Restaurants' Platform Partnership for Social Promotion and Resilient Revenue: Is Reward-based Traffic Really Rewardful?

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Abstract

Restaurants have traditionally operated offline only, but the growth of food delivery platforms has prompted a shift toward online sales. In practice, consumers who share digital coupons offered by the platforms (e.g., Uber Eats and Meituan) in social networks (e.g., Facebook, Twitter and WeChat) will be rewarded for the social traffic, which effectively attracts many restaurants to open the online store. However, this also leads to intensified competition with the restaurant's physical (offline) store. In this paper, we formulate the restaurant's tradeoffs among platform traffic benefit, consumers' heterogeneous utility, and the platform's commission in the online selling decision. Interestingly, we find that the increased platform traffic may be harmful to the restaurant, and even the entire channel system. The platform offering high subsidies may trap restaurants in a pricing dilemma. We also find that restaurants' online selling will induce a negative externality due to online/offline order congestion, but it will not qualitatively change the main findings.

KEYWORDS: platform partnership, social traffic, channel co-opetition, network externality

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1. Introduction

Online selling by platform partnership is common in practice (Tian et al. 2018) but it's not true for restaurants if there were no quickly rising number of food delivery platforms (hereafter, platforms for short). Traditionally, restaurants have operated offline to provide consumers with better perception and utility. However, in recent years, the global food delivery market has grown tremendously, valued at USD 128.32 billion in 2022 and estimated at USD 143.05 billion in 2023 (Globe Newswire 2023). Platforms such as Uber Eats in America and Meituan in China significantly facilitate numerous restaurants' online selling. With increasing attention being paid by restaurants to social traffic, which is the platforms' core competitiveness, the impact of social traffic on consumers' utility, restaurants' profitability, and their cooperation with the platform deserves deepgoing investigation.

Reward-based promotion tools are believed to be effective to boost social traffic in the platform economy (Sun et al. 2020, Lisjak et al. 2021, Kumar et al. 2022). In the food delivery industry, we indeed observe some leading platforms such as Uber Eats and Meituan are launching social promotional subsidies to encourage consumers to interact and place orders in restaurants' online stores (Gao et al.

2020). For example, if a Meituan user shares “red packets” (a type of social digital coupons) with the friends in social media (e.g., WeChat friend groups), both the user and his/her friends will receive the platform’s subsidy which reduces the food price (Gao et al. 2020). Figure 1 illustrates the detailed transferability of Meituan’s social “red packet”. Similarly, another type of social digital coupon, i.e., “promo code”, is widely shared among Uber Eats users. When the promo codes are shared through social media (e.g., Facebook or Twitter), all code users will obtain lucrative subsidies offered by Uber Eats (Uber Eats 2021a). Compared with the traditional coupons in non-social settings, the shareable digital social coupons can successfully induce the herd effect among consumers and create booming social traffic, thereby leading to positive network externality which expands the restaurants’ online market potential (Huang et al. 2018, Gao et al. 2020).

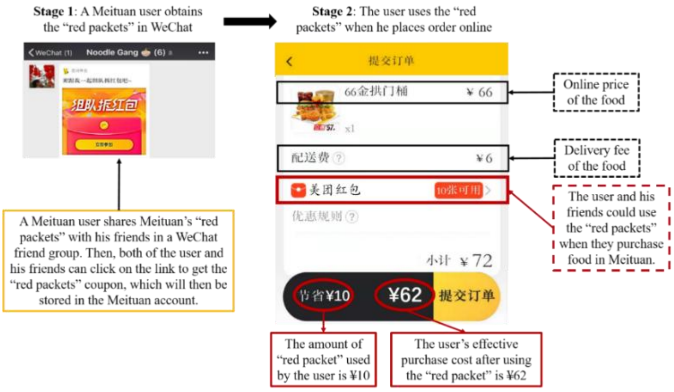


Figure 1. Illustration of Meituan’s “Red Packet”

The role of network externality can be essential and crucial for both the restaurants and platforms when social traffic is considered (Parker and Van Alstyne 2005, Boudreau and Jeppesen 2015). In the literature, network externality is commonly interpreted as the consumers’ utility/initial valuation will be improved when more consumers participate in the consumption of the same product (Katz and Shapiro 1985, Qiu et al. 2015). When the platforms (e.g., Meituan) provide social promotion subsidies (e.g., Meituan’s “red packets”) and the users/consumers share the digital coupons with their friends via social networks (e.g., WeChat group), both the sharers and the receivers could benefit from the platform’s subsidies. Therefore, the consumers in the same social network are stimulated to purchase more foods and even not now, their future purchasing incentives and favor of online restaurants will be increased. This induces the consumers’ herd behavior, as confirmed by many empirical works (Bapna and Umyarov 2015, Bailey et al. 2022), so we formulate this novel property of online restaurant business in this paper. We interestingly observe that, although the consumers’ initial valuation for online foods is discounted compared with offline foods, it can be improved because of the network externality created by the platforms' social promotion.

Intuitively, as the number of online consumers participating in social promotion increases, the platform has to pay massive subsidies to the consumers, which is costly. However, the platform shares part of the restaurant's online revenue at a pre-determined commission rate. For instance, in China, online food delivery platforms like Meituan and Ele.me charge restaurants an average commission of 20% per online order (Daxue Consulting 2022), whereas in the US market, Uber Eats' commission rate can reach as high as 30% (Uber Eats 2021b). This forms the platform's tradeoff when it makes efforts in social promotion. For the restaurants, online selling results in competition between online and offline channels, but the orders can be pooled, leading to both positive and negative channel externality and/or demand spillover. We refer to positive network externality as "network externality" for short in the main context. Therefore, coordination opportunities arise among the platform, the restaurant's online and offline stores, inducing the platform to offer reward-based social promotion to consumers.

We are interested in whether the aforementioned all-win situation exists and, if so, under what conditions. We consider a restaurant that can either sell foods through the offline channel only, referred to as *Benchmark Scenario*), or partner with a food delivery platform by operating an online store, referred to as *Platform Partnership Scenario* in this paper. Our research questions are as follows:

- ✧ How about the restaurant's price decisions when both network externality and channel demand spillover are considered?
- ✧ Will the reward-based social traffic always benefit the channel system?
- ✧ How about consumers' utility and their channel switching behavior?

To answer the forgoing research questions, we incorporate four unique characteristics of restaurant business, including: (1) the positive network externality generated by the food delivery platform's social promotion, (2) the spillover of the positive network externality from the online channel to the offline channel, (3) the negative impact of online orders on the offline channel due to order congestion, and (4) the channel structure in restaurant business, which is significantly different from that in the omnichannel settings.

Several intriguing insights are excavated. First, with the enhanced network externality, the restaurant's online and offline prices may increase/decrease simultaneously, or, show the "one-increase-one-decrease" pattern when the network externality is in a moderate range. This indicates that the online and offline channels may have intensified/softened channel competition, or, channel cooperation with each other (Niu et al. 2021). Second, the restaurant can balance the profit gains from two channels well when the network externality is strong, resulting in an all-win situation for the restaurant and the channel system (McGuire and Staelin 1983) comprising the restaurant's two channels and the platform. However, when the network externality is weak, we find channel competition is intensified, and channel price war is enhanced. This results in an all-lose situation for the restaurant and the channel system. Therefore, the role of network externality in softening channel competition and achieving channel cooperation can be highlighted.

We note that the studies on social promotion/traffic (e.g., Qiu et al. 2015, Jiang and Guo 2015, Qiu and Whinston 2017, Gao et al. 2020, Kumar et al. 2022) and restaurant-platform partnership operations (e.g., Chen et al. 2022, Feldman et al. 2023) have been arising in the recent years. So we follow their steps. However, compared to the existing literature, we investigate the impact of network externality resulting from platforms' social promotion subsidy in the online food delivery industry, which might significantly affect the restaurant's price decisions and the consumers' purchasing behavior between the online and offline channels. We formulate the restaurant's self-channel-competition and its preference of platform partnership in a social network setting. In addition, the recent literature on restaurant-platform partnerships (e.g., Chen et al. 2022, Feldman et al. 2023) focuses on the negative impact caused by online orders on the offline consumers' waiting cost. Differently, we find that the platform's social promotion results in a positive network externality that attracts more consumers to purchase foods. This undoubtedly becomes a hedge against the online orders' negative impact. Hence, we contribute to the literature by identifying the conditions under which the positive network externality among consumers' social networks is valuable for the restaurant and the channel system (i.e., restaurant and platform). Interestingly, we find the positive network externality may act as a negative force that intensifies channel competition and hence, result in a loss of profit for both the restaurant and the platform.

The rest of this paper is organized as follows. Section 2 reviews related literature. In Section 3, we describe the model assumptions, notations, and settings. In Section 4, we analyze the impact of network externality on the food price decisions in two competing channels and show the restaurant's channel structure preference. We examine the robustness of the main results by providing several extensions in Section 5. Section 6 concludes the paper and discusses the future research directions. All the proofs are included in the Appendix.

2. Literature Review

Our work is closely related to the studies on network externality and social learning/promotion. Some literature identifies the value of network externality in various settings. For example, Huang et al. (2018) highlight the importance of network externality and social promotion in mitigating consumers' anxiety about using innovative products or services, particularly when firms sell goods to forward-looking consumers. Niculescu et al. (2018) study an incumbent's proprietary technology openness decision by examining consumers' interactions based on network externality when the competitive entrant's product quality is either exogenously given or endogenously decided. Li et al. (2020) find that there exist positive network externalities in the fundraising mechanism of crowdfunding, which makes the investors more likely to support an entrepreneurial project. Other literature on network externality focuses on how to boost social traffic via consumer interactions, e.g., offering free trial opportunities (Cheng and Liu 2012, Cheng et al. 2015), providing online review channels, adjusting prices, etc. Qiu et al. (2015) point out that the explosion of online videos enables users to diffuse content dynamically in social networks. They empirically examine how social learning and network externalities drive the diffusion of online videos using the data from YouTube. Jiang and Guo (2015) realize that the influence of online reviews on consumers' social learning is important, but the design of review system is less studied. Thus, they examine firms' optimal review system design based on which they show the optimal product price decisions. Qiu and Whinston (2017) note that consumers share their purchase experiences in their social networks and induce social learning for the future consumers. They find an information-revealing pricing strategy that enables a seller to prevent social learning and raise future consumers' willingness to pay. Feng et al. (2019) focus on the role of firms' online product reviews in firms' pricing strategies and use both analytical model and panel data analysis to show how a firm affects online product reviews by manipulating the retail prices. Kumar et al. (2022) observe that content providers' sponsored data with reward tasks can effectively increase social traffic and promote social learning.

They build a game-theoretic model to study a content provider's optimal subsidization decisions.

Compared with the aforementioned studies, we identify the conditions under which the network externality induced by social traffic among consumers is valuable for the restaurant and the entire channel system. The restaurant's online channel, as an entrepreneurial enterprise (Li et al. 2020), can either benefit from the platform's reward-based traffic, or, compete with the offline channel and lead to channel system profit loss. We find the underlying driving force is the restaurant's differentiated pricing strategies, so our paper follows the steps of Jiang and Guo (2015) and Kumar et al. (2022).

Our work is closely related to the literature on multichannel management in platform economy and e-commerce. There are two sub-streams of literature, with the first sub-stream focuses on supplier encroachment. Typical works include Chiang et al. (2003), Tsay and Agrawal (2004), Li et al. (2014), and Li et al. (2018). Their research highlights the benefits of supplier encroachment, which weakens the double marginalization effect and benefits both suppliers and retailers. And the common features of this sub-stream of literature include (1) the competition among different supply chain parties' channels, and (2) the supplier cannot control the retailer's retail prices directly because the retailer procures and then resells products to the consumers. Recently, with the development of platform economy, another sub-stream of literature has noted that suppliers can control the retail prices in multiple channels directly by partnering with the agency platforms. For example, Ryan et al. (2012) reveal that selling through an online agency platform helps expand the market availability, so they formulate the tradeoff between the benefit of market expansion and the expense of participation fee charged by the agency platform. Shen et al. (2019) examine a manufacturer's channel structure with and without a platform partner. They jointly consider the impact of decision sequence and bargaining items between the manufacturer and the platform. Considering the online agency platform's retail service efforts, Ha et al. (2022) study the channel decisions among selling goods through an agency channel, a reselling channel, or both. More recently, Chen et al. (2022) and Feldman et al. (2023) investigate the interaction between food delivery platforms and restaurants and realize that the dine-in/offline consumers will incur a higher waiting cost than the food delivery/online consumers because of order congestion, thus resulting in the negative impact on the restaurants' offline operations. Specifically, Feldman et al. (2023) assume the waiting cost is incurred by the dine-in consumers only and show that a simple revenue sharing contract cannot coordinate the restaurant service system, but a generalized revenue sharing contract in which the platform pays the restaurant a fixed fee and a percentage of the revenue is effective at coordinating the system. Differently, when the waiting costs are incurred by both the dine-in and food delivery consumers, Chen et al. (2022) find that either a revenue sharing contract with a price ceiling or a generalized revenue sharing contract can coordinate the restaurant service system, and thus create a win-win situation.

Our work differs from the aforementioned studies in three aspects. First, we focus on the role of positive network externality induced by social traffic among consumers on the platform, which serves as an important driving force for restaurants' platform partnership. But it is ignored in Chen et al. (2022) and Feldman et al. (2023). Second, we examine how the negative impact of online orders on the restaurant's offline channel and how it affects the restaurant's platform partnership decisions. Interestingly, we find the interactions between the positive network externality and the negative impact of online food selling will not qualitatively change the restaurant's preference of platform partnership. Third, different from the literature on agency selling, we study the role of the platform's social promotion subsidy, which interacts with the restaurant's online and offline price decisions. This significantly differs our work from previous literature such as Li et al. (2018) and Ha et al. (2022).

Lastly, our work is related to the literature on pricing strategies in platform operations. Earlier works (e.g., Hagiu and Wright 2014, Abhishek et al. 2015) mostly use Bertrand model or utility model to formulate the price competition among the platforms and suppliers. When the suppliers engage in retail price competition, Tian et al. (2018) study an online platform's preferences of three selling modes (i.e., the reselling mode, commission mode, and hybrid mode). Hu et al. (2022) study how the retail pass-through between the wholesale price and the retail price influences a platform's preference of wholesale selling and agency selling in the presence of supplier competition. In a most related work, Li and Wang (2021) empirically find that the effectiveness of the government's platform fee regulation depends on the platform's restaurant recommendation of different types of restaurants, which significantly changes the social traffic.

Compared with the foregoing works, we mainly follow the formulation of food delivery platform in Li and Wang (2021). When a restaurant operates two competing channels (online and offline), we interestingly find that the prices in the two channels may exhibit patterns such as "increase/decrease simultaneously" or "one-increase-one-decrease", indicating the softened/intensified price competition or the pricing decision cooperation. We build a game-theoretic model to study how the reward-based platform traffic may hurt the restaurant's profit, which is echoed by Li and Wang (2021).

3. Model Setting

Consider a channel system that consists of a restaurant (denoted by *R*) and an online food delivery platform (the platform hereafter, denoted by *P*, e.g., Meituan and Uber Eats). where the restaurant can sell foods through its offline channel only (referred to as *Benchmark Scenario*), or, sell foods through two channels by partnering with the platform (referred to as *Platform Partnership Scenario*), illustrated by Figure 2. For notational convenience, we use superscript *B* and *P* to label the *Benchmark Scenario* and the *Platform Partnership Scenario*, respectively. All the parameters and notations can be referenced in Appendix.

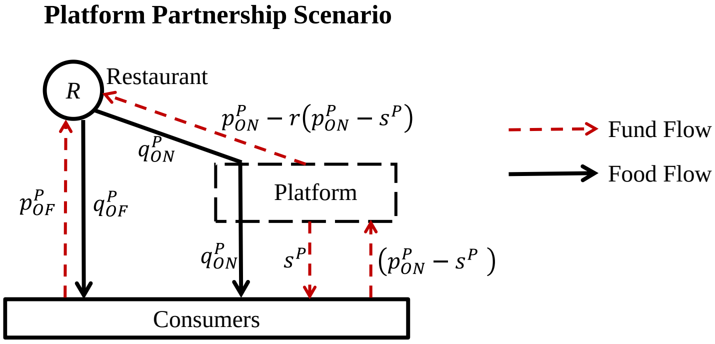


Figure 2. Illustration of *Platform Partnership Scenario*

3.1 Benchmark Scenario

As a benchmark, we first consider the scenario in which the restaurant reaches consumers through the physical store (i.e., the offline channel) and does not partner with the platform. In this scenario, consumers can only buy the restaurant's foods from the offline channel at a price p_{OF} and obtain the consumer initial valuation θ, where θ is also defined as the consumers' heterogeneous willingness to pay (WTP) in the literature (Chiang et al. 2003, Qiu and Whinston 2017), which is uniformly distributed over $[0,1]$ (i.e., $\theta \sim U[0,1]$). Consumers will buy foods when the consumer surplus (or net utility) is positive, i.e., $U_{OF} = \theta - p_{OF} > 0$. Alternatively, $\theta > \theta_{OF}$ should be required, where $\theta_{OF} = p_{OF}$, which is consumers' indifference point between purchase and no purchase. Hence, the offline channel's demand and the restaurant's profit function in *Benchmark* are as follows (denoted by superscript *B*).

$$q_{OF}^{B} = \int_{p_{OF}^{B}}^{1} 1\, d\theta = 1 - p_{OF}^{B}, \tag{1}$$

$$\underset{p_{OF}^{B} > 0}{Max}\ \pi_{R}^{B} = p_{OF}^{B} \cdot q_{OF}^{B}. \tag{2}$$

3.2 Platform Partnership Scenario

If the restaurant opens an online store on the food delivery platform, the restaurant's foods in the offline and online channels are sold at prices p_{OF} and p_{ON}, respectively. In practice, consumers may value the foods sold in the two channels differently because of consumers' different perceptions of product authenticity, delivery time, etc. For example, 49.6% of consumers in China report trust issues with the quality of food sold online (iiMedia Research 2021). Some consumers even express concern about the possibility of delivery riders getting their food dirty (NPR 2019). Therefore, we assume that the consumer initial valuations for the food from offline and online channels are θ and $\delta\theta$, respectively, where $\delta \in (0,1)$ stands for consumer's acceptance of the online channel (Chiang et al. 2003). In the literature, δ is also referred to as the degree of channel homogeneity, which can measure the channel competition intensity (Lus and Muriel 2009). The greater δ is, the fiercer the channel competition is. If consumers purchase foods in the online channel, they will pay the online price (i.e., p_{ON}) and receive the platform's social promotion subsidy (i.e., s), indicating that the real online price paid by the consumers is $p_{ON} - s$ and the consumer surplus in the online channel is $U_{ON} = \delta\theta - (p_{ON} - s)$. If consumers purchase foods in the offline channel, then the consumer surplus is the same as that in *Benchmark Scenario*, that is, $U_{OF} = \theta - p_{OF}$.

Compared with *Benchmark Scenario*, the purchase decision of consumers becomes complex because of the platform's social promotion subsidy (i.e., s) and the positive network externality among consumers. As mentioned in Introduction, the platform's social promotion subsidy tools (e.g., the digital red packets in China and Uber Eats' promo code) shared in consumers' social networks are very effective in boosting social traffic, which can increase the demand size in the online channel (i.e., q_{ON}) and thus generate the positive network externality (i.e., λq_{ON}), where $\lambda > 0$ denotes the intensity of positive network externality (Cheng and Liu 2012, Cheng et al. 2015). With the positive network externality, the consumer initial valuations in the online and offline channels can be improved (Dou et al. 2013). Therefore, the distribution of consumer initial valuation now follows $\theta \sim U[\underline{A}, \overline{A}]$, where $\underline{A} = \lambda q_{ON}$ and $\overline{A} = 1 + \lambda q_{ON}$, implying that the restaurant's market potential is expanded to $1 + \lambda q_{ON}$.

If the online channel is preferred, it is equivalent to saying that the consumer surplus is higher in this channel, i.e., $\begin{cases} U_{ON} = \delta\theta - (p_{ON} - s) > 0 \\ and \\ U_{ON} > U_{OF} = \theta - p_{OF} \end{cases} \Rightarrow \begin{cases} Pr(\theta > \theta_{ON}) \\ and \\ Pr(\theta < \theta_{ON,OF}) \end{cases}$, where $\theta_{ON} = \frac{p_{ON}-s}{\delta}$ and $\theta_{ON,OF} = \frac{p_{OF}-(p_{ON}-s)}{1-\delta}$ are the two indifference points.

Similarly, if the offline channel is preferred, it indicates the consumer surplus is higher in this channel, i.e., $\begin{cases} U_{OF} = \theta - p_{OF} > 0 \\ and \\ U_{OF} > U_{ON} = \delta\theta - (p_{ON} - s) \end{cases} \Rightarrow \begin{cases} Pr(\theta > \theta_{OF}) \\ and \\ Pr(\theta > \theta_{ON,OF}) \end{cases}$.

Note that, $\theta_{ON} < \theta_{OF} < \theta_{ON,OF} < 1 + \lambda q_{ON}$ is required (which equals to $0 < p_{ON} < s + \delta p_{OF}$) to guarantee positive demand in two channels. We have the demand functions of the online and offline channels in *Platform Partnership Scenario* as follows (superscripted as *P*):

$$q_{ON}^P = \int_{\theta_{ON,OF}}^{\overline{A}} \frac{1}{\overline{A}-\underline{A}} d\theta = \frac{s^P}{(1-\delta)\delta} - \frac{1}{(1-\delta)\delta} p_{ON}^P + \frac{1}{1-\delta} p_{OF}^P, \tag{3}$$

$$q_{OF}^P = \int_{\theta_{ON}}^{\theta_{ON,OF}} \frac{1}{\overline{A}-\underline{A}} d\theta = \frac{(1-s^P)\delta - \delta^2 + \lambda s^P}{(1-\delta)\delta} - \frac{1-\lambda}{1-\delta} p_{OF}^P + \frac{\delta-\lambda}{(1-\delta)\delta} p_{ON}^P. \tag{4}$$

The restaurant sells foods through two channels, so we divide the profit into the offline channel profit (i.e., $p_{OF}^P \cdot q_{OF}^P$) and the online channel profit (i.e., $p_{ON}^P \cdot q_{ON}^P$). For the online channel profit, the platform charges a commission at a rate r, which is exogenously given (e.g., the commission rate of Uber Eats in the US market can be 30%). The platform provides online consumers with the promotion subsidy s^P for per unit online order. Therefore, the profit functions of the restaurant and the platform are as follows:

$$\underset{p_{ON}^P>0, p_{OF}^P>0}{Max} \pi_R^P = \underbrace{p_{ON}^P \cdot q_{ON}^P}_{\substack{The\ online\ profit \\ of\ the\ restaurant}} - \underbrace{r(p_{ON}^P - s^P)q_{ON}^P}_{\substack{The\ total\ commission \\ paid\ to\ the\ platform}} + \underbrace{p_{OF}^P \cdot q_{OF}^P}_{\substack{The\ offline\ profit \\ of\ the\ restaurant}}, \tag{5}$$

$$\underset{s^P>0}{Max} \pi_P^P = \underbrace{r(p_{ON}^P - s^P)q_{ON}^P}_{\substack{The\ total\ commission \\ received\ by\ the\ platform}} - \underbrace{s^P q_{ON}^P}_{The\ total\ subsidy}, \tag{6}$$

Comparing the distribution of consumers in *Platform Partnership Scenario* with that in *Benchmark Scenario*, we have the following observations. First, the total market size will expand in *Platform Partnership Scenario* because some consumers who originally do not purchase foods in this restaurant are attracted to the online store due to the social traffic and platform's subsidy, with the proportion $\theta_{OF} - \theta_{ON}$. Second, some consumers switch from the offline channel to the online channel with the proportion $\theta_{ON,OF} - \theta_{OF}$, also due to the platform's subsidy, but it induces channel competition for the restaurant. See Figure 3 for the illustration.

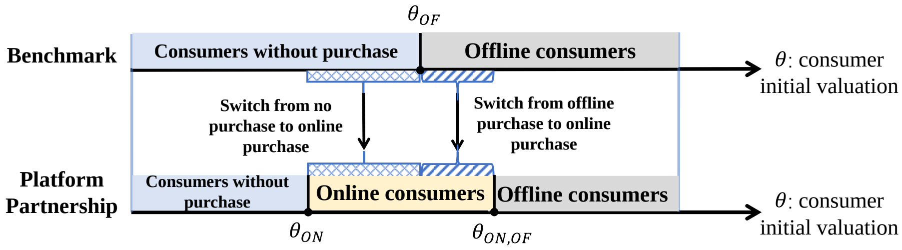


Figure 3. Distribution of potential consumers

3.2 Equilibrium Outcomes

The sequences of events in the two scenarios are as follows: (1) In *Benchmark Scenario*, the restaurant determines the offline food price p_{OF}^{B}. (2) In *Platform Partnership Scenario*, the restaurant determines the online and offline food prices (p_{ON}^{P}, p_{OF}^{P}), and the platform determines the subsidy s^P. By backward induction, we derive the equilibrium outcomes summarized in Table 1. The superscripts B and P represent *Benchmark Scenario* and *Platform Partnership Scenario*, respectively.

Table 1. Equilibrium outcomes

	Benchmark	***Platform Partnership***
Price in offline channel	$p_{OF}^{B} = \frac{1}{2}$	$p_{OF}^{P} = \frac{3(1-\delta)\delta}{\delta(6+r\lambda)-6\delta^2-\lambda^2}$
Price in online channel	N/A	$p_{ON}^{P} = \frac{(1+r)(1-\delta)\delta(3\delta-2\lambda)}{\delta(6+r\lambda)-6\delta^2-\lambda^2}$
Demand in offline channel	$q_{OF}^{B} = \frac{1}{2}$	$q_{OF}^{P} = \frac{\delta[3(1-\delta)-\lambda(1-r)]}{\delta(6+r\lambda)-6\delta^2-\lambda^2}$
Demand in online channel	N/A	$q_{ON}^{P} = \frac{\lambda}{\delta(6+r\lambda)-6\delta^2-\lambda^2}$
Platform's social promotion subsidy	N/A	$s^P = \frac{(1-\delta)\delta(\lambda+2r\lambda-3r\delta)}{6\delta^2+\lambda^2-\delta(6+r\lambda)}$
Platform's profit	N/A	$\pi_P^P = \frac{(1+r)(1-\delta)\delta\lambda^2}{[6\delta^2+\lambda^2-\delta(6+r\lambda)]^2}$
Restaurant's profit	$\pi_R^B = \frac{1}{4}$	$\pi_R^P = \frac{(1-\delta)\delta[3\delta(3+r\lambda)-9\delta^2-(2+r)\lambda^2]}{[6\delta^2+\lambda^2-\delta(6+r\lambda)]^2}$

We make the following assumptions on λ and r to rule out the trivial cases where the prices and sales quantities are non-positive. All the analysis in this paper will be carried out in the feasible region.

Assumption 1. $\lambda < min\{\overline{\lambda}_1, \overline{\lambda}_2\}$, where $\overline{\lambda}_1 = \frac{3r\delta}{1+2r}$ and $\overline{\lambda}_2 = \frac{3(1-\delta)}{1-r}$.

Assumption 2. $0 < r < 1/3$.

Assumptions 1 and 2 can be reasonable. Assumption 1 ensures the offline channel coexists with the online channel since all the consumers will switch to the online channel given a too strong network externality. On the contrary, if the network externality is too weak, the restaurant will have no incentive to open the online channel. Regarding Assumption 2, we observe that the commission rates announced by Uber Eats and Meituan are not higher than 30% (Uber Eats 2021b, Daxue Consulting 2022).

4. Analysis

4.1 Price Decisions with Platform Partnership

In this section, we first analyze the equilibrium outcomes (i.e., prices, subsidy and demand volumes) in *Platform Partnership Scenario* and then investigate how the network externality (i.e., λ) and the consumer acceptance of the online channel (i.e., δ) affect the restaurant's pricing decisions, the platform's subsidy decision, and the profit of channel system. Then, we identify the conditions under which the restaurant prefers *Platform Partnership*. Lemmas 1 and 2 show the analysis of the prices determined by the restaurant and the subsidy offered by the platform.

Lemma 1. With platform partnership, the restaurant's food price in the offline channel increases in λ if $\lambda > \lambda_1$ (i.e., $\frac{\partial p_{OF}^P}{\partial \lambda} > 0\ if\ \lambda > \lambda_1$), and the price in the online channel increases in λ if $\lambda > \lambda_2$ (i.e., $\frac{\partial p_{ON}^P}{\partial \lambda} > 0\ if\ \lambda > \lambda_2$), where $\lambda_1 < \lambda_2$.

Lemma 1 demonstrates that the restaurant's online and offline prices might show either an opposite or a coincident relationship with respect to the network externality (i.e., λ). See Figure 4 for the illustration. When the network externality is weak (i.e., $\lambda < \lambda_1$, Region A1 in Figure 4), both the online and offline prices decrease in λ, indicating that the price competition between the two channels is intensified (Bolandifar et al. 2016). This is because the network externality is so weak that the restaurant has to lower the food price for a larger demand volume in the two channels. However, the reduced online price might induce more consumers to switch from the offline channel to the online channel, resulting in more commissions paid to the platform. Being aware of this, the restaurant tends to lower the offline price to retain the demand volume.

When the network externality is moderate (i.e., $\lambda_1 < \lambda < \lambda_2$, Region A2 in Figure 4), we find that, if λ increases, the online and offline prices show a "one-decrease-one-increase" pattern, indicating that the restaurant achieves channel cooperation by price decisions (Niu et al. 2019, Niu et al. 2021). To explain this finding, we note that the network externality λ and the online channel's demand volume q_{ON}^{P} show a *complementary* relationship in the improvement of consumer initial valuation (i.e., λq_{ON}^{P}). Given a λ that is not sufficiently large, the restaurant is incentivized to increase q_{ON}^{P} to improve consumer initial valuation. The restaurant has two parallel ways: (1) reducing the online price, and (2) increasing the offline price. The former way attracts more consumers who originally do not purchase to purchase in the online channel while the latter way drives some offline consumers to the online channel. Although the platform splits the restaurant's online profit as the commission, mathematically, we show that the benefit from market expansion because of the booming social traffic is more significant, so we have $\frac{\partial p_{OF}^{P}}{\partial \lambda} > 0$ and $\frac{\partial p_{ON}^{P}}{\partial \lambda} < 0$ in Region A2.

When the network externality is strong (i.e., $\lambda > \lambda_2$, Region A3 in Figure 4), both the online and offline prices will increase in λ. This is because the strong network externality is sufficient to increase consumer initial valuation and hence expand the market, resulting in a small q_{ON}^{P} and a higher p_{ON}^{P}. As a result, the channel competition is softened, and the offline price p_{OF}^{P} also increased.

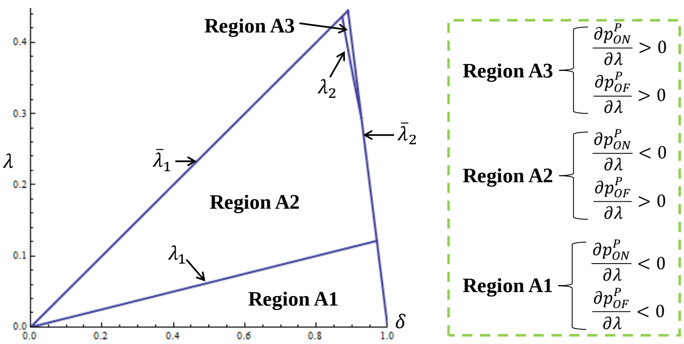


Figure 4. Sensitive analysis of the restaurant's prices in two channels with respect to λ

Lemma 2. With platform partnership: (a) the platform's social promotion subsidy decreases in λ (i.e., $\frac{\partial s^{P}}{\partial \lambda} < 0$), and (b) the consumer's purchase price in the online channel increases in λ (i.e., $\frac{\partial (p_{ON}^{P} - s^{P})}{\partial \lambda} > 0$) if $\lambda > \lambda_3$.

Lemma 2(a) indicates that the network externality λ and the platform's social promotion subsidy have a *substitutable* relationship, so a strong network externality helps save the platform's subsidy cost. Lemma 2(b) shows that the consumer's purchase price (i.e., $p_{ON}^P - s^P$) in the online channel does not necessarily decreases in λ. If the network externality is strong, which intuitively will induce more social traffic and deeper price discount in the online channel, we interestingly find that $p_{ON}^P - s^P$ is increasing in λ. We discuss the detailed reasons in two ranges (i.e., $\lambda_3 < \lambda < \lambda_2$ and $\lambda > \lambda_2$) as follows.

Given $\lambda_3 < \lambda < \lambda_2$, we find that the platform will downwardly adjust the subsidy to save the promotion cost because the restaurant has a strong incentive to lower the online price for a larger demand volume (Lemma 1). This enables the platform to be a free-rider and increases the consumer's effective purchase price in the online channel because p_{ON}^P is not sufficiently lowered (i.e., $\left|\frac{\partial p_{ON}^P}{\partial \lambda}\right| < \left|\frac{\partial s^P}{\partial \lambda}\right|$, see Appendix for detailed proof). If the network externality is further increased (i.e., $\lambda > \lambda_2$), the improvement of consumer initial valuation (i.e., $\lambda q_{ON}^P \uparrow$) mainly relies on λ. This constrains the restaurant's incentive to increase q_{ON}^P, so the online price p_{ON}^P can be increased. Because the platform's subsidy is not increased (see Lemma 2(a)), we find that $p_{ON}^P - s^P$ increases more quickly.

Similar to that in Lemma 1, we find the inclusion of platform's subsidy decision does not qualitatively change the channel price competition and cooperation relationships. That is, depending on the network externality λ, $p_{ON}^P - s^P$ and p_{OF}^P still exhibit either increase/decrease simultaneously or "one-increase-one-decrease" patterns. Please refer to Figure 5 for the illustration.

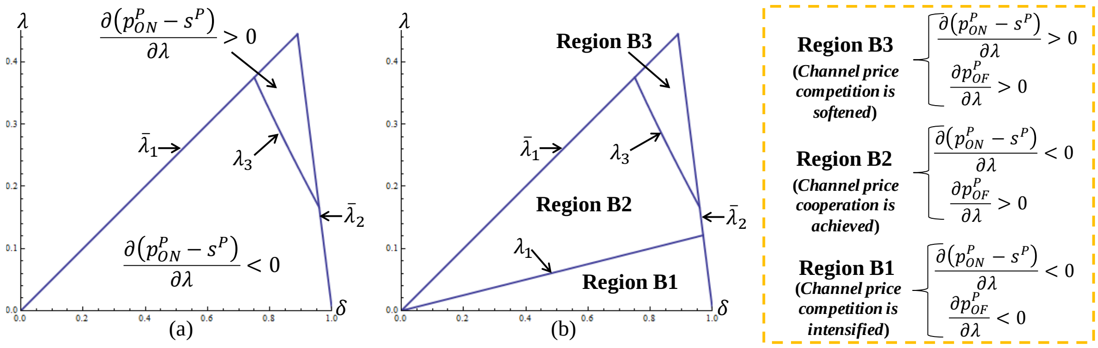


Figure 5. The effective prices in the two channels considering the platform's subsidy

4.2 Demand and Profit Gains with Platform Partnership

The impacts of network externality λ on the price decisions of the restaurant and the platform have been discussed above. Next, defining the profits in the online and offline channels with platform partnership as $\pi_{ON}^{P} = (p_{ON}^{P} - s^{P})q_{ON}^{P}$ and $\pi_{OF}^{P} = p_{OF}^{P} \cdot q_{OF}^{P}$, respectively, we have the following propositions.

Proposition 1. With platform partnership, (a) the online (offline) channel's demand volume increases (decreases) in λ, i.e., $\frac{\partial q_{ON}^{P}}{\partial \lambda} > 0$ ($\frac{\partial q_{ON}^{P}}{\partial \lambda} < 0$), and (b) the share of online (offline) channel's profit in the overall system profit pie increases (decreases) in λ, i.e., $\partial \left(\frac{\pi_{ON}^{P}}{\pi_{OF}^{P}}\right)/\partial \lambda > 0$ ($\partial \left(\frac{\pi_{OF}^{P}}{\pi_{ON}^{P}}\right)/\partial \lambda < 0$).

Combined with Lemma 2(b), one result worth noting is that q_{ON}^{P} always increases in λ even though the consumer's purchase price in the online channel $p_{ON}^{P} - s^{P}$ is high when $\lambda > \lambda_3$. The reasons include: (1) offline demand is shifted to online, and (2) more consumers who originally do not purchase are attracted to the restaurant's online channel because of the social traffic created by a strong network externality.

Specifically, when λ is small, the restaurant will reduce both the online and offline food prices, and the platform is incentivized to provide a high subsidy. The joint effect of a low online price and a high platform subsidy is more significant, making the price cut in the offline channel inefficient. As a result, demand shifts from offline to online. When λ is moderate, Lemma 2 shows that the platform subsidy is low, but the restaurant will reduce the online food price while increasing the offline food price, which can attract more consumers to the online channel. Therefore, we find the demand volume in the online (offline) channel increases (decreases) in λ. When λ is large, although the restaurant's online and offline food prices are high and the platform subsidy is negligible, we interestingly find that the online demand volume will still increase in λ. The reason is that, a large λ works to attract many consumers who originally do not purchase to the online channel, creating new online demand.

Proposition 2. With platform partnership, the restaurant's (platform's) share of total online profit decreases (increases) in λ.

As mentioned above, the platform will snatch part of the restaurant's online profit at a commission rate r. Proposition 2 demonstrates that the restaurant should be more serious to evaluate the platform partnership decision, especially when the network externality λ is large. To explain this, we show in Lemma 1 that the increased network externality leads to a decreased platform subsidy and a high purchase price for the consumers in the online channel, enabling the platform to benefit from a high marginal commission (i.e., $r(p_{ON}^{P} - s^{P})$) and a low cost of subsidizing consumers (i.e., s^{P} is small).

Therefore, the platform is capable of occupying a larger share of the total online profit as λ increases.

4.3 Restaurant's Platform Partnership Decision

Compared with the *Benchmark Scenario*, the restaurant might be able to obtain more profit gains with platform partnership. However, channel competition can be harmful, thus reducing the profit of channel system. Therefore, we first examine whether the channel system benefits from the restaurant's platform partnership or not. With platform partnership, the system profit is $\pi^P = \pi_R^P + \pi_P^P$. We have thresholds δ_1, δ_1, δ_3, λ_4 and λ_5 for notational convenience, where $\delta_2 > \delta_1 > \delta_3$ and $\lambda_4 < \lambda_5$. The expressions of thresholds can be accessed in Appendix S1.

Lemma 3. With platform partnership, there exist three thresholds with respect to δ and λ: δ_1, δ_2 and λ_4, where $\delta_2 > \delta_1$, such that the following hold:

(a) The system profit increases in λ (i.e., $\partial\pi^P/\partial\lambda > 0$) if (a1) $\delta \le \delta_1$, or, (a2) $\delta_1 < \delta < \delta_2$ and $\lambda > \lambda_4$. (b) The system profit decreases in λ (i.e., $\partial\pi^P/\partial\lambda < 0$) if (b1) $\delta_1 < \delta < \delta_2$ and $\lambda < \lambda_4$, or, (b2) $\delta > \delta_2$.

Lemma 4. With platform partnership, there exist three thresholds with respect to δ and λ: δ_3, δ_4 and λ_5, where $\delta_4 > \delta_3$, such that the following hold:

(a) The restaurant's profit increases in λ (i.e., $\partial\pi_R^P/\partial\lambda > 0$) if (a1) $\delta \le \delta_3$, or, (a2) $\delta_3 < \delta < \delta_4$ and $\lambda > \lambda_5$. (b) The restaurant's profit decreases in λ (i.e., $\partial\pi_R^P/\partial\lambda < 0$) if (b1) $\delta_3 < \delta < \delta_4$ and $\lambda < \lambda_5$, or, (b2) $\delta > \delta_4$.

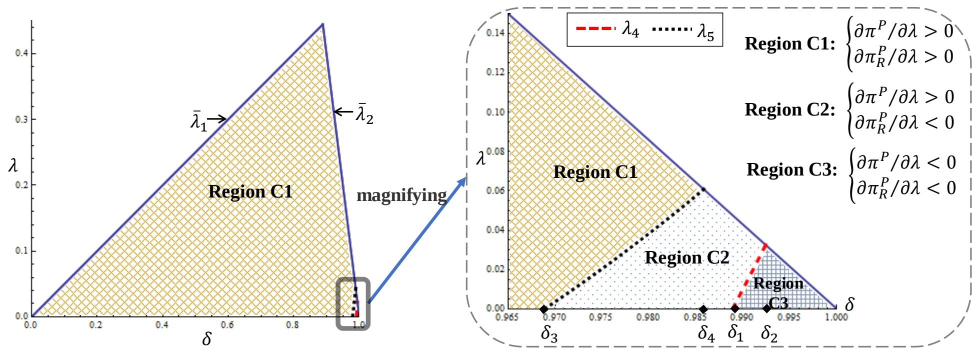


Figure 6. Sensitivity analysis of the system profit and the restaurant's profit in *Platform Partnership Scenario* with respect to λ

We use Figure 6 to illustrate the analytical results in Lemmas 3 and 4. Intuitively, the channel system and the restaurant could benefit greatly from the strong network externality because this significantly improves the consumer initial valuation. However, when the online and offline channels are highly competitive (i.e., δ is very large) and the network externality is very weak (i.e., λ is very small), Lemma 3(b) and Lemma 4(b) arise to be counterintuitive. That is, the channel system profit and the restaurant's profit in *Platform Partnership Scenario* will decrease in the network externality λ. The explanations of these results are as follows.

First, when the online and the offline channels become homogeneous, according to Lus and Muriel (2009), consumers' desire to purchase will shrink, which drives the platform to offer more subsidy to expand the market. The larger λ is, the more subsidy cost will occur (see Lemma 2). This hurt platform's profit. Meanwhile, the restaurant is also driven to stimulate consumption by reducing both the online and offline prices, see Region B1 in Figure 5. Second, in a co-opetitive channel system where the restaurant obtains profits from two channels, reducing the prices urgently usually lacks efficiency because of the "low price trap" (Niu et al. 2019, Niu et al. 2023). Readers can also revisit Proposition 1 for the detailed analysis. That is, although the demand volume in the online channel is boosted by the reduced online price, the demand volume in the offline channel decreases significantly. This exacerbates the channel imbalance that is not beneficial for the entire system.

Then, we compare the restaurant's profits in two scenarios to identify its preferences.

Proposition 3. There exist three thresholds with respect to δ and λ: δ_3, δ_5 and λ_6, where $\delta_5 > \delta_3$, such that the following conditions hold:

(a) The restaurant prefers *platform partnership* (i.e., $\pi_R^P > \pi_R^B$) if (a1) $\delta \leq \delta_3$, or, (a2) $\delta_3 < \delta < \delta_5$ and $\lambda > \lambda_6$. (b) The restaurant prefers *offline channel only* (i.e., $\pi_R^P < \pi_R^B$) if (b1) $\delta_3 < \delta < \delta_5$ and $\lambda < \lambda_6$, or, (b2) $\delta \geq \delta_5$.

Proposition 3 shows that the restaurant's preference of *Platform Partnership* depends on two parameters, i.e., the consumer's acceptance of the online channel δ and the intensity of network externality λ (see Figure 7 for illustration). As Proposition 3 shows, the thresholds δ_3 and δ_5 divide the region of δ into three levels: the online channel is slightly (highly) accepted by consumers, i.e., $\delta \leq \delta_3$ ($\delta \geq \delta_5$), and the consumer's acceptance of the online channel is high but not so high, i.e., $\delta_3 < \delta < \delta_5$. Intuitively, a large δ indicates that the online channel is highly accepted by consumers, and they can obtain a high initial valuation by purchasing in the online channel, implying that the online channel is valuable for the restaurant. Hence, one may conjecture that the restaurant will prefer to build an online store by partnering with the platform (i.e., *Platform Partnership*) given a large δ. When the online channel is very valuable for the restaurant (i.e., $\delta \geq \delta_5$), Proposition 3(b2) confirms the conjecture. However, interestingly, when δ is not very large (i.e., $\delta_3 < \delta < \delta_5$), Proposition 3(b1) shows the opposite can be true. Why? We introduce Corollary 1 to explain this result.

Corollary 1. There exist several thresholds with respect to δ and λ: δ_1, δ_2, δ_3, δ_4, λ_4 and λ_5, where $\delta_2 > \delta_1 > \delta_4 > \delta_3$ and $\lambda_5 > \lambda_4$, such that the following results hold:

(a) With platform partnership, both the channel system profit and the restaurant's profit increase in the network externality λ (i.e., $\partial \pi^P / \partial \lambda > 0$ and $\partial \pi_R^P / \partial \lambda > 0$) when one of the following conditions is satisfied: (a1) $0 < \delta \leq \delta_3$, or (a2) $\delta_3 < \delta < \delta_4$ and $\lambda > \lambda_5$.

(b) With platform partnership, the channel system profit increases in the network externality λ while the restaurant's profit decreases in the network externality λ (i.e., $\partial \pi^P / \partial \lambda > 0$ and $\partial \pi_R^P / \partial \lambda < 0$) when one of the following conditions is satisfied: (b1) $\delta_3 < \delta < \delta_4$ and $\lambda < \lambda_5$, (b2) $\delta_4 < \delta \leq \delta_1$, or (b3) $\delta_1 < \delta \leq \delta_2$ and $\lambda > \lambda_4$.

(c) With platform partnership, both the channel system profit and the restaurant's profit decrease in the network externality λ (i.e., $\partial \pi^P / \partial \lambda < 0$ and $\partial \pi_R^P / \partial \lambda < 0$) when one of the following conditions is satisfied: (c1) $\delta_1 < \delta \leq \delta_2$ and $\lambda < \lambda_4$, or (c2) $\delta_2 < \delta < 1$.

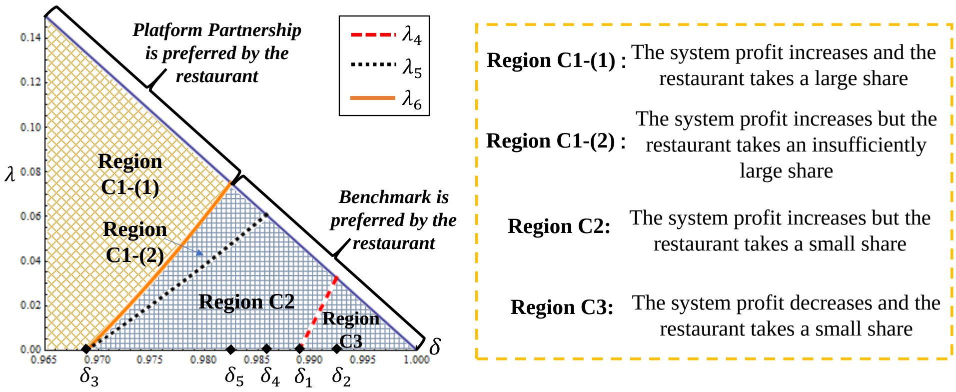


Figure 7. System profit share and the restaurant's platform partnership decisions

The conditions (a), (b) and (c) of Corollary 1 are illustrated by Region C1, Region C2 and Region C3 in Figure 7, respectively. Corollary 1, Lemmas 3 and 4 have explained why the restaurant does not prefer platform partnership when δ is large and λ is small. However, it's worth noting that, although Regions C3 and C2 show the restaurant's same preference, the driving forces are significantly different. When δ is very large and λ is very small (i.e., Region C3 in Figure 7), the channel system profit with platform partnership will decrease in the network externality λ, and the restaurant's profit takes a smaller share in the shrinking system profit. This does not induce the restaurant to prefer platform partnership. In contrast, when δ is not so large and λ is not very small (i.e., Region C2 in Figure 7), we find that the channel system profit with platform partnership could increase given a large network externality λ, but the restaurant's profit share in the system profit is shrinking rapidly as λ increases. Therefore, interestingly, the restaurant could be better off without platform partnership in Region C2.

Another important observation worth noting is that, the restaurant may still not prefer platform partnership in Region C1, even if the channel system profit and the restaurant's profit show increasing trends in this region. Taking a close look at this region, we have Region C1-(1) and Region C1-(2). The former is a region where the restaurant prefers platform partnership, while the latter is a region that does not encourage the restaurant's platform partnership. The explanations are as follows. First, the channel system profit with platform partnership is not sufficiently large in Region C1-(2), which may strengthen the profit allocation competition between the restaurant and the platform. Second, as Proposition 1(b) has shown, the profit of the restaurant's online (offline) channel increases (decreases) in λ. Thus, the increasing network externality λ hurts the restaurant's offline revenue and highlights the importance of the online revenue. However, Proposition 2 indicates that, most of the online profit will go to the platform due to the commission arrangement, making the restaurant gain less in an insufficiently profitable system. Therefore, in Region C1-(2), the restaurant does not prefer platform partnership. Conversely, in Region C1-(1), the system profit pie is enlarged by the network externality sufficiently and the restaurant can obtain an appreciable share in the system. Hence, the restaurant will prefer platform partnership.

We find the interesting results in Figure 7 could bear important implications. First, the results reveal that the restaurant will prefer *Benchmark Scenario* when the foods sold online have nearly identical taste/perception quality to those sold offline (i.e., δ is very large). This helps avoid the over-intensified competition between online and offline channels. Otherwise, in the vast majority of cases, the restaurant will prefer partnering with the platform and operating both the online and offline stores. This is consistent with the current trends in the restaurant industry, where more and more restaurants are opening their online stores on the platforms (Statista 2020, Daxue Consulting 2020, McKinsey 2021).

Second, we find that δ_3 (see Table 6 in the Appendix) is a decreasing function of the commission rate r. As the commission rate increases, the region of "*Benchmark is preferred by the restaurant*" will shrink. This indicates that, if the online commission rate is too high, the restaurant will have less incentive to open the online store at such a high commission cost. This is consistent with the practices in the global restaurant industry, where many restaurants are rethinking their partnership with platforms because of the high commission fees (Forbes 2020). The high commission cost may force the restaurant to operate the offline store only, which corresponds to a large δ_3 in our paper.

4.4 Consumer Surplus and Social Welfare

We have studied the restaurant's preference for platform partnership. Now, we analyze how the restaurant's platform partnership affects the consumer surplus and social welfare. Denote CS^k and CS^k, where $k \in \{P, B\}$, as the consumer surplus in Scenario k. The functions of consumer surplus and social welfare and the outcomes in the two scenarios are presented in Appendix.

Proposition 4. With platform partnership, the consumer surplus is higher if $\lambda > \lambda_7$ (i.e., $CS^P > CS^B \; if \; \lambda > \lambda_7$), and the social welfare is higher if $\lambda > \lambda_8$ (i.e., $SW^P > SW^B \; if \; \lambda > \lambda_8$).

Proposition 4 demonstrates that, the consumer surplus and the social welfare with platform partnership are higher than those in Scenario B when the network externality is strong. This confirms the intuition because both the online and offline consumers' initial valuations will be significantly improved when the network externality exceeds a threshold, thus leading to a higher consumer surplus. Regarding the social welfare, it is the sum of consumer surplus and system profit. Lemma 3 shows that, the system profit will be increased by the enhanced network externality. Therefore, a larger system profit and a higher consumer surplus result in a higher social welfare given a sufficiently strong network externality.

The analysis of consumer surplus and social welfare bears important practical implications. First, if the effect of social promotion is pretty good and strong network externality is generated, the restaurants raising the food prices might not hurt the consumer surplus (Lemma 1 reveals that, when the network externality is strong, both the offline and online prices will be raised by the restaurant, but Proposition 4 shows that the consumer surplus will be improved by the strong network externality even though they pay a high food price). This enables the restaurants to acquire high food prices while also protecting the customer surplus by utilizing the social promotion tools effectively. Second, the strong network externality also helps improve the social welfare. This suggests that the food delivery platforms should develop more effective social promotion tools besides the "red packet" to help the restaurants and consumers achieve win-win situations that also contribute to improving social welfare.

5 Extensions

We provide two extensions in this section to examine our results' robustness. First, we consider a situation where the negative impact of online selling on offline consumers. Second, we incorporate the platform's delivery service to investigate the impact of delivery fees.

5.1 Negative Impact caused by Online Selling

Compared with the traditional setting of physical products, the restaurant business has the important property of "offline-wait-online-free". That is, because both the online and offline food orders are fulfilled by a single kitchen, the surge in online orders will result in offline consumers suffering from congestion and waiting cost, while the online consumers are wait-free due to their well-planned order time (Chen et al. 2022, Feldman et al. 2023). In *Benchmark Scenario*, there are no online orders, and the negative impact is formulated by ρq_{OF}, where ρ denotes the degree of intensity and q_{OF} is the total order size in the channel system. Therefore, the offline consumer surplus is $U_{OF}^{B} = \theta - p_{OF}^{B} - \rho q_{OF}^{B}$. The offline channel's demand volume and the restaurant's profit function are as follows.

$$q_{OF}^{B} = \int_{\theta_{OF}{}^{B}(\rho)}^{1} 1\, d\theta = \frac{1-p_{OF}^{B}}{1+\rho}, \tag{7}$$

$$\underset{p_{OF}^{B}>0}{Max}\ \pi_{R}^{B} = p_{OF}^{B} \cdot q_{OF}^{B}. \tag{8}$$

where $\theta_{OF}{}^{B}(\rho) = p_{OF}^{B} + \rho q_{OF}^{B}$ is consumers' indifference point between purchase and no purchase.

In *Platform Partnership Scenario* (superscripted as *P*), opening an online delivery channel can exacerbate order congestion and increase the waiting time of both online and offline consumers. The offline consumers are generally more sensitive to congestion compared with the online consumers (De Vries et al. 2018), so we follow Feldman et al. (2023) by assuming the negative impact caused by order congestion falls on offline consumers only, which is formulated by $\rho(q_{ON}^{P} + q_{OF}^{P})$. $q_{ON}^{P} + q_{OF}^{P}$ is the total order size in the channel system. The consumer surplus in offline channel becomes $U_{OF}^{P} = \theta - p_{OF}^{P} - \rho(q_{ON}^{P} + q_{OF}^{P})$.

Consumers will prefer the online channel if their surplus is higher in this channel, i.e.,

$$\begin{cases} U_{ON}^P = \delta\theta - (p_{ON}^P - s^P) > 0 \\ and \\ U_{ON}^P > U_{OF}^P = \theta - p_{OF}^P - \rho(q_{ON}^P + q_{OF}^P) \end{cases} \Rightarrow \begin{cases} Pr\left(\theta > \theta_{ON}{}^P(\rho)\right) \\ and \\ Pr\left(\theta < \theta_{ON,OF}{}^P(\rho)\right) \end{cases}, \quad (9)$$

where $\theta_{ON}{}^P(\rho) = \frac{p_{ON}^P - s^P}{\delta}$ and $\theta_{ON,OF}{}^P(\rho) = \frac{p_{OF}^P - (p_{ON}^P - s^P) + \rho(q_{ON}^P + q_{OF}^P)}{1-\delta}$ are the two indifference points. Similarly, if the consumer surplus in the offline channel is higher, i.e.,

$$\begin{cases} U_{OF}^P = \theta - p_{OF}^P - \rho(q_{ON}^P + q_{OF}^P) > 0 \\ and \\ U_{OF}^P > U_{ON}^P = \delta\theta - (p_{ON}^P - s^P) \end{cases} \Rightarrow \begin{cases} Pr\left(\theta > \theta_{OF}{}^P(\rho)\right) \\ and \\ Pr\left(\theta > \theta_{ON,OF}{}^P(\rho)\right) \end{cases}, \quad (10)$$

we have the indifference point $\theta_{OF}{}^P(\rho) = \frac{p_{OF}^P - (p_{ON}^P - s^P) + \rho(q_{ON}^P + q_{OF}^P)}{1-\delta}$. Then, the demand functions in the online and offline channels are as follows:

$$q_{ON}^P = \int_{\theta_{ON,OF}{}^P(\rho)}^{\overline{A}} \left(\frac{1}{\overline{A} - \underline{A}}\right) d\theta = \frac{\delta\rho + (1+\rho)s^P}{\delta(1-\delta-\lambda\rho)} - \frac{1+\rho}{\delta(1-\delta-\lambda\rho)} p_{ON}^P + \frac{1}{1-\delta-\lambda\rho} p_{OF}^P, \quad (11)$$

$$q_{OF}^P = \int_{\theta_{ON}{}^P(\rho)}^{\theta_{ON,OF}{}^P(\rho)} \left(\frac{1}{\overline{A} - \underline{A}}\right) d\theta = \frac{(1-\delta-\rho) - (\delta-\lambda+\rho)s^P}{\delta(1-\delta-\lambda\rho)} - \frac{1-\lambda}{1-\delta-\lambda\rho} p_{OF}^P + \frac{\delta-\lambda+\rho}{\delta(1-\delta-\lambda\rho)} p_{ON}^P. \quad (12)$$

We derive the equilibrium outcomes summarized in Table 4 (presented in Appendix) by backward induction. It is impossible to obtain the analytical results, so we conduct extensive numerical studies to examine how the parameter ρ affects the restaurant's preferences over platform partnership. We have approximately 540000 sets of parameter values. See Table 3 in Appendix for the details. Typical curves are presented in Figure 8, from which we summarize the results of the restaurant's optimal channel preferences in Observation 1.

Observation 1. When channel competition is not too fierce (i.e., δ is not extremely large), the restaurant prefers *Platform Partnership Scenario* (i.e., $\pi_R^P > \pi_R^B$) if the network externality λ exceeds a threshold and the parameter ρ is small. Conversely, the highly intense channel competition renders *Benchmark Scenario* more appealing for the restaurant.

Recall Proposition 3, which shows that if channel competition (i.e., δ) is mild (very intense), the restaurant will overwhelmingly prefer *Platform Partnership Scenario* (*Benchmark Scenario*), regardless of the impact of the network externality λ. However, when channel competition falls into a moderate range, the network externality λ holds the key to the restaurant's channel preferences. In this section, when the negative impact on offline channel is incorporated, Observation 1 indicates that the restaurant's preferences over *Platform Partnership Scenario* follow a very similar structure to that in the main body. The difference lies in that, when δ is not too large, the restaurant's preferences depend on the countervailing relationship between the negative impact (i.e., ρ) and the network externality (i.e., λ). We observe that the restaurant will prefer *Platform Partnership Scenario* if λ exceeds a threshold and ρ is not too large, as illustrated in Figure 8 (a), (b) and (c). This is mainly because the negative impact on the offline channel and the channel competition have a *complementary effect* in the restaurant's channel preferences. Our explanations are as follows.

First, opening an online delivery channel induces order congestion, thereby undermining the offline consumers' utility. Therefore, to improve the offline consumers' utility, the restaurant will reduce the offline food price aggressively. Second, as discussed in Lemma 1, the price reduction in the offline channel is prone to put the restaurant into a "pricing dilemma" where it has to reduce the online and offline prices simultaneously and trigger the fierce channel competition. Being aware of this, one can easily understand that when the negative impact is sufficiently strong (i.e., ρ is large) that the bright side of positive network externality cannot offset it, we thus observe that the restaurant prefers *offline channel only*.

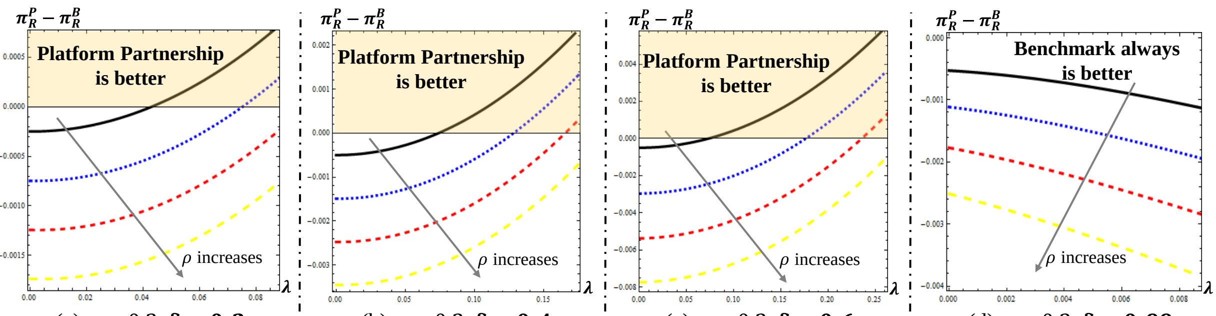
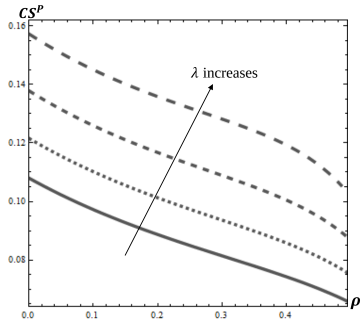


Figure 8. Restaurant's preferences of platform partnership considering the negative impact on the offline channel

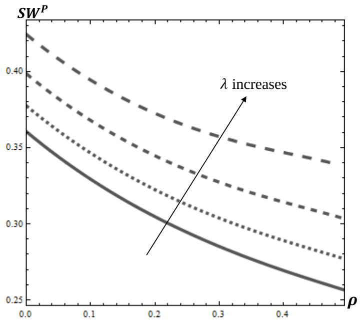
Next, we investigate how the negative impact affects consumer surplus and social welfare in *Platform Partnership Scenario*. The functions of consumer surplus and social welfare have the same form as in the main model. The main findings are illustrated in Figure 9, and we have Observation 2.

Observation 2. In *Platform Partnership Scenario*, both the consumer surplus and the social welfare decrease as the negative impact ρ increases.

As the enhanced negative impact will significantly undermine the offline consumers' utility, the restaurant is incentivized to reduce the offline food price but raise the online food price aggressively for a higher profit. This attracts more consumers to the offline store, which lengthens the offline consumers' waiting time and further undermines their utility. Therefore, it is intuitive to observe that both the consumer surplus and the social welfare decrease in the negative impact ρ. Additionally, we find that the countervailing interaction between the negative impact and the positive network externality still exists. That is, the enhanced positive network externality will offset the negative impact, resulting in the higher consumer surplus and social welfare. These findings remind the restaurant that, the negative impact and positive network externality of the online channel act as two sides of a double-edged sword, and their countervailing interaction affects not only the restaurant's profit but also the social welfare and the consumer surplus. Therefore, restaurants must reconcile these two effects very carefully. For example, expanding the kitchen capacity could be useful to mitigate the negative impact due to order congestion for those restaurants partnering with food delivery platforms.



(a) The impact of ρ on consumer surplus



(b) The impact of ρ on social welfare

Figure 9. The impact of ρ on consumer surplus and social welfare in Scenario P

5.2 Delivery Fee in Online Channel

In practice, the platforms (e.g., Meituan and Uber Eats) operate their logistics systems and provide food delivery services for the restaurants, enabling them to charge consumers delivery fee (Pandaily 2020). For example, Meituan charges an average logistics service fee of ¥3 (≈$0.47) for per online order (Pandaily 2020). When considering the delivery fee, the online consumers' net utility becomes $U_{ON} = \delta\theta - (p_{ON} - s) - c$, where c represents the unit delivery fee. Then, the demand functions in the online and offline channels in the *Platform Partnership Scenario* are

$$q_{ON}^P = \frac{s^P - c}{(1-\delta)\delta} - \frac{1}{(1-\delta)\delta} p_{ON}^P + \frac{1}{1-\delta} p_{OF}^P, \tag{13}$$

$$q_{OF}^P = \frac{\lambda(s^P - c) + \delta(1 - s^P + c) - \delta^2}{(1-\delta)\delta} - \frac{1-\lambda}{1-\delta} p_{OF}^P + \frac{\delta - \lambda}{(1-\delta)\delta} p_{ON}^P. \tag{14}$$

The profit functions of the restaurant and the platform are the same as those in the main model. By backward induction, the equilibrium outcomes in *Platform Partnership Scenario* are derived in Table 5, which are presented in Appendix S1. For convenience, defining the restaurant's profit difference with and without platform partnership in the main model and that in this subsection as $\Delta\underline{\pi_R} = \underline{\pi_R^P} - \underline{\pi_R^B}$ and $\Delta\pi_R = \pi_R^P - \pi_R^B$, respectively, where the expressions of $\underline{\pi_R^P}$ and $\underline{\pi_R^B}$ are presented in Table 1. Comparing $\Delta\underline{\pi_R}$ and $\Delta\pi_R$, we have Proposition 5.

Proposition 5. When the platform's delivery fee is considered, the restaurant's preferences of *Platform Partnership* show the same patterns with that in the main model because $\Delta\pi_R$ is proportional to $\Delta\underline{\pi_R}$, i.e., $\Delta\pi_R = \frac{(2c-\lambda)^2}{\lambda^2}\Delta\underline{\pi_R} = \left(1 + \frac{4c(c-\lambda)}{\lambda^2}\right)\Delta\underline{\pi_R}$ holds for any feasible r, δ and λ.

Proposition 5 demonstrates that the restaurant's preferences of channel strategies will not be altered by the platform's delivery fee. Hence, our main results are robust even though the platform's delivery fee is considered. The only difference is the slope $\frac{(2c-\lambda)^2}{\lambda^2} = 1 + \frac{4c(c-\lambda)}{\lambda^2}$, which reveals that the restaurant may prefer platform partnership more as the platform's delivery fee c increases. That is, if the impact of c dominates, then the restaurant's profit difference with and without platform partnership $\Delta\pi_R$ will be enlarged by c (i.e., $\Delta\pi_R = \left(1 + \frac{4c(c-\lambda)}{\lambda^2}\right)\Delta\underline{\pi_R} \uparrow$), so the restaurant will have a stronger incentive to prefer platform partnership. Otherwise, the slop will be smaller, and the restaurant has less incentive to prefer platform partnership. The reason is that for the consumers, the platform's delivery fee c and subsidy s have a *substitutable* impact on their online purchases. An increasing delivery fee induces the platform to offer more subsidies to the consumers which increases the social traffic. This expands the online market and induces the restaurant to open the online store.

6 Conclusion

Online food delivery service provides restaurants with opportunities to expand their sales through online platforms. In recent years, the global online food delivery market has witnessed vigorous growth. However, consumers may not fully trust the food sold in online channels, which limits the further growth of the online food delivery market. Being aware of this, some platforms (e.g., Meituan and Uber Eats) have launched promotion rewards to subsidize the consumers who share and/or open red packets in their social networks, attempting to increase the social traffic by network externality and thereby expand the online market. With the platforms' subsidies, the online purchase price will be reduced. This may not only result in the price war between restaurants' online and offline channels but also enable the platforms to split a large proportion of online profit via commission arrangements, making the restaurants worse-off with platform partnership. Therefore, the reward-based platform traffic may not be rewardful for the restaurants, and they have to balance the pros and cons when deciding to partner with the platform.

We build a game-theoretic model to formulate the tradeoffs and decision-making mechanism in platform partnership in the presence of the platform's subsidy and the network externality among consumers. The restaurant can sell foods in the offline channel only. If platform partnership is decided, the restaurant will operate two competing channels. We derive non-trivial results that might bear important managerial implications for both the restaurants and the platforms. (1) Given a weak network externality, the platform has strong incentives to offer a high subsidy, resulting in a substantial online price reduction. However, many offline consumers may be attracted to the online channel, so the restaurant has to downward adjust the offline price. In such a case, the platform's subsidy would strongly interfere with the restaurant's price decisions and trap the restaurant in a pricing dilemma. This finding reminds restaurants that a more centralized channel structure (i.e., *Benchmark Scenario*) can be more profitable regardless of the social traffic from the platform. (2) We find that strong network externality always promotes the restaurant to prefer platform partnership, while given weak network externality, operating the offline channel only could be better, especially when the online channel is highly accepted by consumers. The reason is that, although the online channel is highly accepted, the two channels engage in intensified competition that results in market shrinkage (Lus and Muriel 2009). A weak network externality motivates the platform to increase the subsidy, which intensified the price war between restaurant's online and offline channels.

The results in this paper, especially the synergy between the offline and online channels, are insightful to the restaurant business when social traffic plays an important role. Our results can be generalized to the industries with the property of "pooled production + decentralized selling" such as the luxury watches (e.g., the handmade watches of Switzerland) manufacturing, the handicrafts industry (e.g., Chinese embroidery) and the service industry with a centralized service center because the foods are produced and consumed instantly. Having said that, there are some limitations in this study. First, our results may not fit the situation where the products are produced by multiple suppliers/manufacturers/factories and for non-instant consumption (e.g., daily groceries), because the spillover of positive network externality from the online to the offline channel would disappear. And the negative externality due to order congestion would also disappear if the products are non-instant and the consumers' waiting costs are negligible (Feldman et al. 2023). Second, compared with the traditional e-commerce platforms, we do not consider the cross network externalities between the online and offline channels, i.e., the network externalities might arise in two channels and interact with either a substitutable or complementary relationship (Abhishek et al. 2015). Third, we have abstracted away demand uncertainty, especially in the online channel. We predict that online demand uncertainty will induce the platform's more social promotion but the restaurant's profit with platform partnership will not necessarily be reduced, as the channel difference is maintained. We leave the above studies as the promising future research directions.

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