Journal of
*Theoretical and Applied Electronic Commerce Research*

MDPI

*Article*

# Cross-Platform Logistics Collaboration: The Impact of a Self-Built Delivery Service

**Lanbo Li [1,2] and Gang Li [1,*]**

[1] School of Management, The State Key Lab for Manufacturing Systems Engineering, The Key Lab of the Ministry of Education for Process Management & Efficiency Engineering, Xi'an Jiaotong University, Xi'an 710049, China; lilanbo201585@stu.xjtu.edu.cn
[2] Department of Systems Engineering, City University of Hong Kong, Kowloon, Hong Kong, China
* Correspondence: glee@mail.xjtu.edu.cn

**Abstract:** Motivated by the collaboration of a takeout platform and a crowdsourced delivery platform, we developed a stylized model to explore the interplay between the two platforms' decisions. We captured the cross-platform network effects of the two complementary platforms, and investigated how the collaboration between the two platforms shapes the optimal prices, platform profits, and social welfare. We found that the takeout platform optimally adopts a subsidy pricing strategy when its commission rate is relatively high. In addition, when the demand-side network effect coefficient increases, the delivery platform optimally raises the shipping fee to trigger a larger supply of drivers. Furthermore, we found that the takeout platform introducing a self-logistics service reduces the subsidy intensity and raises the subsidy threshold. It also reshapes the strategic two-sided pricing to increase the network benefit when the network effect coefficient grows on one side. Specifically, as the supply-side network effect coefficient increases, instead of lowering the delivery price to increase demand and further increase the drivers' network benefit, the takeout platform optimally raises it under certain conditions. Finally, self-logistics may benefit the takeout platform, while hurting the delivery platform, and it can increase social welfare. Our results, thus, unveil a price regime for platform collaboration and validate the effectiveness of the introduction of self-logistics by takeout platforms.

**Keywords:** e-commerce; platform collaboration; online food delivery; network effects; pricing



Academic Editor: Danny C.K. Ho

Received: 6 November 2024
Revised: 23 December 2024
Accepted: 23 December 2024
Published: 27 December 2024

**Citation:** Li, L.; Li, G. Cross-Platform Logistics Collaboration: The Impact of a Self-Built Delivery Service. *J. Theor. Appl. Electron. Commer. Res.* **2025**, *20*, 3. https://doi.org/10.3390/jtaer20010003



## 1. Introduction

Online-to-offline food delivery platforms such as GrubHub, Uber Eats, DoorDash, Meituan, and Ele.Me have boomed in recent years. The worldwide revenue from online food delivery (OFD) is expected to grow to USD 1.85 trillion by 2029 from over USD 1 trillion estimated in 2023 [1]. An OFD platform offers an online food ordering and home delivery service to customers and allows restaurants to enter the food delivery market without developing their own logistics channel and website, which minimizes their fixed operating cost.

The surge in OFD orders requires that takeout platforms expand their logistics capabilities. A takeout platform collaborates with a third-party crowdsourced delivery platform to fulfill online-to-offline food delivery. For example, Ele.Me announced that the third-party crowdsourced delivery platform "Dianwoda" became its exclusive strategic partner for logistics fulfillment in 2017 [2]. From then on, Ele.Me relied on the intelligent scheduling system of "Dianwoda" to achieve real-time delivery of takeout orders. Furthermore, to make it more convenient for customers to order food online and have it delivered to their doors, Meituan expanded its crowdsourced logistics through partnering with the third-party delivery platforms "FlashEx", "SoFast", and "UUpaotui" in 2023 [3]. In other words, the takeout platform does not directly manage logistics capabilities, but outsources food delivery to an independent delivery platform. The takeout platform offers an online order-taking service and the delivery platform physically delivers the food from restaurants to customers, constituting an entire OFD system.

Unlike traditional two-sided online food delivery (OFD) platforms that combine the functions of online ordering and food delivery, and connect two user groups within the network, cross-platform network effects play a significant role in this OFD system. This means that the number of drivers on the delivery platform and the number of customers on the takeout platform mutually influence each other, and we refer to this phenomenon as cross-platform network effects (see Figure 1). The takeout platform can regulate the demand for takeouts by adjusting the delivery price charged to customers instead of the food price, which is determined by the restaurant and thus beyond the control of the takeout platform. Similarly, the delivery platform can control the supply of logistic services by determining the shipping fee charged to the takeout platform, a proportion of which is paid to crowdsourced drivers as a wage. The independent pricing strategies employed by the two platforms can lead to varying strengths of network effects and spillover effects on the respective platforms. Essentially, a higher wage directly incentivizes the greater participation of drivers, thereby enhancing network effects on the demand side. Whereas a higher delivery price reduces takeout demand, resulting in diminished network effects on the supply side. The intertwining of network effects between the two platforms poses challenges in effectively coordinating the food demand and delivery supply.

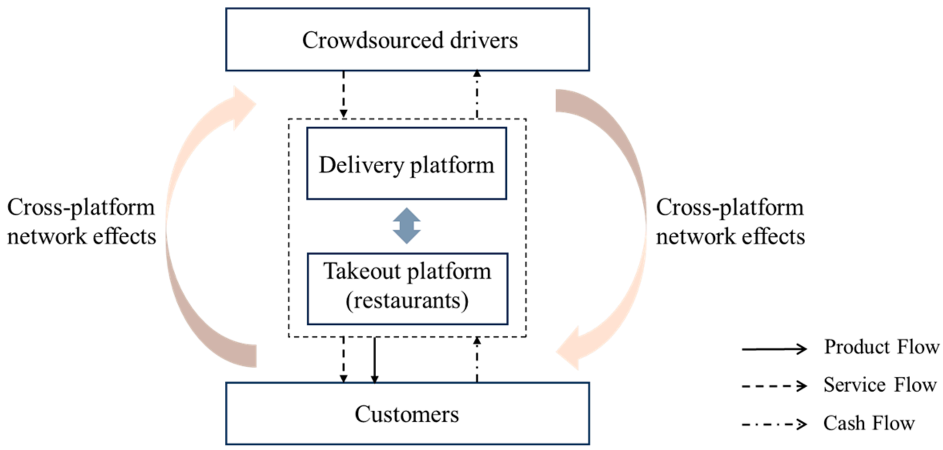


**Figure 1.** Cross-platform network effects based on online food delivery (OFD) system.

In addition to utilizing a crowdsourced service, takeout platforms can also establish their own delivery capabilities. For example, Meituan recruits full-time delivery workers, known as "Meituan Zhuansong". Meituan assigns some takeout orders to its self-established delivery service with higher priority, rather than relying solely on the crowdsourced delivery platform. The interaction between the takeout platform's self-established logistics and the crowdsourced logistics exacerbates the complexity of cross-platform network effects. From one perspective, the introduction of self-built logistics increases the service supply and enhances the demand-side network effects. Conversely, the takeout platform prefers to prioritize full-time delivery workers for fulfilling OFD orders. This discourages crowdsourced drivers, resulting in a reduction in service supply.

Under cross-platform collaboration, the interplay between the two complementary platforms is complicated. The logistics supply on the delivery platform affects the customer demand on the takeout platform, and vice versa. As a result, a platform pricing decision on one side will propagate to the other platform and affect its pricing decisions. Moreover, a takeout platform's introduction of self-built logistics complicates the cross-platform interactions of customers and drivers, which may reshape the collaboration of the two platforms. Consequently, making the right decisions for the two platform is significant challenge for the operation of two independent platforms, especially when the takeout platform utilizes both crowdsourced logistics and self-built logistics for order fulfillment.

Naturally, this motivated us to ask the following research questions: (1) What is the optimal price strategy for the takeout platform when collaborating with an independent delivery platform to achieve OFD? (2) How do the dynamics of cross-platform logistics collaboration affect the optimal delivery price and the optimal shipping fee? (3) What impacts does the self-built delivery service of the takeout platform have on the optimal prices, platform profits, customer surplus, and social welfare?

To address these research questions, we developed a stylized model that encompasses an online food delivery (OFD) market comprising a takeout platform, a crowdsourced delivery platform, restaurants, customers, and drivers. The restaurants utilize the takeout platform to facilitate the sale of their food items. As part of this arrangement, the takeout platform receives a portion of the restaurants' online sales revenue as a commission fee. Additionally, the takeout platform levies a delivery price on customers to cover the cost of delivering the food to their home. The takeout platform delegates the actual delivery tasks to an independent delivery platform, which employs crowdsourced drivers and compensates them with wages. Both the takeout platform and the delivery platform collaborate with each other, while simultaneously striving to maximize their individual profits.

This work yielded several key findings. Firstly, our results revealed that the takeout platform optimally adopted a subsidy pricing strategy for consumers, particularly when the commission rate imposed on the restaurants was relatively high. By subsidizing the delivery price for customers, the takeout platform could benefit from the higher commission fee derived from food sales. However, the takeout platform became less dependent on crowdsourced logistics with the introduction of self-built logistics. Then, the impact of crowdsourced logistics on the pricing of the delivery service diminished. Consequently, the subsidy pricing threshold increased and the subsidy intensity became smaller when the takeout platform self-established a delivery service.

Secondly, the cross-platform network effects, together with the transaction volume which took the minimum of supply and demand, drove a new price regime for platform collaboration. We discovered that, as the demand-side network effect coefficient increased, the delivery platform raised the shipping fee to incentivize more drivers to participate. This led to a higher utility for each customer, and then the takeout platform was able to charge a higher delivery price. This strategic two-sided pricing responded by increasing the network benefit as the network effect coefficient grew on one side. Furthermore, it was surprising that with self-built logistics, the strategic two-sided pricing could be overturned under certain conditions. Specifically, both the optimal delivery price and the optimal shipping fee became higher as the supply-side network effect coefficient increased. In terms of platform profits, we found that by increasing either the supply- or demand-side network effect coefficient, the profits of both the takeout platform and the delivery platform increased.

Lastly, we investigated the impact of a self-built delivery service on the two-sided pricing, platform profits, and social welfare. We find that the implementation of full-time delivery workers by the takeout platform led to a reduction in both the optimal shipping fee and the optimal delivery price. Although this results in a lower profit for the delivery platform, the profit of the takeout platform may increase, depending on the scale and marginal cost of the self-built logistics. While the consumer surplus consistently increased, the welfare of the crowdsourced drivers experienced a decline. Overall, the introduction of self-built logistics into an OFD system has the potential to enhance social welfare under specific conditions. These findings confirm the effectiveness of self-built logistics implemented by a takeout platform and shed light on the collaboration dynamics between takeout platforms and delivery platforms. Furthermore, they provide insights into how takeout platforms can leverage both self-built and crowdsourced delivery systems to optimize online-to-offline retailing operations.

Our key contributions deserve highlighting. First, to the best of our knowledge, we add a missing piece of knowledge to understand the cross-platform interplay between customers of a takeout platform and drivers of a crowdsourced delivery platform under network externalities. Unlike a traditional two-sided platform that straddles both sides to internalize the externalities, neither the takeout platform nor the crowdsourced delivery platform can fully internalize the network effects by itself. Thus, we endeavored to unveil the pricing rationale for platform collaboration. This can help us better manage and leverage the two-sidedness of this OFD system. Second, despite the boom in self-built logistics by takeout platforms in practice, few studies have considered the coordination of takeout demand with logistics supply from both crowdsourced drivers and full-time employees. The introduction of self-built logistics further complicates the cross-platform interaction of customers and drivers. We found, surprisingly, that as the supply-side network effect coefficient increases, the takeout platform should optimally raise the delivery price under certain conditions, instead of lowering it to enlarge the network benefit of drivers, as in conventional wisdom. Our research thus provides guidelines for takeout platforms operating two service sources. Finally, we found that the self-logistics enrich the takeout platform and social welfare under certain conditions, and the consumer surplus consistently increases. Thus, we verified the effectiveness of self-logistics by the takeout platform.

The remainder of this paper proceeds as follows. Section 2 reviews the related literature. In Section 3, we set up our model. In Section 4, we analyze the equilibrium prices of two platforms. In Section 5, we determine the influence mechanism of self-built logistics on the OFD system, customer surplus, and social welfare. Section 6 concludes the study and provides some directions for future research. All proofs are given in Appendix A.

## 2. Literature Review

Three streams of literature are related to our research: pricing in a two-sided market, platform collaboration, and online food delivery.

### *2.1. Pricing in a Two-Sided Market*

The topic of platform pricing has gained significant attention in recent years. A commonly suggested strategic approach for two-sided markets is to offer lower prices to the side that receives less utility from the presence of the other side, discounting on one side, while charging the other side [4–6]. Parker and Van Alstyne [4] examined the profitability of offering free products to either content providers or end consumers, assuming users single-home. Rochet and Tirole [7] generalized the "seesaw principle", where one side is charged a high price to increase profits, while the other side is offered a low price or even subsidized to attract more users. Considering network neutrality and information levels, the seesaw principle remains optimal in "competitive bottlenecks", where one group agent multi-homes [8–10]. Consequently, the seesaw principle is widely applicable in studying two-sided markets across various settings. Armstrong [8] found that positive cross-group externalities reduced platform profits in a hoteling model where two-sided users had a single-home, as platforms must compete fiercely for market share with fixed group sizes. Bakos and Halaburda [11] investigated optimal pricing in competitive two-sided platforms and concluded that the seesaw principle is not an optimal strategy and may be incorrect when both sides multi-home, assuming no double counting. However, if meeting yields equal benefits to the first time, the seesaw principle may prove valid.

A typical two-sided platform operates in both supply and demand markets, effectively pricing on both sides to internalize network externalities. The price interplay of two sides on the same platform is the driving force of the seesaw principle. Our work explores how a takeout platform leverages crowdsourced logistics capacities through collaboration with a delivery platform under cross-platform network effects. The two platforms serve the OFD market by implementing separate pricing strategies on the supply and demand sides to independently maximize their own profits, deviating from the advantages of a traditional two-sided platform. Moreover, Benjaafar and Hu [12] pointed out that transaction volume takes the minimum form of supply and demand in a sharing economy application, to reflect the characteristics at the operational level. These unique structures alter the dynamics between two sides on different platforms, rendering the seesaw principle not applicable. Exploring the optimal two-sided pricing strategy is challenging and vital for both the takeout platform and the delivery platform to better operate in the OFD market.

### 2.2. Platform Collaboration

The emergence of two-sided platforms has disrupted the traditional single-sided market economy and facilitated the growth of the platform-based economy. Numerous studies have focused on analyzing the cooperation dynamics between platforms. Rong et al. [13] conducted an online experiment to investigate social information disclosure within the e-commerce platform ecosystem, and the results encouraged collaboration between social media platforms and e-commerce platforms. Similarly, Zhu et al. [14] developed an analytical model to explore the pricing and investment decisions of a monopoly two-sided platform (Meituan), assuming that cooperation with a social media platform (WeChat) enhanced the externality experienced by buyers. They discovered that cooperation increases demand and total profit. In contrast to their work, our study focuses on cooperation between a takeout platform and a delivery platform, considering cross-platform network externalities and achieving value co-creation through a precise division of labor. We demonstrate that the introduction of self-built logistics improves demand and may benefit the total profit and social welfare.

Cohen and Zhang [15] investigated how competing ride-sharing platforms can introduce a joint service contract, and they found that a well-designed coopetition term can benefit all stakeholders. Liu and Li [16] examined the competition and collaboration between a food delivery platform and a ride-hailing platform that shared a common pool of gig workers. They concluded that platform integration can benefit all stakeholders when the demand for ride-hailing services is relatively small. Liu et al. [17] studied the coopetition issue between two digital platforms by offering complementary products to a rival platform. They found that compatibility can benefit both platforms under certain conditions. A closely related study to ours was conducted by He et al. [18], where they developed a game model to study how an O2O retailing platform can leverage self-scheduling delivery capacities through either outsourcing to a third-party delivery platform or self-built logistics. They proposed a subsidy contract to align the incentives of these two platforms accordingly. We explore a similar issue with the consideration of cross-platform network effects and further examine the impact of self-built logistics on the platform profits and social welfare. Our findings validate the potential benefits of introducing self-built logistics for the OFD system and social welfare under certain conditions.

### 2.3. Online Food Delivery

The last stream of research closely related to our study focuses on online food delivery (OFD), and the literature within this stream examines various aspects of the OFD ecosystem. Chen et al. [19] and Feldman et al. [20] investigated optimal coordinating contracts in the platform–restaurant relationship. In contrast to these studies, our research assumes that the food price is exogenous, and we instead focus on the service price interaction between the takeout platform and the delivery platform due to cross-platform logistics collaboration. Other studies have explored the optimal delivery mode for restaurants. Niu et al. [21] showed that if the online market size is large, restaurants should choose self-logistics, while restaurants should choose platform–logistics considering environmental sustainability. Du et al. [22] examined how the advertising effect of self-logistics and consumer benefits from platform promotions affect the optimal choice strategies for a restaurant's mode of delivery and platform establishment decisions. Du et al. [23] investigated the optimal combination of price strategy and delivery mode for restaurants. In these studies, the delivery service could be provided by the restaurant, the platform, or a third-party firm. In contrast, our model focuses on a scenario where the restaurant only chooses the platform-delivery mode, creating a "delivery-only kitchen". The shipping fee charged by the delivery platform represents the delivery cost for the takeout platform, leading to double marginalization. As a result, the price change tendencies of the two platforms exhibit consistency in network effect coefficients or platform commissions under certain conditions.

Regarding the pricing policies and operation strategies of OFD services, Tong et al. [24] studied the impact of static or dynamic pricing strategies on platform performance in a dyadic two-sided market. Du et al. [25] explored the strategic offering of on-time delivery services with compensation by both a food delivery platform and a restaurant. Liu et al. [26] investigated a merchant's operational decisions for a buy online and pickup in-store service. Chen and Hu [27] examined the optimality of dedicated and pooling delivery strategies in an on-demand delivery system. Lu et al. [28] found a drone–rider collaboration delivery mode lowered delivery cost and raised customer satisfaction compared with a rider delivery mode. Sun et al. [29] considered the full dynamics of the three-sidedness involving consumers, restaurants, and gig drivers in two competitive OFD platforms. Ji et al. [30] evaluated the effects of commission cap policy and wage floor regulation on all stakeholders. Bi et al. [31] optimized a meal delivery routing problem under a shared logistics mode. However, the prior literature has paid little attention to the cooperation issue between a takeout platform and a crowdsourced delivery platform under network externalities. No clear consensus has been reached regarding the strategic interaction between these two platform types, which together form an entire OFD system, and whether the addition of a self-built delivery service enhances the performance of this OFD system. Our paper aimed to fill this research gap by focusing on these aspects.

## 3. Model Setup

### 3.1. Takeout Platform and Customers

To isolate the effect of logistics collaboration between the takeout platform and the delivery platform, we assume that there are multiple restaurants roughly offering food at the same quality at a fixed price $g$ on a takeout platform (labeled $P_t$, e.g., Meituan) with a unit production cost. Without loss of generality, we normalized this to be zero [21,23]. The takeout platform serves as an online food ordering channel and partners with an independent third-party crowdsourced delivery platform (labeled $P_d$) to provide a home delivery service for customers. The takeout platform takes a percentage $\tau$ of the restaurants' sale revenue as the commission for displaying food on their website and gives the rest to the restaurants. Following Du et al. [25] and Niu et al. [21], we assume that $\tau$ is exogenous.

In addition, a unit delivery price $f$ is charged by the takeout platform to customers for delivering food to their home [21,25]. By ordering through the takeout platform, each customer obtains a heterogeneous valuation of $v$ for the food and delivery service, where $v$ is a random variable that is uniformly distributed as $[0, 1]$ [25,26,30,32]. Following the common assumption in the two-sided market literature [8,33], the utility of one side is an increasing function of another side. Consequently, a customer with valuation $v \in [0, 1]$ obtains the following purchase utility:

$$U_c = v - g - f + \beta_c S, \quad (1)$$

we use $\beta_c$ to denote the degree of demand-side network effects, which represents the utility customers derive from one additional driver on the delivery platform for the shorter delivery time that the customer can enjoy. $S$ is the number of active drivers who offer a delivery service. For instance, an increase in service supply makes it easier for customers to find a nearby driver, reducing the delivery time. A customer derives a net utility of zero from an outside option. When the customer utility is greater than zero, the customer purchases the takeout. Thus, the proportion of customers who seek OFD orders is $1 - g - f + \beta_c S$. We assume the potential size of customers is normalized to "1" [22,25]. Therefore, the takeout demand for customers is a function of the service supply and platform decisions, that is

$$D(S, t, f) = 1 - g - f + \beta_c S, \quad (2)$$

### *3.2. The Third-Party Crowdsourced Delivery Platform*

The delivery platform attracts drivers by paying them wages from the transactions with the takeout platform (see Figure 2). The delivery platform determines the shipping fee per order charged to the takeout platform. For each delivery order, the platform shares a percentage $\lambda$ of this revenue (wage) with individual drivers and keeps a proportion $(1 - \lambda)$ of revenue as a commission. As crowdsourced drivers are a scarce resource for which a platform competes with its opponents, the proportion of revenue the delivery platform shares with the drivers is roughly the same across the platforms. For this reason, we assume that $\lambda$ is exogenous [34,35], and we further make the technical assumption that $\lambda \geq \frac{1-\beta_s}{2+\beta_c-3\beta_c\beta_s}$, to consider the practice that drivers receive a larger portion of the delivery fee compared to the delivery platform for each delivery order. By incorporating this assumption, we can rule out the possibility of a corner solution and ensure that the model reflects a more realistic and feasible scenario.

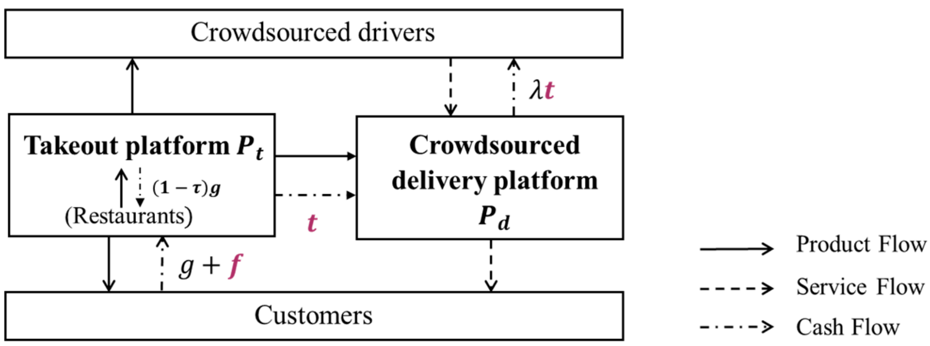


**Figure 2.** The OFD system structure.

Following Li et al. [36], we assume the mass of registered crowdsourced drivers on the delivery platform is "1". The drivers are independent contractors who have heterogenous operational costs $k$, where $k$ follows a distribution with a cumulative distribution function denoted by $F(\cdot)$. They decide whether to undertake the delivery work or not according to the wage the delivery platform guarantees [18,19]. Moreover, the number of OFD orders will also positively affect the supply of drivers, because an increase in OFD orders leads to a denser spatial distribution of customers, reducing the time drivers spend to complete a service. Then, when the delivery platform sets the delivery wage at $\lambda t$, the expected service supply of drivers is $F(\lambda t + \beta_s D)$. For clarity's sake, we assume $k \sim U[0,\ 1]$. Thus, the service supply of drivers as a function of takeout demand and platform decisions is

$$S(D, t, f) = \lambda t + \beta_s D, \tag{3}$$

where $\beta_s$ denotes the degree of supply-side network effects and captures the benefit that drivers receive from one additional consumer for the reduced delivery time. $D$ is the number of customers who seek OFD orders. As drivers mainly receive wages instead of non-monetary incentives [37], we assume that a unit increment in wage brings a higher utility to drivers than that of takeout demand, i.e., $0 < \beta_s, \beta_c \leq \lambda$.

Solving (2) and (3) simultaneously gives $S(f,t)$ and $D(f,t)$:

$$D(f, t) = \frac{1 - f - g + \lambda t \beta_c}{1 - \beta_c \beta_s}, \tag{4}$$

$$S(f, t) = \frac{\lambda t + (1 - f - g)\beta_s}{1 - \beta_c \beta_s}, \tag{5}$$

The relation in (4) and (5) implies a supply–demand balance for the takeout platform and the delivery platform. The two platforms cooperate to fulfill OFD orders to maximize their respective profits, with the actual transaction volume being equivalent to the minimum of logistics supply and customer demand, that is, $\widetilde{D} = min\{S, D\}$ [30,38–40]. To reflect the fact that the takeout platform spends effort to avoid unsatisfied demand [30,38], we only consider the situation where the service supply is adequate, such that $D \leq S$. And throughout this paper, we only consider that both markets are partially covered [9], so that the price and quantity interaction of the two side users is active and to avoid certain trivial cases.

### 3.3. Event Timeline

Since the collaboration between the two platforms is a long-term decision, and the shipping fee that the delivery platform charges to the takeout platform is determined at the time of their collaboration, we assume that the delivery platform announces the shipping fee $t$ charged to the takeout platform for each delivery order in period 1. In period 2, the takeout platform announces the unit delivery price $f$ charged to the customers. And in period 3, after observing these, the crowdsourced drivers on the delivery platform decide whether to provide a delivery service or not, and in the meantime, the customers on the takeout platform decide whether to purchase or not (see Figure 3).


**Figure 3.** Timeline of events.

### 3.4. Notations

We summarize the notations in Table 1:

**Table 1.** Summary of the notations.

| Notations | Definition & Specification |
|---|---|
| $v$ | Valuation of food and delivery service |
| $g$ | Food price |
| $\boldsymbol{f}$ | Delivery price |
| $\tau$ | Commission rate of the takeout platform |
| $\boldsymbol{t}$ | Shipping fee |
| $\lambda$ | Drivers' shared percentage per delivery order |
| $k$ | Operational cost of crowdsourced drivers |
| $n_0$ | Size of self-built delivery workers |
| $\beta_s$ | Supply-side network effect coefficient |
| $\beta_c$ | Demand-side network effect coefficient |
| $c$ | Marginal cost of self-built logistics |
| $D$ | Generated demand for food and delivery service |
| $S$ | Crowdsourced service supply on the delivery platform |
| $\widetilde{D}$ | $\widetilde{D} = min\{S, D\}$, Actual transaction volume of the OFD system |
| $\Pi_{p_t}$ | Total profit of the takeout platform |
| $\Pi_{p_d}$ | Total profit of the delivery platform |

## 4. Benchmark: Exclusive Collaboration with the Third-Party Crowdsourced Delivery Service

We examine the benchmark case, referred to as Case TC, where the takeout platform exclusively collaborates with the crowdsourced delivery platform for home food delivery. To account for the operational flexibility offered by web-based platforms, we assume that both the takeout platform and the delivery platform have zero fixed operation costs. Although one driver is able to deliver multiple orders at a time, we can simply divide these orders into multiple delivery tasks. Then, each driver is assumed to handle a maximum of one takeout order per unit of time [18,19,35]. This assumption is widely used and allows us to isolate and analyze the cross-platform network effects between customers and drivers. For instance, the one-to-one delivery mode was highlighted by the crowdsourced delivery platform "FlashEx" [41]. In addition, items that have a relatively high price are usually delivered by one driver once. The profit-maximizing problems of the takeout platform and the third-party delivery platform under Case TC are

$$Max \underbrace{\Pi_{p_t}}_{f} = (\tau g + f - t) \cdot D, \tag{6}$$

$$Max \underbrace{\Pi_{p_d}}_{t} = (1 - \lambda) t \cdot D, \tag{7}$$

Using backward induction, we can obtain the equilibrium solution in Lemma 1.

**Lemma 1.** *When the takeout platform exclusively collaborates with the third-party crowdsourced delivery platform for food delivery, the optimal shipping fee of the delivery platform and the optimal delivery price of the takeout platform are* $t^{TC} = \frac{1-g+\tau g}{2(1-\lambda\beta_c)}$ *and* $f^{TC} = \frac{3-3g-\tau g-(1-g-3\tau g)\lambda\beta_c}{4(1-\lambda\beta_c)}$*, respectively.*

**Proof.** See Appendix A. □

Then, we can obtain the takeout demand, the service supply, and the equilibrium profits of the takeout platform and the delivery platform by substituting $t^{TC}$ and $f^{TC}$ in Lemma 1 into Equations (4)–(7) as $D^{TC} = \frac{1-g+\tau g}{4(1-\beta_c\beta_s)}$, $S^{TC} = \frac{(1-g+\tau g)(2\lambda+\beta_s-3\lambda\beta_c\beta_s)}{4(1-\lambda\beta_c)(1-\beta_c\beta_s)}$,

${\Pi_{p_t}}^{TC} = \frac{(1-g+\tau g)^2}{16(1-\beta_c\beta_s)}$ and ${\Pi_{p_d}}^{TC} = \frac{(1-\lambda)(1-g+\tau g)^2}{8(1-\lambda\beta_c)(1-\beta_c\beta_s)}$. In Case TC, the commission rate of the takeout platform is relatively low, i.e., $\tau < \tau_{o1}$, to ensure both the food market and the service market are partially covered.

It is evident that when the delivery platform chooses a higher shipping fee to increase the margin, it creates an incentive for the takeout platform to raise the delivery price as well. However, this leads to reduced demand for the takeout platform, ultimately harming its profitability. In order to mitigate this conflict and achieve a balance, a subsidy pricing strategy can be employed by the takeout platform. In other words, the takeout platform charges a delivery price lower than the shipping fee. Proposition 1 establishes the condition under which the takeout platform would opt for a subsidy pricing strategy.

**Proposition 1.** *When $\tau > \tau_1 = \frac{1-g}{3g}$, the takeout platform strategically adopts the subsidy pricing strategy. Mathematically, $f^{TC} - t^{TC} < 0$; otherwise, the takeout platform will choose not to subsidize customers.*

**Proof.** See Appendix A. □

Proposition 1 implies that the takeout platform optimally adopts the subsidy pricing strategy when the commission rate is relatively high. A relatively high commission rate motivates the takeout platform to set a low delivery price, which will attract a great takeout demand (delivery orders). In response, the delivery platform sets a relatively high shipping fee. Under this circumstance, if the takeout platform were to charge a high delivery price, it would experience a significant decrease in takeout demand, which would negatively impact its profitability. To avoid this outcome, the takeout platform chooses to subsidize customers to maintain a healthy level of demand and benefit from the high commission fees earned from the restaurants. This finding offers a plausible explanation for the price subsidies implemented by platforms like Meituan. Instead of solely aiming to increase delivery revenue, these platforms often reduce the delivery price for customers. The adoption of a subsidy pricing strategy enables platforms like Meituan to optimize the capacity and efficiency of their logistics network, while also generating additional revenue streams for crowdsourced drivers.

To show how cross-platform network effects affect the optimal prices of two platforms and to determine the pricing principle of this OFD system, we conducted a comparative static analysis and obtained Proposition 2.

**Proposition 2.**

(i) *Both the optimal shipping fee and the optimal delivery price increase in the demand-side network effect coefficient (i.e., $\frac{\partial t^{TC}}{\partial \beta_c} > 0$; $\frac{\partial f^{TC}}{\partial \beta_c} > 0$) but are independent of the supply-side network effect coefficient.*

(ii) *The takeout platform's profit and the delivery platform's profit increase in both the demand- and supply-side network effect coefficients (i.e., $\frac{\partial {\Pi_{p_t}}^{TC}}{\partial \beta_c} > 0, \frac{\partial {\Pi_{p_d}}^{TC}}{\partial \beta_c} > 0, \frac{\partial {\Pi_{p_t}}^{TC}}{\partial \beta_s} > 0, \frac{\partial {\Pi_{p_d}}^{TC}}{\partial \beta_s} > 0$).*

**Proof.** See Appendix A. □

Proposition 2(*i*) highlights the impact of the increased demand-side network effect coefficient on two-sided prices under the distinguished value co-creation structure for the two complementary platforms. That is, with a larger demand-side network effect coefficient, the delivery platform raises the shipping fee as consumers can obtain a higher utility from more crowdsourced drivers, which further increases the takeout demand and the delivery price. The strategic actions of these two platforms can be generalized to enlarge the network benefits to the side on which the network effect coefficient grows. This strategic two-sided pricing heavily relies on the interdependencies of prices and quantities between the two sides under cross-platform network effects. However, because the transaction volume is equivalent to the takeout demand, which is predominantly influenced by the demand-side network effect coefficient, the optimal prices become independent of the supply-side network effect coefficient. Proposition 2(*ii*) indicates that a larger demand- or supply-side network effect coefficient enhances the profits of both platforms, as there is more demand and supply with the increase of the two coefficients.

When the takeout platform and the delivery platform achieve value co-creation through strategic partnerships, it is noteworthy that the commission charged by one platform can affect the other platform. The following proposition illustrates how platform commissions influence the optimal prices and platform profits.

**Proposition 3.**

(i) *both the optimal shipping fee and the optimal delivery price increase in the drivers' shared percentage, the optimal shipping fee increases in the commission rate of the takeout platform. But if and only if* $\lambda > \frac{1}{3\beta_c}$*, the optimal delivery price increases in the commission rate of the takeout platform; otherwise, it decreases (i.e.,* $\frac{\partial t^{TC}}{\partial \lambda} > 0$*;* $\frac{\partial f^{TC}}{\partial \lambda} > 0$*;* $\frac{\partial t^{TC}}{\partial \tau} > 0$*;* $\frac{\partial f^{TC}}{\partial \tau} > 0$ *when* $\lambda > \frac{1}{3\beta_c}$*, otherwise,* $\frac{\partial f^{TC}}{\partial \tau} < 0$*);*

(ii) *the profits of both platforms increase in the commission rate of the takeout platform. The takeout platform's profit is independent of the drivers' shared percentage, while the delivery platform's profit decreases in it (i.e.,* $\frac{\partial {\Pi_{p_t}}^{TC}}{\partial \tau} > 0$*;* $\frac{\partial {\Pi_{p_d}}^{TC}}{\partial \tau} > 0$*;* $\frac{\partial {\Pi_{p_d}}^{TC}}{\partial \lambda} < 0$*).*

**Proof.** See Appendix A. □

Proposition 3(*i*) shows the takeout platform and the crowdsourced delivery platform synchronize their price changes in the same direction to facilitate value co-creation under certain conditions. One may intuit that, as the drivers' shared percentage increases, the shipping fee will decrease, as they jointly influence the participation decision of the crowdsourced drivers. However, the delivery platform optimally raises the shipping fee due to the reduced demand sensitivity regarding the shipping fee (i.e., $\frac{\partial D}{\partial t} = -\frac{1-\lambda\beta_c}{2(1-\beta_c\beta_s)} < 0$ and $\frac{\partial^2 D}{\partial t \partial \lambda} = \frac{\beta_c}{2(1-\beta_c\beta_s)} > 0$). This, coupled with the increased network effects from a larger service supply, leads the takeout platform to raise the delivery price. As mentioned in Proposition 1, increasing the takeout platform's commission rate weakens the incentive for a higher delivery price, which harms the takeout demand. Then, the delivery platform is encouraged to raise their shipping fee. Under this circumstance, it is surprising to see that the takeout platform may raise the optimal delivery price, despite the potential commission fees from a greater takeout demand. To be specific, on one hand, the takeout platform is motivated to set a lower delivery price as the commission rate increases. On the other hand, the increased shipping fee and demand-side network effects promote the takeout platform to set a higher delivery price (i.e., $f = \frac{1-g-\tau g+t+\lambda t\beta_c}{2}$). Therefore, when the drivers' shared percentage is relatively high, i.e., $\lambda > \frac{1}{3\beta_c}$, the takeout platform optimally raises the delivery price; otherwise, the optimal delivery price declines in the takeout platform's commission rate.

Even though the takeout platform optimally raises the delivery price (i.e., $\lambda > \frac{1}{3\beta_c}$), the impact of enlarged demand-side network effects surpasses that of the increased delivery price. In this sense, the transaction volume grows larger as the takeout platform's commission rate increases (i.e., $D = \frac{1-f-g+\lambda t\beta_c}{1-\beta_c\beta_s}$). Consequently, the two platforms' profits increase in the commission rate of the takeout platform, for both a higher marginal profit and transaction volume.

It is surprising that the takeout platform's profit is independent of the drivers' shared percentage. The reason for this is that, although a higher shared percentage together with an increased shipping fee attracts more crowdsourced drivers, the transaction volume remains unchanged, as the network benefit to customers is exactly offset by the increased delivery price. Moreover, the difference between the optimal delivery price and shipping fee also remains constant in the shared percentage. As a result, the takeout platform's profit is independent of the shared percentage. For the delivery platform, as the drivers' shared percentage increases, the transaction volume is unchanged but the commission fee per order decreases, leading to a decline in the delivery platform's profit.

## 5. The Impact of a Self-Built Delivery Service

Nowadays, more and more takeout platforms invest in their own logistics service. For instance, DoorDash, a well-known takeout platform in the U.S. that excepts partners with the crowdsourced capacities of "Dashers" to provide a home delivery service for customers, has endeavored to hire full-time delivery workers. In China, Meituan established the self-built delivery service named "Meituan Zhuansong". Why do takeout platforms build their own delivery services and cooperate with crowdsourced delivery platforms simultaneously? What impact will this have on the two platforms' price strategies, profits, and social welfare? In this section, we explore these issues (Case TS).

We assume that the number of the takeout platform's full-time delivery workers is $n_0$ $(n_0 < 1)$. This means the overall population of full-time delivery workers does not exceed the labor pool of crowdsourced drivers. Since the establishment of self-logistics capacities is a long-term decision, to isolate the impact of self-built logistics capacities on price decisions, we assume $n_0$ is exogenous. Without loss of generality, we assume the fixed cost of self-built delivery service is zero, as it is a sunk cost. Differently from the heterogenous operational costs of crowdsourced drivers, we assume that the takeout platform incurs a marginal delivery cost, i.e., $c$ for each delivery order [42]. The takeout platform prioritizes fulfilling orders by its own delivery workers, and if there is excess demand, it turns to the third-party delivery platform [43]. Thus, we focus on the situation when the takeout demand exceeds the self-logistics capacities of the takeout platform, i.e., $n_0 < D \leq S + n_0$. Therefore, the quantity of OFD orders delivered by drivers on the crowdsourced delivery platform can be derived by $D - n_0$. The supply of crowdsourced drivers in Case TS is adjusted accordingly as

$$S(D,t,f) = \lambda t + \beta_s \cdot (D - n_0), \tag{8}$$

After the takeout platform introduces $n_0$ full-time delivery workers into the extant logistics network, the total supply of delivery service is $S + n_0$. Thus, the customer utility in Case TS is as below:

$$U_c = v - g - f + \beta_c \cdot (S + n_0), \tag{9}$$

and the corresponding takeout demand as a function of the platform decisions is represented by

$$D(S,t,f) = 1 - g - f + \beta_c \cdot (S + n_{0,}), \tag{10}$$

The supply and demand functions can be obtained by jointly solving (8) and (10):

$$D(f,t) = \frac{1 - f - g + n_0\beta_c + \lambda t\beta_c - n_0\beta_c\beta_s}{1 - \beta_c\beta_s}, \tag{11}$$

$$S(f,t) = \frac{\lambda t + (1-f-g)\beta_s - n_0(1-\beta_c)\beta_s}{1-\beta_c\beta_s}, \tag{12}$$

The profit function of the takeout platform is as follows:

$$\Pi_{p_t} = (\tau g + f - c)\cdot n_0 + (\tau g + f - t)\cdot(D - n_0), \tag{13}$$

The first term is the takeout order revenue fulfilled by self-logistics, and the second term is the takeout order revenue completed by the delivery platform. The profit function of the delivery platform is the following:

$$\Pi_{p_d} = (1-\lambda)t\cdot(D - n_0,) \tag{14}$$

Substituting (11) into the profit functions of the takeout platform and the delivery platform, and following similar approaches to the benchmark, we derive the equilibrium in the presence of both self-logistics and crowdsourced logistics.

**Lemma 2.** *When the takeout platform self-builds logistics capacities such that the full-time delivery workers and crowdsourced drivers coexist to fulfill the OFD orders, the delivery platform's optimal shipping fee and the takeout platform's optimal delivery price are* $t^{TS} = \frac{1-g+\tau g-n_0(2-\beta_c-\beta_c\beta_s)}{2(1-\lambda\beta_c)}$ *and* $f^{TS} = \frac{3-3g-\tau g-(1-g-3\tau g)\lambda\beta_c-n_0[(2-3\beta_c+\beta_c\beta_s)+\lambda\beta_c(2+\beta_c-3\beta_c\beta_s)]}{4(1-\lambda\beta_c)}$*, respectively.*

**Proof.** See Appendix A. □

Then, we can obtain the takeout demand, the service supply, and the equilibrium profits of the takeout platform and the delivery platform by substituting $t^{TS}$ and $f^{TS}$ in Lemma 2 into Equations (11)–(14) as $D^{TS} = \frac{1-g+\tau g+n_0(2+\beta_c-3\beta_c\beta_s)}{4(1-\beta_c\beta_s)}$, $S^{TS} = \frac{(2\lambda+\beta_s-3\lambda\beta_c\beta_s)[(1-g+\tau g)-n_0(2-\beta_c-\beta_c\beta_s)]}{4(1-\lambda\beta_c)(1-\beta_c\beta_s)}$, ${\Pi_{p_t}}^{TS} = A_1\cdot {n_0}^2 + B_1\cdot n_0 + \frac{(1-g+\tau g)^2}{16(1-\beta_c\beta_s)}$ and ${\Pi_{p_d}}^{TS} = \frac{(1-\lambda)(1-g+\tau g-n_0(2-\beta_c-\beta_c\beta_s))^2}{8(1-\lambda\beta_c)(1-\beta_c\beta_s)}$, where $A_1 = \frac{(2+\beta_c-3\beta_c\beta_s)^2}{16(1-\beta_c\beta_s)} - \frac{2-\beta_c-\beta_c\beta_s}{2(1-\lambda\beta_c)}$ and $B_1 = \frac{1-g+\tau g}{2(1-\lambda\beta_c)} + \frac{(1-g+\tau g)(2+\beta_c-3\beta_c\beta_s)}{8(1-\beta_c\beta_s)} - c$.

In Case TS, we assume that the commission rate of the takeout platform is moderate, i.e., $\tau_{o2} < \tau < min\{\tau_{o3}, \tau_{o4}\}$ to ensure the markets are partially covered. Specifically, when the commission rate is very low, the total takeout demand is so small that there is no delivery demand for the third-party platform.

### *5.1. The Impact of a Self-Built Delivery Service on Pricing*

By comparing the optimal delivery price and optimal shipping fee in Case TS with those in Case TC, we derive the impact of self-built logistics on optimal price decisions in Proposition 4.

**Proposition 4.** *Compared with Case TC, adding a self-built delivery service by the takeout platform decreases both the optimal delivery price and the optimal shipping fee, which decrease in* $n_0$ *(i.e.,* $\frac{\partial f^{TS}}{\partial n_0} < 0$, $\frac{\partial t^{TS}}{\partial n_0} < 0$*).*

**Proof.** See Appendix A. □

Intuitively, the introduction of self-built delivery service enlarges the demand-side network effects and attracts more customers to purchase, such that the total takeout demand expands. However, if both the shipping fee and the delivery price remain identical to the benchmark case, the gains of the total takeout demand cannot compensate for the losses in delivery orders for the delivery platform, since the takeout platform prioritizes the usage of full-time delivery workers for order fulfillment. Namely, although the total takeout demand increases, the delivery demand for the third-party crowdsourced delivery platform declines. In consequence, the delivery platform reduces their shipping fee to encourage the takeout platform to lower the delivery price, in order to mitigate the negative impact of the diminished delivery demand on its profits. Moreover, as the scale of the self-logistics increases, the two platforms' optimal prices further decrease.

By comparing with Proposition 1, we further examine the impact of self-built logistics by the takeout platform on the subsidy pricing condition and subsidy intensity, and the results are summarized in Proposition 5.

**Proposition 5.** *For each crowdsourced service delivered order,*

*(i)* *when* $\tau > \tau_2 = \frac{1-g+n_0(2+\beta_c-3\beta_c\beta_s)}{3g}$*, the takeout platform strategically adopts a subsidy pricing strategy. Mathematically,* $f^{TS} - t^{TS} < 0$*; otherwise, the takeout platform chooses not to subsidize customers;*

*(ii)* *the subsidy pricing threshold increases after the introduction of self-built logistics (i.e.,* $\tau_2 > \tau_1$*); and the subsidy intensity decreases in* $n_0$ *(i.e.,* $\frac{\partial\left(t^{TS}-f^{TS}\right)}{\partial n_0} < 0$*).*

**Proof.** See Appendix A. □

Similarly to Proposition 1, when the commission rate of the takeout platform is relatively high, the takeout platform optimally adopts the subsidy pricing strategy. But compared with Case TC, the introduction of the self-logistics raises the subsidy pricing threshold to $\tau_2$, which means the subsidy pricing strategy adopted by the takeout platform seems likely to remain more narrow (see Figure 4, the subsidy pricing strategy region is squeezed with the same parameter values as Proposition 1). Although the takeout platform reduces the delivery price as the optimal shipping fee decreases, the impact of the crowdsourced service on the pricing of the delivery service is weakened. This is because the takeout platform becomes less reliant on the crowdsourced service due to the introduction of the takeout platform's own delivery workers (i.e., $\left|\frac{\partial f}{\partial t}\cdot\frac{\partial t}{\partial n_0}\right| > \frac{\partial f}{\partial n_0} > 0$ and $\frac{\partial f}{\partial t}\cdot\frac{\partial t}{\partial n_0} < 0$). In other words, after the takeout platform introduces the self-logistics, the optimal shipping fee decreases more than the optimal delivery price. And the difference between the optimal delivery price and optimal shipping fee becomes larger as the number of self-built delivery workers increases. As we know, the optimal delivery price and shipping fee are the same if the commission rate of the takeout platform is equal to $\tau_1$ in Case TC. However, all else being equal, the optimal shipping fee is lower than the optimal delivery price in Case TS when the commission rate of the takeout platform remains at $\tau_1$, such that the takeout platform will not offer subsidization to customers. Thus, the takeout platform optimally employs a subsidy pricing strategy at a higher commission rate, resulting in an increased subsidy pricing threshold for the takeout platform with the self-establishment of a delivery service. In addition, when the scale of the self-logistics becomes larger, the subsidy intensity decreases.

However, the examinations of the change in network effects and platform commissions on equilibrium prices and platform profits show some different results from Case TC, as revealed in Propositions 6 and 7.

**Proposition 6.**

*(i)* *Differently from benchmark, the optimal shipping fee increases in the supply-side network effect coefficient. If and only if* $\lambda > \frac{1}{3\beta_c}$*, the optimal delivery price increases in the supply-side*

*network effect coefficient; otherwise, it decreases (i.e.,* $\frac{\partial t^{TS}}{\partial \beta_s} > 0$; $\frac{\partial f^{TS}}{\partial \beta_s} > 0$ *when* $\lambda > \frac{1}{3\beta_c}$, *otherwise,* $\frac{\partial f^{TS}}{\partial \beta_s} < 0$*);*

*(ii) The profits of both the takeout platform and the crowdsourced delivery platform increase in the demand- and supply-side network effect coefficients (i.e.,* $\frac{\partial {\Pi_{p_t}}^{TS}}{\partial \beta_c} > 0$, $\frac{\partial {\Pi_{p_d}}^{TS}}{\partial \beta_c} > 0$, $\frac{\partial {\Pi_{p_t}}^{TS}}{\partial \beta_s} > 0$, $\frac{\partial {\Pi_{p_d}}^{TS}}{\partial \beta_s} > 0$*).*

**Proof.** See Appendix A. □

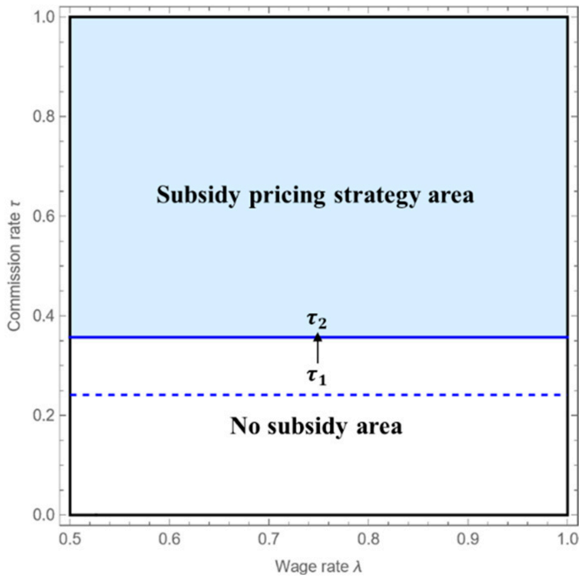


**Figure 4.** Subsidy pricing strategy area in Case TS ($\beta_c = 0.28,\ \beta_s = 0.32,\ g = 0.58,\ n_0 = 0.10$).

As revealed above, the price changes for the two platforms are related to the supply-side network effect coefficient, because the employment of delivery workers by the takeout platform expands the total takeout demand due to an enlarged service supply and encroaches on the crowdsourced delivery orders. Interestingly, Proposition 6 highlights that the strategic two-sided pricing of the benchmark case can be overturned with self-logistics under certain conditions.

Considering an increasing supply-side network effect coefficient, the strategic two-sided pricing suggests reducing the optimal shipping fee in response to promoting a declined delivery price, which in turn can boost takeout demand and increase the network benefits for drivers. Conversely, our research indicates that the delivery platform should, in fact, consider raising their shipping fee. This strategic decision aims to attract a larger number of crowdsourced drivers and stimulate higher demand for the crowdsourced delivery service. This approach takes into account the prevailing practice observed in takeout platforms, where the prioritization of their own delivery workers often discourages crowdsourced drivers from participating. By increasing the shipping fee, the delivery platform can attract more drivers, leading to an improved delivery efficiency.

The increased shipping fee motivates the takeout platform to raise their delivery price, due to both a higher delivery cost and enlarged demand-side network effects. We refer to this as the service cost effect. However, as the takeout platform prioritizes the usage of self-logistics, crowdsourced drivers are discouraged from participating in delivery in Case TS. This influences the takeout demand through cross-platform network externalities, and the takeout platform is inhibited from setting a higher delivery price. We refer to this as the restraintion effect. Therefore, only when the shared percentage is relatively high (i.e.,

$\lambda > \frac{1}{3\beta_c}$), will the service cost effect dominate the restraintion effect (see Figure 5), and the takeout platform finds it optimal to raise the delivery price. In such a case, the strategic two-sided pricing is overturned. Otherwise, the takeout platform optimally reduces the delivery price.

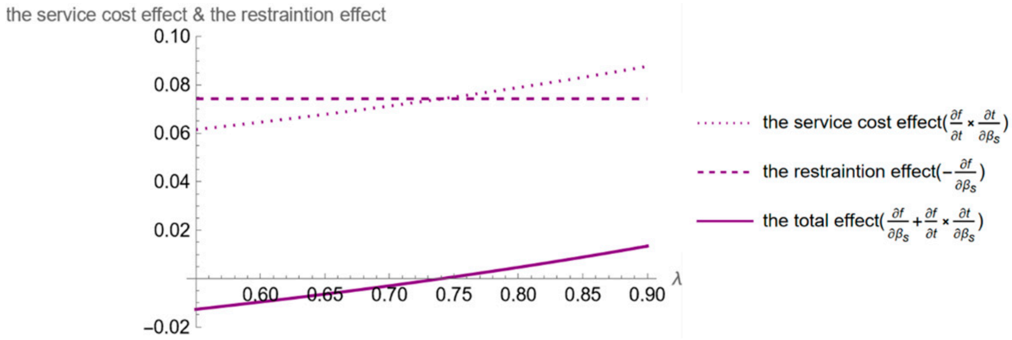


**Figure 5.** The relative magnitude of two effects ($g = 0.45,\ n_0 = 0.33,\ \beta_c = 0.45$).

As in Case TC, the two platforms' profits increase in the network effect coefficients. For the takeout platform, the revenue from both the crowdsourced service delivered orders and self-logistics delivered orders increases in the demand-side network effect coefficient. As the supply-side network effect coefficient increases, the revenue increment of the crowdsourced service delivered orders dominates the revenue decrement of self-logistics delivered orders. This revenue increment rises due to the increased crowdsourced delivery demand, whereas the revenue decrement comes from the reduced marginal profit when the shared percentage is relatively low (i.e., when $\lambda \leq \frac{1}{3\beta_c}$). As the demand- or supply-side network effect coefficient increases, the delivery platform's profit increases for a higher marginal profit and takeout demand.

**Proposition 7.** *With the takeout platform's self-built delivery service, differently from Case TC, the takeout platform's profit increases in the drivers' shared percentage.*

**Proof.** See Appendix A. □

Interestingly, our research reveals that, in the case of the takeout platform implementing self-built logistics, the impact of commission rates on the optimal prices remains consistent with our previous findings. Specifically, we observe that the direction of change of the optimal shipping fee and the optimal delivery price align with each other as the platform commissions increase under certain conditions. However, there is a distinction with the previous finding related to the takeout platform's profit. It is important to recall Proposition 3, which states that the takeout platform's profit is independent of the drivers' shared percentage. However, we have discovered that this proposition does not hold true when the takeout platform establishes its own delivery service. Although the revenue generated from crowdsourced service delivered orders remains unaffected by the shared percentage, it does impact the revenue derived from self-logistics delivered orders. This is because the optimal delivery price increases as the drivers' shared percentage rises. As a consequence, when the shared percentage increases, the profit of the takeout platform also increases. It is crucial to note that these findings are specific to our research, and further investigation and analysis may be necessary to validate and expand upon these observations.

*5.2. The Impact of a Self-Built Delivery Service on the OFD System and Social Welfare*

To gain insights into why the takeout platform chooses to self-establish logistics and to understand the impact of the self-built logistics on the OFD system, we compared equilibrium platform profits in these two cases and derived Proposition 8.

**Proposition 8.** *The takeout platform's self-established delivery service increases its profit when (a) $c \leq c_1$ or; (b) $c_1 < c < c_2$ and $n_0 < \widehat{n_{01}}$; otherwise, it decreases its profit. However, the profit of the delivery platform always decreases.*

*Note: the values of $c_1$, $c_2$, $\widehat{n_{01}}$ are given in Appendix A.*

**Proof.** See Appendix A. □

Proposition 8 implies that when the marginal cost of the self-built logistics is low, or it is moderate and the size of full-time delivery workers is relatively small, adding a self-built delivery service benefits the takeout platform (see the pink region in Figure 6). According to the profit expression of the takeout platform, the impact of the number of full-time delivery workers on the takeout platform's profit is non-monotonic. As depicted by the magenta line in Figure 7, when the marginal cost of self-logistics is at intermediate level (i.e., $c_1 < c < c_2$), a very small number of full-time delivery workers has almost no impact on the takeout platform. When the number of full-time delivery workers becomes larger, the takeout platform's profit initially rises and then declines, depending on the relative magnitude of these two revenue streams. And a moderate number of full-time delivery workers can achieve the maximal profit for the takeout platform.

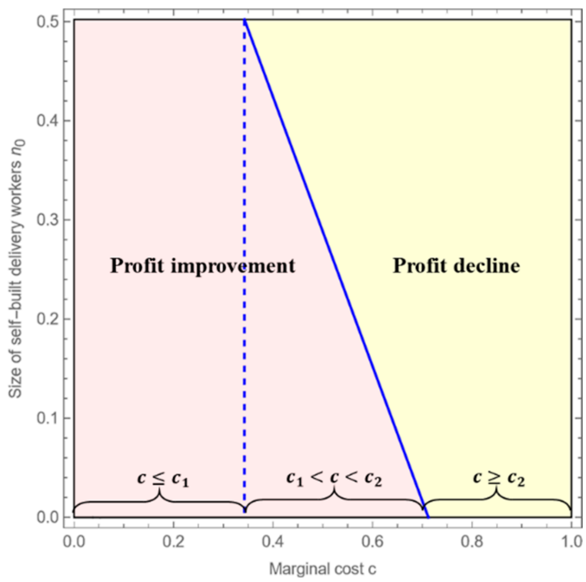


**Figure 6.** Profit change for takeout platform with self-building delivery service ($\lambda = 0.72$, $\beta_s = 0.42$, $\beta_c = 0.38$, $g = 0.41$, $\tau = 0.35$).

Figure 7 presents a surprising finding that a relatively large number of full-time delivery workers is detrimental to the takeout platform. This is because the introduction of full-time delivery workers directly enlarges the service supply, which weakens the impact of the delivery platform's pricing on the takeout platform's delivery price decision. Then, the optimal shipping fee decreases more than the optimal delivery price, resulting in a higher marginal profit for crowdsourced service delivered orders (the blue region in Figure 8). On the contrary, the marginal profit for self-logistics delivered orders is relatively small (the green region in Figure 8) because the marginal cost of the self-built delivery service is at intermediate level. Hence, in comparison with the case where only the crowdsourced delivery service is used (Case TC), a portion of delivery tasks are now undertaken by the takeout platform directly. This shift in delivery responsibility leads to a decline in the takeout platform's profit, since these orders originally had a higher marginal profit when delivered by the crowdsourced delivery platform (the yellow region in Figure 8). Although the introduction of a self-built delivery service reduces the shipping fee, the revenue improvement from the crowdsourced service delivered orders is insufficient to make up for the losses from self-logistics delivered orders. Thus, when the scale of the self-built delivery service is relatively large, the takeout platform's profit declines.

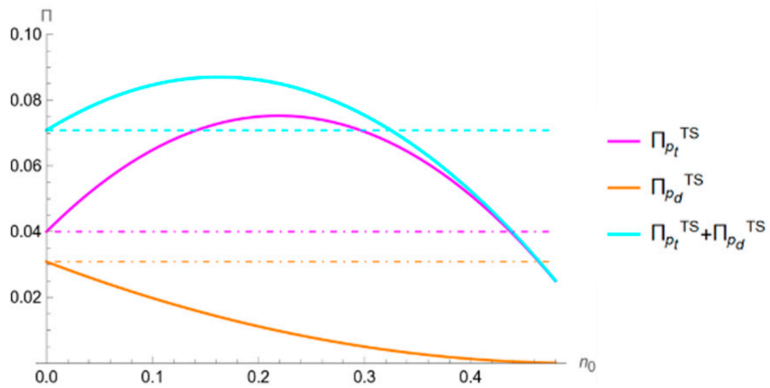


**Figure 7.** The effect of $n_0$ on the takeout platform's profit in Case TS ($\lambda = 0.72,\ \beta_s = 0.42,\ \beta_c = 0.38,\ g = 0.41,\ \tau = 0.35,\ c = 0.39$).

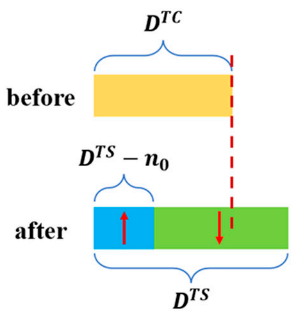


**Figure 8.** The change in the takeout platform's revenue for the two parts.

Proposition 8 also demonstrates that when the marginal cost is relatively low (i.e., $c \leq c_1$), the addition of a self-built delivery service consistently benefits the takeout platform. Under this condition, the losses incurred from self-logistics delivered orders are mitigated, and in certain scenarios, the takeout platform even gains from self-logistics delivered orders (i.e., $\left(\tau g + f^{TC} - t^{TC}\right) - \left(\tau g + f^{TS} - c\right)$ becoming less or $\left(\tau g + f^{TS} - c\right) > \left(\tau g + f^{TC} - t^{TC}\right)$). The expansion in total takeout demand and the revenue increment from crowdsourced service delivered orders outweigh the losses from self-logistics delivered orders. Therefore, the takeout platform becomes better.

Interestingly, as the takeout platform prioritizes the use of its own delivery workers, even if the marginal cost of the self-built delivery service is higher (lower) than that of the crowdsourced delivery service, the introduction of the self-built delivery service may make the takeout platform better (worse). The key factor lies in the number of full-time delivery workers employed. Specifically, if the marginal cost falls within the range $c_1 < t^{TC} < c < c_2$ and the number of the full-time delivery workers is below a certain threshold (i.e., $n_0 < \widehat{n_{01}}$), the takeout platform's profit increases. Conversely, if the marginal cost falls within the range $c_1 < c < t^{TC} < c_2$ and the number of the full-time delivery workers exceeds a certain threshold (i.e., $n_0 > \widehat{n_{01}}$), the takeout platform's profit decreases.

Though the takeout platform may benefit from the introduction of a self-built delivery service, the crowdsourced delivery platform suffers due to reductions in both the delivery demand and marginal profit (see the orange line of Figure 7).

**Corollary 1.** *The introduction of a self-built delivery service increases the total profit of the two platforms when (a)* $c \leq \widetilde{c_1}$ *or; (b)* $\widetilde{c_1} < c < \widetilde{c_2}$ *and* $n_0 < \widehat{n_{02}}$.

*Note: the parameter range of Corollary 1 is the same as Proposition 8, and the values of* $\widetilde{c_1}$, $\widetilde{c_2}$, $\widehat{n_{02}}$ *are given in Appendix A.*

**Proof.** See Appendix A. □

Similarly to Proposition 8, the influence of the number of full-time delivery workers on the overall profit of both platforms relies on the relative revenue changes in orders delivered through the self-logistics and crowdsourced service. In Figure 7, as represented by the cyan line, it can be observed that under specific conditions, the total profit of the OFD system can be higher when the takeout platform establishes its own delivery service. This finding is supported by the results presented in Corollary 1. Corollary 1 elucidates the importance of integrating the full-time delivery service into the existing logistics network of the takeout platform, which already collaborates with a third-party crowdsourced delivery platform. The inclusion of full-time delivery workers expands the overall demand for takeout services and reduces the shipping fee charged by the third-party delivery platform. These findings underscore the potential advantages of introducing and leveraging full-time delivery workers within the takeout platform's logistics network. This strategic move can enhance the overall profitability of the OFD system, while simultaneously benefiting from the synergies between the self-logistics and crowdsourced service.

We have found some inspiring results that validate the effectiveness of self-built logistics for takeout platform, as shown in the following proposition, which was derived through a social metric comparison with case TC.

**Proposition 9.** *In contrast to exclusively relying on the crowdsourced delivery platform (Case TC), the addition of a self-built delivery service has several distinct effects:*

*(i) always increases consumer surplus;*
*(ii) always decreases the welfare of crowdsourced drivers;*
*(iii) has a non-monotonic effect on social welfare.*

**Proof.** See Appendix A. □

The introduction of the self-built delivery service enlarges the total takeout demand and benefits the surplus for each consumer. These two factors drive the total consumer surplus to be increased. Due to the reduced shipping fee and encroaching on the delivery orders of the third-party platform, the surplus per crowdsourced driver declines, while the matching rate remains the same in two cases, and thus the welfare of the crowdsourced drivers always decreases.

Figure 9 illustrates the impact of different combinations of the marginal cost for self-built logistics and number of full-time delivery workers on social welfare. Our findings indicate that when the marginal cost is relatively low or at an intermediate level and the number of full-time delivery workers is relatively small, social welfare consistently increases. This is primarily due to the overall increase in total profits for both platforms under these conditions. Additionally, both the restaurant revenue and customer surplus experience an upward trend, contributing to the overall improvement in social welfare.

These positive factors help offset the decline in welfare for crowdsourced drivers, resulting in a net increase in social welfare. Conversely, when the marginal cost is at an intermediate level and the number of full-time delivery workers is relatively large, or when the marginal cost is relatively high, the decline in total profit for both platforms, coupled with reduced welfare for crowdsourced drivers, outweighs the increase in the restaurants' revenue and customer surplus. Consequently, the social welfare declines under these circumstances.

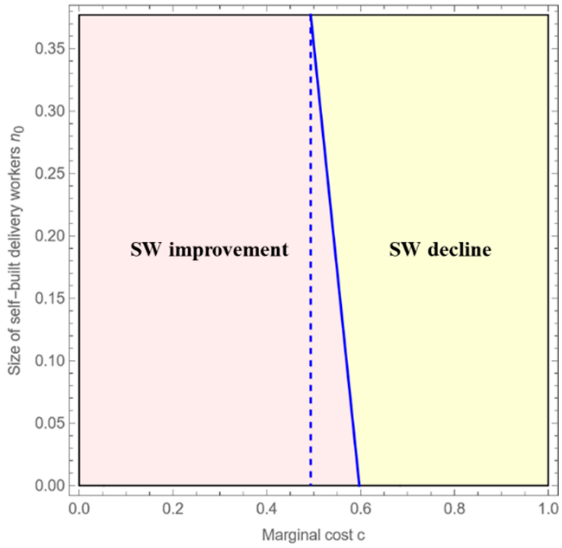


**Figure 9.** The impact of a self-built delivery service on SW ($\beta_s = 0.22, \beta_c = 0.20, g = 0.52, \lambda = 0.72, \tau = 0.35$).

## 6. Conclusions

### *6.1. Discussion of the Main Results*

In this paper, we investigated the collaboration between a takeout platform and third-party crowdsourced delivery platform. The main results and major managerial insights are as follows:

When the takeout platform only utilizes the crowdsourced delivery service to fulfill OFD orders, it is optimal for the takeout platform to adopt a subsidy pricing strategy under certain conditions. This can help to deter the takeout platforms from solely targeting the optimum profit in the logistics segment, instead focusing on optimizing the logistics network and raising the welfare of both customers and drivers through subsidization. In addition, when the demand-side network effect coefficient increases, the delivery platform raises the shipping fee to attract more drivers, in return for increasing the benefits of the network for customers. Then, the takeout platform can charge a higher delivery price to cover the increased shipping fee and to take more profit. This strategic two-sided pricing under cross-platform network effects allows increasing the network externalities for one side, as users benefit more from an additional user on the other side. In addition, due to the double marginalization stemming from cross-platform logistics collaboration, as the platform commission changes, the price changes of the two platforms maintain a consistent direction under certain conditions. Moreover, in terms of platform profits, both platforms perform better with an increase in network effect coefficients, as they contribute to expanding the takeout market coverage by internalizing externalities between the two sides. Meanwhile, it was surprising to discover that the profit of the takeout platform is unrelated to the shared percentage of drivers. Because the transaction volume remains unchanged in the shared percentage, for the customers' network benefit is offset by the increased delivery price.

Furthermore, self-built logistics increase the takeout platform's subsidy pricing threshold and decrease the subsidy intensity, because of the reduced reliance on the crowdsourced service. It is also worth mentioning that the strategic two-sided pricing can be reshaped as the supply-side network effect coefficient increases when the takeout platform self-builds logistics. For instance, as the supply-side network effect coefficient increases, instead of lowering the shipping fee to encourage a decline in delivery price in order to enlarge the supply-side network effects, both the optimal shipping fee and optimal delivery price can be raised under certain conditions. What is more, our research also highlights the value of full-time delivery workers employed by the takeout platform. The implementation of a self-built delivery service consistently increases the customer surplus by enlarging the takeout market coverage and reducing the shipping fee of the delivery platform. This practice can benefit the takeout platform but makes the delivery platform suffer. While the social welfare can increase under certain conditions.

### *6.2. Managerial Implications*

From the perspective of operation management, our study has important implications. First, our study provides insights into the optimal price decisions for both the takeout platform and the crowdsourced delivery platform, as well as the conditions under which customer subsidization is beneficial. To a certain extent, the strategic implementation of a subsidy pricing strategy for the takeout platform can help it to mitigate the profit squeeze caused by a high shipping fee being imposed by the crowdsourced delivery platform. Thus, we unveiled the pricing rationale for platform collaboration through a precise division of labor. Second, we obtained the optimal prices and subsidy pricing conditions when the takeout platform employs full-time delivery workers as well as crowdsourced drivers to perform delivery tasks. We further determined the influence of a self-built delivery service on the OFD system, customer surplus, and social welfare. These findings validate the effectiveness of a self-built delivery service being introduced by the takeout platform for improved customer surplus, OFD system profitability, and social welfare under certain conditions. Finally, in today's economic environment, cross-platform logistics collaboration is commonly observed, as retail platforms pursue lower logistics operation costs, while enhancing customer satisfaction in last-mile delivery. Our research can provide theoretical guidance for instant retail platforms such as Walmart, JD Daojia, Meituan Instashopping, and others in the instant retail industry, which shares characteristics with OFD operations.

### *6.3. Limitations and Future Research*

There are some limitations of this paper. First, we assumed that the self-built logistics capacity of the takeout platform was exogenous, and future studies could examine the effect of the takeout platform's decision for the service capacity. Second, we considered the optimal two-sided prices of an OFD system as constituting one takeout platform and one delivery platform. Future studies could investigate the difference in the vehicle investment being conducted by either the takeout platform or the delivery platform, which could help crowdsourced drivers reduce their operational costs.

**Author Contributions:** Conceptualization, G.L. and L.L.; Methodology, L.L.; Software, L.L.; Validation, G.L. and L.L.; Formal Analysis, L.L.; Writing—Original Draft Preparation, L.L.; Writing—Review and Editing, G.L. and L.L.; Supervision, G.L.; Project Administration, G.L. All authors have read and agreed to the published version of the manuscript.

**Funding:** This research received no external funding.

**Institutional Review Board Statement:** Not applicable.

**Informed Consent Statement:** Not applicable.

**Data Availability Statement:** Data are contained within the article.

**Conflicts of Interest:** The authors declare no conflicts of interest.

## Appendix A. Proofs of All Results

The derivation process of equilibrium outcomes in case TC.

We conduct backward induction to solve this problem. By substituting Equations (4) and (5) into Equation (6) and the constraint conditions, we can obtain the specific profit-maximizing problem of the takeout platform:

$$Max \underbrace{\Pi_{p_t}}_{f} = (\tau g + f - t) \cdot \frac{1 - f - g + \lambda t \beta_c}{1 - \beta_c \beta_s}$$

$$S.t., \ f \geq 1 - g - \frac{\lambda t (1 - \beta_c)}{1 - \beta_s},$$

$$-g + \lambda t \beta_c + \beta_c \beta_s < f < 1 - g + \lambda t \beta_c,$$

$$1 - g - \frac{1 - \lambda t - \beta_c \beta_s}{\beta_s} < f$$

It is easy to verify that $\Pi_{p_t}$ is a concave function of $f$ in Case TC. Using the KKT condition to solve the takeout platform's profit-maximizing problem, the Lagrange function is

$$\begin{aligned} L_1 = (\tau g + f - t) \cdot \frac{1 - f - g + \lambda t \beta_c}{1 - \beta_c \beta_s} + \mu_1 \left( f - 1 + g + \frac{\lambda t (1 - \beta_c)}{1 - \beta_s} \right) \\ + \mu_2 (f + g - \lambda t \beta_c - \beta_c \beta_s) + \mu_3 (1 - g + \lambda t \beta_c - f) \\ + \mu_4 \left( f - 1 + g + \frac{1 - \lambda t - \beta_c \beta_s}{\beta_s} \right) \end{aligned}$$

According to the Kuhn–Tucker condition, we have

$$\begin{cases} \dfrac{\partial \Pi_{p_t}}{\partial f} + \mu_1 + \mu_2 - \mu_3 + \mu_4 = 0 \\ \mu_1 \left( f - 1 + g + \dfrac{\lambda t (1 - \beta_c)}{1 - \beta_s} \right) = 0, \mu_2 (f + g - \lambda t \beta_c - \beta_c \beta_s) = 0 \\ \mu_3 (1 - g + \lambda t \beta_c - f) = 0, \mu_4 \left( f - 1 + g + \dfrac{1 - \lambda t - \beta_c \beta_s}{\beta_s} \right) = 0 \\ \mu_1 \geq 0, \ \mu_2 \geq 0, \ \mu_3 \geq 0, \ \mu_4 \geq 0 \end{cases}$$

There are two possible combinations for the Lagrangian multipliers $\mu_1$, $\mu_2$, $\mu_3$, and $\mu_4$.

(1) If $\mu_1 = \mu_2 = \mu_3 = \mu_4 = 0$, then $f = \frac{1 - g - \tau g + t + \lambda t \beta_c}{2}$, the shipping fee set by the delivery platform should satisfy $t \geq \frac{(1 - g + \tau g)(1 - \beta_s)}{1 + 2\lambda - \beta_s - \lambda \beta_c (1 + \beta_s)}$, $\frac{1 + g - \tau g - 2\beta_c \beta_s}{-1 + \lambda \beta_c} < t < \frac{1 - g + \tau g}{1 - \lambda \beta_c}$, and $t < \frac{2 - 2\beta_c \beta_s - \beta_s (1 - g + \tau g)}{2\lambda - \beta_s - \lambda \beta_c \beta_s}$. Substituting $f = \frac{1 - g - \tau g + t + \lambda t \beta_c}{2}$ into Equation (8), we can obtain the corresponding profit-maximizing problem of the delivery platform:

$$Max \underbrace{\Pi_{p_d}}_{t} = (1 - \lambda) t \cdot \frac{1 - g + \tau g - t + t \lambda \beta_c}{2 - 2\beta_c \beta_s}$$

It is easy to verify that $\Pi_{p_d}$ is a concave function of $t$. The Lagrange function under KKT condition is

$$
\begin{aligned}
L_2 = (1-\lambda)t\cdot\frac{1-g+\tau g-t+t\lambda\beta_c}{2-2\beta_c\beta_s} + {\mu_1}'\left(t-\frac{(1-g+\tau g)(1-\beta_s)}{1+2\lambda-\beta_s-\lambda\beta_c(1+\beta_s)}\right) \\
+{\mu_2}'\left(t-\frac{1+g-\tau g-2\beta_c\beta_s}{-1+\lambda\beta_c}\right)+{\mu_3}'\left(\frac{1-g+\tau g}{1-\lambda\beta_c}-t\right) \\
+{\mu_4}'\left(\frac{2-2\beta_c\beta_s-\beta_s(1-g+\tau g)}{2\lambda-\beta_s-\lambda\beta_c\beta_s}-t\right)
\end{aligned}
$$

According to the Kuhn–Tucker condition, we have

$$
\begin{cases}
\dfrac{\partial \Pi_{p_d}}{\partial t}+{\mu_1}'+{\mu_2}'-{\mu_3}'-{\mu_4}'=0 \\
{\mu_1}'\left(t-\dfrac{(1-g+\tau g)(1-\beta_s)}{1+2\lambda-\beta_s-\lambda\beta_c(1+\beta_s)}\right)=0, {\mu_2}'\left(t-\dfrac{1+g-\tau g-2\beta_c\beta_s}{-1+\lambda\beta_c}\right)=0 \\
{\mu_3}'\left(\dfrac{1-g+\tau g}{1-\lambda\beta_c}-t\right)=0, {\mu_4}'\left(\dfrac{2-2\beta_c\beta_s-\beta_s(1-g+\tau g)}{2\lambda-\beta_s-\lambda\beta_c\beta_s}-t\right)=0 \\
{\mu_1}'\geq 0, {\mu_2}'\geq 0, {\mu_3}'\geq 0, {\mu_4}'\geq 0
\end{cases}
$$

There are two possible combinations for the Lagrangian multipliers ${\mu_1}'$, ${\mu_2}'$, ${\mu_3}'$, and ${\mu_4}'$.

(i) If ${\mu_1}'={\mu_2}'={\mu_3}'={\mu_4}'=0$, then $t^{TC}=\frac{1-g+\tau g}{2(1-\lambda\beta_c)}$, and the drivers' shared percentage and the commission rate of the takeout platform should satisfy $\lambda \geq max\left\{\frac{1-\beta_s}{2+\beta_c-3\beta_c\beta_s}, \beta_s, \beta_c\right\}$ and $\tau<\tau_{o1}$, where $\tau_{o1}=\frac{4(1-\beta_c\beta_s)(1-\lambda\beta_c)}{(2\lambda+\beta_s-3\lambda\beta_c\beta_s)g}-\frac{1-g}{g}$. The optimal delivery price is $f^{TC}=\frac{3-3g-\tau g-(1-g-3\tau g)\lambda\beta_c}{4(1-\lambda\beta_c)}$. The generated takeout demand and crowdsourced service supply are $D^{TC}=\frac{1-g+\tau g}{4(1-\beta_c\beta_s)}$ and $S^{TC}=\frac{(2\lambda+\beta_s-3\lambda\beta_c\beta_s)(1-g+\tau g)}{4(1-\lambda\beta_c)(1-\beta_c\beta_s)}$. The profits of the takeout platform and the delivery platform are ${\Pi_{p_t}}^{TC}=\frac{(1-g+\tau g)^2}{16(1-\beta_c\beta_s)}$ and ${\Pi_{p_d}}^{TC}=\frac{(1-\lambda)(1-g+\tau g)^2}{8(1-\lambda\beta_c)(1-\beta_c\beta_s)}$, respectively.

(ii) If ${\mu_1}'>0$, ${\mu_2}'={\mu_3}'={\mu_4}'=0$, then $t^{TC}=\frac{(1-g+\tau g)(1-\beta_s)}{1+2\lambda-\beta_s-\lambda\beta_c(1+\beta_s)}$, and the drivers' shared percentage and the commission rate of the takeout platform should satisfy $max\{\beta_s, \beta_c\}\leq\lambda<\frac{1-\beta_s}{2+\beta_c-3\beta_c\beta_s}$ and $\tau<\frac{1+2\lambda-\beta_s-\lambda\beta_c(1+\beta_s)}{\lambda g}-\frac{1-g}{g}$. Because the maximal value of $\frac{1-\beta_s}{2+\beta_c-3\beta_c\beta_s}$ is no larger than $\frac{1}{2}$, and in reality, the crowdsourced drivers receive the larger share than the delivery platform. We ignore this scenario here and only focus on the interior solution, such that the service supply constraint is not binding.

(2) If $\mu_1>0$, $\mu_2=\mu_3=\mu_4=0$, then $f=1-g-\frac{\lambda t(1-\beta_c)}{1-\beta_s}$, the shipping fee set by the delivery platform should satisfy $t<\frac{(1-g+\tau g)(1-\beta_s)}{1+2\lambda-\beta_s-\lambda\beta_c(1+\beta_s)}$, $0<t<\frac{1-\beta_s}{\lambda}$. Substituting $f=1-g-\frac{\lambda t(1-\beta_c)}{1-\beta_s}$ into Equation (7), we can obtain the corresponding profit-maximizing problem of the delivery platform:

$$
Max\underbrace{\Pi_{p_d}}_{t}=\frac{(1-\lambda)\lambda t^2}{1-\beta_s}
$$

It is easy to see that $\Pi_{p_d}$ is a monotonic increasing function of $t$. Then, there is no feasible solution.

Hence, we can obtain the equilibrium outcomes for case TC, as shown in Lemma 1.

**Proof of Proposition 1.** Let $\Delta f_{o1}=f^{TC}-t^{TC}$, the takeout platform offers customers subsidization when $\Delta f_{o1}<0$. It is straightforward to show that when $\tau>\tau_1=\frac{1-g}{3g}$, $\Delta f_{o1}<0$. □

**Proof of Proposition 2.** We take the first derivative of $t^{TC}$, $f^{TC}$, $D^{TC}$, ${\Pi_{p_t}}^{TC}$ and ${\Pi_{p_d}}^{TC}$ with respect to $\beta_c$ respectively. $\frac{\partial t^{TC}}{\partial \beta_c} > 0$, $\frac{\partial f^{TC}}{\partial \beta_c} > 0$, $\frac{\partial D^{TC}}{\partial \beta_c} > 0$, $\frac{\partial {\Pi_{p_t}}^{TC}}{\partial \beta_c} > 0$, $\frac{\partial {\Pi_{p_d}}^{TC}}{\partial \beta_c} > 0$. Taking the first derivative of $t^{TC}$, $f^{TC}$, $D^{TC}$, ${\Pi_{p_t}}^{TC}$, and ${\Pi_{p_d}}^{TC}$ with respect to $\beta_s$, respectively. It is straightforward to see that $t^{TC}$ and $f^{TC}$ are not affected by $\beta_s$, $\frac{\partial D^{TC}}{\partial \beta_s} > 0$, $\frac{\partial {\Pi_{p_t}}^{TC}}{\partial \beta_s} > 0$, $\frac{\partial {\Pi_{p_d}}^{TC}}{\partial \beta_s} > 0$. □

**Proof of Proposition 3.** We take the first derivative of $t^{TC}$, $f^{TC}$, $D^{TC}$, ${\Pi_{p_t}}^{TC}$, and ${\Pi_{p_d}}^{TC}$ with respect to $\lambda$ respectively. $\frac{\partial t^{TC}}{\partial \lambda} > 0$, $\frac{\partial f^{TC}}{\partial \lambda} > 0$, $D^{TC}$, ${\Pi_{p_t}}^{TC}$ has no relationship with $\lambda$, $\frac{\partial {\Pi_{p_d}}^{TC}}{\partial \lambda} < 0$. Taking the first derivative of $t^{TC}$, $f^{TC}$, $D^{TC}$, ${\Pi_{p_t}}^{TC}$, and ${\Pi_{p_d}}^{TC}$ with respect to $\tau$, respectively. $\frac{\partial t^{TC}}{\partial \tau} > 0$, $\frac{\partial f^{TC}}{\partial \tau} = -\frac{g(1-3\lambda\beta_c)}{4(1-\lambda\beta_c)}$, if and only if $\lambda > \frac{1}{3\beta_c}$, $\frac{\partial f^{TC}}{\partial \tau} > 0$, otherwise, $\frac{\partial f^{TC}}{\partial \tau} < 0$, $\frac{\partial D^{TC}}{\partial \tau} > 0$, $\frac{\partial {\Pi_{p_t}}^{TC}}{\partial \tau} > 0$, $\frac{\partial {\Pi_{p_d}}^{TC}}{\partial \tau} > 0$. □

The derivation process of equilibrium outcomes in case TS.

We again use backward induction to solve this problem. Substituting Equation (11) into Equation (13), we obtain the takeout platform's profit function under case TS given by

$$Max \underbrace{\Pi_{p_t}}_{f} = (\tau g + f - c)\cdot n_0 + (\tau g + f - t)\cdot\left(\frac{1 - f - g + n_0\beta_c + \lambda t\beta_c - n_0}{1 - \beta_c\beta_s}\right)$$

$$S.t.,\ 1 - g - n_0(1-\beta_c) - \frac{\lambda t(1-\beta_c)}{1-\beta_s} \le f < 1 - g - n_0(1-\beta_c) + \lambda t\beta_c$$

$$-g + \lambda t\beta_c + \beta_c\beta_s + n_0\beta_c(1-\beta_s) < f,$$

$$1 - g - n_0(1-\beta_c) + \beta_c - \frac{1-\lambda t}{\beta_s} < f$$

We can easily obtain that $\Pi_{p_t}$ is a concave function with respect to $f$. Using the Kuhn–Tucker condition to solve the above problem, the Lagrange function is

$$\begin{aligned} L_3 = (\tau g + f - c)\cdot n_0 + (\tau g + f - t)\cdot&\left(\frac{1 - f - g + n_0\beta_c + \lambda t\beta_c - n_0}{1 - \beta_c\beta_s}\right) \\ &+\mu_5\left(f - 1 + g + n_0(1-\beta_c) + \frac{\lambda t(1-\beta_c)}{1-\beta_s}\right) \\ &+\mu_6(1 - g - n_0(1-\beta_c) + \lambda t\beta_c - f) \\ &+\mu_7(f + g - \lambda t\beta_c - \beta_c\beta_s - n_0\beta_c(1-\beta_s)) \\ &+\mu_8\left(f - 1 + g + n_0(1-\beta_c) - \beta_c + \frac{1-\lambda t}{\beta_s}\right) \end{aligned}$$

According to KKT condition, we have

$$\begin{cases} \dfrac{\partial \Pi_{p_t}}{\partial f} + \mu_5 - \mu_6 + \mu_7 + \mu_8 = 0 \\ \mu_5\left(f - 1 + g + n_0(1-\beta_c) + \dfrac{\lambda t(1-\beta_c)}{1-\beta_s}\right) = 0, \mu_6(1 - g - n_0(1-\beta_c) + \lambda t\beta_c - f) = 0 \\ \mu_7(f + g - \lambda t\beta_c - \beta_c\beta_s - n_0\beta_c(1-\beta_s)) = 0, \mu_8\left(f - 1 + g + n_0(1-\beta_c) - \beta_c + \dfrac{1-\lambda t}{\beta_s}\right) = 0 \\ \mu_5 \ge 0,\ \mu_6 \ge 0,\ \mu_7 \ge 0,\ \mu_8 \ge 0 \end{cases}$$

There are two possible combinations for the Lagrangian multipliers $\mu_5$, $\mu_6$, $\mu_7$, and $\mu_8$.

(1) If $\mu_5 = \mu_6 = \mu_7 = \mu_8 = 0$, then $f = \frac{1-g-\tau g+t+\lambda t\beta_c+n_0\beta_c(1-\beta_s)}{2}$, substituting $f = \frac{1-g-\tau g+t+\lambda t\beta_c+n_0\beta_c(1-\beta_s)}{2}$ into the constraint conditions, and the constraint conditions with respect to $t$ of the delivery platform's objective function are changed to be $t \geq \frac{(1-\beta_s)(1-g+\tau g-n_0(2-\beta_c-\beta_c\beta_s))}{1+2\lambda-\beta_s-\lambda\beta_c(1+\beta_s)}$, $\frac{1+g-\tau g-n_0\beta_c-2\beta_c\beta_s+n_0\beta_c\beta_s}{-1+\lambda\beta_c} < t < \frac{1-g+\tau g-n_0(2-\beta_c-\beta_c\beta_s)}{1-\lambda\beta_c}$, and $t < \frac{2-2\beta_c\beta_s-(1-g+\tau g)\beta_s+n_0\beta_s(2-\beta_c-\beta_c\beta_s)}{2\lambda-\beta_s-\lambda\beta_c\beta_s}$. Taking $f = \frac{1-g-\tau g+t+\lambda t\beta_c+n_0\beta_c(1-\beta_s)}{2}$ into Equation (14), we can obtain the profit-maximizing problem for the delivery platform as follows:

$$Max \underbrace{\Pi_{p_d}}_{t} = \frac{(1-\lambda)t(1-g+\tau g-t+\lambda t\beta_c-n_0(2-\beta_c-\beta_c\beta_s))}{2-2\beta_c\beta_s}$$

It is easy to verify that $\Pi_{p_d}$ is a concave function of $t$. The Lagrange function under the KKT condition is

According to the Kuhn–Tucker condition, we have

$$\begin{cases} \frac{\partial \Pi_{p_d}}{\partial t} + \mu_5{}' + \mu_6{}' - \mu_7{}' - \mu_8{}' = 0 \\ \mu_5{}'\left(t - \frac{(1-\beta_s)(1-g+\tau g-n_0(2-\beta_c-\beta_c\beta_s))}{1+2\lambda-\beta_s-\lambda\beta_c(1+\beta_s)}\right) = 0 \\ \mu_6{}'\left(t - \frac{1+g-\tau g-n_0\beta_c-2\beta_c\beta_s+n_0\beta_c\beta_s}{-1+\lambda\beta_c}\right) = 0 \\ \mu_7{}'\left(\frac{1-g+\tau g-n_0(2-\beta_c-\beta_c\beta_s)}{1-\lambda\beta_c} - t\right) = 0 \\ \mu_8{}'\left(\frac{2-2\beta_c\beta_s-(1-g+\tau g)\beta_s+n_0\beta_s(2-\beta_c-\beta_c\beta_s)}{2\lambda-\beta_s-\lambda\beta_c\beta_s} - t\right) = 0 \\ \mu_5{}' \geq 0, \mu_6{}' \geq 0, \mu_7{}' \geq 0, \mu_8{}' \geq 0 \end{cases}$$

There are two possible combinations for the Lagrangian multipliers $\mu_5{}'$, $\mu_6{}'$, $\mu_7{}'$, and $\mu_8{}'$.

(i) If $\mu_5{}' = \mu_6{}' = \mu_7{}' = \mu_8{}' = 0$, then $t^{TS} = \frac{1-g+\tau g-n_0(2-\beta_c-\beta_c\beta_s)}{2(1-\lambda\beta_c)}$, and the drivers' shared percentage and the commission rate of the takeout platform should satisfy $\lambda \geq max\left\{\frac{1-\beta_s}{2+\beta_c-3\beta_c\beta_s}, \beta_s, \beta_c\right\}$ and $\tau_{o2} < \tau < min\{\tau_{o3}, \tau_{o4}\}$, where $\tau_{o2} = \frac{n_0(2-\beta_c-\beta_c\beta_s)}{g} - \frac{1-g}{g}$, $\tau_{o3} = \frac{4(1-\beta_c\beta_s)-n_0(2+\beta_c-3\beta_c\beta_s)}{g} - \frac{1-g}{g}$ and $\tau_{o4} = \frac{4(1-\beta_c\beta_s)(1-\lambda\beta_c)}{(2\lambda+\beta_s-3\lambda\beta_c\beta_s)g} + \frac{n_0(2-\beta_c-\beta_c\beta_s)}{g} - \frac{1-g}{g}$. The optimal delivery price under case TS is $f^{TS} = \frac{3-3g-\tau g-(1-g-3\tau g)\lambda\beta_c-n_0[(2-3\beta_c+\beta_c\beta_s)+\lambda\beta_c(2+\beta_c-3\beta_c\beta_s)]}{4(1-\lambda\beta_c)}$. The generated takeout demand and the crowdsourced service supply are $D^{TS} = \frac{1-g+\tau g+n_0(2+\beta_c-3\beta_c\beta_s)}{4(1-\beta_c\beta_s)}$ and $S^{TS} = \frac{(2\lambda+\beta_s-3\lambda\beta_c\beta_s)(1-g+\tau g-n_0(2-\beta_c-\beta_c\beta_s))}{4(1-\lambda\beta_c)(1-\beta_c\beta_s)}$, respectively. The profits of the takeout platform and the delivery platform are ${\Pi_{p_t}}^{TS} = A_1 \cdot n_0^2 + B_1 \cdot n_0 + \frac{(1-g+\tau g)^2}{16(1-\beta_c\beta_s)}$, where $A_1 = \frac{(2+\beta_c-3\beta_c\beta_s)^2}{16(1-\beta_c\beta_s)} - \frac{2-\beta_c-\beta_c\beta_s}{2(1-\lambda\beta_c)}$ and $B_1 = \frac{1-g+\tau g}{2(1-\lambda\beta_c)} + \frac{(1-g+\tau g)(2+\beta_c-3\beta_c\beta_s)}{8(1-\beta_c\beta_s)} - c$ and ${\Pi_{p_d}}^{TS} = \frac{(1-\lambda)(1-g+\tau g-n_0(2-\beta_c-\beta_c\beta_s))^2}{8(1-\lambda\beta_c)(1-\beta_c\beta_s)}$.

(ii) If $\mu_5{}' > 0$, $\mu_6{}' = \mu_7{}' = \mu_8{}' = 0$, then $t^{TS} = \frac{(1-\beta_s)(1-g+\tau g-n_0(2-\beta_c-\beta_c\beta_s))}{1+2\lambda-\beta_s-\lambda\beta_c(1+\beta_s)}$, and the drivers' shared percentage and the commission rate of the takeout platform should satisfy $max\{\beta_s, \beta_c\} \leq \lambda < \frac{1-\beta_s}{2+\beta_c-3\beta_c\beta_s}$ and $\tau_{o2} < \tau < \frac{1+2\lambda-\beta_s-\lambda\beta_c(1+\beta_s)-n_0(1-\beta_s)}{\lambda g} - \frac{1-g}{g}$. In addition, because the maximal value of $\frac{1-\beta_s}{2+\beta_c-3\beta_c\beta_s}$ is no larger than $\frac{1}{2}$, we ignore this scenario here and only focus on the interior solution, such that the service supply constraint is not binding.

(2) If $\mu_5 > 0$, $\mu_6 = \mu_7 = \mu_8 = 0$, then $f = 1-g-n_0(1-\beta_c) - \frac{\lambda t(1-\beta_c)}{1-\beta_s}$, the shipping fee set by the delivery platform should satisfy $t < \frac{(1-\beta_s)(1-g+\tau g-n_0(2-\beta_c-\beta_c\beta_s))}{1+2\lambda-\beta_s-\lambda\beta_c(1+\beta_s)}$ and $0 <$

$t < \frac{(1-n_0)(1-\beta_s)}{\lambda}$. Substituting $f = 1 - g - n_0(1-\beta_c) - \frac{\lambda t(1-\beta_c)}{1-\beta_s}$ into Equation (14), we can obtain the corresponding profit-maximizing problem of the delivery platform:

$$Max \underbrace{\Pi_{p_d}}_{t} = \frac{(1-\lambda)\lambda t^2}{1-\beta_s}$$

It is clearly to see that $\Pi_{p_d}$ is a monotonic increasing function of $t$. Then, there is no feasible solution.

Hence, we can obtain the equilibrium outcomes for case TS, as shown in Lemma 2. The relative size of the takeout demand and total service supply is $D^{TS} \leq S^{TS} + n_0$.

**Proof of Proposition 4.** Let $\Delta t = t^{TS} - t^{TC}$, $\Delta f = f^{TS} - f^{TC}$, by comparing the optimal delivery price and the shipping fee in case TS with case TC, it is straightforward to show that $\Delta t < 0$, and the corresponding application condition $\lambda \geq \frac{1-\beta_s}{2+\beta_c-3\beta_c\beta_s}$ implies $1 - \beta_s - 2\lambda - \lambda\beta_c + 3\lambda\beta_c\beta_s \leq 0$, then $\Delta f = \frac{n_0}{2}\left(\frac{-2(1-\beta_c)+\beta_c(1-\beta_s-2\lambda-\lambda\beta_c+3\lambda\beta_c\beta_s)}{2(1-\lambda\beta_c)}\right) < 0$. Thus, after self-establishing a delivery service, both the optimal delivery price and optimal shipping fee decrease.
Taking the first derivative of $t^{TS}$ and $f^{TS}$ with respect to $n_0$, respectively, $\frac{\partial t^{TS}}{\partial n_0} < 0$, $\frac{\partial f^{TS}}{\partial n_0} < 0$. Thus, both the optimal delivery price and shipping fee in case TS decrease $n_0$. □

**Proof of Proposition 5.** Let $\Delta f_{o2} = f^{TS} - t^{TS}$, the takeout platform offers customers subsidization when $\Delta f_{o2} < 0$. It is straightforward to show that when $\tau > \tau_2 = \frac{1-g+n_0(2+\beta_c-3\beta_c\beta_s)}{3g}$, $\Delta f_{o2} < 0$. After adding self-built logistics, the subsidy intensity can be denoted by $t^{TS} - f^{TS} = -\Delta f_{o2}$. It can be easily found that $\frac{\partial(-\Delta f_{o2})}{\partial n_0} < 0$. This is to say, the subsidy intensity decrease $n_0$. □

**Proof of Proposition 6.** We take the first derivative of $t^{TS}$, $f^{TS}$, $D^{TS}$, ${\Pi_{p_t}}^{TS}$, and ${\Pi_{p_d}}^{TS}$ with respect to $\beta_c$. $\frac{\partial t^{TS}}{\partial \beta_c} > 0$, $\frac{\partial f^{TS}}{\partial \beta_c} = \frac{2\lambda\left((1-g+\tau g)-\frac{n_0\left(-3+4\lambda+2\lambda\beta_c-\lambda^2\beta_c^2+\beta_s-6\lambda\beta_c\beta_s+3\lambda^2\beta_c^2\beta_s\right)}{2\lambda}\right)}{4(1-\lambda\beta_c)^2}$. Combined with the necessary condition, $\lambda \geq \frac{1-\beta_s}{2+\beta_c-3\beta_c\beta_s}$ implies $1 - \beta_s - 2\lambda - \lambda\beta_c + 3\lambda\beta_c\beta_s \leq 0$ and $\tau_{o2} < \tau$ implies $n_0 < \frac{1-g+\tau g}{2-\beta_c-\beta_c\beta_s}$. And then, $\frac{-3+4\lambda+2\lambda\beta_c-\lambda^2\beta_c^2+\beta_s-6\lambda\beta_c\beta_s+3\lambda^2\beta_c^2\beta_s}{2\lambda} - (2-\beta_c-\beta_c\beta_s) = \frac{(\lambda\beta_c-1)(3-\lambda\beta_c-\beta_s+3\lambda\beta_c\beta_s)}{2\lambda} < 0$. So, $\frac{\partial f^{TS}}{\partial \beta_c} > 0$. $\frac{\partial D^{TS}}{\partial \beta_c} > 0$. Let $\Pi_c = \left(\tau g + f^{TS} - t^{TS}\right)\cdot\left(D^{TS} - n_0\right)$, $\Pi_s = \left(\tau g + f^{TS} - c\right)\cdot n_0$; as a result, $\frac{\partial {\Pi_{p_t}}^{TS}}{\partial \beta_c} = \frac{\partial \Pi_c}{\partial \beta_c} + \frac{\partial \Pi_s}{\partial \beta_c} = \frac{2(1-g+\tau g)n_0(1-\beta_s)+(1-g+\tau g)^2\beta_s}{16(1-\beta_c\beta_s)^2} + \frac{n_0^2\left(4\beta_s+\beta_c\left(2-4\beta_s-6\beta_s^2\right)+\beta_c^2\beta_s\left(-1+2\beta_s+3\beta_s^2\right)\right)}{16(1-\beta_c\beta_s)^2} + \frac{{n_0}^2(-3+\beta_s+\beta_c(\lambda-3\lambda\beta_s))}{-4+4\lambda\beta_c} + \frac{\lambda n_0(1-g+\tau g-n_0(2-\beta_c-\beta_c\beta_s))}{2(1-\lambda\beta_c)^2}$. Because $4\beta_s + \beta_c\left(2 - 4\beta_s - 6\beta_s^2\right) + \beta_c^2\beta_s\left(-1 + 2\beta_s + 3\beta_s^2\right) > 0$, $\frac{\partial {\Pi_{p_t}}^{TS}}{\partial \beta_c} > 0$. $\frac{\partial {\Pi_{p_d}}^{TS}}{\partial \beta_c} > 0$. Taking the first derivative of $t^{TS}$, $f^{TS}$, $D^{TS}$, ${\Pi_{p_t}}^{TS}$, and ${\Pi_{p_d}}^{TS}$ with respect to $\beta_s$. $\frac{\partial t^{TS}}{\partial \beta_s} > 0$, $\frac{\partial f^{TS}}{\partial \beta_s} = -\frac{n_0\beta_c(1-3\lambda\beta_c)}{4(1-\lambda\beta_c)}$, and we can easily obtain that when $\lambda > \frac{1}{3\beta_c}$, $\frac{\partial f^{TS}}{\partial \beta_s} > 0$; when $\lambda \leq \frac{1}{3\beta_c}$, $\frac{\partial f^{TS}}{\partial \beta_s} \leq 0$. $\frac{\partial D^{TS}}{\partial \beta_s} > 0$. $\frac{\partial {\Pi_{p_t}}^{TS}}{\partial \beta_s} = \frac{\beta_c(1-g+\tau g)(1-g+\tau g-2n_0(1-\beta_c))}{16(1-\beta_c\beta_s)^2} - \frac{n_0^2\beta_c^2\left(-2(-1+4\lambda+\beta_s)+\beta_c\left(-1-2\lambda+18\lambda\beta_s+\beta_s^2\right)+\beta_c^2\left(\lambda-9\lambda\beta_s^2\right)\right)}{16(1-\lambda\beta_c)(1-\beta_c\beta_s)^2}$, because $-2(-1+4\lambda+\beta_s) + \beta_c(-1-2\lambda+18\lambda\beta_s+\beta_s^2) + \beta_c^2\left(\lambda-9\lambda\beta_s^2\right) < 0$, $\frac{\partial {\Pi_{p_t}}^{TS}}{\partial \beta_s} > 0$. $\frac{\partial {\Pi_{p_d}}^{TS}}{\partial \beta_s} > 0$. □

**Proof of Proposition 7.** We take the first derivative of $t^{TS}$, $f^{TS}$, $D^{TS}$, ${\Pi_{p_t}}^{TS}$, and ${\Pi_{p_d}}^{TS}$ with respect to $\lambda$. $\frac{\partial t^{TS}}{\partial \lambda} > 0$, $\frac{\partial f^{TS}}{\partial \lambda} > 0$, $D^{TS}$ has no relationship with $\lambda$, $\frac{\partial {\Pi_{p_t}}^{TS}}{\partial \lambda} > 0$, $\frac{\partial {\Pi_{p_d}}^{TS}}{\partial \lambda} < 0$. Taking the first derivative of $t^{TS}$, $f^{TS}$, $D^{TS}$, ${\Pi_{p_t}}^{TS}$, and ${\Pi_{p_d}}^{TS}$ with respect to $\tau$. $\frac{\partial t^{TS}}{\partial \tau}0$, $\frac{\partial f^{TS}}{\partial \tau} = -\frac{g(1-3\lambda\beta_c)}{4(1-\lambda\beta_c)}$, if and only if $\lambda > \frac{1}{3\beta_c}$, $\frac{\partial f^{TS}}{\partial \tau} > 0$, otherwise, $\frac{\partial f^{TS}}{\partial \tau} < 0$,

$\frac{\partial D^{TS}}{\partial \tau} > 0$, $\frac{\partial \Pi_{p_t}{}^{TS}}{\partial \tau} = \frac{g\left((1-g+\tau g)(1-\lambda\beta_c)-n_0\left(-6+\beta_c(-1+2\lambda+7\beta_s)+\lambda\beta_c^2(1-3\beta_s)\right)\right)}{8(1-\lambda\beta_c)(1-\beta_c\beta_s)}$. Because $-6+\beta_c(-1+2\lambda+7\beta_s)+\lambda\beta_c^2(1-3\beta_s)$ is an increasing function of $\beta_s$, taking $\beta_s=1$ into this formula, we obtain $2(\lambda\beta_c-3)(1-\beta_c)<0$. So, $\frac{\partial \Pi_{p_t}{}^{TS}}{\partial \tau} > 0$. $\frac{\partial \Pi_{p_d}{}^{TS}}{\partial \tau} > 0$. □

**Proof of Proposition 8.** Firstly, we verify that $\Pi_{p_t}{}^{TS}$ is a concave function of $n_0$. In other words, we need to prove $A_1$ in the profit expression of the takeout platform is negative. It is worth noting that when we compare the profit of the takeout platform in Case TC and in Case TS, the feasible range of $\tau$ should satisfy $\tau_{o2} < \tau < min\{\tau_{o1}, \tau_{o4}\}$.

We know $A_1 = \frac{(2+\beta_c-3\beta_c\beta_s)^2}{16(1-\beta_c\beta_s)} - \frac{2-\beta_c-\beta_c\beta_s}{2(1-\lambda\beta_c)}$, taking the partial derivative of the first and second term of $A_1$ with respect to $\beta_s$, we obtain $max\left\{\frac{(2+\beta_c-3\beta_c\beta_s)^2}{16(1-\beta_c\beta_s)}\right\} = \frac{(2+\lambda)^2}{16}$ and $min\left\{\frac{2-\beta_c-\beta_c\beta_s}{2(1-\lambda\beta_c)}\right\} = \frac{2-\beta_c-\lambda\beta_c}{2(1-\lambda\beta_c)}$. For $\partial\left(\frac{2-\beta_c-\lambda\beta_c}{2(1-\lambda\beta_c)}\right)/\partial\beta_c = -\frac{1-\lambda}{2(1-\lambda\beta_c)^2} < 0$, and substituting $\beta_c = \lambda$ into $\frac{2-\beta_c-\lambda\beta_c}{2(1-\lambda\beta_c)}$, we obtain $min\left\{\frac{2-\beta_c-\beta_c\beta_s}{2(1-\lambda\beta_c)}\right\} = \frac{2+\lambda}{2(1+\lambda)}$, and then $max\left\{\frac{(2+\lambda)^2}{16} - \frac{2+\lambda}{2(1+\lambda)}\right\} = \frac{9}{16} - \frac{3}{4} < 0$. So, we find that $A_1 < 0$.

Secondly, we compare the takeout platform's profit before and after the introduction of self-built logistics. Let $\Delta\Pi_{p_t} = \Pi_{p_t}{}^{TS} - \Pi_{p_t}{}^{TC}$. $\Delta\Pi_{p_t} = A_1 \cdot n_0^2 + B_1 \cdot n_0$, and $\Delta\Pi_{p_t}$ is a concave function of $n_0$ with zero points being $n_0 = \frac{-B_1-|B_1|}{2A_1}$ and $n_0 = \frac{-B_1+|B_1|}{2A_1}$. Then, if $B_1 > 0$, or equally, $c < c_2$, where $c_2 = \frac{1-g+\tau g}{2(1-\lambda\beta_c)} + \frac{(1-g+\tau g)(2+\beta_c-3\beta_c\beta_s)}{8(1-\beta_c\beta_s)}$, the other zero point aside from 0 is $\widehat{n_{01}} = -\frac{B_1}{A_1} = \frac{2(1-g+\tau g)(1-\lambda\beta_c)(2+\beta_c-3\beta_c\beta_s)+8(1-g+\tau g)(1-\beta_c\beta_s)-16c(1-\lambda\beta_c)(1-\beta_c\beta_s)}{8(1-\beta_c\beta_s)(2-\beta_c-\beta_c\beta_s)-(1-\lambda\beta_c)(2+\beta_c-3\beta_c\beta_s)^2}$.

And from the necessary condition of the delivery platform adopting interior pricing, we obtain $n_0 < \overline{n_0} = min\left\{\frac{1-g+\tau g}{2-\beta_c-\beta_c\beta_s}, \frac{4(1-\beta_c\beta_s)-(1-g+\tau g)}{2+\beta_c-3\beta_c\beta_s}\right\}$.

① When $\overline{n_0} \le \widehat{n_{01}}$, or equally, $c \le c_1$, where $c_1 = \begin{cases} \frac{(1-g+\tau g)(6-\beta_c-5\beta_c\beta_s)(2+\beta_c-3\beta_c\beta_s)}{16(1-\beta_c\beta_s)(2-\beta_c-\beta_c\beta_s)}, & if\ \tau \le \frac{1+g-\beta_c(1+\beta_s)}{g} \\ \frac{((1-g+\tau g)+4(1-\beta_c\beta_s))(2+\beta_c-3\beta_c\beta_s)}{16(1-\beta_c\beta_s)} - \frac{2(1-\beta_c\beta_s)(2-\beta_c-\beta_c\beta_s-(1-g+\tau g))}{(1-\lambda\beta_c)(2+\beta_c-3\beta_c\beta_s)}, & if\ \tau > \frac{1+g-\beta_c(1+\beta_s)}{g} \end{cases}$, the addition of self-built logistics always increases the profit of the takeout platform.

② When $\overline{n_0} > \widehat{n_{01}}$ or equally, $c_1 < c < c_2$, and $n_0 < \widehat{n_{01}}$, the addition of self-built logistics will increase the profit of the takeout platform; otherwise, the takeout platform's profit will decline.

③ And it is straightforward to see that if $B_1 \le 0$, or equally, $c \ge c_2$, the profit of the takeout platform always declines after the addition of self-built logistics.

Lastly, it is easy to see that the addition of self-built logistics always reduces the profit of the delivery platform. □

**Proof of Corollary 1.** The total profits of these two platforms after adding the self-built delivery service is calculated by

$$\Pi_p{}^{TS} = \Pi_{p_t}{}^{TS} + \Pi_{p_d}{}^{TS} = \left(\tau g + f^{TS} - c\right) \cdot n_0 + \left(\tau g + f^{TS} - \lambda t^{TS}\right) \cdot \left(D^{TS} - n_0\right)$$

By substituting $t^{TS}$ and $f^{TS}$ into $\Pi_p{}^{TS}$, we obtain $\Pi_p{}^{TS} = A_2 \cdot n_0{}^2 + B_2 \cdot n_0 + \frac{(1-g+\tau g)^2(3-2\lambda-\lambda\beta_c)}{16(1-\lambda\beta_c)(1-\beta_c\beta_s)}$, where $A_2 = \frac{(2+\beta_c-3\beta_c\beta_s)^2}{16(1-\beta_c\beta_s)} - \frac{(2-\beta_c-\beta_c\beta_s)(2+2\lambda+\beta_c-\lambda\beta_c-3\beta_c\beta_s-\lambda\beta_c\beta_s)}{8(1-\lambda\beta_c)(1-\beta_c\beta_s)}$,

$$B_2 = \frac{(1-g+\tau g)(2+\beta_c-3\beta_c\beta_s)}{8(1-\beta_c\beta_s)} + \frac{(1-g+\tau g)(\beta_c(1-\beta_s)+\lambda(2-\beta_c-\beta_c\beta_s))}{4(1-\lambda\beta_c)(1-\beta_c\beta_s)} - c.$$

Following the similar approach in Proposition 8, $\Delta\Pi_p = {\Pi_p}^{TS} - {\Pi_{p_t}}^{TC} - {\Pi_{p_d}}^{TC} = A_2 \cdot {n_0}^2 + B_2 \cdot n_0$. It is easy to verify that $A_2 < 0$, and $\Delta\Pi_p$ is a concave function of $n_0$ with zero points being $n_0 = \frac{-B_2 - |B_2|}{2A_2}$ and $n_0 = \frac{-B_2 + |B_2|}{2A_2}$. Then, if $B_2 > 0$, or equally, $c < \widetilde{c_2}$, where $\widetilde{c_2} = \frac{(1-g+\tau g)(2+\beta_c-3\beta_c\beta_s)}{8(1-\beta_c\beta_s)} + \frac{(1-g+\tau g)(\beta_c(1-\beta_s)+\lambda(2-\beta_c-\beta_c\beta_s))}{4(1-\lambda\beta_c)(1-\beta_c\beta_s)}$, we can easily calculate that the other zero point aside from zero is

$$\widehat{n_{02}} = -\frac{B_2}{A_2} = \frac{2(1-g+\tau g)\left(2+4\lambda+3\beta_c-4\lambda\beta_c-\lambda\beta_c^2-5\beta_c\beta_s-2\lambda\beta_c\beta_s+3\lambda\beta_c^2\beta_s\right)-16c(1-\lambda\beta_c)(1-\beta_c\beta_s)}{(2-3\beta_c+2\lambda\beta_c+\lambda\beta_c^2+\beta_c\beta_s-3\lambda\beta_c^2\beta_s)(2+\beta_c-3\beta_c\beta_s)+2\lambda(2-\beta_c-\beta_c\beta_s)^2}.$$

And we know $n_0 < \overline{n_0} = min\left\{\frac{1-g+\tau g}{2-\beta_c-\beta_c\beta_s}, \frac{4(1-\beta_c\beta_s)-(1-g+\tau g)}{2+\beta_c-3\beta_c\beta_s}\right\}$.

① When $\overline{n_0} \leq \widehat{n_{02}}$, or equally, $c \leq \widetilde{c_1}$, where

$$\widetilde{c_1} = \begin{cases} \frac{(1-g+\tau g)\left(2\lambda+2\beta_c-3\lambda\beta_c-\lambda\beta_c^2-2\beta_c\beta_s-\lambda\beta_c\beta_s+3\lambda\beta_c^2\beta_s\right)}{8(1-\lambda\beta_c)(1-\beta_c\beta_s)} + \frac{(1-g+\tau g)(2+\beta_c-3\beta_c\beta_s)^2}{16(1-\beta_c\beta_s)(2-\beta_c-\beta_c\beta_s)}, \ if\ \tau \leq \frac{1+g-\beta_c(1+\beta_s)}{g} \\ \frac{2(1-g+\tau g)\left(2+4\lambda+3\beta_c-4\lambda\beta_c-\lambda\beta_c^2-5\beta_c\beta_s-2\lambda\beta_c\beta_s+3\lambda\beta_c^2\beta_s\right)}{16(1-\lambda\beta_c)(1-\beta_c\beta_s)} \\ -\frac{(4(1-\beta_c\beta_s)-(1-g+\tau g))\left(16(1-\beta_c\beta_s)^2+(2\lambda-1)(2-\beta_c-\beta_c\beta_s)^2-(2+\beta_c-3\beta_c\beta_s)^2(2-\lambda\beta_c)\right)}{16(1-\lambda\beta_c)(1-\beta_c\beta_s)(2+\beta_c-3\beta_c\beta_s)}, \ if\ \tau > \frac{1+g-\beta_c(1+\beta_s)}{g} \end{cases}$$

the addition of self-built logistics always increases the total profits of the two platforms.

② When $\overline{n_0} > \widehat{n_{02}}$ or equally, $\widetilde{c_1} < c < \widetilde{c_2}$, and $n_0 < \widehat{n_{02}}$, the addition of self-built logistics will increase the total profits of the two platforms; otherwise, the total profits will decline.

③ And it is straightforward to see that if $B_2 \leq 0$, or equally, $c \geq \widetilde{c_2}$, the total profits of the two platforms always declines after the addition of self-built logistics. □

**Proof of Proposition 9.** The takeout platform's profit and delivery platform's profit are shown in Equations (13) and (14), respectively. It is worth noting that although both full-time delivery workers and crowdsourced drivers coexist in the delivery service market in Case TS, the welfare of the full-time delivery workers is included in Equation (13), which is regarded as part of the takeout platform's delivery revenue. To address the welfare of the self-scheduling drivers, we consider a representative driver who has a certain probability of undertaking the delivery task. To be specific, the welfare of the crowdsourced drivers is given by

$$WD = \frac{D-n_0}{S} \cdot \int_0^{\lambda t+\beta_s\cdot(D-n_0)} (\lambda t + \beta_s \cdot (D-n_0) - k)dk \tag{A1}$$

and the customer surplus is computed as

$$CS = \int_{g+f-\beta_c\cdot(S+n_0)}^1 (v - g - f + \beta_c \cdot (S+n_0))dv \tag{A2}$$

the revenue of restaurants is

$$\Pi_R = (1-\tau)g \cdot D \tag{A3}$$

Then, the social welfare is as follows

$$SW = \Pi_{p_t} + \Pi_{p_d} + \Pi_R + WD + CS \tag{A4}$$

Substituting $S^{TS}$ and $D^{TS}$ into Equations (A1)–(A4), we obtain the customer surplus, welfare of crowdsourced drivers, and social welfare as follows:

$$CS = \frac{(1-g+\tau g+n_0(2+\beta_c-3\beta_c\beta_s))^2}{32(1-\beta_c\beta_s)^2},$$

$$WD = \frac{(2\lambda + \beta_s - 3\lambda\beta_c\beta_s)(1 - g + \tau g - n_0(2 - \beta_c - \beta_c\beta_s))^2}{32(1 - \lambda\beta_c)(1 - \beta_c\beta_s)^2},$$

$$SW = \left( \frac{(1-\lambda\beta_c)(2+\beta_c-3\beta_c\beta_s)^2 - 8\lambda(1-\beta_c\beta_s)(2-\beta_c-\beta_c\beta_s) - 2(1-\lambda)(2+\beta_c-3\beta_c\beta_s)(2-\beta_c-\beta_c\beta_s)}{16(1-\beta_c\beta_s)(1-\lambda\beta_c)} + \frac{(1-\lambda\beta_c)(2+\beta_c-3\beta_c\beta_s)^2 + (2-\beta_c-\beta_c\beta_s)^2(2\lambda+\beta_s-3\lambda\beta_c\beta_s)}{32(1-\lambda\beta_c)(1-\beta_c\beta_s)^2} \right) \cdot n_0^2 + \left( \frac{4\lambda(1-g+\tau g)(1-\beta_c\beta_s) + (1-\lambda\beta_c)(2+\beta_c-3\beta_c\beta_s)(1+g-\tau g) + 2(1-\lambda)\beta_c(1-\beta_s)(1-g+\tau g)}{8(1-\lambda\beta_c)(1-\beta_c\beta_s)} + \frac{(1-\lambda\beta_c)(2+\beta_c-3\beta_c\beta_s)(1-g+\tau g) - (2-\beta_c-\beta_c\beta_s)(2\lambda+\beta_s-3\lambda\beta_c\beta_s)(1-g+\tau g)}{16(1-\lambda\beta_c)(1-\beta_c\beta_s)^2} - c \right) \cdot n_0 + \frac{2(1-g+\tau g)(1+3g-3\tau g)(1-\beta_c\beta_s) + (1-g+\tau g)^2}{32(1-\beta_c\beta_s)^2} + \frac{4(1-\lambda)(1-\beta_c\beta_s)(1-g+\tau g)^2 + (2\lambda+\beta_s-3\lambda\beta_c\beta_s)(1-g+\tau g)^2}{32(1-\lambda\beta_c)(1-\beta_c\beta_s)^2};$$

Then, $\Delta SW = A_3 \cdot n_0^2 + B_3 \cdot n_0$, where

$$A_3 = \frac{(1 - \lambda\beta_c)(2 + \beta_c - 3\beta_c\beta_s)^2 - 8\lambda(1 - \beta_c\beta_s)(2 - \beta_c - \beta_c\beta_s) - 2(1 - \lambda)(2 + \beta_c - 3\beta_c\beta_s)(2 - \beta_c - \beta_c\beta_s)}{16(1 - \lambda\beta_c)(1 - \beta_c\beta_s)} + \frac{(1 - \lambda\beta_c)(2 + \beta_c - 3\beta_c\beta_s)^2 + (2 - \beta_c - \beta_c\beta_s)^2(2\lambda + \beta_s - 3\lambda\beta_c\beta_s)}{32(1 - \lambda\beta_c)(1 - \beta_c\beta_s)^2},$$

$$B_3 = \frac{4\lambda(1 - g + \tau g)(1 - \beta_c\beta_s) + (1 - \lambda\beta_c)(2 + \beta_c - 3\beta_c\beta_s)(1 + g - \tau g) + 2(1 - \lambda)\beta_c(1 - \beta_s)(1 - g + \tau g)}{8(1 - \lambda\beta_c)(1 - \beta_c\beta_s)} + \frac{(1 - \lambda\beta_c)(2 + \beta_c - 3\beta_c\beta_s)(1 - g + \tau g) - (2 - \beta_c - \beta_c\beta_s)(2\lambda + \beta_s - 3\lambda\beta_c\beta_s)(1 - g + \tau g)}{16(1 - \lambda\beta_c)(1 - \beta_c\beta_s)^2} - c.$$

It is easily seen that $A_3 < 0$, and $\Delta SW$ is a concave function of $n_0$ with zero points being $n_0 = \frac{-B_3 - |B_3|}{2A_3}$ and $n_0 = \frac{-B_3 + |B_3|}{2A_3}$. Then, if $B_3 > 0$, or equally, $c < c_4$, where $c_4 = \frac{4\lambda(1-g+\tau g)(1-\beta_c\beta_s) + (1-\lambda\beta_c)(2+\beta_c-3\beta_c\beta_s)(1+g-\tau g) + 2(1-\lambda)\beta_c(1-\beta_s)(1-g+\tau g)}{8(1-\lambda\beta_c)(1-\beta_c\beta_s)} + \frac{(1-\lambda\beta_c)(2+\beta_c-3\beta_c\beta_s)(1-g+\tau g) - (2-\beta_c-\beta_c\beta_s)(2\lambda+\beta_s-3\lambda\beta_c\beta_s)(1-g+\tau g)}{16(1-\lambda\beta_c)(1-\beta_c\beta_s)^2}$, the other zero point aside from zero is

$$\widehat{n_{03}} = -\frac{B_3}{A_3} = \frac{\left[16\lambda(1 - \beta_c\beta_s)^2 + 4(1 - \lambda\beta_c)(1 - \beta_c\beta_s)(2 + \beta_c - 3\beta_c\beta_s)\right] \cdot (1 - g + \tau g)}{\left[16\lambda(1 - \beta_c\beta_s)^2 + 4(1 - \lambda)(1 - \beta_c\beta_s)(2 + \beta_c - 3\beta_c\beta_s) - (2 - \beta_c - \beta_c\beta_s)(2\lambda + \beta_s - 3\lambda\beta_c\beta_s)\right] \cdot (2 - \beta_c - \beta_c\beta_s) - (1 - \lambda\beta_c)(3 - 2\beta_c\beta_s)(2 + \beta_c - 3\beta_c\beta_s)^2} + \frac{8(1 - \lambda)\beta_c(1 - \beta_s)(1 - \beta_c\beta_s)(1 - g + \tau g)}{\left[16\lambda(1 - \beta_c\beta_s)^2 + 4(1 - \lambda)(1 - \beta_c\beta_s)(2 + \beta_c - 3\beta_c\beta_s) - (2 - \beta_c - \beta_c\beta_s)(2\lambda + \beta_s - 3\lambda\beta_c\beta_s)\right] \cdot (2 - \beta_c - \beta_c\beta_s) - (1 - \lambda\beta_c)(3 - 2\beta_c\beta_s)(2 + \beta_c - 3\beta_c\beta_s)^2} + \frac{[2(1 - \lambda\beta_c)(2 + \beta_c - 3\beta_c\beta_s) - 2(2 - \beta_c - \beta_c\beta_s)(2\lambda + \beta_s - 3\lambda\beta_c\beta_s)] \cdot (1 - g + \tau g) - 32c(1 - \lambda\beta_c)(1 - \beta_c\beta_s)^2}{\left[16\lambda(1 - \beta_c\beta_s)^2 + 4(1 - \lambda)(1 - \beta_c\beta_s)(2 + \beta_c - 3\beta_c\beta_s) - (2 - \beta_c - \beta_c\beta_s)(2\lambda + \beta_s - 3\lambda\beta_c\beta_s)\right] \cdot (2 - \beta_c - \beta_c\beta_s) - (1 - \lambda\beta_c)(3 - 2\beta_c\beta_s)(2 + \beta_c - 3\beta_c\beta_s)^2}.$$

We know $n_0 < \overline{n_0} = min\left\{ \frac{1-g+\tau g}{2-\beta_c-\beta_c\beta_s}, \frac{4(1-\beta_c\beta_s)-(1-g+\tau g)}{2+\beta_c-3\beta_c\beta_s} \right\}$.

① When $\overline{n_0} \leq \widehat{n_{03}}$ or equally, $c \leq c_3$, where

$$c_3 = \begin{cases} \frac{1-g+\tau g+(26+\lambda-(2+\lambda)(1-\tau)g)\beta_c-6\lambda(5-g+\tau g)\beta_c^2}{32\beta_c(1-\lambda\beta_c)} - \frac{(1-g+\tau g)\left(1-\beta_c^2\right)}{32\beta_c(1-\beta_c\beta_s)^2} \\ +\frac{-4+\lambda-\lambda(1-\tau)g+\beta_c(3+\lambda+(1-\tau)g(1+3\lambda)-(1+3(1-\tau)g)\lambda\beta_c)}{16(1-\lambda\beta_c)(1-\beta_c\beta_s)} - \frac{(1-g+\tau g)(1-2\beta_c)}{2(2-\beta_c-\beta_c\beta_s)}, \ if \ \ \tau \leq \frac{1+g-\beta_c(1+\beta_s)}{g} \\ \frac{-8\lambda\beta_c^5(1-3\beta_s)^2\beta_s^2+4(3-2\lambda+(1-6\lambda)(1-\tau)g+(1+3g-3\tau g)\beta_s)}{32(1-\lambda\beta_c)(1-\beta_c\beta_s)^2(2+\beta_c-3\beta_c\beta_s)} \\ -\frac{4\beta_c(-19+9\lambda+(-1+3\lambda(1-\tau)+\tau)g+\beta_s(22-7\lambda+(6-13\lambda)(1-\tau)g+(3+5g-5\tau g)\beta_s))}{32(1-\lambda\beta_c)(1-\beta_c\beta_s)^2(2+\beta_c-3\beta_c\beta_s)} \\ +\frac{2\beta_c^4\beta_s(\lambda(11+3g-3\tau g))}{32(1-\lambda\beta_c)(1-\beta_c\beta_s)^2(2+\beta_c-3\beta_c\beta_s)} \\ +\frac{2\beta_c^4{\beta_s}^2(6(2-\lambda(14+3(1-\tau)g))+\beta_s(-40+\lambda(143+27g-27\tau g)+2(6-\lambda)\beta_s))}{32(1-\lambda\beta_c)(1-\beta_c\beta_s)^2(2+\beta_c-3\beta_c\beta_s)} \\ +\frac{\beta_c^2(35-70\lambda+(1-18\lambda)(1-\tau)g)}{32(1-\lambda\beta_c)(1-\beta_c\beta_s)^2(2+\beta_c-3\beta_c\beta_s)} \\ -\frac{\beta_c^2\beta_s(5(49-44\lambda)+(15-68\lambda)(1-\tau)g)}{32(1-\lambda\beta_c)(1-\beta_c\beta_s)^2(2+\beta_c-3\beta_c\beta_s)} \\ +\frac{\beta_c^2{\beta_s}^2(165-38\lambda+(39-34\lambda)(1-\tau)g+(13+7g-7\tau g)\beta_s)}{32(1-\lambda\beta_c)(1-\beta_c\beta_s)^2(2+\beta_c-3\beta_c\beta_s)} \\ -\frac{5\lambda\beta_c^3(3+g-\tau g)}{32(1-\lambda\beta_c)(1-\beta_c\beta_s)^2(2+\beta_c-3\beta_c\beta_s)} - \frac{\beta_c^3\beta_s(58-191\lambda+(2-53\lambda)(1-\tau)g)}{32(1-\lambda\beta_c)(1-\beta_c\beta_s)^2(2+\beta_c-3\beta_c\beta_s)} \\ -\frac{\beta_c^3\beta_s^2(-248+397\lambda-3(4-37\lambda)(1-\tau)g+\beta_s(114-21\lambda+(18-7\lambda)(1-\tau)g+4\beta_s))}{32(1-\lambda\beta_c)(1-\beta_c\beta_s)^2(2+\beta_c-3\beta_c\beta_s)}, if \ \ \tau > \frac{1+g-\beta_c(1+\beta_s)}{g} \end{cases},$$

the addition of self-built logistics always increases the social welfare.

② When $\overline{n_0} > \widehat{n_{03}}$ or equally, $c_3 < c < c_4$, and $n_0 < \widehat{n_{03}}$, the addition of self-built logistics will increase social welfare; otherwise, social welfare will reduce.

③ And it is straightforward to see that if $B_3 \leq 0$, or equally, $c \geq c_4$, the social welfare always declines after the addition of self-built logistics. □

## References


1. Revenue of the Online Food Delivery Market Worldwide from 2017 to 2029, by Segment. 2024. Available online: https://www.statista.com/statistics/1170631/online-food-delivery-market-size-worldwide/ (accessed on 15 September 2024).
2. Dianwoda has Become Ele.Me Exclusive Strategic Partner for Crowdsourced Delivery, with an Average Daily Order of More than 2 Million. 2017. Available online: https://finance.huanqiu.com/article/9CaKrnK4rLC (accessed on 8 November 2023).
3. Meituan Takeout Announces Its Collaboration with FlashEx, SoFast, and UUpaotui. 2023. Available online: https://baijiahao.baidu.com/s?id=1775438801658950877&wfr=spider&for=pc (accessed on 6 October 2023).
4. Parker, G.G.; Van Alstyne, M.W. Two-sided network effects: A theory of information product design. *Manage Sci.* **2005**, *51*, 1494–1504. [CrossRef]
5. Rochet, J.C.; Tirole, J. Platform competition in two-sided markets. *J. Eur. Econ. Assoc.* **2003**, *1*, 990–1029. [CrossRef]
6. Wright, J. One-sided logic in two-sided markets. *Rev. Netw. Econ.* **2004**, *3*, 1. [CrossRef]
7. Rochet, J.C.; Tirole, J. Two-sided markets: A progress report. *Rand J. Econ.* **2006**, *37*, 645–667. [CrossRef]
8. Armstrong, M. Competition in two-sided markets. *RAND J. Econ.* **2006**, *37*, 668–691. [CrossRef]
9. Economides, N.; Tåg, J. Network neutrality on the Internet: A two-sided market analysis. *Inf. Econ. Policy* **2012**, *24*, 91–104. [CrossRef]
10. Hagiu, A.; Hałaburda, H. Information and two-sided platform profits. *Int. J. Ind. Organ.* **2014**, *34*, 25–35. [CrossRef]
11. Bakos, Y.; Halaburda, H. Platform competition with multihoming on both sides: Subsidize or not? *Manag. Sci.* **2020**, *66*, 5599–5607. [CrossRef]
12. Benjaafar, S.; Hu, M. Operations management in the age of the sharing economy: What is old and what is new? *Manuf. Serv. Oper. Manag.* **2020**, *22*, 93–101. [CrossRef]
13. Rong, K.; Zhou, D.; Shi, X.; Huang, W. Social information disclosure of friends in common in an e-commerce platform ecosystem: An online experiment. *Prod. Oper. Manag.* **2022**, *31*, 984–1005. [CrossRef]
14. Zhu, X.; Yang, C.; Liu, K.; Zhang, R.; Jiang, Q. Cooperation and decision making in a two-sided market motivated by the externality of a third-party social media platform. *Ann. Oper. Res.* **2022**, *316*, 117–142. [CrossRef] [PubMed]
15. Cohen, M.C.; Zhang, R. Competition and coopetition for two-sided platforms. *Prod. Oper. Manag.* **2022**, *31*, 1997–2014. [CrossRef]
16. Liu, Y.; Li, S. An economic analysis of on-demand food delivery platforms: Impacts of regulations and integration with ride-sourcing platforms. *Transp. Res. Part E Logist. Transp. Rev.* **2023**, *171*, 103019. [CrossRef]

17. Liu, H.; Amit, R.; Qiao, H.; Wang, S. Digital platform compatibility strategies in platform co-opetition. *J. Bus. Res.* **2024**, *174*, 114489. [CrossRef]
18. He, B.; Mirchandani, P.; Wang, Y. Removing barriers for grocery stores: O2O platform and self-scheduling delivery capacity. *Transp. Res. Part E Logist. Transp. Rev.* **2020**, *141*, 102036. [CrossRef]
19. Chen, M.; Hu, M.; Wang, J. Food delivery service and restaurant: Friend or foe? *Manag. Sci.* **2022**, *68*, 6539–6551. [CrossRef]
20. Feldman, P.; Frazelle, A.E.; Swinney, R. Managing relationships between restaurants and food delivery platforms: Conflict, contracts, and coordination. *Manag. Sci.* **2023**, *69*, 812–823. [CrossRef]
21. Niu, B.; Li, Q.; Mu, Z.; Chen, L.; Ji, P. Platform logistics or self-logistics? Restaurants' cooperation with online food-delivery platform considering profitability and sustainability. *Int. J. Prod. Econ.* **2021**, *234*, 108064. [CrossRef]
22. Du, Z.; Fan, Z.P.; Gao, G.X. Choice of O2O food delivery mode: Self-built platform or third-party platform? Self-delivery or third-party delivery? *IEEE Trans. Eng. Manag.* **2021**, *70*, 2206–2219. [CrossRef]
23. Du, Z.; Fan, Z.P.; Sun, F. O2O dual-channel sales: Choices of pricing policy and delivery mode for a restaurant. *Int. J. Prod. Econ.* **2023**, *257*, 108766. [CrossRef]
24. Tong, T.; Dai, H.; Xiao, Q.; Yan, N. Will dynamic pricing outperform? Theoretical analysis and empirical evidence from O2O on-demand food service market. *Int. J. Prod. Econ.* **2020**, *219*, 375–385. [CrossRef]
25. Du, Z.; Fan, Z.P.; Chen, Z. Implications of on-time delivery service with compensation for an online food delivery platform and a restaurant. *Int. J. Prod. Econ.* **2023**, *262*, 108896. [CrossRef]
26. Liu, M.; Du, S.; Nie, T.; Zhu, Y. Pricing, channel design, and platform operations with buy-online-and-pick-up-in-store in online food delivery market. *Int. J. Prod. Econ.* **2024**, *274*, 109293. [CrossRef]
27. Chen, M.; Hu, M. Courier dispatch in on-demand delivery. *Manag. Sci.* **2024**, *70*, 3789–3807. [CrossRef]
28. Lu, F.; Jiang, R.; Bi, H.; Gao, Z. Order Distribution and Routing Optimization for Takeout Delivery under Drone–Rider Joint Delivery Mode. *J. Theor. Appl. Electron. Commer. Res.* **2024**, *19*, 774–796. [CrossRef]
29. Sun, G.; Kim, Y.; Tan, Y.; Parker, G.G. Dinner at your doorstep: Service innovation via the gig economy on food delivery platforms. *Inf. Syst. Res.* **2024**, *35*, 1216–1234. [CrossRef]
30. Ji, X.; Li, X.; Wang, S. Balance between profit and fairness: Regulation of online food delivery (OFD) platforms. *Int. J. Prod. Econ.* **2024**, *269*, 109144. [CrossRef]
31. Bi, H.; Zhu, X.; Lu, F.; Huang, M. The meal delivery routing problem in e-commerce platforms under the shared logistics mode. *J. Theor. Appl. Electron. Commer. Res.* **2023**, *18*, 1799–1819. [CrossRef]
32. Bahrami, S.; Nourinejad, M.; Yin, Y.; Wang, H. The three-sided market of on-demand delivery. *Transp. Res. Part E Logist. Transp. Rev.* **2023**, *179*, 103313. [CrossRef]
33. Armstrong, M.; Wright, J. Two-sided markets, competitive bottlenecks and exclusive contracts. *Econ. Theory* **2007**, *32*, 353–380. [CrossRef]
34. Hu, B.; Hu, M.; Zhu, H. Surge pricing and two-sided temporal responses in ride hailing. *Manuf. Serv. Oper. Manag.* **2022**, *24*, 91–109. [CrossRef]
35. Afèche, P.; Liu, Z.; Maglaras, C. Ride-hailing networks with strategic drivers: The impact of platform control capabilities on performance. *Manuf. Serv. Oper. Manag.* **2023**, *25*, 1890–1908. [CrossRef]
36. Li, S.; Liu, Y.; Bandyopadhyay, S. Network effects in online two-sided market platforms: A research note. *Decis. Support Syst.* **2010**, *49*, 245–249. [CrossRef]
37. Taylor, J.; Joshi, K.D. Joining the crowd: The career anchors of information technology workers participating in crowdsourcing. *Inf. Syst. J.* **2019**, *29*, 641–673. [CrossRef]
38. Bernstein, F.; DeCroix, G.A.; Keskin, N.B. Competition between two-sided platforms under demand and supply congestion effects. *Manuf. Serv. Oper. Manag.* **2021**, *23*, 1043–1061. [CrossRef]
39. Hu, M.; Liu, Y. Precommitments in two-sided market competition. *Manuf. Serv. Oper. Manag.* **2023**, *25*, 704–718. [CrossRef]
40. Hu, M.; Zhou, Y. Price, Wage, and Fixed Commission in on-Demand Matching. SSRN 2949513. Available online: https://ssrn.com/abstract=2949513 (accessed on 31 August 2020).
41. FlashEx's "One-to-One" Service Has Been Meticulously Crafted, and It Has Received Overwhelmingly Positive Reviews from Users. 2024. Available online: https://www.163.com/dy/article/JBL8DJGA05562MJS.html (accessed on 3 October 2024).
42. Li, L.; Huang, M.; Yue, X.; Wang, X. The strategic analysis of collection delivery points network sharing in last-mile logistics market. *Transp. Res. Part E Logist. Transp. Rev.* **2024**, *183*, 103423. [CrossRef]
43. Tao, J.; Dai, H.; Jiang, H.; Chen, W. Dispatch optimisation in O2O on-demand service with crowd-sourced and in-house drivers. *Int. J. Prod. Res.* **2021**, *59*, 6054–6068. [CrossRef]