

Research Article

Research on the Revenue Management of Network Video Platform Based on Game Theory

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To study how the network video platform can improve revenue and optimize the revenue structure, we construct an asymmetric competition model between free and paid platforms based on game theory, and the impact of the positive and negative cross-network externalities and program differentiation on platform's competition and revenue are analyzed. The results show that changes in the relative relationship of positive and negative cross-network externalities may lead to free platform exiting the consumer market or paid platform exiting the advertising market. Only when the ratio of positive and negative cross-network externalities is moderate, the free and paid platform coexist, and the greater the difference of program, the greater the possibility of coexistence. With the effect of the positive and negative cross-networks externalities, the multi-revenue structure of the payment mode is not always better than the single revenue structure of the free platform. In addition, the impact of the positive and negative cross-network externalities and program differentiation on the revenue of free and paid platforms are nonlinear. If the platform wants to achieve greater revenue through the adjustment of revenue structure, it should fully consider the relative relationship of positive and negative cross-network externalities and program differentiation, otherwise it may bring losses.

1. Introduction

With the development of network economy, the era of “content payment” and “user experience” has greatly affected the development of network media industry, especially the growing network video platform enterprises. More and more online video platforms provide high-quality popular content to attract consumers to become members, and obtain membership income, while inserting advertisements into the content to obtain advertising income [1, 2]. Therefore, most of the existing online video platforms are “paid + advertising” business model, such as YouTube, iQIYI, and Tencent Video, whose income sources are mainly membership fee income and advertising income. However, we generally consider that consumers are usually averse to advertising [3, 4]. The privilege of a VIP membership subscription must include members to advertise or skip advertising. According to research data, iQIYI's total revenue increased from 17.4 billion yuan to 30.6 billion yuan

from 2017 to 2021, in which advertising revenue decreased from 47% to 23.2% and membership revenue increased from 37.6% to 54.6% [1]. As a result, the growth of membership revenue is bound to reduce advertising revenue. As Crampes et al. also believe that the relationship between advertising revenue and member revenue is complementary and antagonistic [5]. Therefore, how to coordinate the two sources of revenue and jointly drive the growth of total revenue is of great importance to the network video platform.

Besides that, the research on revenue sources mainly focuses on traditional media platforms, such as radio and television, and symmetric competitive media market [6–8]. Different from the traditional media platform, on the one hand, the network video platform is a typical two-sided platform, which has obvious “positive” and “negative” cross-network externalities; on the other hand, in reality, the competition of online video platform programs is often asymmetric, there are a large number of different video platforms have completely different pricing methods even

though their program contents are the same. For example, “Flirting Scholar” and “Mr. Vampire” are provided to consumers for free on iQIYI platform, while VIP users can only watch paid programs on Youku platform. And there are program differences in the viewing experience between the two platforms. The highest image quality of free programs is super clear 720p, while paid programs can use blue light 1080p, which has better visual effect [1]. Obviously, the different pricing methods of the two video platforms will lead to different sources of revenue, and there will be asymmetric competition between free and paid platform programs. So, what is the impact of such asymmetric competition on each other’s revenue sources? How should video platforms adjust their revenue sources to achieve greater profits under asymmetric competition? How can the positive and negative cross-network externalities and programs differentiation affect the revenue of online video platforms? Obviously, these problems are very important both in theory and in practice and are worth exploring. This paper will use the quantitative model method to study and discuss these questions.

The rest of the paper is organized as follows: Section 2 contains a literature review; Section 3 covers model description and basic assumptions; Section 4 analyses the equilibrium results; Section 5 studies the revenue structure of video platforms, focusing on the impact of program differentiation and the ratio of positive and negative cross-network externalities on the revenue and revenue structure of free and paid platforms; Section 6 summarizes the full text and points out the innovative conclusions, shortcomings, and future research directions of this paper. All proofs of the main results are relegated to the Appendix (available here).

2. Literature Review

This study is related to these areas of the literature: cross-network externality, media platform competition, and revenue sources.

Cross-network externality is one of the important topics in this paper. According to the existing literature, the typical feature of a two-sided market is the existence of cross-network externalities, which play an important role in enterprises’ decision-making. Many literatures have studied the positive cross-network externality, such as Armstrong, Rochet, et al. studied the influence of positive cross-network externality on media market pricing [9–12]. Some scholars used the empirical research method [13–15]; others used model research method to analyze the impact of positive cross-network externality on the competition of platform enterprises [16, 17]. Li et al. compared and analyzed three online music pricing strategies of ownership, subscription, and mixed pricing by optimizing the model, and the results showed that positive cross-network externalities and consumers’ reserve price for music services had key influences on the pricing strategies of music platforms [18]. Scholars who study video media platform assume that advertising will cause interference to the audience and explore the impact of negative cross-network externality on platform pricing or advertising strategy [1, 19, 20]. For example, Cheng et al.

considered the influence of consumers’ behavior of using VOD on optimal pricing decisions of online video platforms and analyzed the role of negative cross-network externalities [1]. Carroni and Paolini studied price discrimination of content versioning in the presence of content providers and analyzed the impact of content diversity and different negative cross-network externalities on pricing [21]. Xie et al. studied the pricing strategy of multihoming and analyzed the influence of cross-network externalities on pricing [22].

It is not difficult to find that the above literature studies a single “positive” or “negative” cross-network externality. In fact, there are both “positive” and “negative” cross-network externalities in online video platforms. However, the existing literature has not deeply studied the impact of two cross-network externalities on the platform. In addition, a small number of scholars have studied the two cross-network externalities at the same time. For example, Marco and Tanja simply assumed that the positive externality brought by consumers to advertisers is greater than the negative externality caused by advertising aversion [23]. Lin studies the bilateral discriminatory pricing of different content versions and considers the impact of positive and negative cross-network externalities on pricing [24]. Therefore, the research on how the positive and negative cross-network externalities jointly affect the revenue structure of online video platform is worthy of further exploration. In order to make the research more general, this paper also designs a positive and negative cross-network externality ratio, that is, the relative relationship between the positive externality brought by the scale of consumers and the negative externality caused by their advertising aversion. This paper studies the changes in the revenue and revenue structure of the network video platform through the change in the ratio.

Another important topic related to this paper is the research on media platform competition. The existing literature mainly focuses on symmetric market competition and studies the advertising volume, social welfare, and program quality of free and paid platforms. For example, Dukes studied how the specific market competition parameters of the two free platforms affect the advertising level, and the research showed that the higher the degree of media differentiation, the higher the advertising level [6]. Choi studied the differences in the advertising level of TV media in two free and paid symmetrical competitive markets and the impact of the regulation of TV quantity and advertising quantity on social welfare [7]. Peitz et al. compared the advertising volume and program differentiation of media platforms in the two symmetric competition markets and found that when the negative cross-network externality is large, the advertising volume in the free market is larger, and the program differentiation is smaller [8]. However, in reality, free and paid platforms exist simultaneously, but only a few studies describe this asymmetric competition situation; for example, Dietl et al. constructed an asymmetric competition model of free and pay TV and showed that the advertising level and consumer demand of pay TV are always lower than those of free TV [19]. Lin studied and compared the differences of program quality of TV broadcasting platforms under pure payment, free, and mixed mode [25]. Li and Zhang studied the

program quality and advertising competition of TV in paid and free markets [26]. Obviously, the above-mentioned literature mainly focuses on the advertising and quality strategies of media platforms, and does not discuss the optimal revenue structure. Moreover, the platform decision-making (such as advertising volume and program quality) under asymmetric competition is different from that under symmetric competition, which indicates that asymmetric competition will also have different effects on the revenue sources and revenue structure of platforms. Therefore, in order to explore how asymmetric competition will affect the source and structure of platform revenue, this paper constructs an asymmetric competition model of free and paid platform programs.

The third important topic related to this paper is the revenue source of media platform. According to different pricing and advertising strategies, the media platform has two revenue sources: advertising revenue and membership revenue. The early literature mainly focused on the advertising revenue of free media market. For example, Kind et al. believed that in the free market, with the greater the program differentiation, the smaller the degree of advertising aversion or the less the number of competitive platforms, the more advertising volume of media platforms and the higher the total advertising revenue [27]. With the change of business mode of media platform, more and more literature research payment media market. For example, Cramés et al. studied the relationship between advertising revenue and payment revenue of media platforms and found that platforms might set negative prices to attract consumers in order to obtain larger advertising revenue [5]. In particular, when the number of competitor is enough, the consumer price of platforms will be lower than the marginal cost. Godes et al. found that fierce competition will make media enterprises subsidize consumers to obtain higher advertising revenue [28]. King et al. studied the influence of platform differentiation and the number of competitors on platform revenue sources [29]. Amaldoss et al. explored the content provision strategies and profit sources of media platforms by constructing different space allocation ratios between content and advertising, and analyzed the content space allocation and pricing of platforms under free, pure paid, and paid + advertising strategies [30]. The above literature found that program differentiation, negative cross-network externality, and the number of competitors will affect the revenue sources of media platforms, but they ignore the important factor that there is obvious positive cross-network externality in online video platforms and do not involve the comprehensive impact of both positive and negative cross-network externalities on platform revenue sources. In this paper, we consider the influence of the correlation between the positive and negative cross-network externalities and the program differentiation level on the revenue and revenue structure of the network video platform.

3. The Model and Assumptions

We consider a duopoly competitive network video platform market, where each platform provides one video program. According to the actual operation mode of network video platforms (e.g., Youku and iQIYI), each video program has two pricing methods: free and paid for the consumer market.

The free mode refers to the fact that the platform provides free program content containing more advertisements to consumers (for example, the front end of video watched by iQIYI users has at least 60 seconds of advertising, and there will also be 10–30 seconds of advertising in the middle). At this time, the platform only has the source of advertising revenue. The payment method refers to the platform providing the audience with a small amount of advertising program content (for example, the VIP drama series paid by Youku members only has 15 seconds of advertising at the beginning, and there will also be advertisements of 0–15 seconds in the middle, and the advertisement recommendation of VIP users can be manually click to skip). At this time, the platform charges both membership fees from consumers and advertising fees from advertisers. Suppose that video platform 1 is a paid program platform (referred to as the paid platform) and video platform 2 is a free program platform (referred to as the free platform).

In order to facilitate the following analysis, according to the basic characteristics of two-sided platforms, we put forward the following assumptions:

- (1) Let p be the member price of platform 1 and q_i be the consumer demand of the platform i ($i = 1, 2$), a_i and r_i be the advertising volume and advertising price of platform i , and π_{co} and π_{ad} represent the membership revenue and advertising revenue, respectively.

In addition, we do not consider the production cost of platform programs. There are two reasons: Firstly, this paper referred to the relevant literature on the pricing and business models of online media platforms, such as references [22, 24]. This paper analyzed the revenue sources and revenue structures of video platforms from the perspectives of membership revenue and advertising revenue. And this paper focuses on the revenue management of video platforms. Therefore, it does not consider video platforms' cost.

Secondly, generally speaking, the cost of a video platform generally includes the cost of video content (the fourth comment of the reviewers) and the operating cost of the platform (the fifth comments of the reviewers). First of all, the cost of video content refers to the cost of purchasing video content by the platform. Since the birth of online video, the acquisition of video content has always been a one-time buyout method. This method is centered on video copyright transactions. Content producers, such as film companies, sell videos to video platforms through copyright transactions. After paying the copyright fee, the video content will be broadcast to users. At this time, the procurement cost is usually set as a copyright fee model related to video quality or a fixed fee model, and these two content cost functions do not affect the profit model and revenue structure of the video platform in this paper, so this paper assumes that the content cost of the video platform is not considered.

Therefore, referring to the literature [22, 24], in order to highlight the research focus, the production cost of platform program is 0.

Thus, the profit function of video platform i is as follows:

$$\Pi_1 = \pi_{co} + \pi_{ad} = pq_1 + a_1r_1. \quad (1a)$$

$$\Pi_2 = a_2r_2. \quad (1b)$$

- (2) According to Shubik-Levitan utility function [29, 31], we assume that consumer preference is given by the following quadratic function:

$$U = q_1 + q_2 - \left[(1-s)(q_1^2 + q_2^2) + \frac{s}{2}(q_1 + q_2)^2 \right], \quad (2)$$

where $s \in (0, 1]$ measures program content differentiation. It refers to the degree of difference between the program contents of the two video platforms, such as differences in program content type, program duration, program evaluation, and program clarity. The greater the s , the more similar the program content from the perspective of consumers. $s \rightarrow 1$, there is almost no difference in program content. $s \rightarrow 0$, the video program content can completely replace each other.

- (3) According to the literature [28, 29], the consumer surplus of free platform depends on the advertising volume a_i , and the consumer surplus of paid platform depends both on the price p and on the advertising volume a_i . To capture this dependency, we let the consumer cost for watching free program be ta_i , and watching paid program be $p + ta_1$. Where $t > 0$ measures consumers' disutility of being interrupted by ads. The specific manifestation is that consumers will be disgusted by the content of the platform because of the duration and the content of the advertisement. It is also called negative cross-network externality [15, 32]. Consumer surplus can thus be written as

$$CS = U - q_1(p + t_1 a_1) - q_2 t_2 a_2. \quad (3)$$

- (4) Online video platform can get part of the revenue by selling advertising space to advertisers. We assume that there is only one potential advertiser, and advertising revenue increases with advertising volume a_i and consumer demand q_i [29]. We catch this interaction between the advertising and platform consumption by assuming that the total revenue of advertisers on the platform i equals $\eta a_i q_i$, where $a_i r_i$ is the advertising cost paid by advertisers to the platform i . The parameter $\eta > 0$ represents the positive value effect brought by unit consumers to advertisers, such as the click-through rate of the advertisement, the viewing rate of the advertisement, and the purchase rate of the advertisement product or service [13, 14, 33]. It is also called positive cross-

network externality. Then the advertiser's profit function is as follows:

$$\pi = \eta \sum_{i=1}^2 a_i q_i - \sum_{i=1}^2 a_i r_i. \quad (4)$$

- (5) We defined $h = \eta/t$ as "positive and negative cross-network externality ratio" (referred to as cross-network externality ratio), which reflects the relative relationship between positive and negative value effects brought about by consumers and advertisers as well as between positive value effects brought by consumers' scale and negative value effects brought by consumers' aversion to advertising. It can represent the common influence of two cross-network externalities.

According to the above model description and assumptions, we model the interaction between the two platforms as a three-stage game (illustrated in Figure 1). In the first stage, the platform decides the member price and advertising price; in the second stage, the advertiser decides the advertising volume in different platforms; in the third stage, the consumer decides the consumption in the two platforms.

4. Equilibrium Analysis

According to the principle of backward induction, first, the consumers make decisions. By setting $\partial CS / \partial q_i = 0$, to obtain

$$q_1 = \frac{1}{2} - \frac{(2-s)(ta_1 + p) - sta_2}{4(1-s)}. \quad (5a)$$

$$q_2 = \frac{1}{2} - \frac{(2-s)ta_2 - s(ta_1 + p)}{4(1-s)}. \quad (5b)$$

Second, advertisers make decisions. To maximize the advertisers' profits, let $\partial \pi / \partial a_i = 0$, the advertising volume can be written as follows:

$$a_1 = \frac{\eta(1-p) - 2r_1 + s(r_1 - r_2)}{2t\eta}. \quad (6a)$$

$$a_2 = \frac{\eta - 2r_2 - s(r_1 - r_2)}{2t\eta}. \quad (6b)$$

By introducing equations (5a)–(6b) into (1a) and (1b), the profit of video platform is as follows:

$$\begin{aligned} \Pi_1 = p & \frac{(s-2)\eta p + 2(1-s)(\eta + 2r_1)}{8(1-s)\eta} \\ & + r_1 \frac{\eta(1-p) - 2r_1 + s(r_1 - r_2)}{2t\eta}. \end{aligned} \quad (7a)$$

$$\Pi_2 = r_2 \frac{\eta - 2r_2 - s(r_1 - r_2)}{2t\eta}. \quad (7b)$$

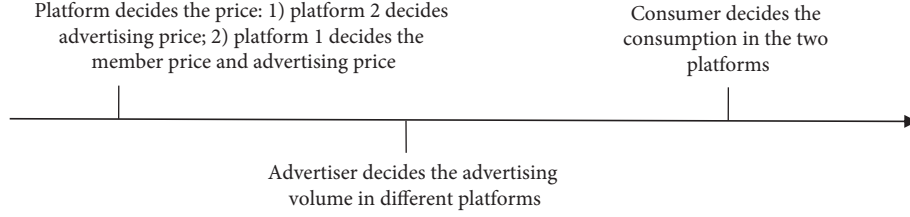


FIGURE 1: The sequence of events.

Finally, platforms solve the maximization problems. To ensure that the second-order conditions for a maximum are satisfied, we conduct a Hessian matrix as follows:

$$H = \begin{bmatrix} \frac{2-s}{4(-1+s)} & \frac{t-\eta}{2t\eta} & 0 \\ \frac{t-\eta}{2t\eta} & \frac{-2+s}{t\eta} & \frac{-s}{2t\eta} \\ 0 & \frac{-s}{2t\eta} & \frac{-2+s}{t\eta} \end{bmatrix}. \quad (7c)$$

When Hessian matrix is negative definite matrix, Lemma 1 can be obtained.

lemma 1. *The equilibrium solution exists when the conditions $0 < s < 1$ and $h_0(s) < \eta/t < h_1(s)$ are satisfied. Additionally, $dh_0(s)/ds < 0, dh_1(s)/ds > 0$.*

Notes,-

$$h_0(s) = \frac{3(8-8s+s^2) - \sqrt{(4-s)(4-3s)(32-32s^2+3s^3)}}{8(1-s)},$$

$$h_1(s) = \frac{3(8-8s+s^2) + \sqrt{(4-s)(4-3s)(32-32s^2+3s^3)}}{8(1-s)}.$$

The equilibrium price, demand, advertising volume, and profit of the platform are obtained as follows:

$$q_1^* = \frac{(32-30s+3s^2)t\eta + 2s\eta^2}{24(8-8s+s^2)t\eta - 32(1-s)(t^2+\eta^2)}, \quad a_1^* = \frac{(1-s)(16-14s+s^2)t - (16-26s+12s^2-s^3)\eta}{2(2-s)[4(1-s)(t^2+\eta^2) - 3(8-8s+s^2)t\eta]},$$

$$q_2^* = \frac{4(6-s)(1-s)t^2 - (4-s)(36-34s+3s^2)t\eta + 2(12-12s+s^2)\eta^2}{8(2-s)[4(1-s)(t^2+\eta^2) - 3(8-8s+s^2)t\eta]}, \quad a_2^* = \frac{(s+s^2-2)t^2 + (12-13s+2s^2)t\eta - 2(1-s)\eta^2}{6(8-8s+s^2)t^2\eta - 8(1-s)t(t^2+\eta^2)},$$

$$\Pi_1^* = \pi_{co}^* + \pi_{ad}^* = \frac{(1-s)(4-3s)\eta^2(st-6t+2\eta)[(32-30s+3s^2)t+2s\eta]}{8(2-s)[4(1-s)(t^2+\eta^2) - 3(8-8s+s^2)t\eta]^2}$$

$$+ \frac{t\eta[2(s-1)(t+\eta) - s\eta][(1-s)(16-14s+s^2)t + (26s-12s^2+s^3-16)\eta]}{2(2-s)[4(1-s)(t^2+\eta^2) - 3(8-8s+s^2)t\eta]^2},$$

$$\Pi_2^* = \frac{\eta[(s+s^2-2)t^2 + (12-13s+2s^2)t\eta - 2(1-s)\eta^2]^2}{2(2-s)[4(1-s)(t^2+\eta^2) - 3(8-8s+s^2)t\eta]^2}. \quad (7d)$$

According to the equilibrium solution, we can establish the following propositions (all proofs in the appendix (available here)).

Proposition 1. *For the paid platform,*

(i) when

$h_0(s) < h < (1-s)(16-14s+s^2)/16-s(26-12s+s^2)$, $p^* > 0, a_1^* \leq 0$, the platform adopts the “pure membership” mode;

(ii) when

$(1-s)(16-14s+s^2)/16-s(26-12s+s^2) < h < (6-s)/2$, $p^* > 0, a_1^* > 0$, the platform adopts the “membership + advertising” mode;

(iii) when $(6-s)/2 < h < h_1(s)$, $p^* < 0, a_1^* > 0$, the platform adopts the “subsidy + advertising” mode.

Proof. See appendix (available here).

Proposition 1 shows that, with the change of the cross-network externality ratio, the paid program platform will

change its pricing and advertising strategies to form a variety of profit modes, as shown in Figure 2. (i) When the cross-network externality ratio is small, that is to say, when the positive effect brought by unit consumers is small and the degree of consumers' advertising aversion is high, there is no advertising on the platform. So, the platform only makes profits by charging consumers membership fees, that is, the platform adopts the "pure membership" profit mode. (ii) With the increase of the cross-network externality ratio, the platform begins to attract advertisers' investment. At this time, the platform can obtain profits from both the consumers and advertisers, that is, the platform adopts the "membership + advertising" profit mode. (iii) When the cross-network externality ratio is large enough, the platform will actively subsidize the consumer market to obtain more advertising revenue, that is, the platform adopts the "subsidy + advertising" profit mode. Therefore, the relative relationship between positive and negative cross-network externalities has a great impact on the revenue structure of paid platform. That is, with the cross-network externality ratio from small to large, the paid platform will experience the evolution of three revenue structures: pure membership, membership + advertising, and subsidy + advertising.

By analyzing the influence of program differentiation on the threshold of cross-network externality ratio, the following corollary can be obtained: \square

Corollary 1. *The greater the program differentiation, the more likely the paid platform to choose the membership mode. On the contrary, the smaller the program differentiation, the more likely the paid platform to choose the advertising mode.*

Proof. See appendix (available here).

From Proposition 1 and Figure 2, we find that the change of program differentiation level will directly affect the range of different profit modes. With the increase of program differentiation, the possibility of platform adopting "pure membership" and "membership + advertising" mode will increase, while the possibility of "subsidy + advertising" mode will decrease. In other words, the greater the program differentiation, the more inclined the platform to charge consumers for membership mode. On the contrary, the smaller the program differentiation, the more inclined the platform to charge advertisers for advertising mode, and even do not hesitate to subsidize consumers to charge advertisers. This is because the greater the program differentiation, the more attractive the paid program content is to consumers. On the other hand, the smaller the program differentiation, the smaller the program competitive advantage of the paid platform in the consumer market, and fewer consumers are willing to pay, so the platform can only choose the advertising mode similar to the free platform.

Intuitively, this corollary is also in line with the reality. iResearch's survey on China's online video VIP members' interests in 2021, shows that 85.4% of the users value the VIP rights of "exclusive video content" and 87.2% of the users value the VIP rights of "the video content in advance or with high image and sound quality" (<https://www.iresearch.com.cn/Detail/report?id=3216&isfree=0>). And the 2021

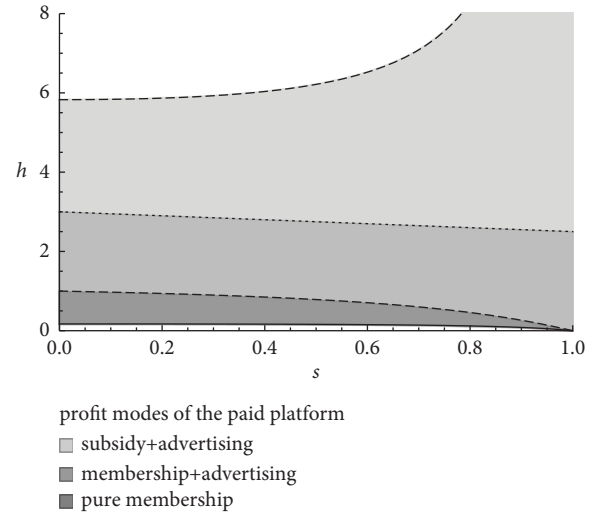


FIGURE 2: The profit modes of paid platform.

China online audiovisual user insight analysis shows that the main reasons for users to pay for membership are "you must pay for the content you want to watch," and "you can watch more content, with better clarity, and better sound effects." (<https://www.qianzhan.com/analyst/detail/220/210715-6609c1b3.html>). The above facts all support the research conclusions: the program differentiation will greatly affect the platform's profit mode. \square

Proposition 2. *For the free platform,*

- (i) when $h_0(s) < h \leq h_2(s)$, $a_2^* \leq 0$, the platform has no profit and exits the market;
- (ii) when $h_2(s) < h < h_3(s)$, $a_2^* > 0$, the platform adopts "free + advertising" mode;
- (iii) when $h_3(s) \leq h < h_1(s)$, $q_2^* \leq 0$, the platform has no consumers and exits the market.

Notes,
$$h_3(s) = \frac{(144 - 172s + 46s^2 - 3s^3 + \sqrt{18432 - 44544s + 39568s^2 - 16080s^3 + 3116s^4} - 276s^5 + 9s^6)/4}{(12 - 12s + s^2)},$$
 $h_2(s) = 12 - 13s + 2s^2 - \frac{\sqrt{128 - 288s + 217s^2 - 60s^3 + 4s^4}/4}{(1-s)},$ and when $0 < s < 1$, $h_2(s) < (1-s)(16 - 14s + s^2)/16 - s(26 - 12s + s^2) < (6-s)/2 < h_3(s)$.

Proof. See appendix (available here).

Proposition 2 shows that when the platform programs' differentiation is to a certain extent, the change of the positive and negative cross-network externalities may lead to the free platform exit the market. Only when the cross-network externality ratio is moderate, the free platform has a revenue source and exists in the market, as shown in Figure 3. The reason is that when the cross-network externality ratio is small (the positive effect brought by unit consumers is small and consumers' advertising aversion is high), advertisers are not willing to invest advertisement, and the free platform is forced to exit the market. Only when the degree of consumer advertising aversion is reduced or the value brought to advertisers by the consumers scale is large

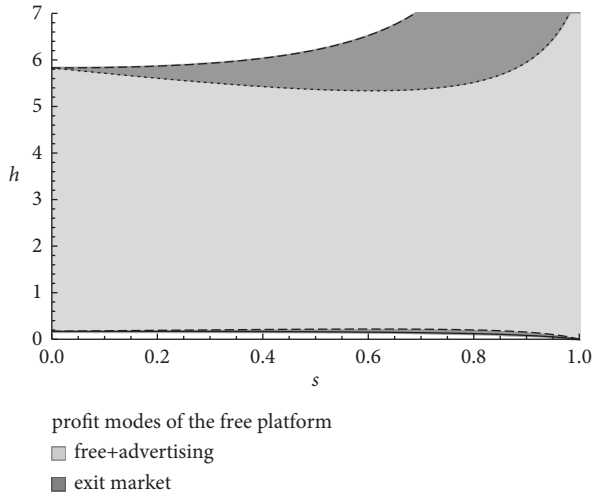


FIGURE 3: The profit modes of free platform.

enough, advertisers start to be willing to invest. When the cross-network externality ratio is large enough, in order to charge advertisers a higher fee, the paid platform will provide subsidies to attract consumers. At this time, the free platform is in an obvious competition disadvantage, and also forced to exit the market without consumer participation.

By comparing the result of Propositions 1 and 2, and similar to the analysis of Corollary 1, Corollarys 2, and 3 obtained. \square

Corollary 2. *The greater the program differentiation, the more likely the free platform is to exist. On the contrary, the smaller the program differentiation, the more likely the free platform is to exit the market.*

Corollary 3. *When the cross-network externality ratio is moderate, free platform and paid platform can coexist, and the greater the program differentiation, the greater the possibility of coexistence.*

Proof. See appendix (available here).

The above conclusions are different from Ferrando's research. Ferrando found that when the proportion of advertising haters is high, at least one enterprise would exit the advertising market, and when the cross-network externalities (negative externalities for advertising haters, positive externalities for advertising lovers) are large, two enterprises would exit the advertising market [20]. However, we find that whether the platform exits the market depends on the cross-network externality ratio. If the ratio is small, at least one platform will exit the advertising market. Especially when the ratio is small enough, the paid platform will exit the advertising market and the free platform will exit the consumer market.

Next, when the two platforms coexist, that is, under this condition $0 < s < 1$ and $h_2(s) < h < h_3(s)$, we will compare their equilibrium results, Proposition 3 and 4 obtained. \square

Proposition 3. *Comparing the demand and advertising volume of the two platforms,*

- (i) *when $h_2(s) \leq h < 2 - 2s/6 - 5s$, $a_1^* \leq a_2^*$. If $s \leq (4/5)$, $q_1^* \geq q_2^*$; If $s > (4/5)$, $q_1^* < q_2^*$.*
- (ii) *when $(2 - 2s/6 - 5s) < h < (6 - s/2)$, $q_1^* < q_2^*$, $a_1^* < a_2^*$.*
- (iii) *when $(6 - s/2) \leq h < h_3(s)$, $q_1^* \geq q_2^*$, $a_1^* > a_2^*$.*

Note, when $0 < s < 1$, $2 - 2s/6 - 5s < (1 - s)(16 - 14s + s^2)/16 - s(26 - 12s + s^2) < (6 - s)/2$.

Proof. See appendix (available here).

To validate the Proposition 3, no loss of generality, we suppose $s = 0.4$ and $s = 0.9$. When $s = 0.4$, the threshold $(2 - 2s/6 - 5s) = 0.3$, $(6 - s/2) = 2.8$. When $s = 0.9$, the threshold $(6 - s/2) = 2.55$. The conclusions conform to those in Figure 4.

Proposition 3 shows that the cross-network externalities and program differentiation will jointly affect the decisions of consumers and advertisers. (i) When the cross-network externality ratio is small (consumer advertising aversion is relatively large), the paid platform adopts the pure membership strategy, and its advertising volume is naturally smaller than the free platform. However, the consumers' demand is affected by the program differentiation. When the program differentiation is large, the paid platform has more competitive advantages, thus attracting more consumers. On the contrary, when the program differentiation is small, consumers prefer to choose the free platform without cost. (ii) When the cross-network externality ratio is in the middle (the positive effect of unit consumers increases or the negative effect of advertising on consumers weakens), the negative impact of program payment on consumer demand plays a dominant role. Therefore, the consumer demand and the advertising volume of the paid platform are lower than those of the free platform. (iii) When the cross-network externality ratio is large enough, the paid platform will adopt the subsidy strategy, so its consumer demand and advertising volume are higher than the free platform. \square

Proposition 4. *Comparing the revenue of the two platforms, when $h_2(s) < h < (6 - 3s/2)$ or $(6 - s/2) \leq h < h_3(s)$, $\Pi_1^* > \Pi_2^*$; otherwise, when $(6 - 3s/2) \leq h < (6 - s/2)$, $\Pi_1^* < \Pi_2^*$.*

Note, when $0 < s < 1$, $((1 - s)(16 - 14s + s^2)/16 - s(26 - 12s + s^2)) < (6 - 3s/2) < ((6 - s)/2)$.

Proof. See appendix (available here).

No loss of generality, we suppose $s = 0.5$, the threshold $(6 - 3s/2) = 2.25$, $(6 - s/2) = 2.75$. Figure 5 illustrates these cutoffs.

Proposition 4 shows that the paid program platform is not always dominant in the asymmetric competitive market of online video platforms. When the cross-network externality ratio is in the middle, the revenue of free platform will be higher than the paid platform. This is because, although the paid platform has a membership fee and an advertising fee two revenue sources, its advertising price and advertising volume are lower than the free platform, making its advertising revenue lower, and the membership revenue is not

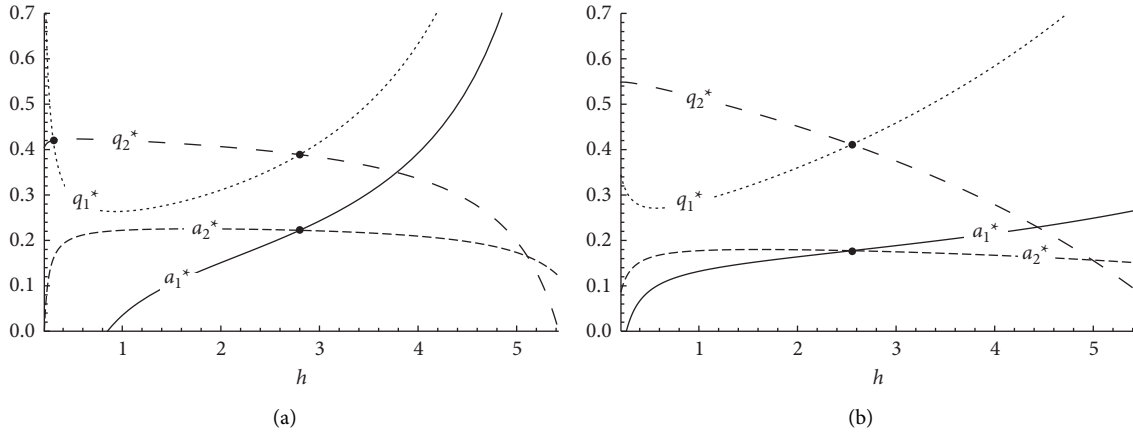


FIGURE 4: The impact of h on q and a . (a) $s = 0.4$ and (b) $s = 0.9$.

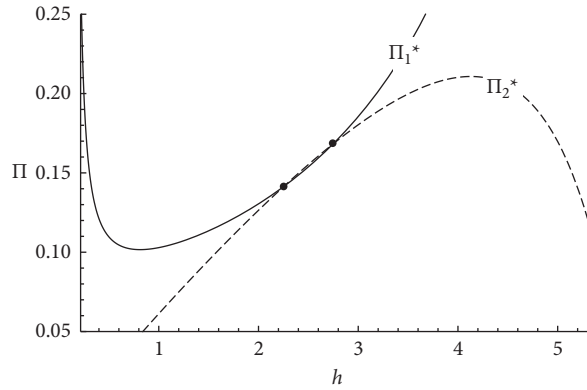


FIGURE 5: The impact of h on Π_1^* and Π_2^* .

enough to make up the advertising revenue gap. When the cross-network externality ratio is small or large, the paid platform can obtain higher membership fees or advertising revenue by subsidizing consumers, so that its total revenue is higher than that of the free platform.

By analyzing the impact of platform differences on the above threshold, similar to the Corollarys 1–3, we can obtain the following Corollary 4. \square

Corollary 4. *When the program differentiation is less than a certain threshold, with the greater the program differentiation, the revenue of free platform is more likely to be higher than that of the paid platform; when the program differentiation exceeds the threshold, on the contrary, the revenue of paid platform is more likely to be higher than that of the free platform.*

Proof. See appendix (available here). \square

5. Revenue and Revenue Structure Analysis

From the previous model analysis, we can see parameters, s , t and η can be considered as important factors affecting the competition and revenue structure of the video platform. The larger s (the smaller the difference in

program content), the more competitive; t and η are positive and negative cross-network externalities from the two-sided video platform, respectively, if the platform takes appropriate measures to adjust the positive and negative cross-network externalities, it can indirectly affect the demand on both sides of the platform, and then affect the two revenue sources of the platform. Next, we will study the differentiation, positive and negative cross-network externalities parameters to discuss their impact on the revenue of free and paid program platform.

In order to show more clearly how can these parameters affect the two revenue sources and revenue structure of the paid platform, we set the proportion of the members' revenue to the total revenue as follows (referred as the proportion of members' revenue):

$$A = \frac{\pi_{co}^*}{\pi_{co}^* + \pi_{ad}^*}, \tag{8}$$

$$= \frac{p^* q_1^*}{p^* q_1^* + r_1^* a_1^*}.$$

The proportion of members' revenue is found from the above equilibrium solution.

$$A = \frac{(1-s)(4-3s)\eta[(-6+s)t+2\eta][(32-30s+3s^2)t+2s\eta]}{G+4(32-116s+132s^2-54s^3+5s^4)t\eta^2+4(1-s)s(4-3s)\eta^3} \quad (9)$$

Notes, $G = 8(1-s)^2(16-14s+s^2)t^3 - (1-s)[768 + (-4s+s^2)(364-124s+9s^2)]t^2\eta$.

By analyzing the proportion of revenue, the following Proposition 5 can be obtained:

Proposition 5. For paid platforms,

(i) when

$$h_0(s) < h \leq ((1-s)(16-14s+s^2)/16 - s(26-12s+s^2)), A = 1;$$

(ii) when

$$(1-s)(16-14s+s^2)/16 - s(26-12s+s^2) < h \leq h_5(s), (1/2) \leq A < 1;$$

(iii) when $h_5(s) < h \leq (6-s/2)$, $0 \leq A < (1/2)$;

(iv) when $(6-s/2) < h < h_1(s)$, $A < 0$.

Proof. See appendix (available here).

No loss of generality, we suppose $s = 0.5$, the threshold $(1-s)(16-14s+s^2)/16 - s(26-12s+s^2) = 0.79$, $h_5(s) = 1.77$, $(6-s/2) = 2.75$. Figure 6 illustrates these cutoffs.

Proposition 5 shows that when the platform programs differentiation is a certain extent, with the change of cross-network externality ratio, the proportion of the members' revenue also changes correspondingly, and the revenue structure of the paid video platform is divided into the following 4 forms: (i) when the cross-network externality ratio is small (the positive effect is small and the advertising aversion is large), the paid platform will choose not to place advertisements to attract consumers to pay and obtain membership revenue. At this time, the paid video platform is the pure membership revenue structure. (ii) As the degree of consumer advertising aversion decreases, the bargaining power of the paid platform in the consumer market decreases, and then it begins to introduce advertising and obtain part of the advertising revenue. At this time, the paid video platform is the revenue structure of "membership + advertising," but is mainly based on membership revenue, supplemented by advertising revenue. (iii) When the cross-network externality ratio further increases, the bargaining power of the paid platform in the advertising market increases, and the advertising revenue of the

platform increases. At this time, the paid video platform still has the revenue structure of "membership + advertising," but the advertising revenue gradually replaces the membership revenue and becomes the main revenue source of the platform. (iv) When the cross-network externality ratio is large enough, the bargaining power of the paid platform in the advertising market is high, and the advertising aversion of consumers is relatively low. Therefore, in order to obtain more advertising revenue, the paid platform does not hesitate to use preferential subsidies to attract consumers. At this time, the paid video platform is still the revenue structure of "membership + advertising," but the platform subsidies make the revenue of members' loss, and the advertising revenue becomes the whole revenue source of the platform.

By analyzing the impact of platform differentiation on the above threshold, similar to the Corollaries 1-4, we can obtain the following Corollary 5: \square

Corollary 5. The greater the platform differentiation, the more likely the paid platform to adopt a membership-based revenue structure. On the contrary, the smaller the platform differentiation, the more likely the paid platform to adopt an advertising-based revenue structure.

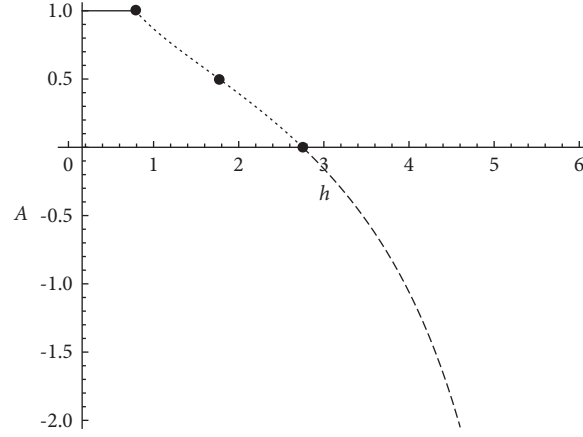
Proof. See appendix (available here).

Through the above analysis, we can find that paid platforms in different situations have different revenue sources and form different revenue structures. Then, how can the paid platform reasonably adjust the revenue of each part to optimize the revenue structure and increase the total revenue? When they coexist with the paid platform, how can free platform increase their advertising revenue? Next, we discuss the impact of program differentiation and cross-network externalities on platform revenue and revenue structure to answer the above questions. \square

5.1. Program Differentiation. By solving the first-order condition about the difference of platform revenue and the proportion of the members' revenue, we can get

$$\frac{\partial \Pi_1^*}{\partial s} = \frac{\partial(\pi_{co}^* + \pi_{ad}^*)}{\partial s} \quad (10)$$

$$\frac{\partial \Pi_2^*}{\partial s} = \partial \left(\frac{\eta[(s+s^2-2)t^2 + (12-13s+2s^2)t\eta - 2(1-s)\eta^2]^2}{2(2-s)[4(1-s)(t^2 + \eta^2) - 3(8-8s+s^2)t\eta]^2} \right) \partial s. \quad (11)$$

FIGURE 6: The impact of h on A ($s = 0.5$).

$$\frac{\partial A}{\partial s} = \frac{(1-s)(4-3s)\eta[(s-6)t+2\eta]\left[\left(32-30s+3s^2\right)t+2s\eta\right]}{G+4\left(32-116s+132s^2-54s^3+5s^4\right)t\eta^2+4(1-s)s(4-3s)\eta^3}\partial s. \quad (12)$$

By analyzing the positive and negative relations of the above expressions (10)–(12), the following Propositions 6–8 can be obtained:

Proposition 6. When the paid platform charges consumers, there are

- (i) “pure membership” mode, $(\partial\Pi_1^*/\partial s) < 0$, $(\partial A/\partial s) = 0$.
- (ii) “membership + advertising” mode, $(\partial\Pi_1^*/\partial s) < 0$, $(\partial A/\partial s) < 0$.

Note, $h_0^{-1}(h) = -(2(1-6h+h^2)/3h) + (2/3)\sqrt{1-9h+20h^2-9h^3+h^4/h^2}$ is the inverse function of $h = h_0(s)$, and s_1 is the inverse function of $h = (1-s)(16-14s+s^2)/16-s(26-12s+s^2)$.

Proof. See appendix (available here).

No loss of generality, we suppose $h = 0.5$ and $h = 2$, the threshold $s_1 = 0.77$. That is to say, when $h = 0.5$ and $s_1 < 0.77$, $\partial\Pi_1^*/\partial s < 0$, $\partial A/\partial s = 0$; when $h = 0.5$ and $s > 0.77$, or $h = 2$, $(\partial\Pi_1^*/\partial s) < 0$, $(\partial A/\partial s) < 0$. Figures 7 and 8 illustrate these cutoffs.

Proposition 6 shows that whether the platform adopts the strategy of “pure membership” or “membership + advertising,” the greater the program differentiation, the higher the total revenue of the platform. In addition, when the platform adopts the strategy of “membership + advertising,” with the program differentiation increases, the proportion of members’ revenue is also increasing. That is, when the platform charges consumers, with the program differentiation increases, the platform is more dependent on the revenue structure of membership fees. \square

Proposition 7. The paid platform subsidizes consumers,

- (i) when $2.5 < h < 3$, $\partial\Pi_1^*/\partial s < 0$,

$$\begin{cases} (\partial A/\partial s) < 0, \text{ if } 6-2h < s < s_2^*, \\ (\partial A/\partial s) > 0, \text{ if } s > s_2^*. \end{cases}$$
- (ii) when $3 < h < 3+2\sqrt{2}$,

$$\begin{cases} (\partial\Pi_1^*/\partial s) > 0, (\partial A/\partial s) < 0, \text{ if } s < s_2^{**}, \\ (\partial\Pi_1^*/\partial s) > 0, (\partial A/\partial s) > 0, \text{ if } s_2^{**} < s < s_3, \\ (\partial\Pi_1^*/\partial s) < 0, (\partial A/\partial s) > 0, \text{ if } s > s_3. \end{cases}$$
- (iii) when $h > 3+2\sqrt{2}$, $(\partial\Pi_1^*/\partial s) < 0$, $(\partial A/\partial s) > 0$.

Note, s_2^* and s_2^{**} is the threshold function of $(\partial A/\partial s) = 0$, s_3 is the threshold function of $\{(\partial\Pi_2^*/\partial\eta) \geq 0, (\partial\Pi_2^*/\partial t) \leq 0, (\partial\Pi_2^*/\partial h) \geq 0, \text{ if } h_2(s) < h \leq h_7(s) (\partial\Pi_2^*/\partial\eta) < 0, (\partial\Pi_2^*/\partial t) > 0, (\partial\Pi_2^*/\partial h) < 0, \text{ if } h_7(s) < h < h_3(s)\}$.

Proof. See appendix (available here).

No loss of generality, we suppose $h = 2.8, 4, 6$. when $h = 2.8$, the threshold $6-2h = 0.4$, $s_2^* = 0.74$; when $h = 4$, the threshold $s_2^{**} = 0.22$, $s_3 = 0.44$. This is illustrated in Figures 9 and 10, which verifies the conclusion of Proposition 7.

Proposition 7 shows that when the paid platform adopts the strategy of “subsidy + advertising,” affected by the relative size of the positive and negative cross-network externalities, the impact of program differentiation on the total revenue and the proportion of the members’ revenue can be divided into three situations: (i) when the cross-network externality ratio is relatively small, the total revenue of the platform increases in s , and the proportion of the members’ revenue is a convex in s (the members loss of platform first increases and then decreases); (ii) when the cross-network externality ratio is in the middle, the total revenue of platform is a concave in s , and the proportion of the members’ revenue is opposite; (iii) When the cross-network externality ratio is large enough, with the increase of program differentiation, the total revenue of the platform increases and the proportion of members’ revenue decreases. In conclusion, when the paid platform subsidizes consumers,

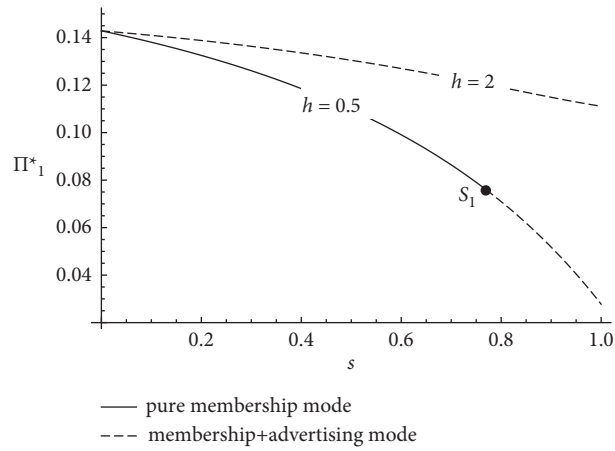


FIGURE 7: The impact of s on Π_1^* .

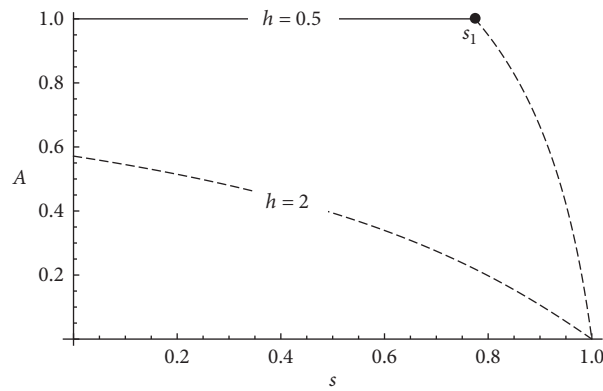


FIGURE 8: The impact of s on A .

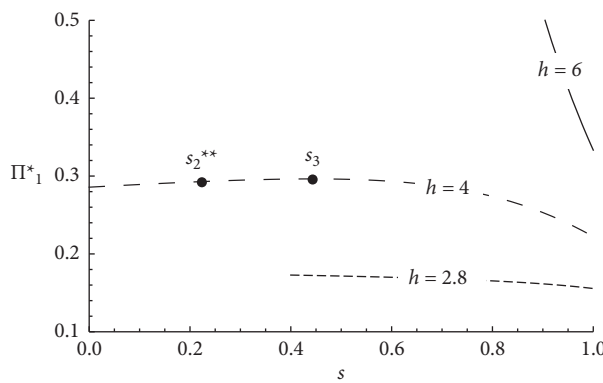
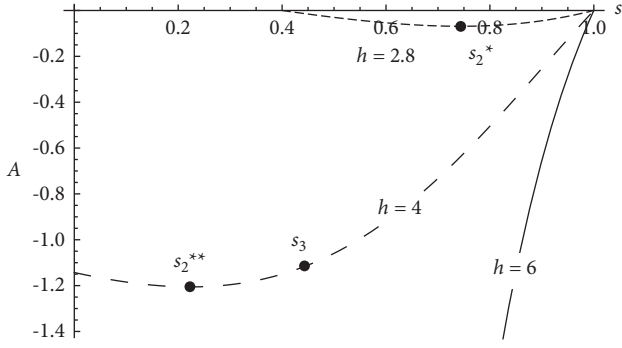


FIGURE 9: The impact of s on Π_1^* .

the impact of the cross-network externality ratio and program differentiation on subsidies are nonlinear, which makes the change of the total revenue of the platform more complicated. Therefore, choosing the strategy of “subsidies + advertising,” platform should pay special attention to the positive and negative cross-network externality on both sides of the market. We should try to increase the

program differentiation to increase revenue when the ratio is small or large. And we only need to maintain a moderate level of program differentiation to obtain higher total revenue when the ratio is in the middle. □

Proposition 8. For the free platforms,

FIGURE 10: The impact of s on A .

- (i) when $3 - 2\sqrt{2} < h \leq (1/8)(15 - \sqrt{65})$,
 $\begin{cases} (\partial\Pi_2^*/\partial s) \leq 0, \text{ if } s \leq \max[s_4^*, h_2^{-1*}(h)], \\ (\partial\Pi_2^*/\partial s) > 0, \text{ if } s > \max[s_4^*, h_2^{-1**}(h)]. \end{cases}$;
- (ii) when $(1/8)(15 - \sqrt{65}) < h \leq 1$, $(\partial\Pi_2^*/\partial s) < 0$;
- (iii) when $1 < h < 3$, $\begin{cases} (\partial\Pi_2^*/\partial s) \geq 0, \text{ if } s \leq s_5, \\ (\partial\Pi_2^*/\partial s) < 0, \text{ if } s > s_5. \end{cases}$;
- (iv) when, $3 < h \leq 3 + 2\sqrt{2}$,
 $\begin{cases} (\partial\Pi_2^*/\partial s) \leq 0, \text{ if } s \leq \max[s_4^{**}, h_3^{-1}(h)], \\ (\partial\Pi_2^*/\partial s) > 0, \text{ if } s > \max[s_4^{**}, h_3^{-1}(h)]. \end{cases}$.

Note, $h_2^{-1*}(h)$, $h_2^{-1**}(h)$ are the inverse function of $h_2(s)$. s_4^* and s_4^{**} are the threshold function of $\partial\Pi_2^*/\partial s = 0$. $h_3^{-1}(h)$ is the inverse function of $h_3(s)$.

Proof. See appendix (available here).

No loss of generality, we suppose $h = 0.5, 0.9, 2, 4$. When $h = 0.5$, the thresholds function $h_2^{-1*}(h)$ and $h_2^{-1**}(h)$ do not exist, $s_4^* = 0.77$; when $h = 2$, the threshold function $s_5 = 0.36$; when $h = 4$, the threshold function $h_3^{-1}(h)$ does not exist, $s_4^{**} = 0.76$. This is illustrated in Figure 11, which verifies the conclusion of Proposition 8.

Proposition 8 shows that in the asymmetric competitive markets, the relative size of positive and negative cross-network externalities can regulate the impact of program differentiation on free platform revenue. (i) When the cross-network externality ratio is small, the revenue of free

platform is a convex in s . At this time, the free platform can obtain higher revenue by taking measures that make the program differentiation large enough or small enough. (ii) With the decrease of consumer advertising aversion or the increase of value brought by unit consumers to advertisers, especially when the two externalities are close, the revenue of free platform increases with the increase of program differentiation, at this time, the free platform can obtain higher revenue if the program differentiation is large enough. (iii) When the cross-network externality ratio further increases (the positive cross-network externality is relatively large or the negative cross-network externality is relatively small), with the increase of program differentiation, the revenue of free platform first increases and then decreases, and the free platform only needs to maintain a moderate level of program differentiation to obtain a higher revenue. (iv) When the cross-network externality ratio is large enough, with the increase of program differentiation, the revenue of free platform first decreases and then increases, which is consistent with the conclusion of case i), but contrary to the conclusion of case iii), if the free platform still maintains a moderate level of program differentiation at this time, it will lead to lower revenue. From the above analysis, affected by the positive and negative cross-network externalities, for free video platforms, it is not always the best to improve the level of program differentiation (especially when the cross-network externality ratio is moderate), nor is it always the worst to reduce the level of program differentiation (especially when the cross-network externality ratio is large and small). Therefore, when adjusting the level of program differentiation, the free video platform should pay special attention to the cross-network externality ratio on both sides of the market, otherwise, it may be counterproductive. \square

5.2. The Positive and Negative Cross-Network Externality.

By solving the first-order condition about the cross-network externalities of platform revenue and the proportion of the members' revenue, we can get

$$\frac{\partial\Pi_1^*}{\partial\eta} = \frac{\partial(\pi_{co}^* + \pi_{ad}^*)}{\partial\eta}. \quad (13a)$$

$$\frac{\partial\Pi_1^*}{\partial t} = \frac{\partial(\pi_{co}^* + \pi_{ad}^*)}{\partial t}. \quad (13b)$$

$$\frac{\partial\Pi_1^*}{\partial h} = \frac{\partial(\pi_{co}^* + \pi_{ad}^*)}{\partial h}. \quad (13c)$$

$$\frac{\partial\Pi_2^*}{\partial h} = \frac{\partial\left(h\left[(s + s^2 - 2) + (12 - 13s + 2s^2)h - 2(1 - s)h^2\right]^2/2(2 - s)\left[4(1 - s)(1 + h^2) - 3(8 - 8s + s^2)h\right]^2\right)}{\partial h}. \quad (14)$$

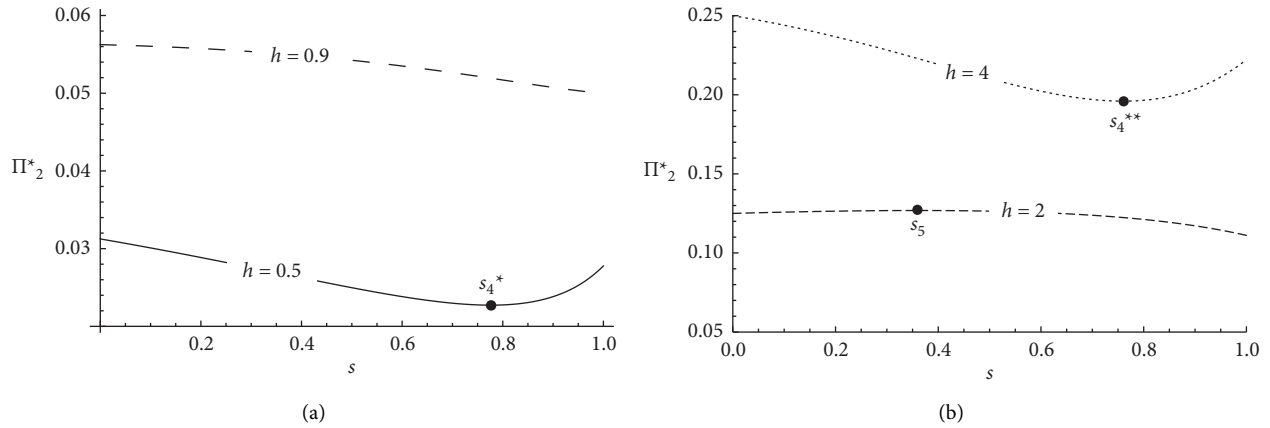


FIGURE 11: The impact of s on Π_2^* .

By analyzing the positive and negative relations of the above expressions (13a)–(14), the following Propositions 9 and 10 can be obtained:

Proposition 9. For paid platforms,

- (i) when $h_0(s) < h < h_6(s)$, $(\partial \Pi_1^* / \partial \eta) < 0$, $(\partial \Pi_1^* / \partial t) > 0$, $(\partial \Pi_1^* / \partial h) < 0$; otherwise, when $h_6(s) < h < h_1(s)$, $(\partial \Pi_1^* / \partial \eta) > 0$, $(\partial \Pi_1^* / \partial t) < 0$, $(\partial \Pi_1^* / \partial h) > 0$.
- (ii) $(\partial A / \partial \eta) < 0$, $(\partial A / \partial t) > 0$, $(\partial A / \partial h) < 0$.

Note, $h_6(s)$ is the threshold function of $(\partial \Pi_1^* / \partial h) = 0$.

Proof. See appendix (available here).

No loss of generality, we suppose $s = 0.5$, the threshold $h_6(s) = 0.81$. When we suppose $t = 1$, the threshold $\eta^* = h_6(s) = 0.81$; when $\eta = 1$, the threshold $t^* = (1/h_6)(s) = 1.23$. This is illustrated in Figures 12–14, which verifies the conclusion of Proposition 9.

Proposition 9 and Figures 12–14 show that, (i) affected by the relative size of the positive and negative cross-network externalities, the influence of cross-network externalities on the total revenue of paid video platforms will have a completely different change trend. In particular, when the program differentiation is certain ($s = 0.5$), if the cross-network externality ratio is sufficiently small ($h < 0.81$, but the scope of adopting the “pure membership fee” strategy is $h < 0.79$), the platform mainly adopts the “pure membership fee” strategy. In addition, the increase of negative cross-network externality is more favorable for the platform to implement the “pure membership fee” strategy. The increase of positive cross-network externality will reduce the platform’s motivation to implement the “pure membership fee” strategy. As the impact of positive cross-network externality on platform revenue is dominant, the total revenue of paid platforms is negatively related to the cross-network externality ratio. With the degree of consumer advertising aversion decreases or the value of unit consumers to advertisers increases ($h > 0.81$), the paid platform will adopt the strategy of “member + advertising” or the strategy of “subsidy + advertising.” At this time, the positive (negative) effect of the positive (negative) cross-network externality on

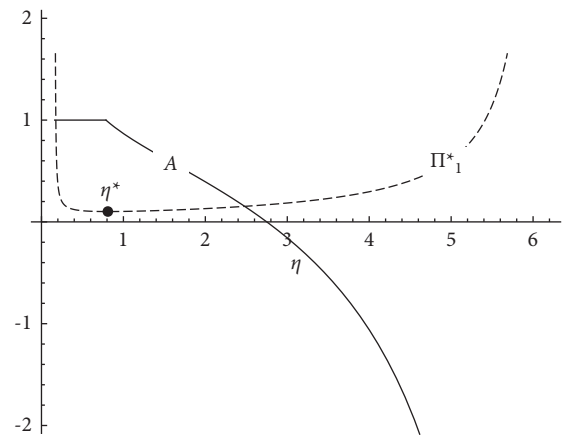


FIGURE 12: The impact of η on Π_1^* and A .

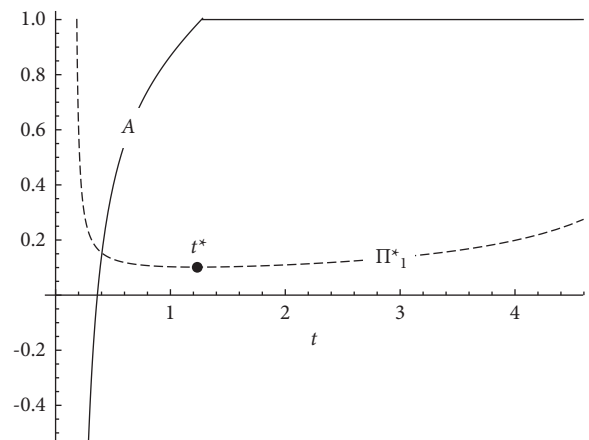


FIGURE 13: The impact of t on Π_1^* and A .

the advertising revenue is greater than (less than) the negative (positive) effect on the member revenue, so the increase in advertising revenue is relatively large, and thus the total revenue of the paid platform will increase. Therefore, the total revenue of paid platform is positively correlated with the cross-network externality ratio (ii) The larger the cross-network externality ratio, that is, the greater

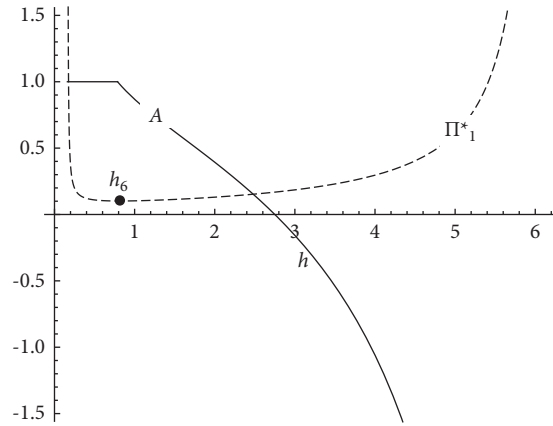


FIGURE 14: The impact of h on Π_1^* and A .

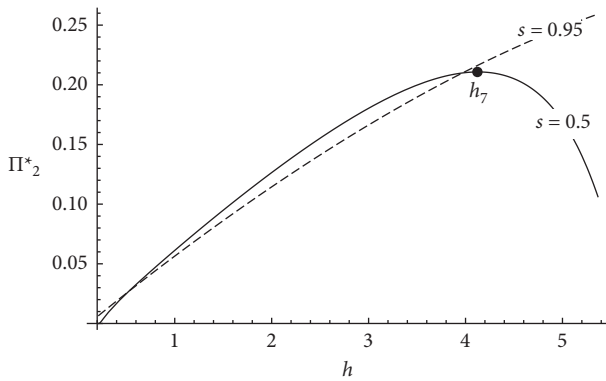


FIGURE 15: The impact of h on Π_2^* .

the positive cross-network externality (or the smaller the negative cross-network externality), the smaller the proportion of the members' revenue. In other words, the greater the value of consumer scale to advertisers, the more dependent the paid video platform on advertising revenue; on the contrary, the greater the degree of consumer advertising aversion, the more dependent the paid video platform on member revenue. \square

Proposition 10. For free platforms,

- (i) when $s < 0.924$, $\{ (\partial\Pi_2^*/\partial\eta) \geq 0, (\partial\Pi_2^*/\partial t) \leq 0, (\partial\Pi_2^*/\partial h) \geq 0, \text{ if } h_2(s) < h \leq h_7(s) \}$
 $\Pi_2^*/\partial\eta < 0, (\partial\Pi_2^*/\partial t) > 0, (\partial\Pi_2^*/\partial h) < 0, \text{ if } h_7(s) < h < h_3(s);$
- (ii) when $s > 0.924$, $(\partial\Pi_2^*/\partial\eta) > 0, (\partial\Pi_2^*/\partial t) < 0, (\partial\Pi_2^*/\partial h) > 0.$

Note, $h_7(s)$ is the threshold function of $(\partial\Pi_2^*/\partial h) = 0$.

Proof. See appendix (available here).

No loss of generality, we suppose $s = 0.5$ and $s = 0.95$, the thresholds $h_7(s) = 4.13$. This is illustrated in Figure 15, which verifies the conclusion of Proposition 10.

Proposition 10 shows that in the asymmetric competitive market, the level of program differentiation can adjust the impact of cross-network externalities on the free platform

revenue. When there is a certain difference between the two video platforms, with the increase of the cross-network externality ratio, the revenue of free platform first increases and then decreases, which is contrary to the conclusion of paid platform. However, when the program difference between the two video platforms is small, the revenue of free platform increases in h . Therefore, when competing with the paid platform, the free video platform should determine whether to take consistent or opposite measures to adjust the revenue with the paid platform according to the size of program differentiation. Specifically, when paid platforms take measures to make the cross-network externality ratio large enough or small enough, while for almost completely replaceable free platforms, measures to make the ratio large enough are beneficial, but measures to make the ratio is small enough are not beneficial; for free platforms with certain difference, regardless of the cross-network externality ratio is sufficient large or small enough, measures are unfavorable because they need to keep the ratio at a moderate level to obtain higher revenue. \square

6. Conclusion

Based on the actual situation of the online video industry, this paper develops an asymmetric competition model with a free program platform and a paid program platform. This paper explores the revenue source and revenue structure of the online video platform and focuses on the factors of positive and negative cross-network externalities and program differentiation. We hope to provide reasonable advice to online video platform for optimizing the revenue structure and improving the total revenue.

The revenue and revenue structure of online video platforms is affected by the program differentiation and positive and negative cross-network externalities. The results show that changes in the relative relationship of positive and negative cross-network externalities may lead to free platform exiting the consumer market or paid platform exiting the advertising market. Only when the ratio of positive and negative cross-network externalities is moderate, the free and paid platform can coexist, and the greater the difference of program, the greater the possibility of coexistence. With

the effect of the positive and negative cross-network externalities, the multi-revenue structure of the payment mode is not always better than the single revenue structure of the free platform. In addition, the impact of the positive and negative cross-network externalities and program differentiation on the revenue of free and paid platforms are nonlinear. If the platform wants to achieve greater revenue through the adjustment of revenue structure, it should fully consider the relative relationship of positive and negative cross-network externalities and program differentiation, otherwise it may bring losses.

The conclusions from our study have some managerial implications. When they adjust the revenue structure and improve the total revenue, the online video platforms must pay attention to coordinating the relative relationship between the positive and negative cross-network externalities and the level of platform program differentiation. Specifically, on the one hand, in the asymmetrical competition market, the paid platform should make some measures to improve the level of program differentiation such as self-made or purchase high-quality, exclusive, and innovative programs; expand the gap between paid and free content and adjust the revenue structure to the “pure membership fee” or “membership + advertising” mode as much as possible. The free platform should also provide UGC or other differentiated program content, strive not to be eliminated by the market, and pay attention to the strategy of competitors, otherwise, it will reduce its own revenue. On the other hand, (1) the paid platforms with different revenue structure should adopt different ways to increase the total revenue. For the platforms of “pure membership fee” revenue structure, they should focus on improving the level of program differentiation, optimizing functions, upgrading channels, updating brand identification system and other measures to improve the member experience; for the platforms of “membership fee + advertising” revenue structure, they should also improve the level of program differentiation, and update the advertising form, precisely advertise targeted advertising, design diversified advertising content to increase the advertisers net revenue, and improve the willingness of them to invest. For the platforms of “subsidy + advertising” revenue structure, they should increase the net revenue of advertisers, but only need to maintain a moderate level of differentiation. (2) For almost completely replaceable free platforms, they should take measures to improve the positive cross-network externality and reduce the negative cross-network externality as much as possible; for free program platforms with considerable differences, they should adjust the cross-network externality ratio to maintain a moderate level, so as to obtain higher revenue.

There are still some deficiencies in this research, but it also provides a direction for future research. First of all, this paper assumes that the parameters of positive and negative cross-network externalities are exogenous. In fact, the platform can take some measures to adjust the parameters, so it is the direction of model improvement to endogenize the cross-network externalities. Secondly, this paper assumes that the video platform has advertising and

membership as two revenue sources. Naturally, the platform has other revenue methods, such as copyright distribution and other value-added services, which can be researched in the future. Third, this paper concludes that improving the level of program differentiation will help to increase the total revenue. However, how to improve the level of program differentiation and what factors will affect the level of program differentiation are issues worth further study. Finally, it is also an interesting research direction to use empirical analysis to study the impact of positive and negative cross-network externalities, platform program differences and other factors on platform revenue, and whether the role of these factors changes when discussing three or more players.

Data Availability

The data used to support the findings of this study are included in the supplementary information file.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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Supplementary Materials

The supplementary material file is the proof appendix, which contains proofs of all Corollaries and propositions in the paper. (*Supplementary Materials*)

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