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EARLY ENTRANT'S STRATEGY FOR COOPERATING WITH A COMPETING FOURTH-PARTY PLATFORM

Wen Xin and Jun Lin*

Abstract. By integrating several third-party platforms that enter the market late (later entrants), a fourth-party platform can effectively compete with the third-party platform that enters the market early (early entrant). Our research develops an analytical framework to address the platform coopetition problem that the early entrant faces, *i.e.*, integrating its service into the fourth-party platform or not, when there is a fourth-party platform in the market. This study provides optimal conditions and platform decisions for platform coopetition and then explores the impact of the implementation of the coopetition strategy on platform prices and consumer demands. Our analytical results show that the coopetition strategy is effective only when the sum of the strengths of direct and indirect network effects is low and the quality difference between the early and later entrants is higher than a certain threshold. Moreover, the early entrant always partially integrates its service into the fourth-party platform when the coopetition strategy is adopted. Such adoption always lowers the prices of the early and later entrants. The implementation of the coopetition strategy always increases the total consumer demand of the early entrant, but it also results in a reduction in the number of consumers in the standalone application of the early entrant.

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1. Introduction

"Winner-take-all" outcomes are possible when network effects exist, as the early entrant with the largest number of users "tips the market" in its favor. Then, the early entrant is sheltered and it is challenging for the later entrants to compete with it [15, 25]. However, the existence of fourth-party platforms, made up of several third-party platforms that enter market late, has reversed this situation. Specifically, this situation makes it possible for later entrants to compete with the third-party platform that enters the market early. The entry barrier established by the early entrant is weakened as the later entrants share their network effects by integrating into the fourth-party platform jointly. In such cases, the early entrant may achieve a higher profit by integrating its service into the fourth-party platform. For instance, the hotel reservation platform Trip.com

Keywords. Game theory, platform coopetition, direct and indirect network effects, fourth-party platform, multiple purchase channels.

School of Management, Xi'an Jiaotong University, 710000 Xi'an, P.R. China.
*Corresponding author: ljun@mail.xjtu.edu.cn

Group, which occupies the largest market share in that industry in China, integrated its service into Amap after Amap integrated several newly-launched hotel reservation platforms[1], while retaining its standalone application.

However, it remains an open question whether and to what degree the early entrant should integrate its service into the fourth-party platform. The early entrant can integrate its service into the fourth-party platform to cannibalize the consumer demand of those later entrants integrated into the fourth-party platform. However, the integration also amplifies the direct and indirect network effects of the fourth-party platform, making the platform more appealing to customers than before the integration. The reason for this is that consumers can be served more quickly as the number of service providers on the fourth-party platform increases, thereby attracting more consumers. In addition, the early entrant incurs additional costs as a result of its integration into the fourth-party platform because it is required to pay the latter commission fees. For instance, Rookie Wrap charges the integrated platforms on its platform CNY 0.6 per package as commission fee[2]. The early entrant can also determine the degree of integration that is the number of providers allocated to offer services on the fourth-party platform. For example, some hotel-reservation platforms, such as Trip.com Group and Fliggy, does not integrate all the housing resources they own into the fourth-party platform, such as Amap and JD.com. The reason for this is that as the provider number of the early entrant on the fourth-party platform increases, the early entrant on the fourth-party platform is more likely to be adopted by consumers. This incurs higher commission fees to the early entrant. This also increases the competitiveness of the fourth-party platform, which further increases the customer churn of the standalone application of the early entrant.

From the perspective of the fourth-party platform, it is unclear whether it should integrate the early entrant. If the coopetition strategy is adopted, then the fourth-party platform can receive commission fees from the early entrant. After the integration, the early entrant not only exists in its standalone application, but also in the application of fourth-party platform. Then, the competition between the early and later entrants may be further intensified. In such cases, the fourth-party platform may have to lower its commission price and make a lower profit than it did prior to the adoption of the coopetition strategy.

Motivated by the abovementioned examples, we study a competitive market structure with a third-party platform who enters the market first and a fourth-party platform comprised of several later entrants. The early and later entrants provide competing services. The key questions here are as follows. Under what conditions would the early entrant and fourth-party platforms reach an agreement on the adoption of the coopetition strategy in the presence of direct and indirect network effects? Furthermore, how does the early entrant decide its degree of integration if the coopetition strategy is adopted? How much commission should a fourth-party platform charge the integrated platforms? Moreover, how do the prices and consumer demands of the early and later entrants change as a result of the adoption of the coopetition strategy?

Our analytical results show that the coopetition strategy is effective only if the sum of the strengths of direct and indirect network effects is low and the quality difference between the early and later entrants is higher than a certain threshold. Specifically, the early entrant always partially integrates its service into the fourth-party platform when coopetition is the equilibrium strategy. Additionally, the degree of partial integration always increases with the increase in the quality difference between the early and later entrants and the strength of network effects but decreases as consumer preference rises. The prices of the early entrant and those platforms that have integrated into the fourth-party platform decrease after the adoption of the coopetition strategy. In addition, when the coopetition strategy is adopted, even if the early entrant has an advantage in terms of quality, its price is lower than those of third-party platforms that have integrated into the fourth-party platform if the advantage is low. Moreover, we find that the adoption of the coopetition strategy increases the total consumer demand of the early entrant while decreasing the number of consumers in its standalone application.

The contributions of this study are as follows. First, to the best of our knowledge, this study is the first to focus on the coopetitive relationships between a two-sided platform and a fourth-party platform comprised of several competing platforms while considering the platform price competition. This paper differs from previ-

[1] https://www.163.com/dy/article/FKPKEFD605118QUG.html.

[2] https://zhidao.baidu.com/question/150335550951392209 9.html?qbl=relate_question_0&word=%E8%8F%9C%E9%B8%9F%E8%A3%B9%E8%A3%B9%E6%8A%BD%E6%88%90.

ously discussed platform coopetition strategy in which the coopetition strategy primarily concentrates on the cooperation between different entities within a platform. In contrast, our study explores the coopetition strategy between two two-sided platforms. This exploration enables us to derive the structured optimal solutions for the platforms and help us understand their motivations to cooperate. This study also contributes to the study concerning multiple purchase channel strategy by incorporating the influence of direct and indirect network effects. Second, our research provides rich management guidance in platform operations. For example, the early entrant and fourth-party platform in the industry exhibiting strong network effects should never adopt the coopetition strategy. If the sum of the strengths of direct and indirect network effects is limited, the early entrant of quality advantage always cooperates with its competing fourth-party platform. In addition, the adoption of coopetition strategy always benefits consumers and consumers using different platforms consistently pay lower prices.

The remainder of this paper is organized as follows. Section 2 reviews the related literature on the coopetition strategy of platforms. Section 3 presents the model. Subsequently, in Section 4, we analyze the equilibrium coopetition strategies and explore the impact of implementing the coopetition strategy on platform prices and consumer demands. Section 5 examines the robustness of our results. The conclusions of this study and recommendations for future research are given in Section 6.

2. Literature review

Our study is related to the studies of coopetition strategy, network effects of platforms, multiple purchase channels and fourth-party platforms.

2.1. Coopetition strategy

Coopetition strategy refers to the cooperation between competing products or firms. Many scholars have examined the coopetition strategy between competing products considering demand cannibalization effect [1, 18,37] and the coopetition relationship between supply chain members within a traditional supply chain [10,23], such as outsourcing and store-brand introduction. However, these studies ignored the influence of network effects, thus cannot be applied to explore the coopetition strategy of platforms.

Some studies have investigated the platform coopetition strategy that provides consumers access to third-party content considering the coopetition relationship between the self-operated content and third-party content [27, 35, 56]. Parker and Van [35] discussed whether and to what degree the platform owner should be open to third-party content to explore new innovations. Using either a case study or an empirical research method, Li and Agarwal [27] and Zhu and Liu [56] have explored how the platform owner coordinates the relationship between the third-party and self-operated content. Chen [8] compared the performance of two coopetition strategies adopted by third-party complementors of a platform using the data from JD.com, and investigated how the behavior of third-party complementors changes as the coopetition relationship between first and third-party sellers on the platform alters. Kostis [26] discussed how platform characteristics influence the intra-platform coopetition strategy. These studies focused on the coopetition within a platform, not considering the coopetition between competing platforms. The research on platform coopetition between competing platforms is limited [11, 54]. Cohen and Zhang [11] constructed analytical models of two competing two-sided platforms to explore whether and when the platforms would cooperate and introduce a new joint service.

In contrast to these studies, we focus on the coopetition between an early entrant and a fourth-party platform consisting of several later entrants providing competing services. Our study is most closely related to the work of Zhou *et al.* [54], who explored whether a two-sided platform is willing to join a fourth-party platform and pointed out that coopetition can generate greater profits for the two-sided and fourth-party platforms, as well as greater consumer surplus and social welfare. They assumed that the prices that consumers must pay are exogenous, thus the impact of price competition on the effectiveness of the coopetition strategy was not considered. In addition, they focused only on the scenario in which all providers on the integrated platform serve consumers in the fourth-party platform once coopetition strategy is adopted, but ignoring the situation where the integrated platform may allow some of its providers to serve consumers in the fourth-party platform. Our work relaxes the assumption and addresses when and how the coopetition strategy should be adopted by an early entrant and a fourth-party platform, further exploring its effect on prices and consumer demands.

2.2. Network effects of platforms

Our work also adds to previous work on network effects of platforms. In the presence of network effects, consumers obtain network value from using a platform in addition to intrinsic value [17]. Many studies have focused on the mechanism by which network effects can be utilized by firms to boost sales [34, 52] or compete against competitors [41, 46] in one-sided platform markets. For example, Xu *et al.* [46] considered a duopoly market in which a differentiated information product and a complementary premium service are offered to consumers, and investigated whether a freemium or bundling strategy should be adopted by the firms in the presence of network effects. Zhang *et al.* [52] considered the setting in which a blockchain-technology-supported platform competes with a traditional platform, and explored whether the platforms should adopt static pricing or dynamic pricing strategy. Some studies have considered the network effects in the two-sided platform market, and many of the extant theoretical studies have focused on pricing strategy and discussed how to best exploit network effects to coordinate the consumer and provider sides [2, 5, 29]. For example, Hyun [21] examined how direct network effects influence platform prices in a competing platform market. Some scholars have further explored the effectiveness of different platform operational strategies for maximizing profits [13, 14, 54] when indirect network effects on the consumer side are present. For example, Dou *et al.* [14] explored the value-added service investment and pricing strategies of a two-sided platform to increase profit. Dou and Wu [13] examined when a two-sided platform should adopt a piggyback strategy to expand its market by recruiting users from external networks in a competing market.

In contrast to these studies, we focus on whether an early entrant platform should integrate its service into a competing fourth-party platform comprised of several later entrant platforms when the early and later entrants compete on prices, which has not been studied previously. To the best of our knowledge, we are the first to investigate the coopetition strategy implemented by competing platforms through sharing direct and indirect network effects on the consumer side when both direct and indirect network effects are present.

2.3. Multiple purchase channels

In our work, there are two channels for consumers to use the service provided by the early entrant when the coopetition strategy is adopted, which closely relates to the studies on multiple purchase channels. Previous studies have mainly investigated the issues in a traditional supply chain setting, such as the partnership between competing channels [16, 22, 36], channel choice of manufacturers and retailers [7, 39, 49] and the interaction of retailer's decision of selling format and manufacture's channel choice [20,38,53]. Our work is most closely related to the first issue. Iacocca and Mahar [22] focused on the pharmaceutical supply chain and investigated whether and to what extent offline pharmacies should cooperate with a mail-order pharmacy to allow customers who purchase through the latter to pick up prescriptions at chain stores owned by the former in particular regions. Pi *et al.* [36] considered the scenario in which a manufacturer sells its product through its online direct channel and two retailer channels, and explored whether and when the two retailers should cooperate on providing value-added service. Fan *et al.* [16] examined the incentives of two online retailers to implement horizontal cooperation considering the channel competition between them.

The above studies focus on the traditional supply chain and cannot be applied to the scenario in which platforms exhibit network effects. However, in practice, when a platform integrates its service into a competing platform, there are several channels for consumers to use the service provided by the platform. Moreover, the presence of network effects further complicates the interplay of cooperation and competition among different channels. Our work complements these studies by exploring whether and when a two-sided platform and a fourth-party platform should cooperate. Specifically, our work discusses whether introducing an extra purchase channel for consumers in the fourth-party platform to use the services offered by the integrated platform is a win–win solution for them.

TABLE 1. The differences between this paper and the most relevant literature.

Paper	Coopetition strategy (price endogenous)	Network effects of platforms	Multiple purchase channels	Fourth-party platforms
Cohen and Zhang [11]	√	√	–	–
Fan *et al.* [16]	√	–	√	–
Dou and Wu [13]	–	√	–	–
Zhou *et al.* [54]	–	√	√	√
Xu *et al.* [47]	–	√	√	√
This paper	√	√	√	√

2.4. Fourth-party platforms

Another stream of literature related to our research is about fourth-party platforms. He *et al.* [19] proposed that the existence of fourth-party platform enables service providers to achieve a continual operation goal and can reduce construction and operating costs greatly. Previous studies have mainly focused on fourth-party logistic platforms [24, 42, 50]. Jiang and Huang [24] proposed an algorithm to better match the consumers and logistic providers on the fourth-party platform. Wang *et al.* [42] proposed a mixed-integer nonlinear programming model to optimize logistics network design in order to maximize the service satisfaction of logistic service providers and consumers. Yu [50] analyzed the advantages of a fourth-party logistic platform which integrates the resources, capabilities and technologies of the logistics service providers, and proposed an information system framework for the platform.

The above studies explore how to operate a fourth-party platform, but do not consider the coopetition strategy between a platform and a fourth-party platform. Our study is most closely related to the work of Xu *et al.* [47]. They discussed how a platform determines the optimal price and drivers decide the optimal service levels when the platform joins a fourth-party platform, but the effect of network effects is ignored.

We summarize the differences between this paper and the most relevant literature in Table 1.

3. Model

We consider a setting where an early entrant platform, e, competes with a fourth-party platform, f, consisting of several later entrant platforms, l, in which platforms e and l provide competing services. The later entrants that have been integrated into platform f are assumed to be homogenous in this paper, which allows us to focus on the coopetition between platforms e and f and obtain analytical results. The equilibrium prices of the later entrants integrated into platform f are assumed to be the same [2]. The reason for this is that when platforms are of same quality, any platform that charges a higher price will lose consumers and thus eventually disappear from the market. The later entrants therefore set their equilibrium prices to maximize their overall profits and share their profits equally. For ease of exposition, these later entrants are viewed as a whole in the following. In addition, we assume that the standalone applications of later entrants are rarely accessed by users due to the entry barrier established by the early entrant. Taking the ride-hailing platform market as an example, most consumers use only highly popular platforms for convenience and hardly utilize the standalone application of later entrants, such as JiShi and QuanZai. Therefore, the later entrants can only provide service by integrating them into platform f. Thus, consumers choose either platform e or f to use the services.

Consumers have different preferences for platforms e and f. Platform f usually also provides complementary services, for example, Amap provides map service besides the ride-hailing service and JD.com provides ticket-reservation service besides the hotel-reservation service. Therefore, platform f may provide a one-stop shopping experience to consumers. In addition, platforms e and l may differ in terms of service quality they provide, such as the service security and after-sales experience, and the quality difference is denoted by q. For example, DiDi, an early entrant in the ride-hailing platform market, has stricter qualifications and management for drivers than other platforms to ensure the consumer safety. DiDi is the only ride-hailing platform that cooperates with the relevant state departments to conduct strict audit and screening of drivers to prevent people who may threaten passenger safety from entering the platform. The service quality of platform e can be lower than that of l. For example, China Postal Express & Logistics, the earliest courier service provider in China, has a lower service quality as compared to those of ZTO, STO and YTO, which enter the market later, considering that it does not provide home delivery service and its logistics efficiency is low. Thus, we model the competition between platforms e and f as horizontally and vertically differentiated platforms based on the stylized Hotelling model. Consumers form a Hotelling line with a length of 1, along which they are uniformly distributed. Platforms e and f are located at the terminals of the Hotelling line, and x denotes the location of a consumer. The disutility caused by the mismatch between the platform and the consumer's most ideal platform is represented by tx and $t(1-x)$ in our model, where t denotes the consumer preference for different platforms. Consumers compare the utility derived from using the two platforms and choose the one that offers greater value.

Following Bakos and Halaburda [5] and Xie *et al.* [45], consumer utility from using each platform is the sum of the intrinsic and network value of the platform, net the platform price as well as the disutility from the mismatch between the platform and the consumer's preference. The intrinsic values of platforms e and f are $v+q$ and v, respectively, in which v is assumed to be large enough to ensure that platforms e and f cover all consumers in the market. Considering that most consumers on service platforms care about not only the number of providers to make sure they can be served quickly but also the number of consumers, we focus on the indirect and direct network effects in the following to obtain clear analytical insights. We consider a setting in which the number of providers is great enough. Taking ride-hailing platforms as an example, platforms can increase the number of providers by purchasing cars on their own or cooperating with taxi companies. However, hiring an additional service provider incurs additional expenses such as insurance costs and basic salary, which could reduce platform profitability. In addition, the numbers of orders served by different providers in practice are almost the same. Taking the logistic platform as an example, the daily delivery volume of a delivery person ranges from 80 to 100 packages[3]. On ride-hailing platforms, more than 80% of drivers work more than 8 h a day[4]. Thus, it is more profitable for platforms to keep their service providers serving at full capacity. Then, the competition of platforms on the provider side can be eliminated, enabling us to focus on the consumer side by assuming that the more consumers there are, the more providers there will be [27, 55]. Considering that consumers obtain a higher direct network value as the number of consumers increases, the direct and indirect network values of consumers are expressed as βy and γy [12, 32], where y denotes the number of consumers on the platform and β and γ denote the strengths of direct and indirect network effects, respectively. Considering that platforms e and f provide the same type of services, the strengths of their direct and indirect network effect are assumed to be identical, without loss of generality. For those consumers who use fourth-party platform f, the network value obtained by consumers is the sum of all network values derived from those platforms that have been integrated into platform f.

When platform e does not integrate its service into fourth-party platform f, consumers can only use the service of platform l if they choose platform f. Then, the utility of a consumer located at x from each platform can be formulated as follows:

$$U_e^i = v + q + \beta y_e + \gamma y_e - tx - p_e, \tag{1}$$

$$U_f^i = v + \beta(1-y_e) + \gamma(1-y_e) - t(1-x) - p_l, \tag{2}$$

where y_e and $1-y_e$ denote the numbers of consumers on platforms e and f, and p_e and p_l denote the prices of platforms e and l, respectively. $(\beta+\gamma)y_e$ and $(\beta+\gamma)(1-y_e)$ denote the direct and indirect network effects obtained by consumers on platforms e and f, respectively. For ease of exposition, we use α denote the sum of the strengths of direct and indirect network effects $\beta+\gamma$.

[3]https://edu.iask.sina.com.cn/jy/gmaSQ0lX8Ulk.html.

[4]https://baijiahao.baidu.com/s?id=1731045634587772696&wfr=spider&for=pc.

When platform e integrates its service into fourth-party platform f, consumers can use the service provided by platform e or l if they choose platform f. It is worth mentioning that the price of platform e in platform f is set to $p_l + q$. If the price is set to one lower than $p_l + q$, then consumers in platform f use only the early entrant for higher utility. As a result, platform l lowers price to keep its customers. By the same logic, the early entrant has no incentive to set a price greater than $p_l + q$. In addition, platform e also serves consumers in its standalone application in such cases. Note that the price discrimination strategy that a platform charges different prices in different versions or channels is widely used [31,44]. For example, CaoCao, a ride-hailing platform, integrates its service into Amap, and charges consumers different prices in its standalone application and in the application of Amap. Trip.com Group integrates its service into JD.com, and the same hotel listed by Trip.com Group charges consumers different prices in its standalone application and the application of JD.com. Note that in such cases, platform e decides on the degree of integration k $(0 \leq k \leq y_e + y_e')$, *i.e.*, the number of its providers serving consumers on platform f. For example, only certain types of providers of CaoCao are allowed to get orders on the Amap. Considering that platforms e and l share network effects in such cases, thus, the utility functions for a consumer from the platforms e and l in the platform f remain the same. Then, the utility for a consumer located at x from the platforms e and f can be formulated as follows:

$$U_e^o = v + q + \beta(y_e + y_e') + \gamma(y_e + y_e') - tx - p_e, \tag{3}$$
$$U_f^o = v + \beta(1 - y_e) + \gamma((1 - y_e - y_e') + k) - t(1 - x) - p_l, \tag{4}$$

where y_e' denotes the number of consumers using platform e in fourth-party platform f. According to the abovementioned assumption that the more consumers there are, the more providers there will be, following Liang *et al.* [30], we use $\beta(y_e + y_e') + \gamma(y_e + y_e')$ and $\beta(1 - y_e) + \gamma((1 - y_e - y_e') + k)$ to denote the direct and indirect network effects obtained by consumers on platforms e and f, where $y_e + y_e'$ and $1 - y_e - y_e'$ denote the total numbers of consumers that use the service provided by platforms e and l.

Platform owners pay service providers a fixed fee on each sale transacted through their platforms [6,40]. The prices paid by platforms e and l to service providers are assumed to be the same [4], denoted by c. The reason for this is that service providers, who have similar costs, pick the platform with the highest per-transaction price to maximize their earnings. This assumption can be supported by the practice on ride-hailing platforms in which drivers on different platforms earn approximately CNY 1.2 per kilometer in China[5]. In addition, those platforms that integrate into platform f pay the latter a per-transaction fee on each sale transacted through platform f [48]. Without loss of generality, the marginal cost of the platforms is normalized to zero. We formulate platform profits in the independent case as follows:

$$\Pi_e^i = y_e(p_e - c), \tag{5}$$
$$\Pi_l^i = (1 - y_e)(p_l - c - \omega_l), \tag{6}$$
$$\Pi_f^i = (1 - y_e)\omega_l, \tag{7}$$

where $p_e - c$ and $p_l - c - \omega_l$ denote the unit profitability of platforms e and l in the independent case, and ω_l represents the commission price that must be paid by platform l.

Platform profits in the coopetition case are formulated as follows:

$$\Pi_e^o = y_e(p_e - c) + y_e'((p_l + q) - c - \omega_e). \tag{8}$$
$$\Pi_l^o = (1 - y_e - y_e')(p_l - c - \omega_l). \tag{9}$$
$$\Pi_f^o = (1 - y_e - y_e')\omega_l + y_e'\omega_e \tag{10}$$

where the commission prices that must be paid by platforms e and l are denoted by ω_e and ω_l, respectively. $p_e - c$ and $p_l + q - c - \omega_e$ denote the unit profitability of platform e in its standalone application and in the application of platform f, respectively. In practice, platform f often charges platforms e and l the same commission price

[5]https://baijiahao.baidu.com/s?id=1776439590010440655&wfr=spider&for=pc.

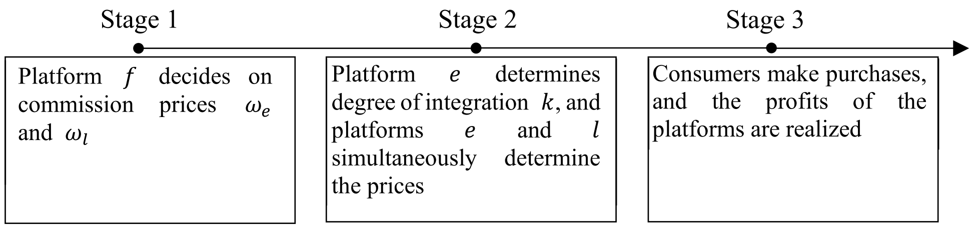

FIGURE 1. Sequence of events in the basic model.

TABLE 2. Notations.

Parameter	Definition
q	Quality difference of the services provided by platforms e and l
v	Intrinsic value of consumers on platform f
α	Sum of the strengths of the direct and indirect network effects on the consumer side of the platforms
β	Strength of the direct network effects on the consumer side of the platforms
γ	Strength of the indirect network effects on the consumer side of the platforms
t	Consumer preference for different platforms
c	Unit price paid by platforms e and l to service providers
y_e, y_l	Consumer demand of platform e in its standalone application and that of platform l
y'_e	Consumer demand of platform e in the application of platform f
Π_e^j, Π_l^j, Π_f^j	Profit of platforms e, l and f in the independent (i) or coopetition case (o), $j = i, o$
Decision variable	**Definition**
k	Degree of integration determined by platform e
p_e, p_l	Prices paid by a consumer to platforms e and l
ω_e, ω_l	Commission prices paid by platforms e and l to platform f to join

to be fair. Thus, we assume that $\omega_e = \omega_l$ in our baseline model and relax the assumption in Section 5.1. The fourth-party platform may also charge the integrated platforms commission fees that are proportional to the platform price if the price information is visible [3, 33, 51], which is discussed in Section 5.2. Furthermore, in Section 5.3, we compare the different commission fee schemes and determine which one should be adopted by the fourth-party platform.

Figure 1 illustrates the time sequence of the decision. First, fourth-party platform f determines the commission prices that should be paid by the integrated platforms. Then, platform e decides on the degree of integration k. Meanwhile, platforms e and l set their prices. Finally, consumers choose to utilize either early entrant platform e or fourth-party platform f. We also explore the scenario when platforms f and e make decisions on commission prices and degree of integration simultaneously in Section 5.4. There are two potential market structures, the independent case, where platform e does not integrate its service into platform f, and the coopetition case, where platform e integrates its service into platform f. Table 2 summarizes the notations used in this paper.

4. Equilibrium analysis

This section first derives each platform's decisions in the independent case as the benchmark. Then, we investigate the conditions under which coopetition is the equilibrium strategy, that is, compared to the independent case, adopting the coopetition strategy increases the profits of both early entrant and fourth-party platforms. Then, we explore how the implementation of the equilibrium coopetition strategy affects prices and consumer demands.

4.1. Independent case

When platform e does not integrate its service into platform f, the consumer who is indifferent between using platform e and platform f, x^*, can be derived by letting $U_e^i = U_f^i$ as follows:

$$x^* = \frac{(2y_e - 1)\alpha + q + t - p_e + p_l}{2t}. \tag{11}$$

Consumers located on the left-hand side of the indifferent point choose platform e, whereas those on the right-hand side choose platform f. We assume that consumers are able to predict the number of users in equilibrium when they make a purchase decision [9,43]. Thus, the number of consumers choosing platform e can be derived by solving $y_e = \frac{(2y_e-1)\alpha+q+t-p_e+p_l}{2t}$. Substituting y_e into equations (5) and (6), the equilibrium prices can be obtained by solving the first-order conditions for the two profit-maximizing platform. Anticipating the response functions of platforms e and l, platform f determines commission price ω_l ($\omega_l > 0$) to maximize its profit. We summarize the analytical results in the independent case in Lemma 1. All proofs are provided in the appendix.

Lemma 1. *In the independent case, the prices and consumer demands of platforms e and l are* $p_e^i = \frac{q}{6} + \frac{3t-3\alpha}{2} + c$, $y_e^i = \frac{q+9t-9\alpha}{12t-12\alpha}$, $p_l^i = -\frac{2q}{3} + 2t - 2\alpha + c$, *and* $y_l^i = \frac{3t-3\alpha-q}{12t-12\alpha}$, *respectively. The commission price charged by platform f is* $\omega_l^{i^*} = -\frac{(q-3t+3\alpha)}{2}$.

It is worth mentioning that we set $\alpha < t$ and $9\alpha - 9t < q < 3t - 3\alpha$ to guarantee that neither platform is squeezed out of the market and prices are nonnegative. Several observations related to the lemma are worth highlighting. First, even though platform e has a quality advantage, its price may be lower than that of platform s. Specifically, we have that $p_e^i < p_l^i$ when $q < \frac{3(t-\alpha)}{5}$ because platform l must raise its price to compensate for extra cost $\omega_l^{i^*}$ charged by platform f. Second, except for the scenario in which its quality disadvantage is great, platform e always occupies a larger market share, which is at least $\frac{3}{4}$ if $q \geq 0$. This result is expected because platform l bears extra costs, the commission fees charged by platform f; thus, platform e can set prices that are more enticing to consumers and capture a larger market share. Third, the commission price that should be paid by platform l increases as consumer preference rises and decreases with the increase in quality difference and the strength of network effects. The reason for this is that platform l can raise its price as consumer preference increases and thus earns more profit. Then, platform f can raise the commission price to take a share of the increased profit made by platform l. As the quality difference or the strength of network effects increases, the relative competitiveness of platform e over l increases, which reduces the number of consumers that choose platform f. The commission price is then lowered by platform f to help platform l close the gap with platform e in terms of competitiveness and, thus, attract more consumers.

4.2. Coopetition case

When platform e integrates its service into platform f, those consumers choosing platform f either use the service provided by platform e or l. The number of consumers served by platform e in platform f is determined by the proportion of the former's available providers in platform f. In other words, as the number of service providers of platform e in platform f grows, so does its consumer demand. Therefore, $y_e' = \frac{k}{(1-y_e-y_e')+k}(1-y_e)$, where k denotes the available number of service providers of platform e in platform f, reflecting the degree of integration determined by platform e.

The consumer who is indifferent between using platform e and platform f, x^*, can be derived by letting $U_e^o = U_f^o$ as follows:

$$x^* = \frac{(k + 2y_e - 1)\alpha + q + t - p_e + p_l}{2t}. \tag{12}$$

Thus, the number of consumers choosing platform e can be derived by solving $y_e = \frac{(k+2y_e-1)\alpha+q+t-p_e+p_l}{2t}$.

We derive the equilibrium using backward induction. First, substituting y_e into equations (8) and (9), the equilibrium prices can be obtained by solving the first-order conditions for the two profit-maximizing platforms: $p_e = \frac{(3k-3)\alpha-2kt+q+3t+3c+\omega_l}{3}$ and $p_l = \frac{(3k-3)\alpha-4kt-q+3t+3c+2\omega_l}{3}$. At the same time, the early entrant determines the degree of integration for maximizing its own profit. Platform e's problem is to solve the following:

$$\begin{aligned} &\max_{k}\; y_e(p_e - c) + y_e'(p_l + q - c - \omega_e) \\ &\text{s.t. } y_e(p_e - c) + y_e'(p_l + q - c - \omega_e) \geq \Pi_e^i, \end{aligned} \tag{13}$$

where Π_e^i denotes the profit obtained by the early entrant in the independent case.

Then, anticipating the response functions of platforms e and l, platform f determines commission prices ω_l and ω_e ($\omega_l > 0$, $\omega_e > 0$) to maximize its profit. Note that platforms f and e adopt the coopetition strategy only when their profits are no less than those in the independent case. Therefore, platform f determines commission prices by solving the following:

$$\begin{aligned} &\max_{\omega_e,\omega_l}\; (1 - y_e - y_e')\omega_l + y_e'\omega_e \\ &\text{s.t. } (1 - y_e - y_e')\omega_l + y_e'\omega_e \geq \Pi_f^i, \\ &\qquad y_e(p_e - c) + y_e'(p_l + q - c - \omega_e) \geq \Pi_e^i, \end{aligned} \tag{14}$$

where Π_f^i denotes the profit obtained by platform f in the independent case. By solving the above problem, we derive the conditions for adopting the coopetition strategy.

Proposition 1. *Only when* $\alpha < \frac{2t}{3}$ *and* $q \geq -\frac{9\alpha(\alpha-t)}{27\alpha-28t}$, *platforms* e *and* f *cooperate. Then,* $k^* = \frac{-9\alpha^2+(9t-27q)\alpha+28tq}{99\alpha^2-216t\alpha+116t^2}$, $\omega_e^{o^*} = \omega_l^{o^*} = \frac{(2t-3\alpha)k^*}{2} - \frac{(q-3t+3\alpha)}{2}$, $p_e^o = \frac{(3k^*-9)\alpha}{6} + \frac{q}{6} + \frac{3t}{2} - \frac{k^*t}{3} + c$ *and* $p_l^o = -\frac{2tk^*}{3} - \frac{2q}{3} + 2t - 2\alpha + c$.

Figure 2 and Proposition 1 demonstrate that the coopetition strategy is adopted only when the sum of the strengths of direct and indirect network effects α is low and the quality difference between early and later entrants q is high. Note that $-\frac{9\alpha(\alpha-t)}{27\alpha-28t} < 0$, which implies that the coopetition strategy should always be adopted when the sum of the strengths of direct and indirect network effects is low and the early entrant has a quality advantage. For platform e, when its quality is higher or slightly lower than that of later entrants, its profit always increases as a result of the adoption of the coopetition strategy. In such cases, platform e consistently acquires more network effects than platform f does by adopting the coopetition strategy. Then, the profit increment of platform e derived from direct and indirect network effects can fully cover its profit loss incurred by the commission fees charged by platform f. By contrast, for platform f, even if it can receive commission fees from platform e and attracts more consumers away from the standalone application of platform e, adopting the coopetition strategy may damage the interests of platform f. If platform e is partially integrated into platform f, then the competitiveness of the former is enlarged, as previously discussed, and increases with the sum of the strengths of direct and indirect network effects. When the strength of network effects is great, the competitiveness of platform e is greatly enlarged after adopting the coopetition strategy, which causes a sharp decline in the price and market share of platform l. Moreover, the commission price determined by platform f decreases compared with that in the independent case. Thus, platform f would not integrate the early entrant when the strength of network effects is great.

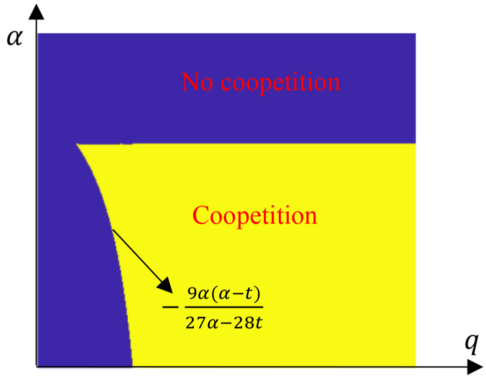

FIGURE 2. Conditions for adopting the coopetition strategy.

Proposition 1 also provides the fourth-party platform's optimal commission price and the degree of integration of the early entrant when coopetition is the equilibrium strategy. The fourth-party platform sets a commission price that maximizes its profit while ensuring that the early entrant adopts the coopetition strategy. According to the commission price charged by the fourth-party platform, platform e always partially integrates its service into platform f, that is, $k^* < y_e^o + y_e'$. When the degree of integration k is low, the additional network effects enjoyed by platform e compared to platform f are low since the number of consumers using platform e in platform f is low. However, a high k indicates that more consumers use platform e in platform f, which increases the network effects of platform e more but cannibalizes the consumer demand of platform e's standalone application greatly, thus yielding higher commission costs. Therefore, platform e would never fully integrate itself into platform f.

Proposition 1 provides the owners of early entrant and fourth-party platforms important managerial implications. First, the early entrant and fourth-party platforms in industry exhibiting significant network effects will never cooperate. This also indicates that the strength of network effects plays an important role in the optimality of coopetition strategy between early entrant and fourth-party platforms. Second, when the industry exhibits limited network effects, the early entrant of quality advantage and fourth-party platform always cooperate. This also implies that the owner of platforms should take quality difference into consideration while deciding whether to cooperate or not. Third, when the early entrant and fourth-party platforms cooperate, only a portion of service providers owned by early entrant are allowed to serve consumers on the fourth-party platform.

We next investigate how the commission price and optimal degree of integration vary with the parameters when coopetition is the equilibrium strategy.

Proposition 2. *When coopetition is the equilibrium strategy, (a)* $\frac{\partial \omega_e^{o*}}{\partial q} < 0$, $\frac{\partial \omega_e^{o*}}{\partial \alpha} < 0$, *and* $\frac{\partial \omega_e^{o*}}{\partial t} > 0$; *(b)* $\frac{\partial k^*}{\partial q} > 0$, $\frac{\partial k^*}{\partial \alpha} > 0$, *and* $\frac{\partial k^*}{\partial t} < 0$.

Proposition 2(a) reveals that the commission price charged by the fourth-party platform decreases with the quality difference and the sum of the strengths of direct and indirect network effects but increases with the consumer preference. Prior to the adoption of the coopetition strategy, as the quality difference increases, the early entrant becomes more competitive, thus, the profit of the fourth-party platform decreases, while that of the early entrant increases. Therefore, the fourth-party platform would offer a lower commission price to motivate the early entrant to adopt the coopetition strategy. The reason for this is that the profit loss incurred by a reduced commission price, ω_e, is overwhelmed by the demand expansion effect on the fourth-party platform. As the strength of network effects increases, both the early and later entrants cut their prices to attract more consumers and maximize the benefits of network effects. Since neither the early entrant nor later entrants can afford a high commission cost when price competition intensifies, the fourth-party platform reduces the commission price accordingly to encourage the adoption of the coopetition strategy. As consumer preference increases, more consumers choose to utilize the standalone application of the early entrant rather than switching to the fourth-party platform if the coopetition strategy is adopted. Thus, given the ω_e value being fixed, the early entrant bears a lower commission cost and maintains a higher profit under the coopetition strategy. Therefore, the fourth-party platform raises $\omega_e^{o^*}$ as consumer preference rises to increase its profit.

Proposition 2(b) shows that the optimal degree of integration k^* always increases with q and α but decreases with t. Platform e partially integrates its service into platform f, sharing part of its network effects, which causes platform e's standalone application to lose consumers. When q is high, platform e sets a high k^* to increase its consumer demand in the fourth-party platform, which does not incur excessive customer churn from its standalone application. When the strength of network effects is high, platform e also sets a high k^* to greatly increase its network value and erode the market share of platform l. However, platform e lowers k^* when consumer preference t rises because, as consumer preference rises, the influence of network effects on consumers' platform choice decreases. Then, the coopetition strategy becomes less appealing for platform e because of the lower increase in its total consumer demand.

Proposition 2 provides guidance on how early entrant and fourth-party platforms should adjust their degree of integration and commission price as the parameters vary when coopetition exists as the equilibrium strategy. First, if the quality of early entrant increases faster than that of later entrants, early entrant should allow more of its service providers to serve consumers on the fourth-party platform, correspondingly, the fourth-party platform should lower its commission price. Second, if the number of service providers on the platform plays a greater effect on consumer purchase decisions, then early entrant should integrate more service providers on the fourth-party platform and the fourth-party platform should lower commission price. Third, as consumers care more about the horizontal difference between platforms, the early entrant should lower its number of service providers serving on the fourth-party platform, and the fourth-party platform should raise the commission price in response.

We next investigate, when coopetition is the equilibrium strategy, the relative size of prices of platforms e and l and how the prices of them vary compared with those before adopting the coopetition strategy.

Proposition 3. *Suppose that coopetition is the equilibrium strategy. (a) Compared with the independent case, the prices of platforms e and l always decrease, and the decreasing rate of platform l is higher than that of platform e. Specifically, we have* $p_e^o - p_e^i = \frac{k^*(3\alpha-2t)}{6}$, $p_l^o - p_l^i = -\frac{2tk^*}{3}$, *and* $p_e^o - p_e^i - \left(p_l^o - p_l^i\right) = \frac{k^*(2t+3\alpha)}{6}$. *(b) If* $q < \frac{45\alpha^2-111\alpha t+58t^2}{106t-69\alpha}$, *then* $p_e^o < p_l^o$; *otherwise,* $p_e^o \geq p_l^o$. $p_e^o < p_l^o + q$ *always holds.*

According to Proposition 1, we have that $\alpha < \frac{2t}{3}$ when coopetition is the equilibrium strategy. Therefore, the implementation of the coopetition strategy always lowers the prices of platforms e and l. This finding is intuitive because platform e acquires additional network effects under the coopetition strategy, which impels platform l to cut its price to attract customers. Platform e also lowers its price in response to the increased competition. Moreover, platform e lowers its price less than platform l does, considering that the former enjoys more extra network effects after adopting the coopetition strategy.

Proposition 3(b) indicates that even if platform e has a quality advantage, its price may be lower than that of platform l when coopetition is the equilibrium strategy. The reason for this is that when the coopetition strategy is adopted, some consumers of platform e in the standalone application switch to platform f. Thus, platform e is willing to offer a lower price than that of platform l to prevent too much customer loss from its standalone application. Customer loss decreases as the difference in quality increases. Thus, platform e offers a higher price than that of platform l when q is high. In addition, Proposition 3(b) indicates that the price of platform e in its standalone application is always lower than that in the application of platform f, *i.e.*, $p_e^o < p_l^o + q$ when coopetition is the equilibrium strategy. This is intuitive because platform e is willing to offer a low price for its standalone application to attract as many consumers to use its standalone application and reduce the commission fees it must pay.

Proposition 3 provides the owners of platforms three important managerial implications regarding pricing strategy. First, when coopetition exists as the equilibrium strategy, early entrant of limited quality advantage may charge consumers a lower price, compared with later entrants existing in the fourth-platform. Second, when coopetition strategy is adopted, the price of the early entrant in the fourth-party platform should be set higher than that in its standalone application. Third, after coopetition strategy is adopted, both early and later entrants should lower their prices. Moreover, the later entrants lower their prices more, compared with the early entrant.

We then investigate how the total consumer demand of platform e and the consumer demand in its standalone application vary when the two platforms cooperate.

Proposition 4. *When coopetition is the equilibrium strategy, the total consumer demand of platform e always increases, while its consumer demand in the standalone application always decreases. Specifically, we have* $y_e^o + y_e' - y_e^i = \frac{k^*(10t-9\alpha)}{12t-12\alpha}$ *and* $y_e^o - y_e^i = -\frac{k^*(2t-3\alpha)}{12t-12\alpha}$.

Proposition 4 demonstrates that the integration of platform e in platform f increases the total consumer demand of platform e but cannibalizes the consumer demand of platform e in its standalone application. The reason behind is that platform e bears commission costs after the adoption of the coopetition strategy. Therefore, platform e cannot set an attractive price as before, and some consumers switch to platform f to use platform e or l. However, the total number of consumers using platform e increases because of the higher network effects it offers. This finding indicates that the coopetition strategy is adopted by the early entrant platform at the expense of the market share of its standalone application.

The findings in Proposition 4 can be used to predict how the consumer demands of involved platforms vary after adopting the coopetition strategy. The consumer demand of early entrant in its standalone application always decreases, by contrast, the total consumer demand of early entrant always increases.

5. Extension

5.1. Fixed commission fee scheme with price discrimination

In the baseline model, we assume that the fourth-party platform charges the early and later entrants the same commission prices. Here, we extend our model to examine the coopetition strategy when the fourth-party platform can charge the early and later entrants different commission prices. The time sequence of the decision is the same as that described in the basic model.

Proposition 5. *If platform f charges platforms e and l different commission prices (i.e.,* $\omega_e \neq \omega_l$*), then only when* $\alpha < \alpha_1$ *and* $q > q_1$ *can platforms e and f cooperate, and* $k^* = \frac{-36\alpha^2+(72t-12q)\alpha+16qt-36t^2}{99\alpha^2-312\alpha t+208t^2}$*; otherwise,* $k^* = 0$*, where* α_1 *is the only feasible solution to* $99\alpha^2 - 312\alpha t + 208t^2 = 0$, $\alpha_1 > \frac{2t}{3}$*, and* $q_1 = -\frac{9(\alpha^2-2\alpha t+t^2)}{3\alpha-4t}$.

Proposition 5 shows that the equilibrium strategy remains qualitatively the same as that in the basic model if $\omega_e \neq \omega_l$. The other qualitative results, except for how the different commission prices vary with parameters, can also be analytically proven and remain the same as those displayed in the basic model.

We conduct numerical experiments to explore the robustness of the results that cannot be analytically proven and how the fourth-party platform determines the commission prices. The consumer preference varies from low ($t = 1$) to high ($t = 10$). The sum of the strengths of direct and indirect network effects α is set to a value no more than the consumer preference. The difference in quality q varies within an interval in which neither platform is driven out of the market, regardless of whether the coopetition strategy is adopted. The price paid by the owners of platforms e and l to the providers c is set to a value no more than the prices determined by platforms e and l, p_e and p_l, respectively. The above settings ensure that the numerical experiments cover all the cases. Figure 3 indicates that the results on how the commission prices vary with the parameters displayed in the baseline model still hold when the coopetition strategy is adopted as the equilibrium and $\omega_e \neq \omega_l$.

The numerical analysis provides guidelines on how the fourth-party platform should set commission prices under a fixed commission fee scheme with price discrimination. Figure 4 demonstrates that the fourth-party

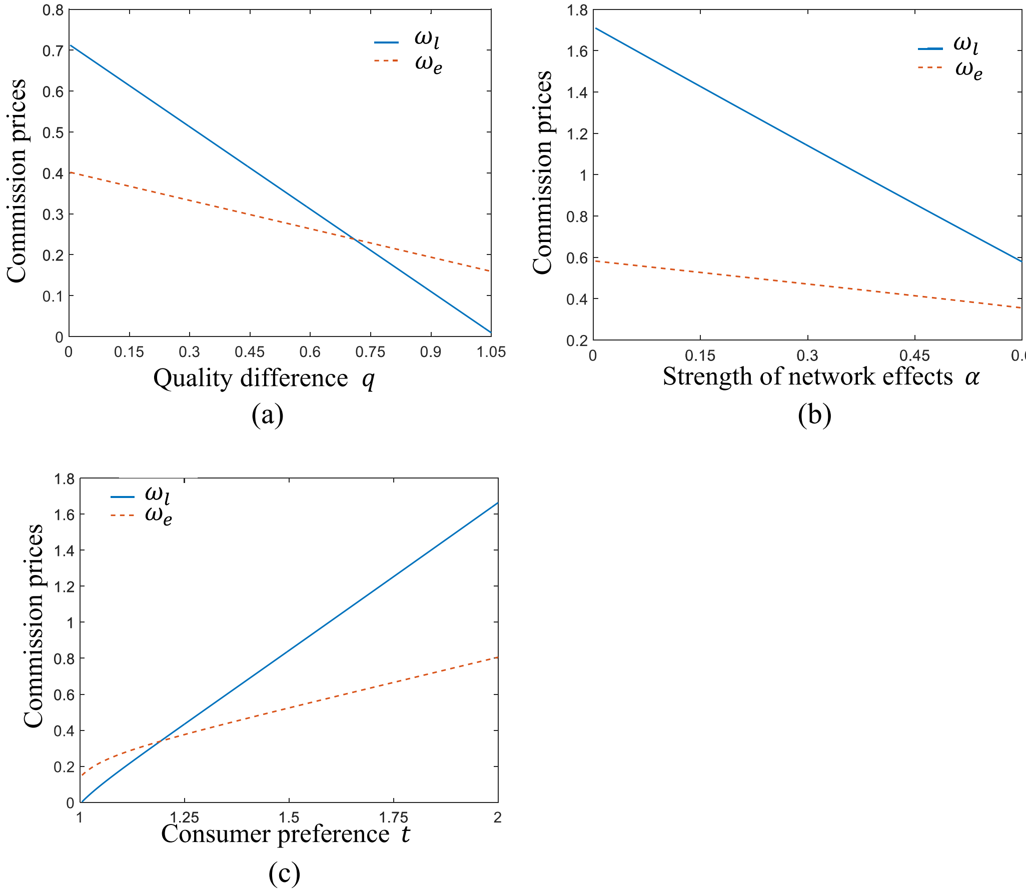

FIGURE 3. How commission prices vary with parameters when $\omega_e \neq \omega_l$. (a) Commission prices with respect to q. *Notes.* $\alpha = 0.6$, $t = 1$ and $c = 0.1$. (b) Commission prices with respect to α. *Notes.* $t = 1$, $q = 0.2$ and $c = 0.1$. (c) Commission prices with respect to t. *Notes.* $\alpha = 0.9$, $q = 0.2$ and $c = 0.1$.

platform sets different commission prices for the early and later entrants only when the quality difference q is great; otherwise, it charges them the same commission prices, *i.e.*, $\omega_e = \omega_l$. The reason for this is that when q is great, charging early and later entrants the same commission prices drives the latter out of business; charging low-quality platform a lower commission price can lessen competition. However, this commission price structure may reduce the profitability of the early entrant and weaken its incentive to adopt the coopetition strategy. The early entrant accepts the contract and adopts the coopetition strategy only when its quality advantage is great.

5.2. Proportional commission fee scheme

In the basic model, we assume that the fourth-party platform charges the integrated platforms a fixed commission fee per transaction. However, in practice, if price information can be observed, then the fourth-party platform may charge third-party platforms a proportional commission fee per transaction. Thus, in this section, we extend our model to examine the coopetition strategy when the fourth-party platform charges early and later entrants proportional commission fees, denoted by $\delta(0 < \delta < 1)$. The game sequence is the same as that in the basic model. We first formulate the profits of early entrant, later entrant and fourth-party platforms

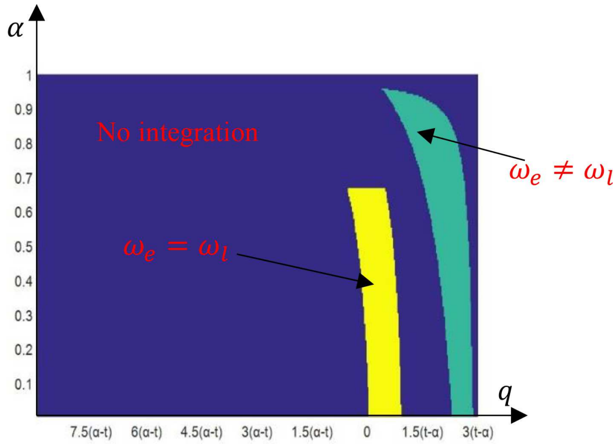

FIGURE 4. Design of the fixed commission fee scheme with price discrimination with $t = 1$ and $c = 0.1$.

before platform e integrates its service into platform f as follows:

$$\Pi_e^i = y_e(p_e - c). \tag{15}$$

$$\Pi_l^i = (1 - y_e)(p_l(1 - \delta) - c). \tag{16}$$

$$\Pi_f^i = (1 - y_e)p_l\delta. \tag{17}$$

When platform e integrates its service into platform f, the early entrant determines the degree of integration to maximize its profit.

$$\begin{aligned} &\max_k \ (y_e(p_e - c) + y_e'((p_l + q)(1 - \delta) - c)) \\ &\text{s.t. } y_e(p_e - c) + y_e'((p_l + q)(1 - \delta) - c) \geq \Pi_e^i. \end{aligned} \tag{18}$$

Anticipating the response functions of platforms e and l, platform f determines commission rate δ to maximize its profit. We assume that the fourth-party platform charges early and later entrants the same commission rate once the coopetition strategy is adopted. Note that platforms f and e adopt the coopetition strategy only when their profits are no less than those in the independent case. Therefore, we have that

$$\begin{aligned} &\max_\delta \ (y_e'(p_l + q)\delta + (1 - y_e - y_e')p_l\delta) \\ &\text{s.t. } y_e'(p_l + q)\delta + (1 - y_e - y_e')p_l\delta \geq \Pi_f^i, \\ &\qquad y_e(p_e - c) + y_e'((p_l + q)(1 - \delta) - c) \geq \Pi_e^i. \end{aligned} \tag{19}$$

The parameter settings are consistent with those in Section 5.1. The numerical analysis indicates that most of the results on the equilibrium strategy under a proportional commission fee scheme are qualitatively identical to those displayed in the basic model. Differently, coopetition is the equilibrium strategy under a proportional commission fee scheme only when the early entrant has a quality advantage, as shown in Figure 5. The reason for this is that the fourth-party platform sets a high commission rate and can fully extract the extra profit of later entrants before the coopetition strategy is adopted under the proportional commission fee scheme. The fourth-party platform must lower the commission rate to motivate the early entrant to adopt the coopetition strategy. However, doing so leads to a decline in the commission fees received by the fourth-party platform from later entrants. When the early entrant has a quality advantage, it occupies a larger market share, and then, the

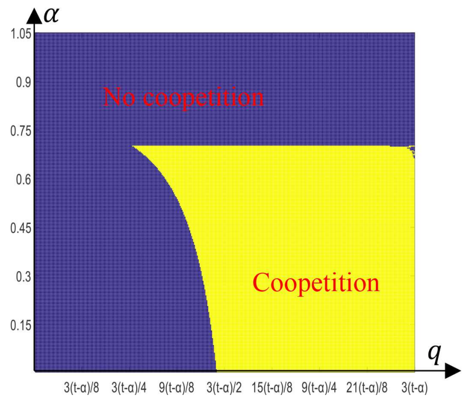

FIGURE 5. Equilibrium strategy under the proportional commission fee scheme with $t = 1$ and $c = 0.1$.

commission fees charged by the fourth-party platform from the early entrant compensate for the profit loss from later entrants. Thus, in such cases, it is more profitable for the fourth-party platform to promote the adoption of the coopetition strategy and charge both early and later entrants commission fees.

The numerical results also show how the commission rate δ varies with the parameters. Different from the results in the baseline model, Figures 6a and 6b show that the commission rate increases with α and decreases with t, whereas Figure 6c displays that it first decreases and then increases as q increases. As the strength of network effects increases, the adoption of the coopetition strategy generates more profit for the early entrant, encouraging the fourth-party platform to charge a higher commission rate. Moreover, when the network effect strength is large compared to when it is low, the commission rate per unit change in the strength of network effects grows more, as shown in Figure 6a. When the consumer preference is great, it becomes difficult for platforms to attract consumers by offering a low price. Then, both the early and later entrants raise their prices to achieve more profit. If the commission rate remains unchanged, the commission cost that must be paid by the early entrant is so great that the early entrant cannot earn extra profit by adopting coopetition strategy. Thus, a lower commission rate is offered by the fourth-party platform to promote the adoption of coopetition strategy. It is worth of mentioning that the commission rate per unit change in the consumer preference decreases more when the consumer preference is low compared to when it is great, as shown in Figure 6b. It is interesting that the commission rate increases as q rises when q is great. In such cases, the customer churn of the standalone application of the early entrant is rather low, and the market expansion effect always compensates for the additional commission costs. Therefore, the fourth-party platform raises the commission rate to extract more surplus from the early entrant.

The numerical results further show how the degree of integration varies with the parameters. Different from the results in the baseline model, Figures 7a–7c show that k^* first increases and then decreases with increasing α, t and q. When the strength of network effects is great, the commission rate increases greatly as the strength of network effects increases, and the commission cost increases if the degree of integration remains. Thus, the early entrant lowers the degree of integration to maximize its own profit as the strength of network effects increases. As the consumer preference increases, the early entrant raises the degree of integration as consumer preference increases when the consumer preference is low. Because in such cases, the unit profitability of early entrant in the fourth-party platform increases greatly, and can fully cover the profit loss incurred by the extra customer churn. In contrast to how the commission rate changes with q, the degree of integration changes with q in the opposite manner by the comparison of Figures 6c and 7c. The reason for this is that the price of early entrant increases with q. When the commission rate increases with q, the price increase of early entrant cannot

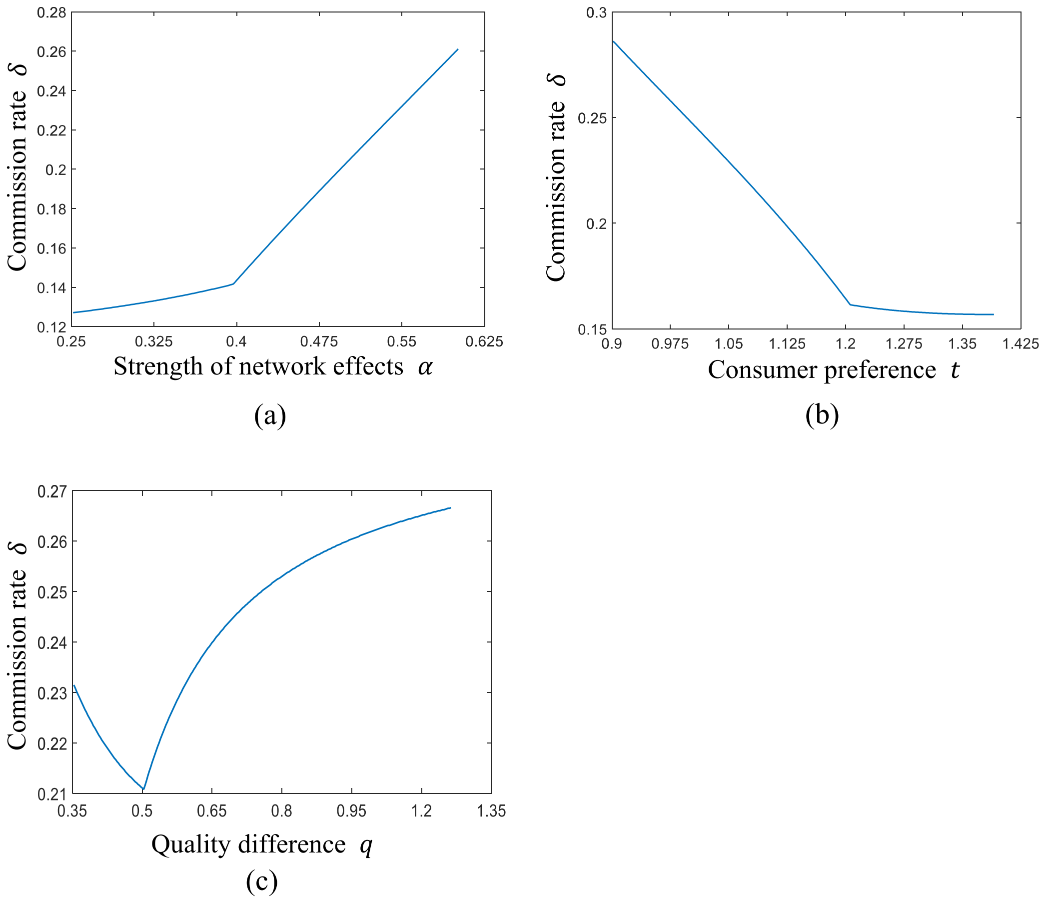

FIGURE 6. How the commission rate varies with the parameters when the coopetition strategy is adopted. (a) Commission rate with respect to α. *Notes.* $t = 1$, $q = 1$ and $c = 0.1$. (b) Commission prices with respect to t. *Notes.* $\alpha = 0.6$, $q = 1$ and $c = 0.1$. (c) Commission rate with respect to q. *Notes.* $\alpha = 0.6$, $t = 1$ and $c = 0.1$.

offset the extra commission fees it must pay, the unit profitability of early entrant in the fourth-party platform decreases. Thus, the early entrant lowers the degree of integration to avoid excessive commission fees.

The numerical results also show that qualitatively the same as that in the baseline model, the prices of the early and later entrants always decrease after the coopetition strategy is adopted. In contrast, after the coopetition strategy is implemented, the price of the later entrants is always lower than that of the early entrant if the early entrant has a quality advantage. This is because the price competition between early and later entrants is unaffected by the adoption of the proportional commission fee scheme.

5.3. Comparing the different commission fee schemes

In this section, based on the analytical results in Sections 5.1 and 5.2, we compare the fixed and proportional commission fee schemes from the perspective of profit and explore which scheme is adopted by the fourth-party platform if both schemes are feasible.

We first compare the profit of the fourth-party platform under different commission fee schemes before the coopetition strategy is adopted. It can be analytically proven that prior to the adoption of the coopetition

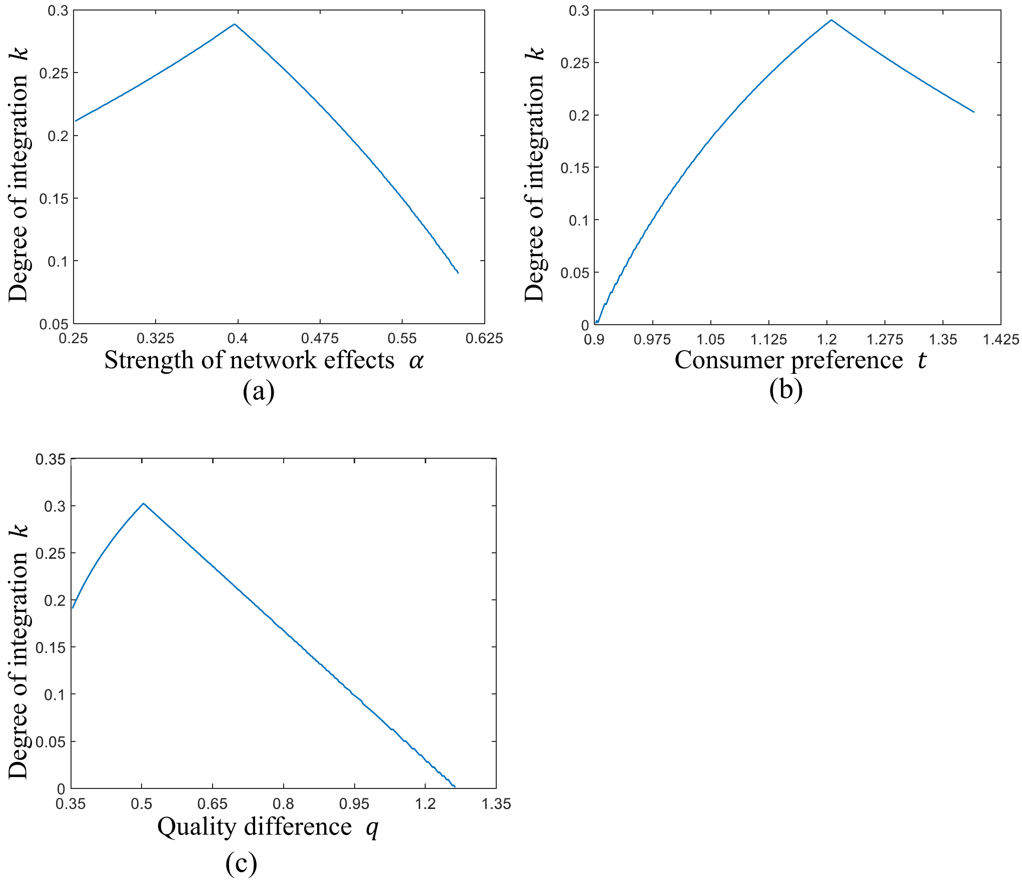

FIGURE 7. How the degree of integration varies with the parameters when the coopetition strategy is adopted. (a) Optimal degree of integration with respect to α. *Notes.* $t = 1$, $q = 1$ and $c = 0.1$. (b) optimal degree of integration with respect to t. *Notes.* $\alpha = 0.6$, $q = 1$ and $c = 0.1$. (c) Optimal degree of integration with respect to q. *Notes.* $\alpha = 0.6$, $t = 1$ and $c = 0.1$.

strategy, the fourth-party platform generates a higher profit under the proportional commission fee scheme as opposed to the fixed commission fee scheme. Because the fourth-party platform does not need to worry about the later entrants exiting, then it can extract as much profit as it can from later entrants by adjusting the commission rate under the proportional commission fee scheme.

We then compare the profits of platforms under different commission fee schemes after the coopetition strategy is adopted. Figure 8a shows that the fourth-party platform achieves a higher profit under the fixed commission fee scheme than under the proportional scheme only when q is of a medium size, *i.e.*, $\bar{q} < q < q'$. The reason for this is that when q is high, *i.e.*, $q \geq q''$, the proportional commission fee scheme always promotes the adoption of the coopetition strategy, and the fourth-party platform retains more profit than it would under the fixed commission fee scheme. When q is low, *i.e.*, $q \leq \bar{q}$, the profit of the fourth-party platform remains the same since coopetition cannot be the equilibrium strategy, regardless of which commission fee scheme is implemented. The fourth-party platform then charges only later entrants to earn a profit. When q is of a medium size, *i.e.*, $\bar{q} < q < q'$, under the proportional commission fee scheme, the commission rate decreases if the coopetition strategy is adopted and the commission fees derived from the early entrant are low due to its limited market

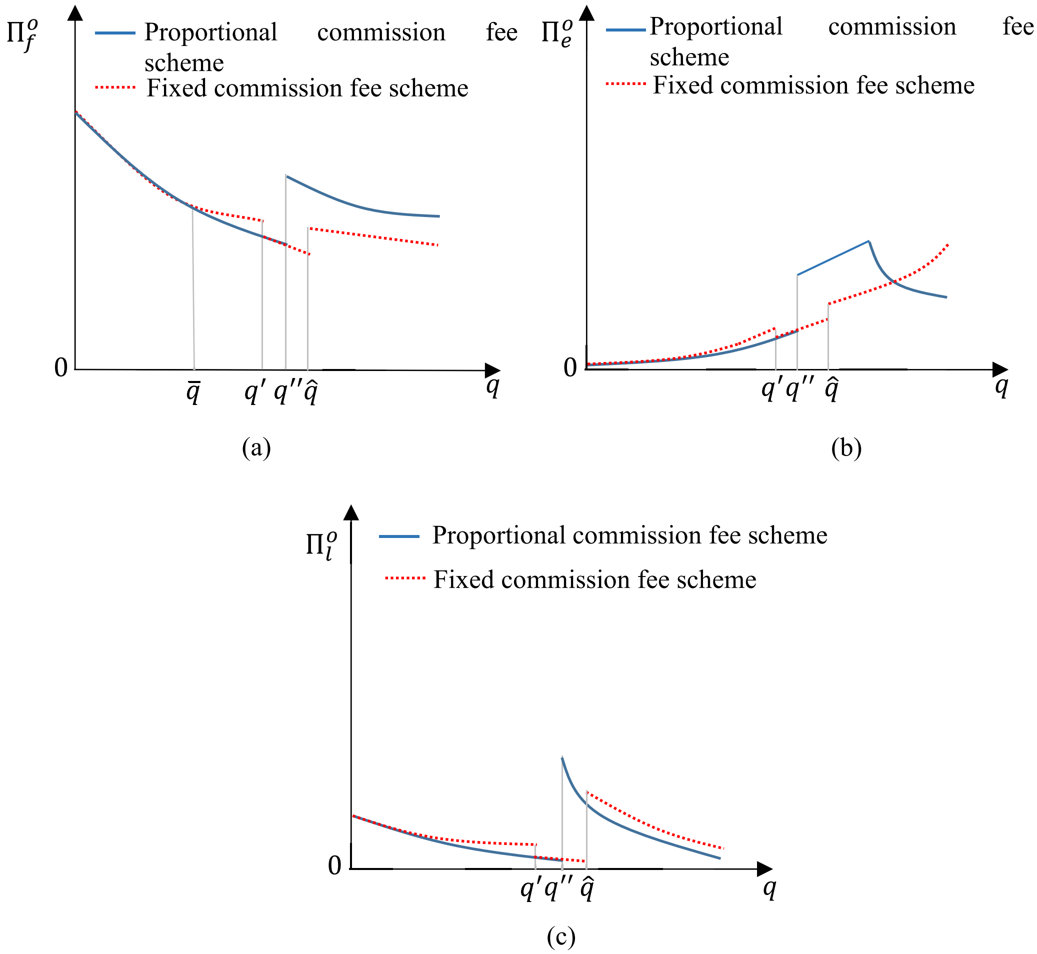

FIGURE 8. Comparing the profit of the platforms under different commission fee schemes. (a) Profit of the fourth-party platform. (b) Profit of the early entrant. (c) Profit of the later entrants.

share; thus, it cannot cover the profit loss derived from later entrants. Then, the early entrant does not integrate its service into the fourth-party platform. In contrast, in such cases, early and later entrants achieve more profit under the fixed commission fee scheme because platform competition is lessened. Then, the fourth-party platform can extract more commission fees while the early entrant is willing to integrate its service into the fourth-party platform. In addition, considering that coopetition strategy is adopted only when $q < q'$, $q > q''$ and $q > \hat{q}$, the profits of fourth-party platform jump when $q = q'$, $q = q''$ and $q = \hat{q}$.

We then compare the profits of early and later entrants under different commission fee schemes. Figure 8b indicates that the early entrant may benefit more from the adoption of the fixed commission fee scheme, as it can lead to the implementation of the coopetition strategy and increase its profit. Figure 8c shows that later entrants may also achieve a higher profit under the fixed commission fee scheme, as compared to the proportional one. The reason for this is that platforms retain excessive profits under the fixed commission fee scheme, whereas their extra profits are fully extracted by the fourth-party platform under the proportional commission fee scheme. In addition, as the same reason explained before, the profits of early and later entrants jump when $q = q'$, $q = \hat{q}$ and $q = q''$.

5.4. Sequences of decision-making

In the baseline model, we consider the setting in which platform f first proposes the commission price, then platform e decides the degree of integration. However, in practice, considering that platform f has control over the access opened to platform e, the former may adjust the commission price once the degree of integration is observed. Therefore, in this section, we explore the scenario in which platforms f and e simultaneously determine the commission price and the degree of integration.

Proposition 6. *Suppose that platforms f and e simultaneously determine the commission price and the degree of integration. (a) Platforms e and f cooperate only when $\alpha < \frac{2t}{3}$. Then, $k^* = \frac{-18\alpha^2+(-12q+27t)\alpha+13tq-9t^2}{36\alpha^2-87\alpha t+50t^2}$, $\omega_e^{o^*} = \omega_l^{o^*} = -\frac{(12(t-\alpha))(-\frac{11t^2}{2}+(q+\frac{33\alpha}{4})t-\frac{9\alpha^2}{4})}{36\alpha^2-87\alpha t+50t^2}$, $p_e^o = \frac{(3\alpha-2t)k^*}{3}+c+\frac{q}{3}+t+\frac{\omega_e^{o^*}}{3}-\alpha$ and $p_l^o = \frac{(3\alpha-4t)k^*}{3}+c-\frac{q}{3}+t+\frac{2\omega_e^{o^*}}{3}-\alpha$. (b) The qualitative results displayed in Propositions 2–4 still hold.*

Proposition 6(a) indicates that platforms e and f always cooperate if the strength of network effects is low when they make decisions simultaneously. This is because even if the quality of early entrant is low and its degree of integration is small, such setting enables the fourth-party platform to earn extra profit by charging a higher commission price while ensuring that the early entrant is willing to implement the integration. Compared with the results displayed in Proposition 1, Proposition 6(a) also implies that the fourth-party platform can promote the adoption of coopetition strategy by reserving the right to flexibly adjust the commission price. Proposition 6(b) demonstrates that the results on how commission price and degree of integration vary with parameters, and how platform prices and consumer demands change after the coopetition strategy is adopted remain qualitatively the same as those in the baseline model, and are irrespective of the sequence of decision-making.

Proposition 7. *When coopetition strategy exists as the equilibrium under the two decision-making sequences (i.e., $\alpha < \frac{2t}{3}$ and $q \geq -\frac{9\alpha(\alpha-t)}{27\alpha-28t}$), the fourth-party platform always achieves a higher profit when it proposes the commission price before the early entrant determines the degree of integration, compared with that when they make decisions simultaneously.*

Proposition 7 shows that the sequence in which the fourth-party platform proposes commission price depends on the quality difference between early and later entrants. It is interesting that it is more profitable for the fourth-party platform to propose the commission price before the degree of integration is set when the quality difference is great. The reason behind is that the predetermined commission price alleviates the concern of early entrant regarding high commission fees, which motivates it to set a larger degree of integration and yields higher commission fees for the fourth-party platform.

6. Conclusions

Cooperation between platforms has been widely used in practice and well-studied in previous studies. However, few studies have investigated the coopetition strategy between a platform and a fourth-party platform comprised of several later entrants that provide competing services with network effects. We discuss when and how the coopetition strategy is adopted and further investigate its impact on prices and consumer demands. Moreover, we provide guidance on how the fourth-party platform should adjust the commission price as parameters vary. The results show that when early and later entrants are charged the same commission prices, the coopetition strategy is adopted only if the sum of the strengths of direct and indirect network effects is low and the quality of the early entrant is higher or slightly lower than that of the later entrants. In addition, when the coopetition strategy is adopted, the early entrant always partially integrates its service into the fourth-party platform. The adoption of the coopetition strategy always reduces the prices of early and later entrants. In addition, implementing the coopetition strategy increases the total consumer demand of the early entrant while lowering its consumer demand in the standalone application. For the commission price when coopetition is adopted as the equilibrium strategy, the fourth-party platform charges a lower price as the quality difference and strength of network effects increase; however, it charges a higher price as the consumer preference rises.

We also discuss the coopetition strategy and its influence on platform prices and consumer demands under different commission fee schemes. Under the fixed commission fee scheme with discrimination, the equilibrium strategy qualitatively remains the same. When coopetition is adopted as the equilibrium strategy, the fourth-party platform charges the early and later entrants the same commission prices if the quality difference between them is low; otherwise, it charges them different ones. Under the proportional commission fee scheme, the coopetition strategy is adopted only when the strength of network effects is low and the early entrant has a significant quality advantage. The commission rate increases with strength of network effects and decreases with consumer preference, whereas it first decreases and then increases as quality difference of platforms increases. Different from the results under fixed commission fee scheme, the optimal degree of integration determined by the early entrant first increases and then decreases with increasing strength of network effects, consumer preference and quality difference of platforms. Regarding the results on the influence of adopting the coopetition strategy, most of them still hold. In contrast, when the coopetition strategy is adopted and the early entrant has a quality advantage, the price of the later entrant is always lower than that of the early entrant under the proportional commission fee scheme.

We further compare the two commission fee schemes and find that before the coopetition strategy is adopted, it is more profitable for the fourth-party platform to adopt the proportional commission fee scheme. After the coopetition strategy is adopted, the fourth-party platform earns a higher profit under the fixed commission fee scheme only when the quality difference is of medium size. Moreover, in such cases, early and later entrants also retain a higher profit than that under the proportional commission fee scheme.

We also investigate the coopetition strategy when fourth-party platform and early entrant make decisions on commission price and degree of integration simultaneously. In such cases, platforms always should adopt the coopetition strategy when the strength of network effects is low. Interestingly, the fourth-party platform may be more inclined to propose a fixed commission price first, which does not vary with the degree of integration determined by the early entrant.

Our study has managerial implications for platform owners faced with decisions on whether to adopt the coopetition strategy when a fourth-party platform is present. First, in the platform markets where the sum of strengths of direct and indirect network effects is strong, the fourth-party platform will not integrate the early entrant in. In addition, only the early entrant of high quality is willing to integrate its service into the fourth-party platform. Second, the adoption of coopetition strategy lessens the price competition and benefits the consumers by offering them lower platform prices, regardless of the type of commission fee scheme. Moreover, the adoption of coopetition strategy can lead to a win–win outcome to early entrant and fourth-party platform in which the popularity of fourth-party platform further increases and the early entrant occupies a larger market. Third, the later entrants already integrated into the fourth-party platform may benefit from the integration of early entrant when the fourth-party platform charges the integrated platforms proportional commission fees.

Our study contributes to the extant literature on platform coopetition by investigating the conditions under which the early entrant and its competing fourth-party platform cooperate to achieve a win–win outcome, as well as exploring the effect of adopting the coopetition strategy on prices, consumer demands and so on. The model and analysis in the study can potentially serve as a foundation for further studies on platform coopetition and fourth-party platforms. Our work demonstrates that the coopetition between early entrant and fourth-party platforms can generate higher profits for both parties and explores the corresponding mechanism design.

There exist many possible extensions of our research in the future. First, we restrict our study to the case of homogenous later entrants in the fourth-party platform to develop analytical insights. We expect that our key insights will continue to hold for heterogeneous later entrants but leave rigorous analysis to future research. Second, the per-transaction fees paid by different platform owners to service providers are assumed to be the same in this study. Future research can further investigate how different per-transaction fees affect the effectiveness of coopetition strategy. Finally, we consider the scenario in which there is only one early entrant in the market; however, considering the scenario of two or more early entrants may provide new insights.

Appendix A.

Proof of Lemma 1. By substituting $y_e = \frac{-\alpha+q+t-p_e+p_l}{2t-2\alpha}$ into the equations (5) and (6), we can verify that the second-order derivatives of the profit functions are negative with respect to price. Using the first-order conditions, we can derive the equilibrium prices as follows: $p_e = \frac{q+3t-3\alpha+3c+\omega_l}{3}$ and $p_l = \frac{-q+3t-3\alpha+3c+2\omega_l}{3}$.

Then, substituting the equilibrium prices and demands into equation (7), the second-order derivatives of the profit functions can be proven to be negative with respect to ω_l. The commission price ω_l can be obtained, there is $\omega_l^{i^*} = -\frac{(q-3t+3\alpha)}{2}$. Then, the equilibrium prices, demand, and profits can be derived. To guarantee that neither platform is squeezed out of the market and the prices are non-negative, there is $t > \alpha$ and $9\alpha - 9t < q < 3t - 3\alpha$. □

Proof of Proposition 1. By substituting $y_e = \frac{(k-1)\alpha+q+t-p_e+p_l}{2t-2\alpha}$ into the equations (8) and (9), we can verify that the second-order derivatives of the profit functions are negative. Using the first-order conditions, we can derive the equilibrium prices as follows: $p_e = \frac{(3k-3)\alpha-2kt+q+3t+3c+\omega_l}{3}$ and $p_l = \frac{(3k-3)\alpha-4kt-q+3t+3c+2\omega_l}{3}$.

Then, we substitute the equilibrium prices and demand into the equation (10). Assuming that $\omega_e = \omega_l$, the second-order derivatives of the profit functions can be proven to be negative with respect to ω_l. Thus, the optimal commission price ω_l can be obtained, there is $\omega_e^{o^*} = \omega_l^{o^*} = \frac{(2t-3\alpha)\gamma k}{2} - \frac{(q-3t+3\alpha)}{2}$. Then, the equilibrium prices, demand and profits can be derived.

Knowing the commission price and equilibrium prices, the early entrant and fourth-party platform decides on whether to adopt the coopetition strategy, further, the early entrant decides on the degree of integration.

We first obtain the constraints on k and q to ensure the integration is plausible and will not squeeze either platform out of the market. There is $q < \min(3t-3\alpha+(9\alpha-10t)k, 3t-3\alpha)$. When $\alpha < \frac{2t}{3}$, there is $k \leq \frac{q+9t-9\alpha}{2t-3\alpha}$; otherwise, no constraints exist on k.

We next explore whether and how adopting coopetition strategy can increase the profit of the early entrant. The profit difference of early entrant is: $\Pi_e^o - \Pi_e^i = -\frac{(99\alpha^2-216t\alpha+116t^2)k^2}{72t-72\alpha} - \frac{2(9\alpha^2+(27q-9t)\alpha-28tq)k}{72t-72\alpha}$, a quadratic function about k. The coefficient of k^2 is negative when $\alpha < \hat{\alpha}$, and non-negative when $\alpha > \hat{\alpha}$. Where $\hat{\alpha}$ is the solution to $99\alpha^2 - 216t\alpha + 116t^2 = 0$. Analyzing the coefficient of k, it is always positive.

Thus, when $\alpha < \hat{\alpha}$, there exists optimal $k^* = \frac{-9\alpha^2+(9t-27q)\alpha+28tq}{99\alpha^2-216t\alpha+116t^2}$, which can be proven to satisfy the constraint on k. When $\alpha > \hat{\alpha}$, the optimal k is either 0 or the upper bound of k.

We further explore whether the profit of fourth-party platform increases after adopting the coopetition strategy: $\Pi_f^o - \Pi_f^i = \frac{(-3\alpha k+2tk-3\alpha-q+3t)^2}{24t-24\alpha} - \frac{(q-3t+3\alpha)^2}{24t-24\alpha} = \frac{\gamma k(2t-3\alpha)((2t-3\alpha)k+6t-6\alpha-2q)}{24t-24\alpha}$. Substituting the upper bound of q, $3t - 3\alpha + (9\alpha - 10t)k$ into $(2t - 3\alpha)k + 6t - 6\alpha - 2q$, the value is always positive. Thus, the profit of fourth-party platform increases only when $\alpha < \frac{2t}{3}$, and there is $\frac{2t}{3} < \hat{\alpha}$. □

Proof of Proposition 2. We further explore how the $\omega_e^{o^*}$ varies with parameters when $\alpha < \frac{2t}{3}$ and $q \geq -\frac{9\alpha(\alpha-t)}{27\alpha-28t}$. With respect to the q, t and α, respectively, there are $\frac{\partial\omega_e^{o^*}}{\partial q} = \frac{-9\alpha^2+39t\alpha-30t^2}{99\alpha^2-216t\alpha+116t^2} < 0$, $\frac{\partial\omega_e^{o^*}}{\partial t} = \frac{15390\alpha^4+(1917q-65502t)\alpha^3+(-3852qt+105102t^2)\alpha^2+(1956qt^2-75168t^3)\alpha+20184t^4}{(99\alpha^2-216t\alpha+116t^2)^2} > 0$ and $\frac{\partial\omega_e^{o^*}}{\partial\alpha} = \frac{-19140t^4+(-1956q+69948\alpha)t^3+(-95769\alpha^2+3852\alpha q)t^2+(58320\alpha^3-1917\alpha^2 q)t-13365\alpha^4}{(99\alpha^2-216t\alpha+116t^2)^2} < 0$. Then, we explore how the k^* varies with parameters when $\alpha < \frac{2t}{3}$ and $q > -\frac{9\alpha(\alpha-t)}{27\alpha-28t}$. With respect to the q, t and α, respectively, there are $\frac{\partial k^*}{\partial q} = \frac{28t-27\alpha}{99\alpha^2-216t\alpha+116t^2} > 0$, $\frac{\partial k^*}{\partial t} = \frac{(-3060\alpha^2+6264t\alpha-3248t^2)q+\alpha(-1053\alpha^2+2088t\alpha-1044t^2)}{(99\alpha^2-216t\alpha+116t^2)^2} < 0$ and $\frac{\partial k^*}{\partial\alpha} = \frac{(2673\alpha^2-5544t\alpha+2916t^2)q+t(1053\alpha^2-2088t\alpha+1044t^2)}{(99\alpha^2-216t\alpha+116t^2)^2} > 0$. □

Proof of Proposition 3. We first compare the price of early entrant after and before adopting the coopetition strategy. The price difference of early entrant is: $p_e^o - p_e^i = \frac{(3k^*-9)\alpha}{6} + \frac{q}{6} + \frac{3t}{2} - \frac{k^*t}{3} - (\frac{q}{6} + \frac{3t-3\alpha}{2}) = \frac{k^*(3\alpha-2t)}{6}$. When $\alpha < \frac{2t}{3}$, $p_e^o - p_e^i < 0$. We then compare the price of later entrants after and before adopting the coopetition strategy. The price difference of later entrants is: $p_l^o - p_l^i = -\frac{2tk^*}{3} - \frac{2q}{3} + 2t - 2\alpha - (-\frac{2q}{3} + 2t - 2\alpha) = -\frac{2tk^*}{3} < 0$.

We compare the prices of early entrant and later entrant platforms after adopting the coopetition strategy. The price difference between them is: $p_e^o - p_l^o = \frac{(3k^*-9)\alpha}{6} + \frac{q}{6} + \frac{3t}{2} - \frac{k^*t}{3} - (-\frac{2tk^*}{3} - \frac{2q}{3} + 2t - 2\alpha) = \frac{(3k^*+3)\alpha}{6} + \frac{tk^*}{3} + \frac{5q}{6} - \frac{t}{2}$. Substituting $k^* = \frac{-9\alpha^2+(9t-27q)\alpha+28tq}{99\alpha^2-216t\alpha+116t^2}$ into $p_e^o - p_l^o$, the value is $\frac{((69\alpha-106t)q+45\alpha^2-111\alpha t+58t^2)(\alpha-t)}{99\alpha^2-216t\alpha+116t^2}$. There is $45\alpha^2 - 111\alpha t + 58t^2 > 0$ when $\alpha < \frac{2t}{3}$. Then, substituting the upper bound of q, $\frac{-63\alpha^2+123\alpha t-58t^2}{57\alpha-66t}$ in $(69\alpha - 106t)q + 45\alpha^2 - 111\alpha t + 58t^2$, the value is negative. There is $p_e^c < p_l^c$ when $q < \frac{45\alpha^2-111\alpha t+58t^2}{106t-69\alpha}$, $p_e^c > p_l^c$ when $q > \frac{45\alpha^2-111\alpha t+58t^2}{106t-69\alpha}$.

There is $(p_l^o + q) - p_e^o = (-\frac{\alpha}{2} - \frac{t}{3})k^* - \frac{\alpha}{2} + \frac{q}{6} + \frac{t}{2}$, then substitute $k^* = \frac{-9\alpha^2+(9t-27q)\alpha+28tq}{99\alpha^2-216t\alpha+116t^2}$ into $(p_l^o + q) - p_e^o$, the value is $\frac{(30\alpha^2-41\alpha t+10t^2)q-45\alpha^3+156\alpha^2t-169\alpha t^2+58t^3}{99\alpha^2-216t\alpha+116t^2}$, the value is positive when $q = -\frac{9\alpha(\alpha-t)}{27\alpha-28t}$, and is positive when $q = \frac{-63\alpha^2+123\alpha t-58t^2}{57\alpha-66t}$. Thus, $p_l^o + q > p_e^o$ always holds. □

Proof of Proposition 4. We first explore how the total demand of the early entrant varies after the coopetition strategy is adopted. The total demand of the early entrant is $\frac{(-9-9k^*)\alpha+10k^*t+q+9t}{12t-12\alpha}$ and $\frac{q+9t-9\alpha}{12t-12\alpha}$ in the coopetition and independent cases, respectively. There is $\frac{(3k^*-9)\alpha+(9-2k^*)t+q}{12t-12\alpha} + k^* - \frac{q+9t-9\alpha}{12t-12\alpha} = \frac{k^*(10t-9\alpha)}{12t-12\alpha} > 0$. We then explore how the demand of early entrant in its standalone application varies. There is $\frac{(3k^*-9)\alpha+(9-2k^*)t+q}{12t-12\alpha} - \frac{q+9t-9\alpha}{12t-12\alpha} = \frac{k^*(3\alpha-2t)}{12t-12\alpha} < 0$. □

Appendix B. Fixed commission fee scheme with discrimination

The equilibrium prices under fixed commission fee scheme are as follows: $p_e = \frac{(3k-3)\alpha-2kt+q+3t+3c+\omega_l}{3}$ and $p_l = \frac{(3k-3)\alpha-4kt-q+3t+3c+2\omega_l}{3}$, which are the same as that in the basic model. Then, substituting the equilibrium prices and demand into the profit function of fourth-party platform $y_e'\omega_e + (1-y_e-y_e')\omega_l$, we obtain $-\frac{\omega_l^2}{6\gamma(t-\alpha)} + \frac{((3k-3)\alpha-4kt-q+3t)\omega_l}{6(t-\alpha)} + k\omega_e$ which is a quadratic function about ω_l. The second-order derivatives of the profit functions can be proven to be negative with respect to ω_l. Thus, the optimal commission price ω_l can be obtained, there is $\omega_l = -\frac{(4t-3\alpha)k}{2} - \frac{(q-3t+3\alpha)}{2}$.

We then explore the decision of early entrant on the degree of integration. Substituting $\omega_l = -\frac{(4t-3\alpha)k}{2} - \frac{(q-3t+3\alpha)}{2}$ into the profit function of the early entrant, there is $\frac{(-63\alpha^2+192t\alpha-128t^2)k^2}{72(t-\alpha)} + \frac{((-18\alpha^2+(-6q+18t)\alpha+8tq)\gamma-72\omega_e(t-\alpha))k}{72(t-\alpha)} + \frac{(81\alpha^2+(-18q-162t)\alpha+(q+9t)^2)}{72(t-\alpha)}$, which is a quadratic function about k. The optimal k is either the corner or the interior solution. The corner solution is 0, or the $\frac{q+9t-9\alpha}{8t-9\alpha}$ which is calculated by $k = y_e + y_e'$. The interior solution is $-\frac{((-18\alpha^2+(-6q+18t)\alpha+8tq)-72\omega_e(t-\alpha))}{2(-63\alpha^2+192t\alpha-128t^2)}$.

Anticipating the degree of integration determined by the early entrant, we then investigate how the fourth-party platform determines the commission price that the early entrant must pay, ω_e, to maximize its own profits. Suppose that $k = \frac{q+9t-9\alpha}{8t-9\alpha}$, there is $\omega_e > -\frac{(3\alpha-4t)(27\alpha^2+21\alpha q-39\alpha t-20qt+12t^2)}{24(9\alpha-8t)(\alpha-t)}$. Suppose that $k = -\frac{((-18\alpha^2+(-6q+18t)\alpha+8tq)-72\omega_e(t-\alpha))}{2(-63\alpha^2+192t\alpha-128t^2)}$, substituting the k into the profit function of the fourth-party platform. We obtain a quadratic function with respect to ω_e. There is $H\omega_e^2 + J\omega_e + L$. The second-order derivatives of the profit functions can be proven to be negative, thus there exists optimal $\omega_e = -\frac{J}{2H}$ which maximizes the profit of the fourth-party platform. Where $H = \frac{18(\alpha-t)(99\alpha^2-312\alpha t+208t^2)}{(63\alpha^2-192\alpha t+128t^2)^2}$, $J = \frac{(459\alpha^3-1980\alpha^2t+2736\alpha t^2-1216t^3)q+1377\alpha^4-7749\alpha^3t+16020t^2\alpha^2-14256t^3\alpha+4608t^4}{(63\alpha^2-192\alpha t+128t^2)^2}$ and $L = \frac{864(t-\alpha)(-\frac{8t^2}{3}+(q+\frac{17\alpha}{4})t-\frac{\alpha(q+3\alpha)}{2})^2}{(63\alpha^2-192\alpha t+128t^2)^2} - \frac{(q-3t+3\alpha)^2}{24(t-\alpha)}$.

Substituting $\omega_e = -\frac{J}{2H}$ into $\Pi_f^o - \Pi_f^i$, there is $\frac{32(-\frac{9t^2}{4}+(q+\frac{9\alpha}{2})t-\frac{3\alpha(q+3\alpha)}{4})^2}{9(99\alpha^2-312\alpha t+208t^2)(t-\alpha)}$. When $\alpha < \alpha_1$, there is $\Pi_f^o - \Pi_f^i > 0$. Where α_1 is the solution to $99\alpha^2 - 312\alpha t + 208t^2 = 0$. When $\alpha < \alpha_1$, the coefficient of $k^2 < 0$, to make sure $\Pi_e^o - \Pi_e^i > 0$, there is $q > q_1$. Where $q_1 = -\frac{9(\alpha^2-2\alpha t+t^2)}{3\alpha-4t}$.

Then, there is $k^* = \frac{-36\alpha^2+(72t-12q)\alpha+16qt-36t^2}{99\alpha^2-312\alpha t+208t^2}$, $\frac{\partial k^*}{\partial q} = \frac{16t-12\alpha}{99\alpha^2-312t\alpha+208t^2} > 0$, $\frac{\partial k^*}{\partial t} = \frac{(-2160\alpha^2+4992t\alpha-3328t^2)q+\alpha(-4104\alpha^2+7848t\alpha-3744t^2)}{(99\alpha^2-312t\alpha+208t^2)^2} < 0$ and $\frac{\partial k^*}{\partial \alpha} = \frac{(1188\alpha^2-3168t\alpha+2496t^2)q+t(4104\alpha^2-7848t\alpha+3744t^2)}{(99\alpha^2-312t\alpha+208t^2)^2} > 0$.

We then compare the prices of early entrant and later entrant platforms after and before adopting the coopetition strategy. There is $p_e^o - p_e^i = \frac{(9k^*-9)\alpha}{6} - \frac{4k^*t}{3} + \frac{q}{6} + \frac{3t}{2} - (\frac{q}{6} + \frac{3t-3\alpha}{2}) = \frac{k^*(9\alpha-8t)}{6} < 0$ and $p_l^o - p_l^i = \frac{(6\alpha-8t)k^*}{3} - \frac{2q}{3} + 2t - 2\alpha - (-\frac{2q}{3} + 2t - 2\alpha) = 2k^*(\alpha - t) < 0$. The price difference of early entrant and later entrants after adopting coopetition strategy is $p_e^o - p_l^o = \frac{(9k^*-9)\alpha}{6} - \frac{4k^*t}{3} + \frac{q}{6} + \frac{3t}{2} - (\frac{(6\alpha-8t)k^*}{3} - \frac{2q}{3} + 2t - 2\alpha)$. Substituting the upper bound of q into above expression, there is $2(k^* - 1)(\alpha - t)$.

Comparing the demand of early entrant after and before adopting the coopetition strategy, the total demand of the early entrant is $\frac{(9k^*-9)\alpha+(9-8k^*)t+q}{12t-12\alpha} + k^*$ and $\frac{q+9t-9\alpha}{12t-12\alpha}$ in the coopetition and independent cases, respectively. There is $\frac{(9k^*-9)\alpha+(9-8k^*)t+q}{12t-12\alpha} + k^* - \frac{q+9t-9\alpha}{12t-12\alpha} = \frac{k^*(4t-3\alpha)}{12t-12\alpha} > 0$. We then explore how the demand of early entrant in its standalone application varies. There is $\frac{(9k^*-9)\alpha+(9-8k^*)t+q}{12t-12\alpha} - \frac{q+9t-9\alpha}{12t-12\alpha} = \frac{k^*(9\alpha-8t)}{12t-12\alpha} < 0$.

Appendix C. Proportional commission fee scheme

In the independent case, by substituting $y_e = \frac{-\alpha+q+t-p_e+p_l}{2t-2\alpha}$ into equations (15) and (16), we can verify that the second-order derivatives of the profit functions are negative. Using the first-order conditions, we can derive the equilibrium prices as follows: $p_e^i = t - \alpha + \frac{q}{3} + c$ and $p_l^i = t - \alpha - \frac{q}{3} + c$. Then, the equilibrium prices, demand, and profits can be derived. The profits of early entrant, later entrants, and fourth-party platforms are $\Pi_e^i = \frac{(q+3t-3\alpha)^2}{18(t-\alpha)}$, $\Pi_l^i = \frac{(q-3t+3\alpha)^2(1-\delta)}{18(t-\alpha)}$ and $\Pi_f^i = \frac{(q-3t+3\alpha)^2\delta}{18(t-\alpha)}$.

In the coopetition case, by substituting $y_e = \frac{(k-1)\alpha+q+t-p_e+p_l}{2t-2\alpha}$ into the equations (18) and (19), we can verify that the second-order derivatives of the profit functions are negative. Using the first-order conditions, we can derive the equilibrium prices as follows: $p_e^o = \frac{(3\alpha-2t)k}{3} + \frac{q}{3} + t - \alpha$ and $p_l^o = \frac{(3\alpha-4t)k}{3} - \frac{q}{3} + t - \alpha$. Then, the equilibrium prices, demand and profits can be derived. The profits of early entrant, later entrants, and fourth-party platforms are $\Pi_e^o = \frac{((3\alpha-2t)k+q+3t-3\alpha)^2}{18(t-\alpha)} - k(\delta-1)((\alpha - \frac{4t}{3})k + \frac{2q}{3} + t - \alpha)$, $\Pi_l^o = \frac{(1-\delta)((3-3k)\alpha+4kt+q-3t)^2}{18(t-\alpha)}$ and $\Pi_f^o = k\delta((\alpha - \frac{4t}{3})k + \frac{2q}{3} + t - \alpha) + \frac{\delta((3-3k)\alpha+4kt+q-3t)^2}{18(t-\alpha)}$.

We then explore the degree of integration determined by the early entrant for maximizing own profits. The profit of early entrant is a quadratic function with respect to the k. Thus, the optimal k is either corner or the interior solution. The corner solution is 0, or the $\frac{q+3t-3\alpha}{2t-3\alpha}$ which is calculated by $k = y_e + y_e'$. The interior solution is $\frac{9\alpha^2\delta+((3-18\delta)t-6q(\delta-\frac{1}{2}))\alpha+(9\delta-3)t^2+6q(\delta-\frac{2}{3})t}{(18\delta-9)\alpha^2-42t(\delta-\frac{5}{7})\alpha+(24\delta-20)t^2}$.

Appendix D. Different sequence of decision-making

Proof of Proposition 6. We discuss the scenario in which the early entrant and fourth-party platform simultaneously make their decisions on degree of integration and commission price. Note that the independent case remains the same as that when fourth-party platform proposes commission price before the early entrant makes its decision. In the coopetition case, substituting $y_e = \frac{(k-1)\alpha+q+t-p_e+p_l}{2t-2\alpha}$ into the equations (8) and (9), we can verify that the second-order derivatives of the profit functions are negative. Using the first-order conditions, we can derive the equilibrium prices as follows: $p_e = \frac{(3k-3)\alpha-2kt+q+3t+3c+\omega_l}{3}$ and $p_l = \frac{(3k-3)\alpha-4kt-q+3t+3c+2\omega_l}{3}$.

Then, substitute the equilibrium prices and demand into the equations (8) and (10). Assuming that $\omega_e = \omega_l$, the second-order derivatives of the profit functions can be proven to be negative with respect to k and ω_l. Thus, the optimal degree of integration and commission price ω_l can be obtained, there is $k^* = \frac{-18\alpha^2+(-12q+27t)\alpha+13tq-9t^2}{36\alpha^2-87\alpha t+50t^2}$ and $\omega_e^{o^*} = \omega_l^{o^*} = -\frac{(12(t-\alpha))(-\frac{11t^2}{2}+(q+\frac{33\alpha}{4})t-\frac{9\alpha^2}{4})}{36\alpha^2-87\alpha t+50t^2}$. Then, the equilibrium prices, demand and profits can be derived. To guarantee that the integration will not squeeze either platform out of the market, there is $\max(-\frac{3(21\alpha^2-47\alpha t+26t^2)}{4t}, -\frac{9(2\alpha^2-3\alpha t+t^2)}{12\alpha-13t}, 9\alpha-9t) < q < \min(-\frac{45\alpha^2-87\alpha t+40t^2}{6(4\alpha-5t)}, 3t-3\alpha)$.

We next explore whether and how adopting coopetition strategy can increase the profit of the early entrant. The profit difference of early entrant is: $\Pi_e^o - \Pi_e^i = \frac{-2349\alpha^5+(648q+14553t)\alpha^4+(-288q^2-3006qt-34965t^2)\alpha^3+(1104q^2t+5394qt^2+41031t^3)\alpha^2 +(-1354q^2t^2-4340qt^3-23634t^4)\alpha+536q^2t^3+1304qt^4+5364t^5}{2(36\alpha^2-87\alpha t+50t^2)^2} - \frac{(-9\alpha+q+9t)^2}{-72\alpha+72t} = (1134\alpha^4 - 756\alpha^3 q - 4347\alpha^3 t + 2835\alpha^2 qt + 6345\alpha^2t^2 - 3372\alpha qt^2 - 4176\alpha t^3 + 1292qt^3 + 1044t^4)\frac{18\alpha^2+12\alpha q-27\alpha t-13qt+9t^2}{72(36\alpha^2-87\alpha t+50t^2)^2(\alpha-t)}$. When $\alpha < \frac{2t}{3}$, $\Pi_e^o - \Pi_e^i > 0$ always holds; otherwise, $\Pi_e^o - \Pi_e^i > 0$ only if $q > \dot{q}$, where $\dot{q}$ is the solution to $1134\alpha^4 - 756\alpha^3q - 4347\alpha^3t + 2835\alpha^2qt + 6345\alpha^2t^2 - 3372\alpha qt^2 - 4176\alpha t^3 + 1292qt^3 + 1044t^4 = 0$. We further explore whether the profit of fourth-party platform increases after adopting the coopetition strategy: $\Pi_f^o - \Pi_f^i = (24(t-\alpha))\frac{(-\frac{11t^2}{2}+(q+\frac{33\alpha}{4})t-\frac{9\alpha^2}{4})^2}{(36\alpha^2-87\alpha t+50t^2)^2} - \frac{(q-3t+3\alpha)^2}{24t-24\alpha} = (3\alpha-2t)(18\alpha^2+12\alpha q-27\alpha t-13qt+9t^2)\frac{162\alpha^3+36\alpha^2q-621\alpha^2t-111\alpha qt+741\alpha t^2+74qt^2-282t^3}{24(36\alpha^2-87\alpha t+50t^2)^2(\alpha-t)}$, $\Pi_f^o - \Pi_f^i > 0$ only when $\alpha < \frac{2t}{3}$.

With respect to the q, t and α, respectively, there are $\frac{\partial\omega_e^{o*}}{\partial q} = \frac{12(\alpha-t)t}{36\alpha^2-87\alpha t+50t^2} < 0$, $\frac{\partial\omega_e^{o*}}{\partial t} = \frac{2187\alpha^4+(432q-9180t)\alpha^3+(-864qt+15183t^2)\alpha^2+444t^2(q-\frac{957t}{37})\alpha+3300t^4}{(36\alpha^2-87\alpha t+50t^2)^2} > 0$ and $\frac{\partial\omega_e^{o*}}{\partial\alpha} = \frac{-2508t^4+(-444q+7848\alpha)t^3+(864(q-\frac{21\alpha}{2}))\alpha t^2-(432(q-\frac{87\alpha}{8}))\alpha^2t-972\alpha^4}{(36\alpha^2-87\alpha t+50t^2)^2} < 0$. Then, we explore how the k^* varies with parameters when $\alpha < \frac{2t}{3}$. With respect to the q, t and α, respectively, there are $\frac{\partial k^*}{\partial q} = \frac{-12\alpha+13t}{36\alpha^2-87\alpha t+50t^2} > 0$, $\frac{\partial k^*}{\partial t} = \frac{-594\alpha^3+(-576q+1152t)\alpha^2+(1200qt-567t^2)\alpha-650qt^2}{(36\alpha^2-87\alpha t+50t^2)^2} < 0$ and $\frac{\partial k^*}{\partial\alpha} = \frac{567t^3+(531q-1152\alpha)t^2+(594\alpha^2-936\alpha q)t+432\alpha^2q}{(36\alpha^2-87\alpha t+50t^2)^2} > 0$.

We then compare the platform prices and demand after and before adopting the coopetition strategy. We have $p_e^o - p_e^i = -\frac{(-2t+3\alpha)(18\alpha^2+12\alpha q-27\alpha t-13qt+9t^2)}{216\alpha^2-522\alpha t+300t^2} < 0$, $p_l^o - p_l^i = \frac{18t^3+(-26q-54\alpha)t^2+(36\alpha^2+24\alpha q)t}{108\alpha^2-261\alpha t+150t^2} < 0$ and $p_e^o - p_e^i - (p_l^o - p_l^i) = (2t+3\alpha)\frac{-18\alpha^2-12\alpha q+27\alpha t+13qt-9t^2}{216\alpha^2-522\alpha t+300t^2} > 0$. In addition, we have $y_e^o + y_e' - y_e^i = \frac{27\alpha^2+(-24q-87t)\alpha+30t(q+2t)}{72\alpha^2-174\alpha t+100t^2} - \frac{9\alpha-q-9t}{12(\alpha-t)} = -(9\alpha-10t)\frac{18\alpha^2+12\alpha q-27\alpha t-13qt+9t^2}{(12(\alpha-t))(36\alpha^2-87\alpha t+50t^2)} > 0$ and $y_e^o - y_e^i = \frac{78t^2+(4q-141\alpha)t+63\alpha^2}{72\alpha^2-174\alpha t+100t^2} - \frac{9\alpha-q-9t}{12(\alpha-t)} = (-2t+3\alpha)\frac{18\alpha^2+12\alpha q-27\alpha t-13qt+9t^2}{(12(\alpha-t))(36\alpha^2-87\alpha t+50t^2)} < 0$. □

Proof of Proposition 7. We compare the profit of fourth-party platform when coopetition exists as the equilibrium strategy under the two different sequences of decision-making. We have $(24(t-\alpha))\frac{(-\frac{11t^2}{2}+(q+\frac{33\alpha}{4})t-\frac{9\alpha^2}{4})^2}{(36\alpha^2-87\alpha t+50t^2)^2} - \frac{150(-\frac{29t^2}{5}+(q+\frac{21\alpha}{2})t-\frac{3\alpha(q+15\alpha)}{10})^2(t-\alpha)}{(99\alpha^2-216\alpha t+116t^2)^2} = (9(\alpha-t))(2511\alpha^4+108\alpha^3q-12906\alpha^3t-1017\alpha^2qt+23823\alpha^2t^2+1884\alpha qt^2-18876\alpha t^3-964qt^3+5452t^4)(-2t+3\alpha)^2\frac{27\alpha^2+4\alpha q-56\alpha t-3qt+29t^2}{2(36\alpha^2-87\alpha t+50t^2)^2(99\alpha^2-216\alpha t+116t^2)^2} < 0$. □

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Data availability statement

We conducted this research through a stylized model. No data were generated or used during the study.

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