads to better performance than when the online platform sets commission price to V2 only. In addition, V2 produces the worst economic performance when the online platform sets commission price to V1 only. Therefore, V2 is unwilling to see that and will take necessary actions to prevent such a commission pricing strategy.

5 Vendors' battle for the right commission pricing strategy

The last section examines the online platform's optimal choice of commission pricing strategy and the economic impact of different commission pricing strategies on the two vendors. Based on the findings of Corollary 1, we can argue that, from the perspective of V1, it is preferable for the online platform to set commission price to V1 only, since this strategy allows V1 to get more profit. Therefore, V1 always has the desire to fight for an exclusive commission pricing right. However, from the perspective of V2, it is better for the online platform to set commission price to both vendors rather than with V1 only. Therefore, from the vendors' perspective, V1 and V2 will take extra measures to fight for the commission pricing right that maximizes their own benefits. Now we discuss the options of the battle for commission pricing rights between V1 and V2 and their effects on system equilibrium.

5.1 V1's behavior

Based on Corollary 1, the optimal solution for V1 is to secure an exclusive commission pricing right. However, securing an exclusive commission pricing right has to meet two conditions. The first condition, $(\pi_1^A - \pi_1^C) + \pi_O^A > \pi_O^C$, is to ensure that under an exclusive commission pricing right by the online platform, V1 has enough profit to make up the online platform's profit loss, so that the online platform will have a profit that is not less than the case where the online platform sets commission price to both vendors. It means an exclusive commission pricing right by the online platform requires V1 to have an ability to make a "bigger pie" to cover the online platform's loss. The second condition, $\pi_1^A - \pi_1^C > \pi_2^C - \pi_2^A$, is to ensure that V2 cannot stop V1 from getting the exclusive commission pricing right. Only when both conditions are satisfied, can V1 win the commission pricing right battle. We derive the following proposition to show V1's behavior.

Proposition 2.

1) When $\mathbf{1 < \rho \leq IP3}$, V1 cannot capture the exclusive commission pricing right, since

a) If $\mathbf{1 < \rho \leq IP2}$, V1's profit is not enough to make a "bigger pie";

b) If $\mathbf{IP2 < \rho \leq IP3}$, the pie is not big enough to break through V2's obstruction.

2) When $\mathbf{IP3 < \rho < \frac{4}{3}}$, V1 can capture the exclusive commission pricing right.

where $\mathbf{IP2 = \frac{2\sqrt{5}-1}{3}}$ and $\mathbf{IP3 = 1 + \frac{1}{\sqrt{30}}}$.

Proposition 2 highlights that whether V1 can secure an exclusive commission pricing right is highly dependent on the gap of competitive advantage between V1 and V2. As illustrated in Corollary 1, only V1 has an incentive to compete for an exclusive commission pricing right. However, having an incentive to do so does not guarantee the success of securing the right. The first part of Proposition 2 shows that V1 has no guarantee of capturing the exclusive commission pricing right for two reasons. First, V1 cannot make a "bigger pie" for the online platform nor achieve a Pareto improvement when the margin of the competitive advantage between V1 and V2 is lower than a critical threshold ($\rho \leq IP2$). Second, as the margin of the competitive advantage between the two vendors increases to the extent that it is higher than the critical threshold ($\rho > IP2$), this "bigger pie" can be made. However, because of the obstruction from V2, who would prefer the online platform to employ a bilateral commission pricing strategy instead of a unilateral commission pricing strategy, the increased "pie" is still not sufficient for V1 to overthrow V2's countermeasure. Therefore, only when the margin of the competitive advantage between the two vendors further increases to a certain extent ($IP3 < \rho < \frac{4}{3}$), can V2 not stop V1, and eventually V1 can capture the exclusive commission pricing right. Hence, we can conclude that, fundamentally, to secure the exclusive commission pricing right, V1 has to take necessary strategic and tactical actions, such as improving cost efficiency and adding product value, to increase its competitive advantage over the rival vendor.

5.2 V2's behavior

This section examines V2's behavior in the battle for its desirable commission pricing strategy.

Proposition 3. ***At any time, V2 has no desire to capture the exclusive commission pricing right but stop V1 from doing so, and V2 can only afford to stop V1 when $\mathbf{1 < \rho \leq IP3}$.***

For V2, there is no incentive to fight for the exclusive commission pricing right since its economic performance will be worse than that when the online platform sets commission price to both V1 and V2. However, V2 will stop V1 from getting the exclusive commission pricing right to prevent the worst case scenario when the gap of competitive advantage between V1 and V2 is relatively small. Otherwise, V1 is able to break through V2's obstruction.

According to Propositions 2 and 3, *Strategy A* and *Strategy C* are the focus of the battle between V1 and V2. The profits of V1, V2, and the online platform under *Strategy A* and *Strategy C* determine the victor or loser in the battle, and consequently the final commission price strategy. To depict the effect of V1's and V2's behavior in the battle for their preferable commission price strategies based on the gap of competitive advantage, we firstly provide an original Figure 2 without battle to show the profits of both vendors and the online platform under *Strategy A* and *Strategy C.* Then the effect of vendors' behavior on profit is shown in Figure 3. The detail of the numerical example illustration can be found in Appendix.

Figure 2 provides us a profit graph of both vendors and online platform without the battle battling behavior under *Strategy A* and *Strategy C*. This figure also confirms the conclusions obtained by Corollary 1. Figure 2 clearly shows that V1 prefers the online platform to adopt *Strategy A*, while the online platform and V2 want to adopt *Strategy C*. Proven by Propositions 2 and 3, the battle behavior between V1 and V2 may change the commission pricing strategy adopted by the online platform. Here we use Figure 3 to provide a visual illustration to show the influence of the battle behavior between V1 and V2.

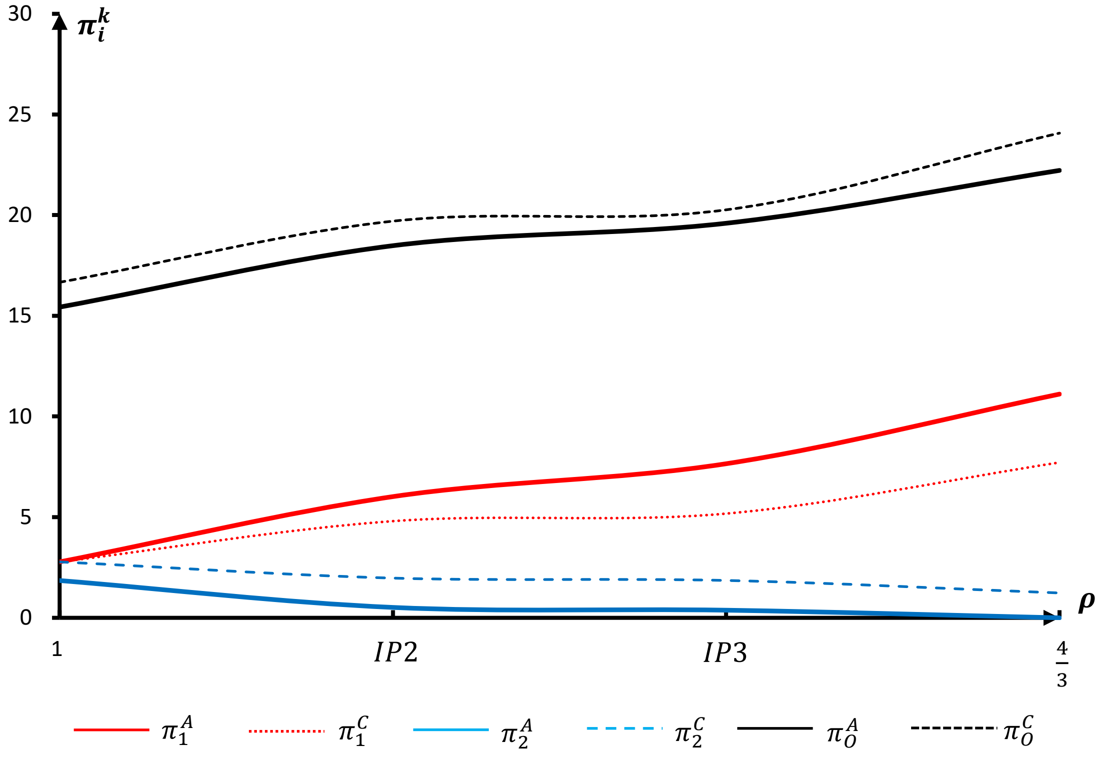

Figure 2. Profits without vendors' battle behavior

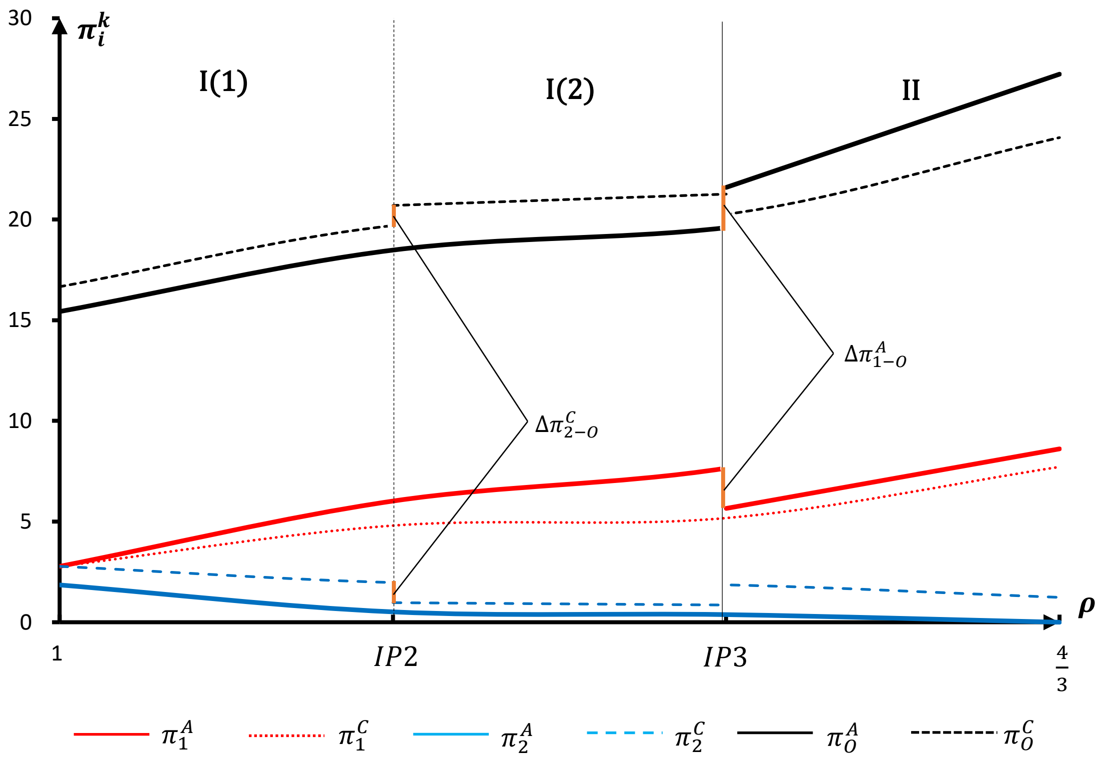

Figure 3. Effect of vendors' battle behavior on profits

From Figure 3, we can see that, overall, the maximum profit of V2 decreases, whereas the maximum profit of V1 increases, when the gap of competitive advantage between V1 and

V2 extends. The feasible interval is divided into two subregions. In region I, the exclusive commission pricing right with the online platform cannot be reached by V1. In region I(1), even though V1 has a desire for the exclusive commission pricing right, the resulting "pie" is not big enough for the online platform and V1 to achieve *Pareto* improvement. Hence, bilateral commission pricing right between the online platform and vendors is maintained. In region I(2), although the resulting "pie" from V1's exclusive commission pricing right is big enough for V1 and the online platform to achieve *Pareto* improvement, V2 can stop such an exclusive right by sharing a fraction of its profit $\Delta\pi_{2-O}^{C}$ with the online platform. As a result, the maximum profit of V2 under bilateral commission pricing right (π_2^C, dotted blue line) moves down $\Delta\pi_{2-O}^{C}$ units and the maximum profit of the online platform under bilateral commission pricing right (π_O^C, dotted black line) moves up $\Delta\pi_{2-O}^{C}$ units. In interval II, V1 has enough capability to break through V2's obstacle because of its competitive advantage over V2, and therefore it is able to get the exclusive commission pricing right by sharing a fraction of its profit of $\Delta\pi_{1-O}^{A}$ units with the online platform. As a result, V1's profit under the exclusive commission pricing strategy moves down $\Delta\pi_{1-O}^{A}$ units (π_1^A, full red line) but is still greater than its profit under the bilateral commission pricing strategy (π_1^C, dotted red line), and the online platform's profit increases to a higher level under exclusive commission pricing to V1 (π_O^A, full black line) than under bilateral commission pricing strategy (π_O^C, dotted black line).

5.3 Impact analysis

In this section, we examine the impact of vendors' battle over commission pricing strategies on the entire supply chain and consumers from the perspectives of economic performance and retail prices.

Proposition 4.

1) ***For the entire supply chain, when*** $1 < \rho \leq IP4$***, then*** $\pi_{SC}^{C} \geq \pi_{SC}^{A} > \pi_{SC}^{B}$***; when*** $IP4 < \rho < \frac{4}{3}$***, then*** $\pi_{SC}^{A} > \pi_{SC}^{C} > \pi_{SC}^{B}$***, where*** $IP4 = \frac{17+\sqrt{43}}{18}$
2) ***For customers,*** $p_1^A > p_1^C$ ***and*** $p_2^A > p_2^C$***.***

From Proposition 4, we can see that, for the entire supply chain, the total profit in the case where the online platform sets commission price to V2 exclusively is the worst. Hence, in that respect, an exclusive commission pricing strategy between the online platform and the weaker vendor should be avoided. This finding is also in line with current industry practices, in which, the online platform firms often adopt the bilateral commission pricing strategy or exclusive commission pricing strategy to the industry leader only if an exclusive commission pricing strategy is implemented. Recalling the key threshold $IP3$ of the exclusive commission pricing right battle in Propositions 2, 3 and Figure 3, we can know that $IP3 < IP4$. Therefore, even when $IP3 < \rho < IP4$, the entire supply chain delivers the best economic performance under the bilateral commission pricing strategy. V1 still has the economic capability to exercise its power to get the exclusive commission pricing right, and V2 does not have the economic capability to tip the balance. For customers, the exclusive commission pricing strategy with the powerful vendor raises both vendors' retail prices compared to the bilateral commission pricing strategy, which hurts consumers.

6 Commission price

According to the analysis in Section 5, we know that when $IP3 < \rho < \frac{4}{3}$, V1 can capture the exclusive commission pricing right and both V1 and the online platform will get better economic performance than when the online platform sets commission prices to vendors. The following proposition provides some insights on the commission prices with the transfer of commission pricing rights.

Proposition 5. $\boldsymbol{s_1^A > s_1^C}$**.**

This proposition indicates the change of commission prices before and after V1 gets the exclusive commission pricing right. It is interesting to see that, when V1 gets the exclusive commission pricing right, it does not push down the commission price, but instead pushes up the commission price. This contradicts the common sense that V1's aim for an exclusive commission pricing is to reduce the commission price paid to the online platform. Therefore, we can conclude that V1 obtains the exclusive commission pricing right at the expense of bearing the higher commission price. Despite all of this, because of a relatively large gap of the competitive advantage between V1 and V2, i.e., $IP3 < \rho < \frac{4}{3}$, the exclusive commission pricing strategy between the online platform and V1 produces better economic performance for both. Intuitively, the platform firm benefits from the higher commission fee received from both vendors and, for the powerful vendor, the advantage gained from the competition with the rival vendor can outweigh the cost incurred from higher commission fee.

7 Conclusion

This paper considers an online retail supply chain in which two vendors sell perfectly substitutable products through an online platform. As the Stackelberg leader, there are three alternative strategies for the online platform to set the commission price with the vendors, including setting commission price to V1 only, V2 only, and both V1 and V2. Under each commission pricing strategy, we analyze the game model and obtain the equilibrium solutions. We then examine the effect of the three different commission pricing strategies on the firms' economic performance individually and collectively and explore the two vendors' tactical behavior when battle for their own preferable commission pricing strategies. Our analysis results provide some interesting insights:

First, from the perspective of the online platform, it is optimal to choose the strategy of setting commission price to both V1 and V2, since it can get the most profit compared with the other two commission pricing strategies. From the perspective of the vendors, V1 may have a desire to capture the exclusive commission pricing right but faces obstruction from V2 who wants to prevent V1 from getting the exclusive commission pricing right. V2 is capable of doing so if the gap of competitive advantages between the two vendors is marginal. However, when the competitive advantage gap between the two vendors increases to a certain extent ($IP3$), V1 can secure the exclusive commission pricing right and both the online platform and V1 can achieve *Pareto* improvement. Surprisingly, the exclusive commission pricing right that V1 battles for will push up the commission price paid to the online platform, which may contradict the common sense of setting a lower commission price. However, the trade-off between the economic benefit gained from horizontal competition and the cost from commission fees determines the optimal choice of commission pricing strategies for the two vendors.

This research makes the following key contributions. This study examines the effects of alternative commission pricing strategies on operational decisions (e.g., price and quantity), and consequential economic performance. However, in the context of a triadic interfirm network, firms will often take necessary actions to maximize their own benefit, or alternatively minimize the negative impact of the deal reached by the other two parties. By modeling the vendors' behavior when battling for their own preferable commission pricing strategy, our research provides an approach to explore potential behavioral changes in a triadic network setting. Our research responds to the proposition that structural and behavioral approaches represent incommensurable ideas, and we show that a combined theoretical strategy appears well-adapted to the complex realities of interfirm networks. Therefore, we join the attempts to return network research to a theory-driven mode rather than a purely method-driven mode (Madhaven et al, 2004; Shipilov and Li, 2008). Second, our findings provide several interesting managerial insights that have the potential to help firms in various forms and market positions to make important strategic and operational decisions to improve their competitiveness. From a practical perspective, previous research has indicated that an exclusive commission pricing right is a preferred option for vendors to set commission fees with platform firms. Our analysis results show that this applies to the more powerful vendor but is not the case for the smaller vendor, as they benefit most from the bilateral commission pricing strategy. An exclusive commission pricing right can deliver better economic performance for both the more powerful vendor and the online platform. However, it is not sustainable because such a performance improvement is at the expense of both vendors paying a higher commission fee and the smaller vendor losing out in the horizontal competition with the rival vendor. From the online platforms' perspective, their success is not just about profit but depends on good customer value (e.g., competitive retail prices and good shopping experiences) and the multi-win among all the vendors regardless of their size or economic power.

Despite the contributions outlined above, this study also has some limitations, and addressing them points out several directions for future research. First, we assume that the two competing vendors sell perfectly substitutable products through the online platform. Although such an assumption can apply to many product categories in the retail sector, one future research direction could be to extend to a more general case including both perfectly and partially substitutable products. Second, a linear and additive deterministic demand function is adopted in this research. Although this widely adopted form of demand function has an advantage of being more analytically tractable, market uncertainty may affect the outcome of alternative commission pricing strategies. One future extension is to use a stochastic demand function to explore how the results might be influenced by demand uncertainty. Furthermore, for online platform firms, one main factor that determines commission price is often the cost (e.g., fulfilment), but this factor is not considered since perfect product substitution often leads to same fulfilment cost. One important extension is to incorporate fulfillment cost into the modeling for a more general product substitution case. Finally, our modeling and analysis of commission pricing strategy on online retail platforms are studied under the assumption of information symmetry. One future extension is to consider the problem under the setting of asymmetric information.

References

Abhishek, V., Jerath, K., & Zhang, Z. J. (2015). Agency selling or reselling? Channel structures in electronic retailing. *Management Science*, 62(8), 2259-2280.

BBC (2018). BBC Business news, Amazon 2017 sales jump by nearly a third, https://www.bbc.co.uk/ne ws/business-42911123, accessed on 23/10/2018

Cai, G.G. (2010). Channel selection and coordination in dual-channel supply chains. *Journal of Retailing*, 86(1), 22-36.

Cao, L., & Li, L. (2015). The impact of cross-channel integration on retailers' sales growth. *Journal of Retailing*, 91(2), 198-216.

Chen, X., Li, L., & Zhou, M. (2012). Manufacturer's pricing strategy for supply chain with warranty period-dependent demand. *Omega*, 40(6), 807-816.

Chen, X., & Wang, X. (2015). Free or bundled: channel selection decisions under different power structures. *Omega*, 53, 11-20.

Chen, X., Wang, X., & Chan, H. K. (2017). Manufacturer and retailer coordination for environmental and economic competitiveness: A power perspective. *Transportation Research Part E: Logistics and Transportation Review*, 97, 268-281.

Chen, X., Wang, X., & Xia, Y. (2019a). Production Coopetition Strategies for Competing Manufacturers that Produce Partially Substitutable Products. *Production and Operations Management*, 28(6), 1446-1464.

Chen, X., Wu, S., Wang, X., & Li, D. (2019b). Optimal pricing strategy for perishable food supply chain. *International Journal of Production Research*, 57(9): 2755-2768.

Feng, Q., & Lu, L. X. (2012). The strategic perils of low cost outsourcing. *Management Science*, 58(6), 1196-1210.

Gallino, S., & Moreno, A. (2014). Integration of online and offline channels in retail: The impact of sharing reliable inventory availability information. *Management Science*, 60(6), 1434-1451.

Gao, D., Wang, N., He, Z., & Jia, T. (2017). The bullwhip effect in an online retail supply chain: a perspective of price-sensitive demand based on the price discount in E-Commerce. *IEEE Transactions on Engineering Management*, 64(2): 134-148.

Geng, X., Tan, Y., & Wei, L. (2018) How Add-on Pricing Interacts with Distribution Contracts. *Production and Operations Management*, 27(4), 605-623.

Hagiu, A., & Wright, J. (2015). Marketplace or reseller? *Management Science*, 61(1), 184-203.

Hao, L., Guo, H., & Easley, R. F. (2017). A mobile platform's in-app advertising contract under agency pricing for app sales. *Production and Operations Management*. 26, 189-202.

Huang, J., Leng, M., & Parlar, M. (2013). Demand functions in decision modeling: A comprehensive survey and research directions. *Decision Sciences*, 44(3), 557-609.

Jiang, B., Jerath, K., & Srinivasan, K. (2011). Firm strategies in the “mid tail” of platform-based retailing. *Marketing Science*, 30(5), 757-775.

Lin, L. (2017). Alibaba’s Net Income, Revenue Surge on Growth in Online Sales, The Wall Street Journal, https://www.wsj.com/articles/alibabas-revenue-surges-fueled-by-consumer-demand-1502 970818, Accessed on 23/10/2018

Lin, L. & Abkowitz, A. (2017) JD.com’s Growth Outpaces China’s E-Commerce Market, The Wall Street Journal, https://www.wsj.com/articles/jd-coms-growth-outpaces-chinas-e-commerce-marke t-1501072430. Accessed on 23/10/2018

Luo, Z., Chen, X., Chen, J., & Wang, X. (2017). Optimal pricing policies for differentiated brands under different supply chain power structures. *European Journal of Operational Research*, 259(2), 437-451.

Luo, Z., Chen, X., & Kai, M. (2018). The effect of customer value and power structure on retail supply chain product choice and pricing decisions. *Omega*, 77, 115-126.

Madhavan, R., Gnyawali, D. R., & He, J. (2004). Two's company, three's a crowd? Triads in cooperative-competitive networks. *Academy of Management Journal*, 47(6), 918-927.

Mantin, B., Krishnan, H., & Dhar, T. (2014). The strategic role of third-party marketplaces in retailing. *Production and Operations Management*, 23(11), 1937-1949.

Mukhopadhyay, S. K., Zhu, X., & Yue, X. (2008). Optimal contract design for mixed channels under information asymmetry. *Production and Operations Management*, 17(6), 641-650.

Ryan, J. K., Sun, D., & Zhao, X. (2012). Competition and coordination in online marketplaces. *Production and Operations Management*, 21(6), 997-1014.

Shipilov, A. V., & Li, S. X. (2008). Can you have your cake and eat it too? Structural holes' influence on status accumulation and market performance in collaborative networks. *Administrative Science Quarterly*, 53(1), 73-108.

Statista (2018). Retail e-commerce sales worldwide from 2014 to 2021 (in billion U.S. dollars), https://www.statista.com/statistics/379046/worldwide-retail-e-commerce-sales/, accessed on 23/10/2018

Tan, Y., & Carrillo, J. E. (2017). Strategic analysis of the agency model for digital goods. *Production and Operations Management*, 26(4), 724-741.

Tian, L., Vakharia, A. J., Tan, Y., & Xu, Y. (2018). Marketplace, reseller, or hybrid: strategic analysis of an emerging E-commerce model. *Production and Operations Management*, 27(8), 1595-1610.

Trivedi, M. (1998). Distribution channels: An extension of exclusive retailership. *Management Science*, 44(7), 896-909.

Wang, Y., Jiang, L., & Shen, Z. J. (2004). Channel performance under consignment contract with revenue sharing. *Management science*, 50(1), 34-47.

Yoo, W. S., & Lee, E. (2011). Internet channel entry: A strategic analysis of mixed channel structures. *Marketing Science*, 30(1), 29-41.

Appendix

Numerical example illustration

Figures 2 and 3 are produced based on numerical examples. According to Table 3, the maximum profits of both vendors and the online platform are now written as the form that is dependent on the maximum marginal profit δ_1 and δ_2, and the sensitivity of sale quantity to price β. Additionally, the ratio of maximum marginal profit $\rho = \delta_1/\delta_2$ shows the gap of competitive advantage between V1 and V2. The maximum profits can be rewritten as another form. We take $\pi_1^A = \frac{(3\delta_1 - 2\delta_2)^2}{36\beta}$ as an example. π_1^A can be rewritten as $\pi_1^A = \frac{(3\delta_1 - 2\delta_2)^2}{36\beta} = \frac{\delta_2^2(3\delta_1/\delta_2 - 2)^2}{36\beta} = \frac{(3\rho-2)^2\delta_2^2}{36\beta}$. The sensitivity of sale quantity to price β and maximum marginal profit of V2, δ_2 are fixed and assigned a value. Note that although $\delta_2 = \alpha_2 - c_2$, we can assign δ_2 directly. Without loss of generality, we define the sensitivity of sale quantity to price is $\beta = 1$ (\$/per unit), that is, each additional unit of sale quantity will reduce the retail price by one unit. The maximum marginal profit of V2 is defined as $\delta_2 = 10$ (\$/per unit), that is, under the condition without commission price, the maximum marginal profit that V2 can gain is \$10 for each product. The assumption of V1 having a competitive advantage over V2 leads to that V1 has a higher maximum marginal profit V2, i.e., $\delta_1 > \delta_2$. Thus $\rho > 1$. According to Propositions 2 and 3, the gap of competitive advantage ρ is an important variable affecting the conclusion. Thus the gap of competitive advantage ρ is chosen as a key independent variable to be the x-axis of figures. Since ρ has a feasible interval $\left(1, \frac{4}{3}\right)$, then Figure 2 can be drawn by going through each unit in the feasible interval. Based on Inflection Points 2 and 3, we can obtain Figure 3 and show the battle behaviors between V1 and V2.

Proof of Lemma 1

When the online platform sets commission price to V1, V2 passively accepts the commission price decided by the online platform and V1. In this case, $s_2 = s_1$. According to the first order condition of $\pi_{S1}(q_1)$, we can get the reaction function with respect to s_1 is $q_1 = \frac{\delta_1 - s_1 - \beta q_2}{2\beta}$. Substituting q_1 into $\pi_O(s_1)$, we have $\pi_O(s_1) = \frac{s_1(\delta_1 - s_1 + \beta q_2)}{2\beta}$. Then, $\frac{d\pi_O(s_1)}{ds_1} =$

$\frac{-2s+\beta q_2+\delta_1}{2}$ and $\frac{d^2\pi_O(s_1)}{ds_1^2}=-\frac{1}{\beta}<0$, we can get $s_1=\frac{\delta_1+\beta q_2}{2}$. Substituting s_1 into $\pi_1(q_1)$ and $\pi_2(q_2)$, we have $\frac{d\pi_1(q_1)}{dq_1}=\frac{-4\beta q_1-3\beta q_2+\delta_1}{2}$, $\frac{d^2\pi_1(q_1)}{dq_1^2}=-2\beta<0$, $\frac{d\pi_2(q_2)}{dq_2}=\frac{-2\beta q_1-6\beta q_2-\delta_1+2\delta_2}{2}$, and $\frac{d^2\pi_2(q_2)}{dq_2^2}=-3\beta<0$. So $\pi_1(q_1)$ is concave in q_1 and $\pi_2(q_2)$ is concave in q_2. We get $q_1^A=\frac{3\delta_1-2\delta_2}{6\beta}$ and $q_2^A=\frac{4\delta_2-3\delta_1}{9\beta}$. Therefore, $s_1^A=s_2^A=\frac{3\delta_1+2\delta_2}{9}$, $p_1^A=c_1+\frac{15\delta_1-2\delta_2}{18}$, $p_2^A=c_2+\frac{16\delta_2-3\delta_1}{18}$, $\pi_1^A=\frac{(3\delta_1-2\delta_2)^2}{36\beta}$, $\pi_2^A=\frac{(3\delta_1-4\delta_2)^2}{54\beta}$, and $\pi_O^A=\frac{(3\delta_1+2\delta_2)^2}{162\beta}$. Because p_1^A, p_2^A, q_1^A, and q_2^A should be nonnegative, then $1<\rho<\frac{4}{3}$ must be satisfied.

When the online platform sets commission price to V2, V1 passively accepts the commission price decided by the online platform and V2. In this case, $s_1=s_2$. According to the first order condition of $\pi_{S2}(q_2)$, we can get the reaction function with respect to s_2 is $q_2=\frac{\delta_2-s_2-\beta q_1}{2\beta}$. Substituting q_2 into $\pi_O(s_2)$, we have $\pi_O(s_2)=\frac{s_2(\delta_2-s_2-\beta q_1)}{2\beta}$. Then, $\frac{d\pi_O(s_2)}{ds_2}=\frac{-2s_2+\beta q_1+\delta_2}{2\beta}$ and $\frac{d^2\pi_O(s_2)}{ds_2^2}=-\frac{1}{\beta}<0$, we can get $s_2=\frac{\delta_2+\beta q_1}{2}$. Substituting s_2 into $\pi_1(q_1)$ and $\pi_2(q_2)$, we have $\frac{d\pi_1(q_1)}{dq_1}=\frac{-6\beta q_1-2\beta q_2+2\delta_1-\delta_2}{2}$, $\frac{d^2\pi_1(q_1)}{dq_1^2}=-3\beta<0$, $\frac{d\pi_2(q_2)}{dq_2}=\frac{-3\beta q_1-4\beta q_2+\delta_2}{2}$, and $\frac{d^2\pi_2(q_2)}{dq_2^2}=-2\beta<0$. So $\pi_1(q_1)$ is concave in q_1, and $\pi_2(q_2)$ is concave in q_2. We get $q_1^B=\frac{4\delta_1-3\delta_2}{9\beta}$ and $q_2^B=\frac{4\delta_1-3\delta_2}{6\beta}$. Therefore, $s_1^B=s_2^B=\frac{2\delta_1+3\delta_2}{9}$, $p_1^B=c_1+\frac{16\delta_1-3\delta_2}{18}$, $p_2^B=c_2+\frac{15\delta_2-2\delta_1}{18}$, $\pi_1^B=\frac{(4\delta_1-3\delta_2)^2}{54\beta}$, $\pi_2^B=\frac{(2\delta_1-3\delta_2)^2}{36\beta}$, and $\pi_O^B=\frac{(3\delta_2+2\delta_1)^2}{162\beta}$. Because p_1^B, p_2^B, q_1^B, and q_2^B should be nonnegative, then $1<\rho<\frac{3}{2}$ must be satisfied.

Under a discriminatory pricing setting, the online platform sets commission price to both V1 and V2; that is, $s_1\neq s_2$. According to the first order condition of $\pi_1(q_1)$ and $\pi_2(q_2)$, we can get the reaction function with respect to s is $q_1=\frac{-2s_1+s_2+2\delta_1-\delta_2}{3\beta}$ and $q_2=\frac{s_1-2s_2-\delta_1+2\delta_2}{3\beta}$. Substituting q_1 and q_2 into $\pi_O(s_1,s_2)$, we have $\pi_O(s_1,s_2)=\frac{-2s_1^2+2s_1s_2-2s_2^2+2s_1\delta_1-s_2\delta_1-s_1\delta_2+2s_2\delta_2}{3\beta}$. Then, $\frac{\partial\pi_O(s_1,s_2)}{\partial s_1}=\frac{-4s_1+2s_2+2\delta_1-\delta_2}{3\beta}$, $\frac{\partial\pi_O(s_1,s_2)}{\partial s_2}=\frac{2s_1-4s_2-\delta_1+2\delta_2}{3\beta}$, $\frac{\partial^2\pi_O(s_1,s_2)}{\partial s_1^2}=-\frac{4}{3\beta}<0$, $\frac{\partial^2\pi_O(s_1,s_2)}{\partial s_2^2}=-\frac{4}{3\beta}<0$, and $\frac{\partial^2\pi_O(s_1,s_2)}{\partial s_1\partial s_2}=\frac{\partial^2\pi_O(s_1,s_2)}{\partial s_2\partial s_1}=$

$\frac{2}{3\beta}$, so $\begin{vmatrix} \frac{\partial^2 \pi_O(s_1,s_2)}{\partial s_1^2} & \frac{\partial^2 \pi_O(s_1,s_2)}{\partial s_1 \partial s_2} \\ \frac{\partial^2 \pi_O(s_1,s_2)}{\partial s_2 \partial s_1} & \frac{\partial^2 \pi_O(s_1,s_2)}{\partial s_2^2} \end{vmatrix} = \frac{4}{3\beta^2} > 0$. Therefore, $\pi_O(s_1, s_2)$ is jointly concave in s_1 and s_2. From $\frac{\partial \pi_O(s_1,s_2)}{\partial s_1} = \frac{\partial \pi_O(s_1,s_2)}{\partial s_2} = 0$ we have $s_1^C = \frac{\delta_1}{2}$ and $s_2^C = \frac{\delta_2}{2}$. Substituting s_1^C and s_2^C into q_1 and q_2, we have $q_1^C = \frac{2\delta_1 - \delta_2}{6\beta}$, $q_2^C = \frac{2\delta_2 - \delta_1}{6\beta}$. Therefore, $p_1^C = c_1 + \frac{5\delta_1 - \delta_2}{6}$, $p_2^C = c_2 + \frac{5\delta_2 - \delta_1}{6}$, $\pi_1^C = \frac{(2\delta_1 - \delta_2)^2}{36\beta}$, $\pi_2^C = \frac{(\delta_1 - 2\delta_2)^2}{36\beta}$, and $\pi_O^C = \frac{\delta_1^2 + \delta_2^2 - \delta_1\delta_2}{6\beta}$. Because p_1^C, p_2^C, q_1^C, and q_2^C should be nonnegative, then $1 < \rho < 2$ must be satisfied.

Proof of Proposition 1

From the derivation of equilibrium solutions in Table 2, it is easy to know $\pi_O^A - \pi_O^B = \frac{5(\delta_1 - \delta_2)(\delta_1 + \delta_2)}{162\beta} > 0$. In addition, $\pi_O^C - \pi_O^A = \frac{18\delta_1^2 - 39\delta_1\delta_2 + 23\delta_2^2}{162\beta} = \frac{18\rho^2 - 39\rho + 23}{162\beta/\delta_2^2}$, define numerator $f_1(\rho) = 18\rho^2 - 39\rho + 23 = 0$, because $(-39)^2 - 4 * 18 * 23 < 0$, then for all $1 < \rho < \frac{4}{3}$, $f_1(\rho) > 0$. Hence, $\pi_O^C > \pi_O^A$. Therefore, $\pi_O^C > \pi_O^A > \pi_O^B$.

Proof of Corollary 1

(a) For V1, $\pi_1^A - \pi_1^C = \frac{(5\delta_1 - 3\delta_2)(\delta_1 - \delta_2)}{36\beta} > 0$. $\pi_1^A - \pi_1^B = -\frac{5\delta_1^2 - 12\delta_1\delta_2 + 6\delta_2^2}{108\beta} = -\frac{5\rho^2 - 12\rho + 6}{108\beta/\delta_2^2} > 0$ for all $1 < \frac{\delta_1}{\delta_2} < \frac{4}{3}$. $\pi_1^B - \pi_1^C = \frac{20\delta_1^2 - 36\delta_1\delta_2 + 15\delta_2^2}{108\beta} = \frac{20\rho^2 - 36\rho + 15}{108\beta/\delta_2^2}$. Define $f_2(\rho) = 20\rho^2 - 36\rho + 15 = 0$; two roots can be derived, $\rho_3 = \frac{9-\sqrt{6}}{10}$ and $\rho_4 = \frac{9+\sqrt{6}}{10}$, and both are positive. Because $f_2(1) = -1 < 0$, then $\rho_3 < 1 < \rho_4$. In addition, $f_2\left(\frac{4}{3}\right) = \frac{32}{9}$, Therefore, we have when $1 < \rho < \rho_4$, $f_2(\rho) < f_2(\rho_4) = 0$, namely, $\pi_1^B < \pi_1^C$, and when $\rho_4 < \rho < \frac{4}{3}$, we have $f_2(\rho) > f_2(\rho_4) = 0$, namely, $\pi_1^B > \pi_1^C$. Here we define $\frac{9+\sqrt{6}}{10}$ as an Inflection Point 1, or IP1 for short.

(b) For V2, $\pi_2^C - \pi_2^B = -\frac{(3\delta_1 - 5\delta_2)(\delta_1 - \delta_2)}{36\beta} > 0$, $\pi_2^B - \pi_2^A = -\frac{6\delta_1^2 - 12\delta_1\delta_2 + 5\delta_2^2}{108\beta} = -\frac{6\rho^2 - 12\rho + 5}{108\beta/\delta_2^2}$. Define $f_3(\rho) = 6\rho^2 - 12\rho + 5 = 0$, two roots can be derived, $\rho_5 = \frac{6-\sqrt{6}}{6}$ and $\rho_6 = \frac{6+\sqrt{6}}{6}$, and both are positive. Because $f_3(1) = -1 < 0$ and $f_3\left(\frac{4}{3}\right) = -\frac{1}{3}$, then

$\rho_5 < 1 < \frac{4}{3} < \rho_6$. Hence, $f_3(\rho) < 0$ for all $1 < \rho < \frac{4}{3}$. Therefore, $\pi_2^B > \pi_2^A$.

Proof of Proposition 2

V1 can successfully capture the exclusive commission pricing right when two conditions are satisfied for $1 < \rho < \frac{4}{3}$, namely, $(\pi_1^A - \pi_1^C) + \pi_O^A > \pi_O^C$ and $\pi_1^A - \pi_1^C > \pi_2^C - \pi_2^A$.

The first condition is to ensure that under an exclusive commission pricing right, V1 can make bigger pie. $[(\pi_1^A - \pi_1^C) + \pi_O^A] - \pi_O^C = \frac{9\delta_1^2 + 6\delta_1\delta_2 - 19\delta_2^2}{324\beta} = \frac{9\rho^2 + 6\rho - 19}{324\beta/\delta_2^2}$. Define $f_4(\rho) = 9\rho^2 + 6\rho - 19$, let $f_4(\rho) = 0$, two roots can be derived, $\rho_7 = \frac{-1-2\sqrt{5}}{3}$ and $\rho_8 = \frac{-1+2\sqrt{5}}{3}$. It is easy to know that $1 < \frac{2\sqrt{5}-1}{3} < \frac{4}{3}$, so we have when $1 < \rho \le \frac{2\sqrt{5}-1}{3}$, $f_4(\rho) \le 0$, and when $\frac{2\sqrt{5}-1}{3} < \rho < \frac{4}{3}$, $f_4(\rho) > 0$. That is, when $1 < \rho \le \frac{2\sqrt{5}-1}{3}$, then $(\pi_1^A - \pi_1^C) + \pi_O^A \le \pi_O^C$, which means capturing the exclusive commission pricing right will hurt both V1 and the online platform at least, hence V1 has no desire to do that. While $\frac{2\sqrt{5}-1}{3} < \rho < \frac{4}{3}$, then $(\pi_1^A - \pi_1^C) + \pi_O^A > \pi_O^C$, hence V1 has a desire to capture the exclusive commission pricing right. However, whether V1 can successfully capture the exclusive commission pricing right depends on the second condition. Here we define $\frac{2\sqrt{5}-1}{3}$ as an Inflection Point 2, or IP2 for short.

The second condition is to ensure that V2 cannot stop V1 from getting the exclusive commission pricing right. $(\pi_1^A - \pi_1^C) - (\pi_2^C - \pi_2^A) = \frac{30\delta_1^2 - 60\delta_1\delta_2 + 29\delta_2^2}{108\beta} = \frac{30\rho^2 - 60\rho + 29}{108\beta/\delta_2^2}$. Define $f_5(\rho) = 30\rho^2 - 60\rho + 29$, let $f_5(\rho) = 0$, two roots can be derived, $\rho_9 = 1 - \frac{1}{\sqrt{30}}$ and $\rho_{10} = 1 + \frac{1}{\sqrt{30}}$. It is easy to know that $1 < 1 + \frac{1}{\sqrt{30}} < \frac{4}{3}$, so we have when $1 < \rho \le 1 + \frac{1}{\sqrt{30}}$, $f_4(\rho) < 0$, and when $1 + \frac{1}{\sqrt{30}} < \rho < \frac{4}{3}$, $f_4(\rho) > 0$. That is, when $1 < \rho \le 1 + \frac{1}{\sqrt{30}}$, then $\pi_1^A - \pi_1^C < \pi_2^C - \pi_2^A$, which means V2 can stop V1. In addition, when $1 + \frac{1}{\sqrt{30}} < \rho < \frac{4}{3}$, $\pi_1^A - \pi_1^C > \pi_2^C - \pi_2^A$, which means V2 cannot stop V1. Here we define $1 + \frac{1}{\sqrt{30}}$ as an Inflection Point 3, or IP3 for short.

Because $IP2 < IP3$, so the feasible interval $\rho \in \left(1, \frac{4}{3}\right)$ is divided into three parts.

When $\rho \in (1, IP2]$, V1 has no desire; and when $\rho \in (IP2, IP3]$, V1 has the desire but V2 stops it; and when $\rho \in \left(IP3, \frac{4}{3}\right)$, V1 has desire and V2 cannot stop it, namely, the exclusive commission pricing right is captured finally.

Proof of Proposition 3

From Corollary 1, we know that $\pi_2^C > \pi_2^B$, so exclusive commission pricing strategy with the online platform is worse for V2, so it has no desire to do that. However, once V1 captures the exclusive commission pricing right, the profit of V2 will be much worse since $\pi_2^B > \pi_2^A$. Therefore, V2 can do something, such as share a fraction of its profit with the online platform, to stop V1 and maintain the case where the online platform sets commission prices to both vendors, the opposite of the second condition in the proof of Proposition 2, namely, $\pi_1^A - \pi_1^C < \pi_2^C - \pi_2^A$ ensures that V2 can stop V1 from getting the exclusive commission pricing right. Therefore, according to the proof of Proposition 2, only when $1 < \rho \leq IP3$, can V2 do so.

Proof of Proposition 4

1. $\pi_{SC}^C - \pi_{SC}^B = -\frac{41\delta_1^2 - 102\delta_1\delta_2 + 54\delta_2^2}{324\beta} = -\frac{41\rho^2 - 102\rho + 54}{324\beta/\delta_2^2}$. Define $f_6(\rho) = 41\rho^2 - 102\rho + 54$, let $f_6(\rho) = 0$, two roots can be derived, $\rho_{11} = \frac{3(17-\sqrt{43})}{41}$ and $\rho_{12} = \frac{3(17+\sqrt{43})}{41}$. It is easy to know that $\frac{3(17-\sqrt{43})}{41} < 1 < \frac{3(17+\sqrt{43})}{41} < \frac{4}{3}$, hence for all $1 < \rho < \frac{4}{3}$ $f_6(\rho) < 0$. Therefore, $\pi_{SC}^C > \pi_{SC}^B$. $\pi_{SC}^A - \pi_{SC}^B = \frac{13(\delta_1 - \delta_2)(\delta_1 + \delta_2)}{324\beta} > 0$. In addition, $\pi_{SC}^C - \pi_{SC}^A = -\frac{54\delta_1^2 - 102\delta_1\delta_2 + 41\delta_2^2}{324\beta} = -\frac{54\rho^2 - 102\rho + 41}{324\beta/\delta_2^2}$. Define $f_7(\rho) = 54\rho^2 - 102\rho + 41$, let $f_7(\rho) = 0$, two roots can be derived, $\rho_{13} = \frac{17-\sqrt{43}}{18}$ and $\rho_{14} = \frac{17+\sqrt{43}}{18}$. It is easy to know $\frac{17-\sqrt{43}}{18} < 1 < \frac{17+\sqrt{43}}{18} < \frac{4}{3}$, so when $1 < \rho \leq \frac{17+\sqrt{43}}{18}$, then $\pi_{SC}^C \geq \pi_{SC}^A$; when $\frac{17+\sqrt{43}}{18} < \rho < \frac{4}{3}$, then $\pi_{SC}^A > \pi_{SC}^C$. Here we define $\frac{17+\sqrt{43}}{18}$ as an Inflection Point 4, or IP4 for short.
2. $p_1^A - p_1^C = p_2^A - p_2^C = \frac{\delta_2}{18} > 0$, so we get $p_1^A > p_1^C$ and $p_2^A > p_2^C$.

Proof of Proposition 5

From Table 2, we have $s_1^A - s_1^C = \frac{-3\delta_1 + 4\delta_2}{18} > 0$ for all $1 < \rho < \frac{4}{3}$.