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To or Not to Cooperate with Third-Party E-commerce Platform: The Influence of Commission Fee and Service Level

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Abstract: The third-party e-commerce platform is now widely adopted by small and medium sized retailers. For the retailer, commission fee and service level provided by the platform are two key factors influencing the pricing strategy and sales profit. However, these two factors are rarely considered in previous operations models. Taking both factors into consideration, we formulate the decision-making problem of third-party e-commerce as a Stackelberg game where the platform is the leader and the retailer is the follower. Given the platform's commission fee, we derive optimal sales price for the retailer and optimal service level for the platform. Our result shows that the platform's service level must be high enough to guarantee a positive profit and the effect of commission fee is dependent. Precisely, when the commission fee is small (or large) enough, the retailer and the platform can reach a consensus to increase (or to decrease) it. When it is moderate, they will bargain with each other, i.e., the retailer wants to decrease commission fee but the platform wants to increase it. Based on these observations, retailers are able to choose sales channel with more profit by comparing online store and offline shop.

Keywords: E-commerce, Marketing, Retail operations, Commission fee, Service level

1. INTRODUCTION

With the rapid growth of online shopping, an e-commerce model has been widely studied in both theoretical and practical fields (please see [1,2] and also the references therein). Various kinds of retailers have chosen online e-commerce platform to sell product [3,4]. In practice, there are two main modes for retailers to adopt e-commerce platform. Under the first mode, retailers manage online platforms by themselves and sell product through their own platforms, such as Suning.com and Gome.com.cn (two larger proprietary online shops in China) and Walmart.com. We call this kind of mode *self-operation* pattern. Under the second mode, retailers cooperate with one third-party e-commerce platform and pay certain commission fee to sell product through the platform, like the business operated on Taobao Marketplace, Yahoo Shopping, and Amazon's Marketplace. We call this second mode *third-party* pattern. Dukes and Liu briefly compare these two patterns from the perspective of consumers' search environments[5]. From the angle of business operations, the retailer has to possess enough working capital and master more professional skills to operate one self-operation e-commerce platform. As a result, more retailers, especially small and medium sized retailers, choose the third-party platform to sell product. Like in China, more than 6 million small and medium sized retailers sell product on Taobao Marketplace [6].

For small and medium sized retailers, the third-party e-commerce platform brings them two main benefits. Firstly, the unit sales cost can be reduced because of the low cost of online store [7]. Secondly, the online store may create more demand for retailers because of the popularity of online shopping which is almost not restricted by space-time [8]. At the beginning of e-commerce, these two benefits are certainly remarkable. However, as the monopolization of third-party platform, these benefits are both subject to the platform's commission fee and service level for retailers. This fact has already been confirmed by the evidences of China.

On one hand, the bargaining power of monopoly e-commerce platform becomes stronger and stronger and the platform has an intention to increase commission fee. Recently, Meituan.com and Dianping.com, two largest

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third-party online group-buying platforms in China, have increased the commission fee universally since their combination. For example, the commission fee for KTV (a very popular singing entertainment in China) is increased from 2% to 12% [9]. On the other hand, the competition among online retailers is becoming fiercer and fiercer because of a surge in online stores, and it is more difficult for retailers to attract a substantial number of shoppers visiting their online stores. To help retailers attract enough online shoppers, the e-commerce platform has to make greater efforts on improving service level, including broad advertising, in-depth data mining, etc. In return, retailers should pay the platform more commission fee.

Anyway, the benefits of e-commerce have been becoming less and less significant for online retailers in the third-party pattern. In reality, a larger number of retailers are with a considerable loss in Chinese e-commerce. For example, there are more than 6 million small and medium sized retailers operating online stores on Taobao Marketplace but only less than 0.3 million gain profit, that is, more than 95% retailers are with a loss [6]. Another example is from Chinese Agricultural Product E-commerce Development Report, which shows that only 1% retailers gain profit, 7% are with a huge loss, 88% are with a slight loss, and 4% are at a break-even level among nearly 4000 e-retailers of agricultural products [10]. Under new situation, one of the greatest challenges currently faced by small and medium sized retailers is whether or not to cooperate with one third-party platform. If so, the following challenge is to determine optimal pricing strategy based on the platform’s commission fee and service level. Correspondingly, for the third-party platform, the most challenge is determining appropriate commission fee and service level to achieve a win-win situation in which the retailer will gain more profit through online channel than offline channel. From the perspective of game theory, we strive to answer these questions by exploring the influence of commission fee and service level on gross profit for both participants in this paper.

There are many works on tradeoff between offline strategy and online strategy for retailers in the literature. The most are from the perspective of channel coordination (please see [11-15] and also the references therein). In these studies, it is usually assumed that the retailer can operate offline shop and online store simultaneously. As a result, the main problem is to coordinate the sales prices for both channels maximizing the total profit, such as the challenge faced by Suning.com and Gome.com.cn. However, for most small and medium sized retailers, especially for the new entrants, they don’t have enough capital and technology to engage in both channels. From this point of view, we assume that the retailer has to make a choice between online channel and offline channel based on the respective profit in this paper.

There have obviously been very few works considering the effect of e-commerce platform’s commission fee and service level on retailer’s decisions. To the best of our knowledge, Ni et al. firstly studies the influence of commission fee and service level under one special group-buying environment [16]. In this paper, we also focus on the effect of commission fee and service level on the benefits of e-commerce and derive the optimal decisions for both the retailer and the platform from the perspective of game theory. We find that the platform’s service level has a significant influence on retailer’s choice. Consequently, the platform’s relative cost effectiveness in operational deployment of demand expanding must be high enough to attract retailers choosing online strategy rather than offline strategy. Considering the effect of commission fee, the retailer and the platform will bargain with each other given a moderate commission fee. That is, the retailer wants to decrease commission fee but the platform wants to increase it. However, given a small (or a large) commission fee, both of them have a consistent desire and thus can reach a consensus to increase (or to decrease) commission fee. Based on these analyses, we further propose a basic procedure for retailers to choose sales channel by comparing the profit of online store and offline shop.

The rest of this paper is organized as follows. We introduce the basic model for the market in Section 2 and the detailed analysis is given in Section 3. Finally, Section 4 provides conclusions and future research directions.

2. THE BASIC MODEL

Consider one retailer's two choices of sales channel, through a self-operation offline shop or through an online store on one third-party e-commerce platform. If the retailer chooses the offline channel, we assume the local potential demand scale is λ and also normalize $\lambda = 1$ without loss of generality. Let random variable v represent local consumer's valuation, which is drawn from the interval of $[a, b]$ with cumulative distribution function $F(\cdot)$ and probability density function $f(\cdot)$ where $0 \le a < b \le 1$. Therefore, given the sales cost c_{off} and sales price p_{off}, the retailer's profit adopting offline strategy is $R_{off}^{r} = (p_{off} - c_{off})(1 - F(p_{off}))$. Of course, it needs the condition $c_{off} < b$. And thus, the retailer's offline pricing problem can be formulated as follows:

$$\max_{p_{off}} R_{off}^{r} = (p_{off} - c_{off})(1 - F(p_{off})) \tag{1}$$

If the retailer chooses the online strategy cooperating with one third-party e-commerce platform, the retailer will receive one of main benefits of e-commerce, i.e., decreased unit sales cost. Thus, we have $c_{on} < c_{off}$ where c_{on} is the unit sales cost through the third-party platform. On the other hand, the online e-commerce channel can attract much wider range of consumers than the offline channel, which means the online consumers' valuation has a larger span than the offline consumers. Thus, we assume that the online consumer's valuation is drawn from the interval of $[\alpha, \beta]$ with cumulative distribution function $G(\cdot)$ and probability density function $g(\cdot)$ where $0 \le \alpha \le a < b \le \beta \le 1$.

Considering service efficiency, we assume that the platform's investment in service level has a decreasing return to the scale of potential demand. Namely, it is harder to provide the next unit of potential demand than the last one. This diminishing return of service effort can be captured by the quadratic form of service cost. Following [17], we assume that the cost of providing service level e, i.e., realizing an online potential demand scale of e, is $\frac{1}{2}\eta e^2$ where $\eta > 0$ denotes the service cost factor and captures the platform's relative cost effectiveness in operational deployment of demand expanding. In return, the third-party platform extracts a certain commission fee ρ from the retailer's unit sales of product. Thus, given the unit online sales cost c_{on} and sales price p_{on}, the retailer's profit adopting online strategy is equal to $R_{on}^{r} = (p_{on} - \rho - c_{on})(1 - G(p_{on}))e$. And the third-party platform's profit is equal to $R_{on}^{t} = \rho(1 - G(p_{on}))e - \frac{1}{2}\eta e^2$.

In this paper, we model the relationship between the third-party platform and the retailer as a sequential non-cooperative game, where the third-party platform is the leader and the retailer is the follower. This kind of static bi-level game model is usually called Stackelberg game. During the process of our Stackelberg game, the third-party platform first announces the unit commission fee ρ and the service level e, and the retailer then decides the online sales price p_{on} according to the platform's decisions. Besides the sequential game order, we also assume they both know the market information including their respective cost structures and consumer's value distribution, and they also know each other perfectly. Therefore, the online market decision-making problem can be formulated as follows:

$$\begin{cases} \max\limits_{\rho,e} R_{on}^{t} = \rho(1-G(p_{on}^{*}))e - \frac{1}{2}\eta e^{2} \\ p_{on}^{*} \text{ is derived from solving the following problem} \\ \max\limits_{p_{on}} R_{on}^{r} = (p_{on}-\rho-c_{on})(1-G(p_{on}))e \end{cases} \tag{2}$$

Generally, the retailer can decide to sell product either through an offline shop or through an online store by comparing the resulting profit of problem (1) and problem (2). However, the precise decision is not intuitive and it depends on both the specific market parameters and the retailer's bargaining power. In the following sections, we will give the detailed analysis.

3. CHANNEL CHOOSING FOR THE RETAILER

To get technical results and managerial insights, we assume that both $F(\cdot)$ and $G(\cdot)$ are uniform distributions. In the following, we will first derive the optimal decisions for both the offline strategy and the online strategy, and then choose the sales channel with more profit for the retailer.

3.1 Optimal decisions for offline strategy

Based on our assumption that the local consumer's valuation v follows the uniform distribution on $[a,b]$, we can rewrite the problem (1) as follows:

$$\max_{p_{off}} R_{off}^{r} = (p_{off}-c_{off})(1-\frac{p_{off}-a}{b-a}) \tag{4}$$

The solution to problem (4) is straightforward and we directly derive the optimal offline sales price for the retailer as Proposition 1.

PROPOSITION 1. *For the offline strategy, the retailer's optimal sales price and maximal profit are respectively equal to*

(1) $p_{off}^{*} = \frac{b+c_{off}}{2}$ *and* $R_{off}^{r*} = \frac{(b-c_{off})^{2}}{4(b-a)}$ *when* $a < \frac{b+c_{off}}{2}$ *;*

(2) $p_{off}^{*} = a$ *and* $R_{off}^{r*} = a-c_{off}$ *when* $a \geq \frac{b+c_{off}}{2}$ *.*

From the Proposition 1, we find when the lower bound of consumer's valuation is large enough, i.e., $a \geq \frac{b+c_{off}}{2}$, the retailer's dominant offline strategy is a kind of *volume* policy. Otherwise, if $a < \frac{b+c_{off}}{2}$, the retailer's dominant offline strategy is a kind of *margin* policy. Here, a margin policy services only one part of customers with larger valuation and a volume policy services all the customers.

3.2 Optimal decisions for online strategy

In this section, we study the optimal decision-making problem formulated by (2) using the game-theoretical approach. The leader in every decision scenario makes his decision to maximize his own profit, conditioned on the follower's response. The problem is solved backwards. Thus, we first derive the optimal decision for the retailer and then for the platform.

For the online market, consumer's valuation v follows the uniform distribution on $[\alpha,\beta]$ where $0\le\alpha\le a<b\le\beta\le 1$. From the formulation of problem (2), given the platform's commission fee ρ and servicer level e, the basic problem for the retailer can be generalized as follows:

$$\max_{p_{on}} R_{on}^{r}=(p_{on}-\rho-c_{on})(1-\frac{p_{on}-\alpha}{\beta-\alpha})e \tag{5}$$

It is obviously that problem (5) is an optimization with a quadratic function. The solution is straightforward, and thus we directly give the optimal solution as shown in Proposition 2.

PROPOSITION 2. *For the online strategy, given the platform's commission fee ρ and servicer level e, the retailer's optimal online sales price is equal to* $p_{on}^{*}=\max\{\alpha,\frac{\beta+c_{on}+\rho}{2}\}$.

First, we find that the retailer's optimal price depends on ρ but doesn't depend on e. Second, the boundary value of ρ is equal to $\rho_0=2\alpha-\beta-c_{on}$. If $\rho<\rho_0$, then $p_{on}^{*}=\alpha$. Otherwise, if $\rho\ge\rho_0$, then $p_{on}^{*}=\frac{\beta+c_{on}+\rho}{2}$. Of course, the feasible value of ρ should be no less than 0.

Next, we solve the optimal commission fee ρ and servicer level e for the third-party platform (the leader) based on the retailer's optimal reaction. From the above analysis, when $\rho_0=2\alpha-\beta-c_{on}>0$ the basic problem for the platform is generalized as follows:

$$\max_{\rho,e} R_{on}^{t}=\begin{cases}\rho e-\frac{1}{2}\eta e^2, & if\ 0<\rho<\rho_0\\ \rho e(1-\frac{\frac{\beta+c_{on}+\rho}{2}-\alpha}{\beta-\alpha})-\frac{1}{2}\eta e^2, & if\ \rho\ge\rho_0\end{cases} \tag{6}$$

Of course, when $\rho_0=2\alpha-\beta-c_{on}\le 0$, the platform's profit function of problem (6) will degenerate to $R_{on}^{t}=\rho e(1-\frac{(\beta+c_{on}+\rho)/2-\alpha}{\beta-\alpha})-\frac{1}{2}\eta e^2$ for all $\rho>0$. It is obviously that the function $R(\rho)=\rho e(1-\frac{(\beta+c_{on}+\rho)/2-\alpha}{\beta-\alpha})-\frac{1}{2}\eta e^2$ is quadratic with ρ and gets its maximum value at $\rho=\frac{\beta-c_{on}}{2}$. Additionally, we have that the objective function R_{on}^{t} of problem (6) is linearly increasing with ρ when $\rho \le \rho_0$ and quadratic with ρ when $\rho \ge \rho_0$. Therefore, the solution of problem (6) depends on the values of market parameters as shown in Proposition 3.

PROPOSITION 3. *For the online strategy, given the market parameters* α, β, *and* c_{on}, *if*

(1) $\alpha < \frac{3\beta + c_{on}}{4}$, *i.e.,* $\rho_0 < \frac{\beta - c_{on}}{2}$, *then the platform's profit is increasing with* $\rho \in (0, \frac{\beta - c_{on}}{2}]$ *and then decreasing with* $\rho \ge \frac{\beta - c_{on}}{2}$. *And thus, the optimal commission fee and service level are equal to* $\rho^* = \frac{\beta - c_{on}}{2}$ *and* $e^* = \frac{(\beta - c_{on})^2}{8\eta(\beta - \alpha)}$, *respectively;*

(2) $\alpha \ge \frac{3\beta + c_{on}}{4}$, *i.e.,* $\rho_0 \ge \frac{\beta - c_{on}}{2}$, *then the third-party e-commerce platform's profit is increasing with* $\rho \in (0, \rho_0]$ *and then decreasing with* $\rho \ge \rho_0$. *And thus, the optimal commission fee and service level are equal to* $\rho^* = \rho_0$ *and* $e^* = \frac{\rho_0}{\eta}$, *respectively.*

Based on Proposition 2 and Proposition 3, we directly have the retailer's optimal online sales price as shown in Proposition 4.

PROPOSITION 4. *For the online strategy, given the market parameters* α, β, *and* c_{on}, *the retailer's optimal online sales price is equal to* $p_{on}^* = \frac{3\beta + c_{on}}{4}$ *when* $\alpha < \frac{3\beta + c_{on}}{4}$ *and* $p_{on}^* = \alpha$ *when* $\alpha \ge \frac{3\beta + c_{on}}{4}$.

Summarily, given any value of $\rho > 0$ in the third-party pattern, we can solve the platform's optimal service level e^* as $e^*(\rho) = \begin{cases} \frac{\rho}{\eta}, & if\ 0 < \rho < \rho_0 \\ \frac{\rho(\beta - c_{on} - \rho)}{2\eta(\beta - \alpha)}, & if\ \rho \ge \rho_0 \end{cases}$. And thus, the retailer's optimal sales price is equal to $p_{on}^*(\rho) = \begin{cases} \alpha, & if\ 0 < \rho < \rho_0 \\ \frac{\beta + c_{on} + \rho}{2}, & if\ \rho \ge \rho_0 \end{cases}$. Substituting ρ and the corresponding $e^*(\rho)$ and $p_{on}^*(\rho)$ into the profit functions of (5) and (6), we find that both the retailer's and the platform's profits are positive given $\rho \in (0, \beta - c_{on})$ but neither is larger than 0 given $\rho \ge \beta - c_{on}$. That is, the feasible range of commission fee is $\rho \in (0, \beta - c_{on})$ in the third-party e-commerce pattern.

3.3 Optimal channel choosing

Although the optimal sales profit is positive given $\rho \in (0, \beta - c_{on})$, the retailer has to compare online strategy and offline strategy to choose the one with more profit. Next, we firstly derive the feasible range of commission fee during which it is more profitable adopting online strategy than offline strategy for the retailer, and then give the detailed analysis about optimal decisions based on this tradeoff. For convenience, we divide the market into two scenarios, i.e., $\alpha < \frac{3\beta + c_{on}}{4}$ and $\alpha \ge \frac{3\beta + c_{on}}{4}$ in the following.

3.3.1 The scenario with $\alpha < \frac{3\beta + c_{on}}{4}$

In this scenario, we have two possible cases, i.e., $\rho_0 \le 0$ or $\rho_0 > 0$ considering the value of ρ_0.

CASE 1 $\rho_0 \le 0$, i.e., $\alpha \le \frac{\beta + c_{on}}{2}$. In this case, any feasible commission fee $\rho \in (0, \beta - c_{on})$ is always larger than ρ_0, i.e., $\rho > \rho_0$, and thus we have $p_{on}^*(\rho) = \frac{\beta + c_{on} + \rho}{2}$ and $e^*(\rho) = \frac{\rho(\beta - c_{on} - \rho)}{2\eta(\beta - \alpha)}$ from the analysis in Section 3.2. Consequently, the retailer's profit function can be generalized as $R_{on}^r(\rho) = (p_{on} - \rho - c_{on})(1 - \frac{p_{on} - \alpha}{\beta - \alpha})e = \frac{\rho(\beta - \rho - c_{on})^3}{8\eta(\beta - \alpha)^2}$.

For $R_{on}^r(\rho)$, the first-order derivative is equal to $\frac{dR_{on}^r(\rho)}{d\rho} = \frac{(\beta - c_{on} - \rho)^2}{8\eta(\beta - \alpha)^2}(\beta - c_{on} - 4\rho)$.

Let $\frac{dR_{on}^r(\rho)}{d\rho} = 0$, we have three roots, i.e., $\rho^1 = \rho^2 = \beta - c_{on}$ and $\rho^3 = \frac{\beta - c_{on}}{4}$. Therefore, we have that $R_{on}^r(\rho)$ is firstly increasing with $\rho \in (0, \frac{\beta - c_{on}}{4}]$ and then decreasing with $\rho \in [\frac{\beta - c_{on}}{4}, \beta - c_{on})$.

Let $\rho = \frac{\beta - c_{on}}{4}$, we have that the maximum value of $R_{on}^r(\rho)$ is equal to $R_{on}^r(\frac{\beta - c_{on}}{4}) = \frac{27(\beta - c_{on})^4}{2048\eta(\beta - \alpha)^2}$. And thus, the condition for the retailer to adopt online strategy rather than offline strategy is $R_{on}^r(\frac{\beta - c_{on}}{4}) = \frac{27(\beta - c_{on})^4}{2048\eta(\beta - \alpha)^2} > R_{off}^{r*}$, i.e., $\eta < \frac{27(b-a)(\beta - c_{on})^4}{512(\beta - \alpha)^2(b - c_{off})^2}$ when $a < \frac{b + c_{off}}{2}$ and $\eta < \frac{27(\beta - c_{on})^4}{2048(\beta - \alpha)^2(a - c_{off})}$ when $a \ge \frac{b + c_{off}}{2}$. To simplify the expression, let $\eta_{\max} = \dfrac{27(b-a)(\beta - c_{on})^4}{512(\beta-\alpha)^2(b-c_{off})^2}$ when $a < \dfrac{b+c_{off}}{2}$ and $\eta_{\max} = \dfrac{27(\beta - c_{on})^4}{2048(\beta-\alpha)^2(a-c_{off})}$ when $a \geq \dfrac{b+c_{off}}{2}$. And thus, the condition can be regarded as $\eta < \eta_{\max}$.

Under the condition of $\eta < \eta_{\max}$, there are two values of ρ, supposing ρ_1 and ρ_2, resulting in $R_{on}^{r}(\rho_1) = R_{on}^{r}(\rho_2) = R_{off}^{r*}$. Given the values of market parameters, we can easily calculate the precise values of both ρ_1 and ρ_2, while which is not the focus of our study. Thus, we keep ρ_1 and ρ_2 throughout this paper. Because of $R_{on}^{r}(0) = R_{on}^{r}(\beta - c_{on}) = 0$, we further have that $0 < \rho_1 < \dfrac{\beta - c_{on}}{4} < \rho_2 < \beta - c_{on}$. Because of $R_{on}^{t}(\rho, e^*(\rho)) > 0$ with $\rho \in (0, \beta - c_{on})$, we have that the feasible range of ρ is $\rho \in [\rho_1, \rho_2]$ for both the retailer and the platform to cooperate in the third-party e-commerce pattern.

Again from the analysis of Section 3.2, given any value of $\rho \in (0, \beta - c_{on})$, the platform's profit function is $R_{on}^{t}(\rho) = \rho e(1 - \dfrac{(\beta + c_{on} + \rho)/2 - \alpha}{\beta - \alpha}) - \dfrac{1}{2}\eta e^2 = \dfrac{\rho^2(\beta - c_{on} - \rho)^2}{8\eta(\beta-\alpha)^2}$ which is firstly increasing with $\rho \in (0, \dfrac{\beta - c_{on}}{2}]$ and then decreasing with $\rho \in [\dfrac{\beta - c_{on}}{2}, \beta - c_{on})$. Therefore, we now have a more clear understanding on commission fee. Precisely, for $\rho \in [\rho_1, \dfrac{\beta - c_{on}}{4}]$, both the retailer's and the platform's profits are increasing with ρ. For $\rho \in [\dfrac{\beta - c_{on}}{4}, \rho_{\max}]$ where $\rho_{\max} = \min\{\rho_2, \dfrac{\beta - c_{on}}{2}\}$, the retailer's profit is decreasing with ρ but the platform's profits is still increasing with ρ. We note that it is impossible to realize a commission fee $\rho > \rho_{\max}$ when $\rho_{\max} = \rho_2$, otherwise the retailer's online profit will be less than offline strategy. Similarly, if $\rho_{\max} = \dfrac{\beta - c_{on}}{2}$, the retailer's profit and the platform's profits are both decreasing with $\rho > \rho_{\max}$ which means both the retailer and the platform don't want to realize a commission fee $\rho > \rho_{\max}$.

Generally, the *active* feasible range of ρ is reduced to $\rho \in [\dfrac{\beta - c_{on}}{4}, \rho_{\max}]$ for both the retailer and the platform where $\rho_{\max} = \min\{\rho_2, \dfrac{\beta - c_{on}}{2}\}$ in this CASE 1 with $\alpha \leq \dfrac{\beta + c_{on}}{2}$. It is worth to note that in an *active* feasible range of ρ the retailer wants to decrease commission fee but the platform wants to increase it, which means they have to bargain with each other during the active range of commission fee. Oppositely, in an *inactive* range of ρ, the retailer and the platform can reach a consensus and achieve an efficient win-win situation. Under this kind of win-win situation, both of them consistently want to increase (or decrease) commission fee to gain a more profit. Thus, the active range of commission fee is more significant and valuable than the inactive range for the real cooperation. From this point of view, we focus on the analysis of active feasible range of ρ throughout this paper.

CASE 2 $\rho_0 > 0$, i.e., $\alpha > \frac{\beta + c_{on}}{2}$. In this case, we have $p^*_{on}(\rho) = \alpha$ and $e^*(\rho) = \frac{\rho}{\eta}$ given $\rho \in (0, \rho_0]$, and $p^*_{on}(\rho) = \frac{\beta + c_{on} + \rho}{2}$ and $e^*(\rho) = \frac{\rho(\beta - c_{on} - \rho)}{2\eta(\beta - \alpha)}$ given $\rho \ge \rho_0$ again from the analysis in Section 3.2. And thus, the retailer's profit function can be generalized as $R^r_{on}(\rho) = \begin{cases} (\alpha - \rho - c_{on})\frac{\rho}{\eta}, & if\ 0 < \rho < \rho_0 \\ \frac{\rho(\beta - \rho - c_{on})^3}{8\eta(\beta - \alpha)^2}, & if\ \rho_0 \le \rho < \beta - c_{on} \end{cases}$. For this function, we have that $(\alpha - \rho - c_{on})\frac{\rho}{\eta}$ is increasing with $\rho \in (0, \frac{\alpha - c_{on}}{2}]$ and then decreasing with $\rho \in [\frac{\alpha - c_{on}}{2}, \beta - c_{on})$, and $\frac{\rho(\beta - \rho - c_{on})^3}{8\eta(\beta - \alpha)^2}$ is increasing with $\rho \in (0, \frac{\beta - c_{on}}{4}]$ and then decreasing with $\rho \in [\frac{\beta - c_{on}}{4}, \beta - c_{on})$.

Meanwhile, the platform's profit function is $R^t_{on}(\rho) = \begin{cases} \frac{\rho^2}{2\eta}, & if\ 0 < \rho < \rho_0 \\ \frac{\rho^2(\beta - c_{on} - \rho)^2}{8\eta(\beta - \alpha)^2}, & if\ \rho_0 \le \rho < \beta - c_{on} \end{cases}$. Obviously, the function $\frac{\rho^2}{2\eta}$ is increasing with $\rho \ge 0$, and the function $\frac{\rho^2(\beta - \rho - c_{on})^2}{8\eta(\beta - \alpha)^2}$ is firstly increasing with $\rho \in (0, \frac{\beta - c_{on}}{2}]$ and then decreasing with $\rho \in [\frac{\beta - c_{on}}{2}, \beta - c_{on})$.

Because of $\rho_0 = 2\alpha - \beta - c_{on} > 0$, we have $\frac{\beta - c_{on}}{4} < \frac{\alpha - c_{on}}{2}$ in this case. However, the relationship between ρ_0 and $\frac{\beta - c_{on}}{4}$ as well as $\frac{\alpha - c_{on}}{2}$ is uncertain and depends on actual market situations. And thus, we have three possible sub-cases to discuss according to the value of ρ_0, i.e., $0 < \rho_0 \le \frac{\beta - c_{on}}{4}$, $\frac{\beta - c_{on}}{4} < \rho_0 \le \frac{\alpha - c_{on}}{2}$, and $\frac{\alpha - c_{on}}{2} < \rho_0 < \frac{\beta - c_{on}}{2}$. Notice that the retailer's decision-making procedure in CASE 2 is consistent with CASE 1. As a result, we omit the analyses for CASE 2 and give a brief summary for all the possible cases after the next section.

3.3.2 The scenario with $\alpha \geq \frac{3\beta + c_{on}}{4}$

In this scenario, we first have that $0 < \frac{\beta - c_{on}}{2} \leq \rho_0 = 2\alpha - \beta - c_{on}$ and the platform's profit is firstly increasing with $\rho \in (0, \rho_0]$ and then decreasing with $\rho \in [\rho_0, \beta - c_{on})$ from the Proposition 3 in Section 3.2. Moreover, we also have $\rho_0 = 2\alpha - \beta - c_{on} \geq \frac{\beta - c_{on}}{2} > \frac{\alpha - c_{on}}{2}$ because of $\beta > \alpha$ in this scenario, which means that the retailer's profit is firstly increasing with $\rho \in (0, \frac{\alpha - c_{on}}{2}]$ and then decreasing with $\rho \in [\frac{\alpha - c_{on}}{2}, \beta - c_{on})$. Therefore, the active feasible range of ρ for both the platform and the retailer is reduced to $\rho \in [\frac{\alpha - c_{on}}{2}, \rho_0]$ in the third-party e-commerce. Based on the analysis in Section 3.2, the retailer's optimal online sales price is α and the corresponding service level is $e^*(\rho) = \frac{\rho}{\eta}$ given $\rho \in [\frac{\alpha - c_{on}}{2}, \rho_0]$, and thus the retailer's profit function is equal to $R_{on}^r(\rho) = (\alpha - \rho - c_{on})\frac{\rho}{\eta}$.

In this scenario, the condition for the retailer to choose online strategy is $\max R_{on}^r(\rho) = R_{on}^r(\frac{\alpha - c_{on}}{2}) = (\alpha - \frac{\alpha - c_{on}}{2} - c_{on})\frac{\alpha - c_{on}}{2\eta} > R_{off}^{r*}$, i.e., $\eta < \frac{(b-a)(\alpha - c_{on})^2}{(b - c_{off})^2}$ when $a < \frac{b + c_{off}}{2}$ and $\eta < \frac{(\alpha - c_{on})^2}{4(a - c_{off})}$ when $a \geq \frac{b + c_{off}}{2}$. Letting $\eta_{\max} = \frac{(b-a)(\alpha - c_{on})^2}{(b - c_{off})^2}$ when $a < \frac{b + c_{off}}{2}$ and $\eta_{\max} = \frac{(\alpha - c_{on})^2}{4(a - c_{off})}$ when $a \geq \frac{b + c_{off}}{2}$, the condition can be simplified as $\eta < \eta_{\max}$. Given $\eta < \eta_{\max}$, there are two values of ρ resulting in $R_{on}^r(\rho_1) = R_{on}^r(\rho_2) = R_{off}^{r*}$ with $0 < \rho_1 < \frac{\alpha - c_{on}}{2} < \rho_2 < \beta - c_{on}$. And thus, the active feasible range of ρ for the retailer to adopt online strategy rather than offline strategy is further reduced to $\rho \in [\frac{\alpha - c_{on}}{2}, \rho_{\max}]$ where $\rho_{\max} = \min\{\rho_0, \rho_2\}$.

3.3.3 A brief summary

Now, we have found that only when the platform's service cost factor is small enough, i.e., $\eta < \eta_{\max}$, is it more profitable for the retailer to sell product through an online store rather than an offline shop. Table 1 concludes the upper bound of the platform's service cost factor for all the above cases.

Table 1. Upper bound of the platform's service cost factor, i.e., $\eta_{\max}$

Offline market situation a , b , c_{off}	Online market situation α , β , c_{on}	Feasible range of $\eta \in (0, \eta_{\max})$ $\eta_{\max}$
$0 \le a < \frac{b + c_{off}}{2}$	$0 \le \alpha \le \frac{5\beta + 3c_{on}}{8}$	$\frac{27(b-a)(\beta - c_{on})^4}{512(\beta - \alpha)^2 (b - c_{off})^2}$
	$\frac{5\beta + 3c_{on}}{8} < \alpha \le \frac{2\beta + c_{on}}{3}$	$\frac{4(2\alpha - \beta - c_{on})(b-a)(\beta - \alpha)}{(b - c_{off})^2}$
	$\frac{2\beta + c_{on}}{3} < \alpha \le 1$	$\frac{(b-a)(\alpha - c_{on})^2}{(b - c_{off})^2}$
$\frac{b + c_{off}}{2} \le a \le 1$	$0 \le \alpha \le \frac{5\beta + 3c_{on}}{8}$	$\frac{27(\beta - c_{on})^4}{2048(\beta - \alpha)^2 (a - c_{off})}$
	$\frac{5\beta + 3c_{on}}{8} < \alpha \le \frac{2\beta + c_{on}}{3}$	$\frac{(2\alpha - \beta - c_{on})(\beta - \alpha)}{(a - c_{off})}$
	$\frac{2\beta + c_{on}}{3} < \alpha \le 1$	$\frac{(\alpha - c_{on})^2}{4(a - c_{off})}$

Suppose $\eta < \eta_{\max}$, Table 2 further summarizes the active feasible range of commission fee, optimal service level, and optimal sales price respectively for the platform and the retailer. Notice that $\rho_0 = 2\alpha - \beta - c_{on}$, and ρ_2 is the larger one of ρ resulting in that the retailer's online profit is equivalent to the offline profit.

Table 2. Active commission fee, optimal service level and sales price given $\eta \in (0, \eta_{\max})$

Online market situation	Active feasible range of $\rho \in [\rho_{\min}, \rho_{\max}]$		Optimal decisions given ρ	
α, β, c_{on}	$\rho_{\min}$	$\rho_{\max}$	$e^*(\rho)$	$p^*_{on}(\rho)$
$0 \le \alpha \le \frac{5\beta + 3c_{on}}{8}$	$\frac{\beta - c_{on}}{4}$	$\min\{\rho_2, \frac{\beta - c_{on}}{2}\}$	$\frac{\rho(\beta - c_{on} - \rho)}{2\eta(\beta - \alpha)}$	$\frac{\beta + c_{on} + \rho}{2}$
$\frac{5\beta + 3c_{on}}{8} < \alpha \le \frac{2\beta + c_{on}}{3}$	ρ_0			
$\frac{2\beta + c_{on}}{3} < \alpha < \frac{3\beta + c_{on}}{4}$	$\frac{\alpha - c_{on}}{2}$	$\min\{\rho_2, \frac{\beta - c_{on}}{2}\}$ if $\rho_2 > \rho_0$	$\frac{\rho(\beta - c_{on} - \rho)}{2\eta(\beta - \alpha)}$ for $\rho > \rho_0$	$\frac{\beta + c_{on} + \rho}{2}$ for $\rho > \rho_0$
			$\frac{\rho}{\eta}$ for $\rho \le \rho_0$	α for $\rho \le \rho_0$
		ρ_2 if $\rho_2 \le \rho_0$	$\frac{\rho}{\eta}$	α
$\frac{3\beta + c_{on}}{4} \le \alpha < \beta$	$\frac{\alpha - c_{on}}{2}$	$\min\{\rho_0, \rho_2\}$	$\frac{\rho}{\eta}$	α

4. CONCLUSIONS

Thanks to the popularity of online shopping, the third-party e-commerce platform is now widely adopted by small and medium sized retailers. The commission fee and service level provided by the platform influence the retailer's pricing strategy and sales scale, and thus affect the respective profitability of online store. Taking these factors into consideration, we formulate the decision-making problem as a Stackelberg game for the online market. Firstly, we find that the service level has a significant effect on the respective profits and thus the platform's relative cost effectiveness in operational deployment of demand expanding must be high enough for both the platform and the retailer. Secondly, we find that the effect of commission fee is dependent on its value. When the commission fee is small (or large) enough, both the retailer and the platform have an intention to increase (or decrease) it, which means that the retailer and the platform can reach a consensus. However, when the commission fee is moderate, the retailer wants to decrease it but the platform wants to increase it. Given any value of commission fee, we also derive the optimal decisions respectively for both participants.

There are several directions for future research. First, this paper only considers the decision-making problem with one retailer and one platform. It is of interest to consider the case under a competitive environment. Second, for the retailer who has enough money and energy or who has already operated one channel, it is also of interest to coordinate the sales prices from the perspective of channel coordination. Finally, instead of uniform distribution for the customers' valuation, one can consider a general distribution and examine the effect of distribution variation on equilibrium outcomes. One can also extend the analysis to the case with random demand. However, it might be outrageously complex and challenging.

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