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Research Article

Pricing Strategies of Registration System and Transaction System in Live Broadcast Platform

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This paper investigates a supply chain consisting of the monopoly live broadcast platform, content producers, and consumers. Based on the two-sided market theory, the platform's pricing strategies and their analysis are considered under the registration system and the transaction system. Firstly, it shows that platform users' scale and profit are positively correlated with the intergroup network externality from both sides and the intragroup network externality inside the consumer group and negatively correlated with the intragroup network externality inside the content producer group. Secondly, the platform profit, registration fee charged to content producers, and transaction fee charged to consumers are negatively correlated to the content production cost and positively related to consumers' content quality sensitivity coefficient. When consumers are more sensitive to content quality, they are positively correlated to content quality. Finally, the registration fee charged by the platform to consumers is positively correlated with the content production cost, negatively correlated with the content quality level, and positively associated with the consumer content quality sensitivity coefficient.

1. Introduction

With the innovation of Internet technology and the popularity of mobile smart devices, live broadcast platforms came into being. Since 2014, thanks to relevant policy support, game live broadcast platforms represented by Douyu, Huya, and Panda TV and short video entertainment live broadcast platforms represented by TikTok and Kwai have emerged one after another. Since 2019, Internet celebrity live broadcasts represented by Li Jiaqi and Wei Ya have pushed live e-commerce broadcasts to the forefront of the industry. The growth of online entertainment and consumer demand during the COVID-19 epidemic has further stimulated the rapid development of the live broadcasting industry. According to the 46th Statistical Report on Internet Development in China released by China Internet Information Center, as of June 2020, the overall scale of Chinese Internet users was 940 million, and the scale of live broadcast users reached 562 million, which increases 44.3 million people over March 2020, accounting for 59.8% of the overall scale of Internet users [1]. Various live broadcast platforms have established a vast user group relying on new technologies and media forms.

Compared with traditional video websites, the live broadcast platform has a similar membership mode in user charging fees. The platform asks users for corresponding membership fees according to the quality level of content. With the continuous changes in the operating mode, the platform exhibits two-sided market characteristics different from the previous one-sided video sites. The platform acts as an intermediary to attract content producers, consumers, and other users to join the platform for transactions. The effectiveness of one user entering the platform depends on the user scale of the other user on the platform, so there are significant network externalities among users. Different types of live broadcast platforms have different operating mechanisms and profit modes. The user scale of entertainment live broadcast platforms accounts for more than half of the overall domestic live broadcast market, whose profit mode is mainly based on membership and live broadcast reward sharing. The core revenue of e-commerce webcast platforms comes from technical service fees and transaction commission sharing. The enterprise live broadcast platforms provide customized services for related industries and charge corresponding entry fees according to customer needs and provide one-stop platform services. In general, the profit of the platform mainly includes membership income and live streaming rewards. While the platform offers high-quality products and services, it charges users a certain platform entry fee or membership fee. Consumers make rewards or transactions by purchasing virtual products. Then, the platform divides the transaction revenue with content producers. This paper summarizes the charging methods as two charging modes: the registration system and the transaction system.

In recent years, the relevant literature has focused on the live broadcast industry's operating mechanism and governance dilemmas. From the perspective of two-sided markets, Cheng and Wang pointed out that live broadcast platforms use network effects to achieve exponential growth of users. Through case analysis, the internal governance mechanism of the platform to attract and manage content producers and recipients is discussed [2]. Li et al. applied the network externalities to construct the consumer utility function and discussed the influence of network externalities on the number of rewards, pricing, platform, and anchor revenue [3]. Mei and Hou analyzed the participants involved in the operation of e-commerce live broadcast and discussed the business mode and current status of the live broadcast industry [4]. Given the current governance issues of webcasting, Xu proposed to build a webcasting governance system from the perspective of government legislation and industry technical support [5]. The literature mentioned above rarely studies the internal pricing mechanism of live broadcast platforms from the two-sided market and network effects. Therefore, this paper takes the live broadcast platform as the research object and studies the platform pricing strategy based on the two-sided market and network externality theory.

Relevant scholars have analyzed the two-sided market from three perspectives: market definition, market classification, and market characteristics. Rochet and Armstrong, respectively, defined two-sided markets from pricing structure and network externalities [6, 7]. Evans classified two-sided markets from the viewpoint of market functions, market complexity, and market competition [8, 9]. Xu et al. examined the typical characteristics of a two-sided market economy between the multiproduct monopoly industry and the network industry. They pointed out that the cross-network effect between users is significant [10]. By analyzing the evolution history and conditions of two-sided markets, Huang found that most two-sided markets are transformed from one-sided markets, and two-sided demand exists simultaneously. The platform can condense and maintain a sufficient number of bilateral users, and buyers and sellers have cross-network externalities [11]. The research on the theory of a two-sided market has been relatively mature and complete. Therefore, based on Armstrong's two-sided market theory, this paper will build a market model composed of live broadcast platforms, content producers, and consumers.

There has been a lot of research studies on the pricing issues of different types of two-sided platforms, for example, group buying platforms, computer operating system platforms, electronic game platforms, telecommunications platforms, online car-hailing platforms, online shopping and dating platforms, logistics information platforms, cloud manufacturing platforms, and e-commerce platforms as the research objects, respectively. Related scholars introduced different influencing factors and focused on the pricing strategies of bilateral media under monopoly and duopoly. They presented various influencing factors and investigated the pricing strategies of two-sided platforms under monopoly and duopoly [12–21]. Most literatures study platform pricing from the perspective of intergroup network externality, while few literatures consider the influence of network externalities within the group when establishing models. It is also worth noting that users mainly think about content quality and user experience rather than price when joining a live broadcast platform. At present, most models are not suitable for live broadcast platforms where users have significant intragroup network externalities and content quality sensitivity. Therefore, this paper will consider the characteristics of live broadcast platforms, intergroup, and intragroup network externalities to discuss the influence of factors, such as platform content production cost, content quality, and user quality sensitivity, on platform profit and pricing.

As an innovative industry, the live broadcast platform has the typical characteristics of a two-sided market. The fees charged by the platform to users are not determined by the marginal profit, and the optimal value cannot be obtained according to the previous one-sided market pricing strategy. Related research studies mainly focus on platform operation mechanisms, governance dilemmas, legal supervision, and so on, ignoring the two-sided platform characteristics of live broadcast platforms. In response to the abovementioned objective phenomena, this paper uses two-sided market theory, game theory, and other theoretical methods to study the pricing strategy of the live broadcast platform under the registration system and the transaction system.

The contributions of this paper are as follows. Firstly, it investigates the internal pricing decisions of live broadcast platforms from two aspects of the two-sided market and network effects. Secondly, it reflects consumers' sensitivity to content quality and intergroup network externality to establish user utility. Finally, it considers the platform's actual operation and studies the platform's pricing strategy under multiple transaction systems. In the two systems, the specific industry characteristics of the live broadcast platform are considered, and parameters such as network externalities, platform content quality, and user sensitivity to quality are introduced to analyze the impact of these factors on platform revenue and pricing. The paper provides feasible suggestions for pricing strategies and profit models of the live broadcast industry.

2. Research Assumptions and Modelling

2.1. Description of the Models. This paper studies a two-sided market consisting of a monopolistic live broadcast platform, content producers, and consumers. Under the monopoly market structure, the platform has two groups of participants: content producers and consumers. The transactions between them are realized through the platform. According to the platform's market position and operating mode, the platform faces the problem of how to charge participating users registration fees (the fees for using platform services) and transaction fees (the fees for purchasing virtual products on the platform). The charging mode is shown in Figure 1.

The difference between the two modes is that the platform under the registration system charges both content producers and consumers. In reality, the registration fee can be regarded as the membership fee charged by the platform to users. For example, Bilibili, a live broadcast platform in China, charges consumers and content producers for membership. Users can enjoy the platform's value-added service by purchasing the platform's membership. However, under the transaction system, the platform only charges consumers. The platform determines the share ratio of the live broadcast rewards and the transaction fees. Content producers conduct the live broadcast through the technology and services provided by the platform. Consumers participate in the live broadcast of the content producer and pay rewards to the anchors they like. After getting the tips, the platform will share the revenue with the content producers according to a specific ratio.

According to Armstrong's definition of the two-sided market, two groups of users trade through the platform. The utility of one group of users joining the platform depends on the number of other users joining the platform. Therefore, intergroup network externality is a significant two-sided market feature of the live broadcast platform. As the number of content producers and consumers increases, the number of consumers and content producers will increase, respectively. Therefore, there is a positive external network externality between the two groups of users. The increase in content producers will intensify resource competition on the platform, which will reduce the participation of new users. Therefore, there are negative internal network externalities within content producers. The increase in consumers will attract new users to join the platform, so there is a positive internal network externality within the consumer users.

Based on the above views, it assumes that there are only two groups of users and two charging modes on the platform: group s (content producers), group b (consumers), mode 1 (registration system), mode 2 (single transaction system), and mode 3 (multiple transactions system). The involved parameters and meanings are shown in Table 1.

In order to facilitate the analysis, the operating cost of the platform is not considered, and the goal of platform operation is to maximize revenue. Based on the above assumptions, a two-stage game model is established. In the first stage, the platform determines the charging mode under the registration system and the transaction system. In the second stage, the users choose whether to join the platform according to their own utility threshold. Under the premise of two charging modes and the scale of users joining the platform, the platform determines the optimal pricing for content producers and consumers under the two modes by solving the problem of maximizing revenue.

2.2. Registration System Mode. One of the main charging modes adopted by the Internet live broadcast platform is to charge users membership fees according to a certain period, which is described as the registration fee in the registration system mode. Under this charging mode, the platform charges registration fees from content producers and consumers. As a well-known video website in China, Bilibili's membership fee standard is shown in Table 2.

When the platform charging mode is the registration system, the platform will charge content producers p_{s1} for entering the platform, and consumers will be charged a membership fee p_{s1} for joining the platform. Referring to Amstrong [6] and Zhao's model [19], the utility of users and profit of the platform are, respectively,

$$U_{s1} = \alpha_s n_{b1} - \beta_s n_{s1} - p_{s1} - cq + v_{s1}, \tag{1}$$

$$U_{b1} = \alpha_b n_{s1} + \beta_b n_{b1} - p_{b1} + \theta q + v_{b1}, \tag{2}$$

$$\pi_1 = p_{s1} n_{s1} + p_{b1} n_{b1}. \tag{3}$$

Two groups of users decide whether to join the platform based on their respective utility. They will only choose to join the platform when their total utility is greater than zero. Therefore, when $U_i\,(i = s, b) = 0$, the critical values of user utility are $v_{s1}^* = \beta_s n_{s1} + p_{s1} + cq - \alpha_s n_{b1}$ and $v_{b1}^* = p_{b1} - \alpha_b n_{s1} - \beta_b n_{b1} - \theta q$, respectively. The users decide to join the platform only when the utility is not lower than v^*, and v is uniformly distributed in $(0, 1)$. Therefore, according to the utility probability distribution function $P(v \geq v^*) = 1 - P(v < v^*) = 1 - F(v^*) = 1 - v^*$, the minimum user scale to join the platform is, respectively,

$$n_{s1} = 1 \times P\left(v \geq v_{s1}^*\right) = 1 + \alpha_s n_{b1} - \beta_s n_{s1} - p_{s1} - cq, \tag{4}$$

$$n_{b1} = 1 \times P\left(v \geq v_{b1}^*\right) = 1 + \alpha_b n_{s1} + \beta_b n_{b1} - p_{b1} + \theta q. \tag{5}$$

According to the assumptions in Section 2.1, $0 \leq 1 \times P(v \geq v^*) \leq 1$ must be satisfied. Therefore, $v^* \in (0, 1)$ must be satisfied. From equations (4) and (5), we get that

$$n_{s1} = \frac{\left(1 - p_{s1} - cq\right)\left(1 - \beta_b\right) + \left(1 - p_{b1} + q\theta\right)\alpha_s}{\left(1 + \beta_s\right)\left(1 - \beta_b\right) - \alpha_s \alpha_b}, \tag{6}$$

$$n_{b1} = \frac{\left(1 - p_{b1} + q\theta\right)\left(1 + \beta_s\right) + \left(1 - p_{s1} - cq\right)\alpha_b}{\left(1 + \beta_s\right)\left(1 - \beta_b\right) - \alpha_s \alpha_b}. \tag{7}$$

Substituting equations (6) and (7) into equations (3) and solving the first-order condition of profit maximization: $\partial\pi_1/\partial p_{s1} = 0$ and $\partial\pi_1/\partial p_{b1} = 0$. The equilibrium registration fees are, respectively,

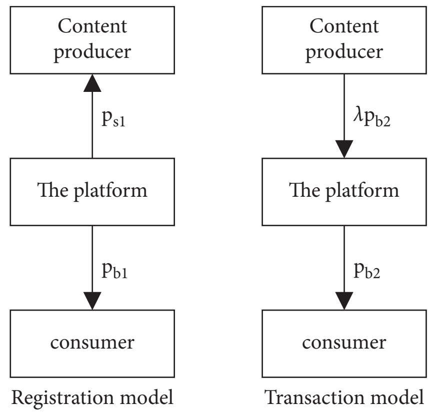

FIGURE 1: Platform charging mode.

TABLE 1: Denotations for modelling.

Parameters	Meanings
n_{ij}	The number of the group i in the platform under the charging mode $j (i = s, b, j = 1, 2, 3)$, where $n_{ij} \in (0, 1)$
p_{s1}	The registration fee charged by the platform to the content producers under the registration system
p_{b1}	The registration fee charged by the platform to the consumers under the registration system
p_{b2}	The transaction fee charged by the platform to the consumers under the transaction system
α_i	The intergroup network externality coefficient that a single user inside the group joining the platform brings to users outside the group i, where $\alpha_i \in (0, 1)$
β_i	The intragroup network externality that a single user joining the platform brings to users inside the group i, where $\beta_i \in (0, 1)$
v_{ij}	The basic utility of users to join the platform, which is uniformly distributed on $(0, 1)$
c	The cost for producers to produce content with relevant quality levels, where $c \in (0, 1)$
q	The quality level of content produced by content producers, where $q \in (0, 1)$
λ	The transaction share ratio between the platform and the content producer, where $\lambda \in (0, 1)$
θ	The consumer's sensitivity to the quality level of the platform's content, where $\theta \in (0, 1)$

TABLE 2: Membership fee of Bilibili.

Membership cycle	Membership fee charged by the platform
Month	25 ¥
Quarter	68 ¥
Year	168 ¥

$$p_{s1}^* = \frac{(1 + q\theta)(1 + \beta_s)(\alpha_s - \alpha_b) + (1 - cq)[2(1 + \beta_s)(1 - \beta_b) - \alpha_b(\alpha_s + \alpha_b)]}{4(1 + \beta_s)(1 - \beta_b) - (\alpha_s + \alpha_b)^2}, \tag{8}$$

$$p_{b1}^* = \frac{[2(1 + \beta_s)(1 - \beta_b) - \alpha_s(\alpha_s + \alpha_b)](1 + q\theta) - (1 - cq)(1 - \beta_b)(\alpha_s - \alpha_b)}{4(1 + \beta_s)(1 - \beta_b) - (\alpha_s + \alpha_b)^2}. \tag{9}$$

From equation (8), when $\alpha_s > \alpha_b, 4(1 + \beta_s)(1 - \beta_b) > (\alpha_s + \alpha_b)^2$ and $[2(1 + \beta_s)(1 - \beta_b) - \alpha_s(\alpha_s + \alpha_b)](1 + q\theta) > (1 - cq)(1 - \beta_b)(\alpha_s - \alpha_b)$, it is easy to find that $p_{s1}^* > 0$ and $p_{b1}^* > 0$. The Hessian matrix of the platform's profit function on (p_{s1}, p_{b1}) is

$$\begin{pmatrix} \dfrac{\partial^2 \pi}{\partial p_{s1}^2} & \dfrac{\partial^2 \pi}{\partial p_{s1} \partial p_{b1}} \\ \dfrac{\partial^2 \pi}{\partial p_{b1} \partial p_{s1}} & \dfrac{\partial^2 \pi}{\partial p_{b1}^2} \end{pmatrix} = \begin{pmatrix} \dfrac{-2(1 - \beta_b)}{(1 + \beta_s)(1 - \beta_b) - \alpha_s\alpha_b} & \dfrac{-(\alpha_s + \alpha_b)}{(1 + \beta_s)(1 - \beta_b) - \alpha_s\alpha_b} \\ \dfrac{-(\alpha_s + \alpha_b)}{(1 + \beta_s)(1 - \beta_b) - \alpha_s\alpha_b} & \dfrac{-2(1 + \beta_s)}{(1 + \beta_s)(1 - \beta_b) - \alpha_s\alpha_b} \end{pmatrix}. \tag{10}$$

From equation (10), when $(1+\beta_s)(1-\beta_b)-\alpha_s\alpha_b>0$, it is easy to see that $\partial^2\pi/\partial p_{s1}^2<0$, $\partial^2\pi/\partial p_{b1}^2<0$ and $\partial^2\pi/\partial p_{s1}^2\partial^2\pi/\partial p_{b1}^2-\partial^2\pi/\partial p_{s1}\partial\ p_{b1}-\partial^2\pi/\partial p_{b1}\partial p_{s1}=4\ (1+\beta_s)(1-\beta_b)-(\alpha_s+\alpha_b)^2/[(1+\beta_s)(1-\beta_b)-\alpha_s\alpha_b]^2>0$. Therefore, the matrix is negative definite; that is, equations (8) and (9) are the optimal solutions of the platform profit function with respect to p_{s1} and p_{b1}. Substituting equation (7) and equation (8) into equation (5) and equation (6), the optimal user scales and the optimal profit of the platform are, respectively,

$$n_{s1}^*=\frac{(1+q\theta)(\alpha_s+\alpha_b)+2(1-cq)(1-\beta_b)}{4(1+\beta_s)(1-\beta_b)-(\alpha_s+\alpha_b)^2}, \tag{11}$$

$$n_{b1}^*=\frac{(1-cq)(\alpha_s+\alpha_b)+2(1+q\theta)(1+\beta_s)}{4(1+\beta_s)(1-\beta_b)-(\alpha_s+\alpha_b)^2}, \tag{12}$$

$$\pi_1^*=\frac{(1-cq)[2+(1+q\theta)(\alpha_s+\alpha_b)]+q\theta(1+\beta_s)(2+q\theta)}{4(1+\beta_s)(1-\beta_b)-(\alpha_s+\alpha_b)^2}-\frac{(1-2cq)\beta_b-\beta_s-c^2q^2(1-\beta_b)}{4(1+\beta_s)(1-\beta_b)-(\alpha_s+\alpha_b)^2}. \tag{13}$$

2.3. Transaction System Modes. When the platform's charging mode is the transaction system, consumers reward the content producers by purchasing digital goods and virtual products on the platform. The platform shares the revenue with content producers according to the share ratio. The exchange standard of China's major Internet live broadcast platforms is shown in Table 3.

In order to solve the equilibrium solution of transaction price and profit, this section supposes that the consumer only trades once. However, in reality, it is common to find that users have multiple transactions. Therefore, in this section, we will consider both single and multiple transactions.

2.3.1. Single Transaction of Consumers. Under the single transaction mode, consumers pay the transaction fee p_{b2} to the platform. The platform shares the revenue with content producers according to the transaction share ratio λ. Based on the above description, the utility of content producers and consumers is as follows:

$$U_{s2}=\alpha_s n_{b2}-\beta_s n_{s2}+\lambda p_{b2}-cq+v_{s2}, \tag{14}$$

$$U_{b2}=\alpha_b n_{s2}+\beta_b n_{b2}-p_{b2}+\theta q+v_{b2}, \tag{15}$$

$$\pi_2=(1-\lambda)p_{b2}n_{b2}. \tag{16}$$

Two groups of users will only choose to join the platform when their total utility is greater than zero. Therefore, when $U_i\,(i=s,b)=0$, the critical values of user utility are $v_{s2}^*=\beta_s n_{s2}+cq-\alpha_s n_{b2}-\lambda p_{b1}$ and $v_{b2}^*=p_{b2}-\alpha_b n_{s2}-\beta_b n_{b2}-\theta q$, respectively. According to the utility probability distribution function $P(v\geq v^*)=1-P(v<v^*)=1-F(v^*)=1-v^*$, the minimum user scales of content producers and consumers are, respectively,

Table 3: The exchange ratio between virtual goods and RMB.

The platform	Digital goods and RMB exchange ratio
Bilibili	1000 : 1
Huya	1000 : 1
TikTok	10 : 1

$$n_{s2}=1\times P(v\geq v_{s2}^*)=1+\alpha_s n_{b2}-\beta_s n_{s2}+\lambda p_{b2}-cq, \tag{17}$$

$$n_{b2}=1\times P(v\geq v_{b2}^*)=1+\alpha_b n_{s2}+\beta_b n_{b2}-p_{b2}+\theta q. \tag{18}$$

From equations (17) and (18), we get that

$$n_{b2}=\frac{(1-cq)\alpha_b+(1+\beta_s)(1+\theta q)-(1+\beta_s-\alpha_b\lambda)p_{b2}}{(1+\beta_s)(1-\beta_b)-\alpha_s\alpha_b}. \tag{19}$$

Substituting equations (19) into equations (16) and solving the first-order condition of profit maximization: $\partial\pi_2/\partial p_{b2}=0$. The equilibrium transaction price set by the platform to the user is

$$p_{b2}^*=\frac{1+(1-cq)\alpha_b+(1+\theta q)(1+\beta_s)}{2(1+\beta_s-\alpha_b\lambda)}. \tag{20}$$

From equation (20), $p_{b2}^*>0$ always holds. When $(1+\beta_s)(1-\beta_b)-\alpha_s\alpha_b>0$, the second derivative of π_2 with respect to p_{b2}, $\partial^2\pi_2/\partial p_{b2}^2=-2(1-\lambda)(1+\beta_s-\alpha_b\lambda)/[(1+\beta_s)(1-\beta_b)-\alpha_s\alpha_b]<0$. Therefore, equation (20) is the optimal solution of the platform profit function with respect to p_{b2}. Substituting equation (20) into equation (16) and (19), the equilibrium consumer user scale and the profit of the platform are obtained as

$$n_{b2}^*=\frac{(1-cq)\alpha_b+(1+\theta q)(1+\beta_s)}{2[(1+\beta_s)(1-\beta_b)-\alpha_s\alpha_b]}, \tag{21}$$

$$\pi_2^*=\frac{[(1-cq)\alpha_b+(1+\theta q)(1+\beta_s)]^2(1-\lambda)}{4[(1+\beta_s)(1-\beta_b)-\alpha_s\alpha_b](1+\beta_s-\alpha_b\lambda)}. \tag{22}$$

2.3.2. Multiple Transactions of Consumers. When consumers have multiple transactions on the platform, the content producer utility, consumer utility, and platform profit functions are as follows:

$$U_{s3}=\alpha_s n_{b3}-\beta_s n_{s3}+\lambda p_{b2}n_{b3}-cq+v_{s3}, \tag{23}$$

$$U_{b3}=\alpha_b n_{s3}+\beta_b n_{b3}-p_{b2}n_{s3}+\theta q+v_{b3}, \tag{24}$$

$$\pi_3=(1-\lambda)p_{b2}n_{b3}n_{s3}. \tag{25}$$

When $U_{s3}\geq 0$ and $U_{b3}\geq 0$, the users of both sides decide to join the platform. Similarly, the critical values of the utility joining the platform can be obtained by solving the equation $U_{s3}=U_{b3}=0$. According to the probability distribution function of v_{s3}^* and v_{b3}^*, the minimum scales of content producers and consumers are as follows:

$$n_{s3} = 1 \times P\left(v \geq v_{s3}^{*}\right) = 1 + \alpha_s n_{b3} - \beta_s n_{s3} + \lambda p_{b2} n_{b3} - cq, \tag{26}$$

$$n_{b3} = 1 \times P\left(v \geq v_{s3}^{*}\right) = 1 + \alpha_b n_{s3} + \beta_b n_{b3} - p_{b2} n_{s3} + \theta q. \tag{27}$$

From equations (26) and (27), the final user scale expressions are

$$n_{s3} = \frac{(1-cq)\left(1-\beta_b\right) + (1+\theta q)\left(\alpha_s + p_{b2}\lambda\right)}{\left(1+\beta_s\right)\left(1-\beta_b\right) - \alpha_s\alpha_b + p_{b2}\alpha_s + p_{b2}^2\lambda - p_{b2}\alpha_b\lambda}, \tag{28}$$

$$n_{b3} = \frac{(1-cq)\alpha_b + \left(1+\beta_s\right)(1+\theta q) - (1-cq)p_{b2}}{\left(1+\beta_s\right)\left(1-\beta_b\right) - \alpha_s\alpha_b + p_{b2}\alpha_s + p_{b2}^2\lambda - p_{b2}\alpha_b\lambda}. \tag{29}$$

Substituting equations (28) and (29) into equations (25), the equilibrium profit of the platform is

$$\pi_3^{*} = p_{b2}(1-\lambda)\left[(1-cq)\left(\alpha_b - p_{b2}\right) + \left(1+\beta_s\right)(1+\theta q)\right]\left[\frac{\left(1-\beta_b\right)(1-cq) + \left((1+\theta q)\left(\alpha_s + p_{b2}\lambda\right)\right]}{\left[\left(1+\beta_s\right)\left(1-\beta_b\right) - \alpha_s\alpha_b + p_{b2}\alpha_s + p_{b2}^2\lambda - p_{b2}\alpha_b\lambda\right]^2}. \tag{30}$$

3. Equilibrium Analysis for Modes

Table 4 shows the results of platform equilibrium user pricing and profit under different charging modes.

Proposition 1. *Regardless of the registration system or the transaction system, the optimal user scale of the platform is positively correlated with α_s, α_b, and β_b and negatively correlated with β_s.*

For the brevity, we suppose $A_1 = 4(1+\beta_s)(1-\beta_b) - (\alpha_s+\alpha_b)^2$, $A_2 = 2(1-cq)(1-\beta_b) + (1+q\theta)(\alpha_s+\alpha_b)$, $A_3 = (1-cq)(\alpha_s+\alpha_b) + 2(1+\beta_s)(1+q\theta)$, $B_1 = (1+\beta_s)(1-\beta_b) - \alpha_s\alpha_b$, $B_2 = 1+\beta_s - \alpha_b\lambda$, $B_3 = (1-cq)\alpha_b + (1+\theta q)(1+\beta_s)$, and $B_4 = (1-cq)(1-\beta_b) + (1+\theta q)\alpha_s$. It is easy to find that the values of the above A and B are always greater than zero.

Solve the first derivative of n_{s1}^{*} and n_{b1}^{*} with respect to α_s, α_b, β_s, and β_b under the registration system and get

$$\begin{gathered}
\frac{\partial n_{s1}^{*}}{\partial \alpha_s} = \frac{\partial n_{s1}^{*}}{\partial \alpha_b} = \frac{1+\theta q + 2\left(\alpha_s+\alpha_b\right)A_2}{A_1} > 0, \frac{\partial n_{b1}^{*}}{\partial \alpha_s} = \frac{\partial n_{b1}^{*}}{\partial \alpha_b} = \frac{1-cq+2\left(\alpha_s+\alpha_b\right)A_3}{A_1} > 0 \\
\frac{\partial n_{s1}^{*}}{\partial \beta_s} = \frac{-4\left(1-\beta_b\right)A_2}{A_1} < 0, \frac{\partial n_{s1}^{*}}{\partial \beta_b} = \frac{2(1-cq) + 4\left(1+\beta_s\right)A_2}{A_1} > 0, \\
\frac{\partial n_{b1}^{*}}{\partial \beta_s} = \frac{-2\left(\alpha_s+\alpha_b\right)A_3}{A_1} < 0, \text{and } \frac{\partial n_{b1}^{*}}{\partial \beta_b} = \frac{4\left(1+\beta_s\right)A_3}{A_1} > 0.
\end{gathered} \tag{31}$$

Solve the first derivative of n_{b2}^{*} with respect to α_s, α_b, β_s, and β_b under the transaction system and get

$$\frac{\partial n_{b2}^{*}}{\partial \alpha_s} = \frac{\alpha_b B_3}{2B_1} > 0, \frac{\partial n_{b2}^{*}}{\partial \alpha_b} = \frac{(1-cq)B_1 + \alpha_s B_3}{2B_1^2} > 0, \frac{\partial n_{b2}^{*}}{\partial \beta_s} = \frac{-\alpha_b B_4}{2B_1^2} < 0 \text{ and } \frac{\partial n_{b2}^{*}}{\partial \beta_b} = \frac{\left(1+\beta_s\right)B_3}{2B_1^2} > 0. \tag{32}$$

Proposition 1 shows that in the two modes, as the intergroup externality intensity of content producers and consumers increases, the user scale of consumers and content producers will increase accordingly. As the strength of the intragroup network externality of consumers increases, more consumers choose to join the platform. Affected by the consumers' network externality, the user scale of content producers will also increase, so the overall user scale of the platform will become bigger. With the increase in network externality within the content producers' group, content producers are faced with limited consumer user and platform resources. Competition has become more intense and the utility of joining the platform decreases, so the content producer user scale will decrease. Affected by the content producers' intergroup network externality, the scale of consumer users will also decrease accordingly.

Proposition 2. *Regardless of the registration system or the transaction system, the optimal profit of the platform is*

Table 4: Equilibrium result.

Mode	Equilibrium result
Registration system	$p_{s1}^{*} = (1+q\theta)(1+\beta_s)(\alpha_s-\alpha_b) + (1-cq)[2(1+\beta_s)(1-\beta_b) - \alpha_b(\alpha_s+\alpha_b)]/4(1+\beta_s)(1-\beta_b) - (\alpha_s+\alpha_b)^2$ $p_{b1}^{*} = [2(1+\beta_s)(1-\beta_b) - \alpha_s(\alpha_s+\alpha_b)](1+q\theta) - (1-cq)(1-\beta_b)(\alpha_s-\alpha_b)/4(1+\beta_s)(1-\beta_b) - (\alpha_s+\alpha_b)^2$ $\pi_1^{*} = (1-cq)[2+(1+q\theta)(\alpha_s+\alpha_b)] + q\theta(1+\beta_s)(2+q\theta)/4(1+\beta_s)(1-\beta_b) - (\alpha_s+\alpha_b)^2$ $-(1-2cq)\beta_b - \beta_s - c^2q^2(1-\beta_b)/4(1+\beta_s)(1-\beta_b) - (\alpha_s+\alpha_b)^2$
Transaction system	$p_{b2}^{*} = 1 + (1-cq)\alpha_b + (1+\theta q)(1+\beta_s)/2(1+\beta_s-\alpha_b\lambda)$ $\pi_2^{*} = [(1-cq)\alpha_b + (1+\theta q)(1+\beta_s)]^2(1-\lambda)/4[(1+\beta_s)(1-\beta_b) - \alpha_s\alpha_b](1+\beta_s-\alpha_b\lambda)$ $\pi_3^{*} = p_{b2}(1-\lambda)[(1-cq)(\alpha_b-p_{b2}) + (1+\beta_s)(1+\theta q)][(1-\beta_b)(1-cq) + ((1+\theta q)(\alpha_s+p_{b2}\lambda))]/[(1+\beta_s)(1-\beta_b) - \alpha_s\alpha_b + p_{b2}\alpha_s + p_{b2}^2\lambda - p_{b2}\alpha_b\lambda]^2$

positively correlated with α_s, α_b, and β_b and negatively correlated with β_s.

Solve the first derivative of π_1^* with respect to α_s, α_b, β_s, and β_b under the registration system and get

$$\frac{\partial\pi_1^*}{\partial\alpha_s} = \frac{\partial\pi_1^*}{\partial\alpha_b} = \frac{A_2 A_3}{A_1} > 0, \frac{\partial\pi_1^*}{\partial\beta_s} = -\frac{A_2^2}{A_1^2} < 0 \text{ and } \frac{\partial\pi_1^*}{\partial\beta_b} = \frac{A_3^2}{A_1^2} > 0. \tag{33}$$

Solve the first derivative of π_2^* with respect toα_s, α_b, β_s, and β_b under the transaction system and get

$$\begin{aligned} \frac{\partial\pi_2^*}{\partial\alpha_s} &= \frac{\alpha_b(1-\lambda)B_3^2}{4B_1^2 B_2} > 0, \frac{\partial\pi_2^*}{\partial\alpha_b} = \frac{\lambda(1-\lambda)B_3^2}{4B_1 B_2^2} \\ &+ \frac{(1-cq)(1-\lambda)B_3}{2B_1 B_2} + \frac{\alpha_s(1-\lambda)B_3^2}{4B_1^2 B_2} > 0, \\ \frac{\partial\pi_2^*}{\partial\beta_s} &= -(1-\lambda)B_3\left[\frac{B_3}{4B_1 B_2^2} - \frac{(1+\theta q)}{2B_1 B_2} + \frac{(1-\beta_b)B_3}{4B_1^2 B_2}\right] \\ &< 0 \ \frac{\partial\pi_2^*}{\partial\beta_b} = \frac{(1+\beta_s)(1-\lambda)B_3^2}{4B_1^2 B_2} > 0. \end{aligned} \tag{34}$$

Proposition 2 shows that the platform's revenue mainly depends on the registration fee charged to all users and the transaction fee charged to consumers in the two modes. With the enhancement of the network externality intensity of content producers and consumers, regardless of the registration system and transaction system, each additional user on both sides will increase the overall user scale of the platform. More users joining the platform means that the platform can charge more registration fees and transaction fees, so the platform revenue increases. As more and more content producers join the platform, fierce competition among users will occur. The utility of content producers diminishes and the scale of users decreases, so platform revenues decrease. However, as the network externalities within the consumer group increase, the utility of consumers joining the platform will also increase. Therefore, the user scale of consumers and content producers will increase, and the platform revenue will increase.

Proposition 3. *Under the two charging modes, platform profits π_1 and π_2 are negatively correlated with the content producer's production cost. When $\alpha_s > \alpha_b$, the registration fee charged by the platform to content producers is negatively correlated with the production cost and the registration fee charged to consumers is positively correlated with the production cost. Under the transaction system, the transaction fee charged to consumers is negatively correlated with the production cost.*

Solve the first derivative of π_1^*, p_{s1}^*, and p_{b2}^* with respect to c under the registration system and get

$$\begin{aligned} \frac{\partial\pi_1^*}{\partial c} &= \frac{-qA_2}{A_1} < 0, \frac{\partial p_{s1}^*}{\partial c} = \frac{-q\left[A_1 + (\alpha_s+\alpha_b)(\alpha_s-\alpha_b)\right]}{2A_1} \\ &< 0 \text{ and } \frac{\partial p_{b1}^*}{\partial c} = \frac{q(\alpha_s-\alpha_b)(1-\beta_b)}{A_1} > 0. \end{aligned} \tag{35}$$

Solve the first derivative of π_2^* and p_{b2}^* with respect to c under the transaction system and get

$$\frac{\partial\pi_2^*}{\partial c} = \frac{-q\alpha_b(1-\lambda)B_3}{2B_1 B_2} < 0, \text{and } \frac{\partial p_{b2}^*}{\partial c} = \frac{-q\alpha_b}{2B_2} < 0. \tag{36}$$

Proposition 3 shows that as the content quality cost increases, the utility of consumers joining the platform under the registration system will increase, while the utility of content producers joining the platform will decrease. As a result, the scale of consumer users joining the platform will increase, while the scale of content producers will decrease accordingly.

Under the transaction system, with the increase in production costs, the utility and scale of content producers decrease. Affected by user network externality, the scale of consumer users on the platform decreases. Therefore, the platform reduces transaction fees to increase the scale of consumer users on the platform. Regardless of the registration system or the transaction system, as the cost of content production increases, platform profits will decrease.

Proposition 4. *Under the registration system, the optimal platform profit π_1 is negatively related to the content quality q conditionally. The registration fees charged to content producers p_{s1} are negatively correlated with quality level conditionally. The registration fees charged to content producers p_{s1} are positively correlated with the quality level conditionally. The registration fees charged to consumers p_{b1} are positively correlated with the quality level. Under the transaction system, the optimal platform profit π_2 and the transaction fee p_{b2} are positively correlated with the quality level when $\theta > c\alpha_b/(1+\beta_s)$. The optimal platform profit π_2 and the transaction fee are negatively correlated with q when $\theta < c\alpha_b/(1+\beta_s)$.*

Solve the first derivative of π_1^*, p_{s1}^*, and p_{b1}^* with respect to q under the registration system and get

$$\begin{aligned} \frac{\partial\pi_1^*}{\partial q} &= \frac{\theta\left[A_3 + cq(\alpha_s+\alpha_b)\right] - c\left[(1+2q\theta)(\alpha_s+\alpha_b) + 2(1-\beta_b)\right] + 2c^2 q(1-\beta_b)}{A_1}, \\ \frac{\partial p_{b1}^*}{\partial q} &= \frac{2c(\alpha_s-\alpha_b)(1-\beta_s) + \theta\left[A_1 + (\alpha_s+\alpha_b)(\alpha_s-\alpha_b)\right]}{2A_1}, \\ \frac{\partial p_{s1}^*}{\partial q} &= \frac{-c\left[A_1 + (\alpha_s+\alpha_b)(\alpha_s-\alpha_b)\right] + 2(\alpha_s-\alpha_b)(1+\beta_s)\theta}{2A_1}. \end{aligned} \tag{37}$$

It is easy to find that $\partial p_{b1}^*/\partial q > 0$. When $\theta > c$, $\theta[A_3 + cq(\alpha_s + \alpha_b)] > c[(1 + 2q\theta)(\alpha_s + \alpha_b) + 2(1 - \beta_b)]$ holds. Therefore, $\partial\pi_1^*/\partial q > 0$ holds. When $\theta < c$ and $\alpha_s + \alpha_b > 2[\theta(1 + \beta_s)(1 + \theta) - c(1 - \beta_b)(1 - c)]/[c(1 + \theta) - \theta(1 - c)]$, $\partial\pi_1^*/\partial q < 0$ holds. When $\theta > c[A_1 + (\alpha_s + \alpha_b)(\alpha_s - \alpha_b)]/2(\alpha_s - \alpha_b)(1 + \beta_s)$, we get $\partial p_{s1}^*/\partial q > 0$.

Solve the first derivative of π_2^* and p_{b2}^* with respect to q under the transaction system and get

$$\frac{\partial\pi_2^*}{\partial q} = \frac{[(1 + \beta_s)\theta - c\alpha_b](1 - \lambda)B_3}{2B_1B_2}, \frac{\partial p_{b2}^*}{\partial q} = \frac{(1 + \beta_s)\theta - c\alpha_b}{2B_2}. \quad (38)$$

When $\theta > c\alpha_b/(1 + \beta_s)$, we can get that $\partial\pi_2^*/\partial q > 0$ and $\partial p_{b2}^*/\partial q > 0$.

Proposition 4 shows that under the platform transaction mode, when consumers are more sensitive to the quality of live content, consumers tend to accept high-quality live content. If the content quality of the live broadcast platform is higher, users are more willing to pay for the platform. The profit of platform will increase accordingly. When consumers are less sensitive to platform content quality, users' willingness and utility to pay for live broadcasts are not high. The number of users who are willing to pay will decrease. Therefore, platform profits decrease. With the increase in platform content quality, the platform will charge consumers higher registration fees. When consumers' quality sensitivity is low, with the improvement of content quality and cost, the platform will reduce the pricing for content producers and increase the pricing for consumers in order to maintain the number of users and ensure the revenue.

Proposition 5. *Regardless of the registration system and transaction system, the optimal platform profit and user pricing are positively correlated with consumers' sensitivity to content quality.*

Solve the first derivative of π_1^*, p_{s1}^*, and p_{b1}^* with respect to θ under the registration system and get

$$\frac{\partial\pi_1^*}{\partial\theta} = \frac{qA_3}{A_1} > 0, \frac{\partial p_{s1}^*}{\partial\theta} = \frac{q(\alpha_s - \alpha_b)(1 + \beta_s)}{A_1} > 0 \ \frac{\partial p_{b1}^*}{\partial\theta} = \frac{q[A_1 + (\alpha_s + \alpha_b)(\alpha_s - \alpha_b)]}{2A_1} > 0. \quad (39)$$

Solve the first derivative of π_2^* and p_{b2}^* with respect to θ under the transaction system and get

$$\frac{\partial\pi_2^*}{\partial\theta} = \frac{q(1 + \beta_s)(1 - \lambda)B_3}{2B_1B_2} > 0, \ \frac{\partial p_{b2}^*}{\partial\theta} = \frac{q(1 + \beta_s)}{2B_2} > 0. \quad (40)$$

Proposition 5 shows that whether the charging mode is the registration or transaction, as consumers' content quality sensitivity increases, platform revenue and pricing will increase. If users are sensitive to content quality, they have high expectations for the quality of service and content. When the platform content quality level is high, the user's utility will increase. Therefore, the user scale will increase. Affected by the network externality, the platform's revenue and pricing will increase.

Proposition 6. *Under the transaction system, the optimal platform profit is negatively correlated with the transaction share ratio and the user pricing is positively correlated with transaction share ratio.*

Solve the first derivative of π_2^* and p_{b2}^* with respect to λ under the registration system and get

$$\frac{\partial\pi_2^*}{\partial\lambda} = -\frac{(1 + \beta_s - \alpha_b)B_3^2}{2B_1B_2^2} < 0, \ \frac{\partial p_{b2}^*}{\partial\lambda} = \frac{\alpha_b B_3}{2B_2^2} > 0. \quad (41)$$

Proposition 6 shows that as the proportion of transaction sharing increases, the platform's pricing for consumers and profit will increase. For content producers, the utility of joining the platform largely depends on the share ratio and the scale of platform users. The platform attracts more superior content producers to join the platform by increasing the share ratio, but profits will be reduced accordingly. Affected by the strength of the content producers' intergroup network externality, as the user scale of content producers increases, the scale of consumer users will also increase. Therefore, the platform raises the user price and increases platform revenue.

Proposition 7. *The platform profit under the registration system mode is higher than that under the single transaction system mode.*

From equations (12) and (21), it can be seen that Φ is a decreasing function of λ, which satisfies $\Phi(\lambda) = \pi_2 - \pi_1$ and $\Phi =_{\max} \Phi(0) = -C^2/4(1 + \beta_s)A_1B_1 < 0$. Therefore, $\pi_2 < \pi_1$.

Proposition 7 shows that regardless of the influence of network externality and other factors, the optimal platform profit under the registration system is always higher than that under the transaction system. This is because the scale of content producers and consumers who join the platform is always much higher than the scale of users willing to transact. Therefore, the main profit mode of platform live broadcast is still the registration system. The platform needs to rely on its own services and technology to build a good platform content environment and provide users with more value-added services to attract more users to join the platform and increase the scale of platform fee members.

In reality, the main revenue of Bilibili consists of membership fees and live broadcast rewards. Bilibili has attached great importance to film and television copyrights in recent years. Compared with other live broadcast platforms, the quality of the platform's videos and content have been significantly improved. Therefore, the platform attracted a large number of users to join the platform. Through the issuance of joint credit cards with banks, it expanded the number of membership and increased the revenue of the membership business.

4. Numerical Analysis

To illustrate the rationality and effectiveness of the models, this section will test the propositions and conclusions by assigning values to each parameter and analyzing the correlation between the relevant parameters and the equilibrium results.

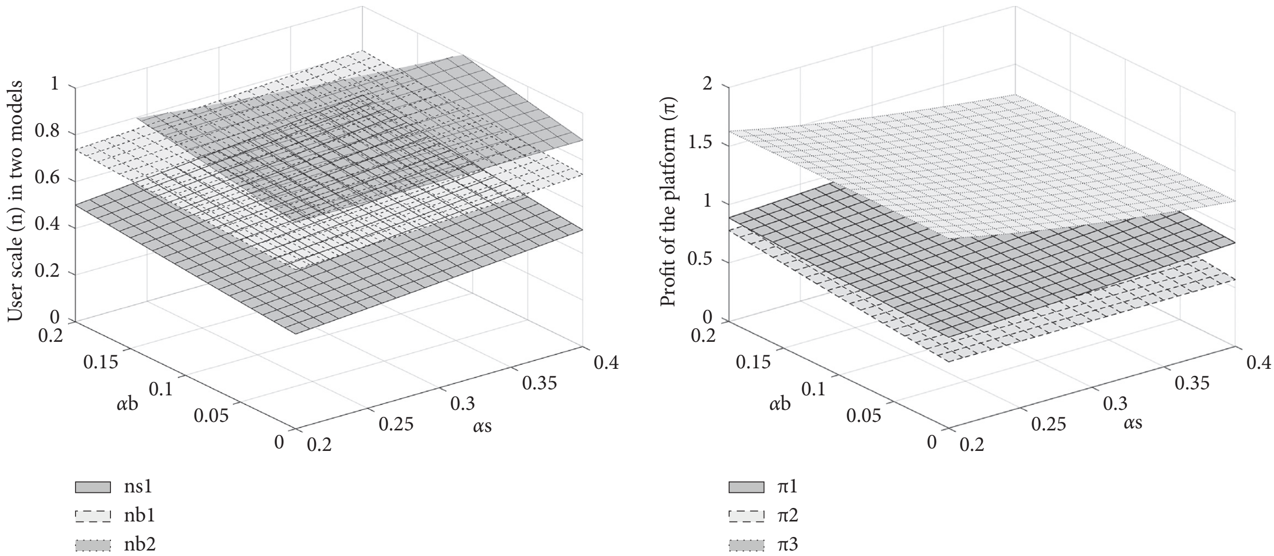

Figure 2: The impact of intergroup network externality on user scale and profits.

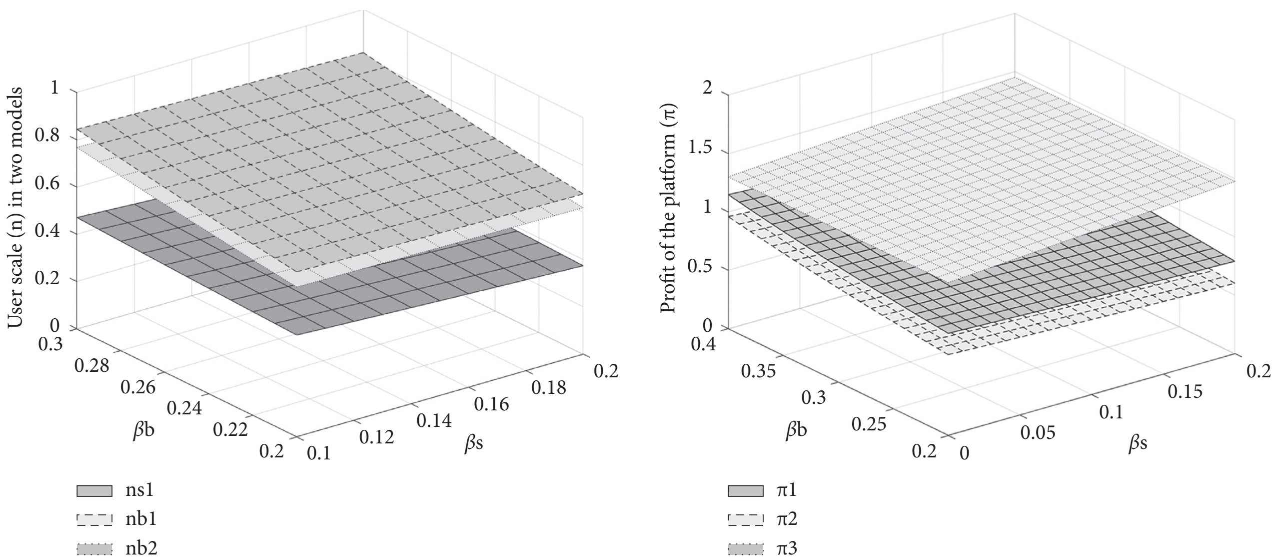

Figure 3: The impact of intragroup network externality on user scale and profit.

4.1. Impact of Intergroup Network Externalities. Assign the parameters $\beta_s = 0.2$, $\beta_b = 0.4$, $q = 0.3$, $c = 0.5$, $\theta = 0.5$, and $\lambda = 0.4$. Parameters $\alpha_s, \alpha_b \in [0, 0.4]$. Figure 2 shows that with the increase in intergroup network externality, the user scale and equilibrium profit of the platform increase, and the revenue under the transaction fee mode is less than the revenue under the registration mode, which is consistent with Propositions 1, 2, and 7.

4.2. Impact of Intragroup Network Externalities. Assign the parameters $\alpha_s = 0.4$, $\alpha_b = 0.2$, $q = 0.3$, $c = 0.5$, $\theta = 0.5$, and $\lambda = 0.4$. Parameters $\beta_s, \beta_b \in [0.1, 0.6]$. Figure 3 shows that as the network externalities within the consumer group increase, the user scale and equilibrium profits of the platform increase. As the network externalities within the content producer group increase, the user scale and profits of the platform decrease, which is consistent with Propositions 1 and 2. The profit under the registration system is higher than the platform profit under the single transaction system, which is consistent with Proposition 7. From Figures 2 and 3, the profit under the multiple transaction is higher than that under the registration system and single transaction system.

4.3. Impact of Content Production Cost. Assign the parameters $\beta_s = 0.4$, $\beta_b = 0.6$, $\alpha_s = 0.6$, $\alpha_b = 0.4$, $q = 0.5$, $\theta = 0.6$, and $\lambda = 0.4$. Parameters $c \in [0, 1]$. Figure 4 shows that with the increase in the content production cost, the platform charges less for content producers and more for consumers

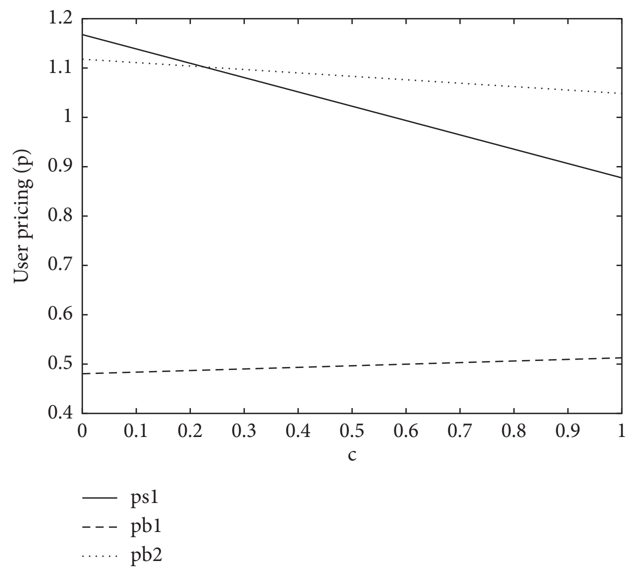

Figure 4: The impact of content production cost on user pricing.

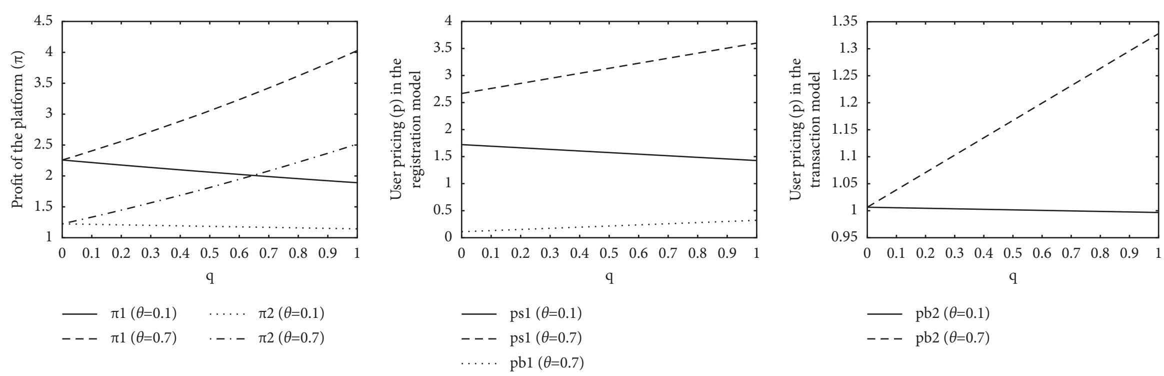

Figure 5: The impact of platform content quality on profit and user pricing.

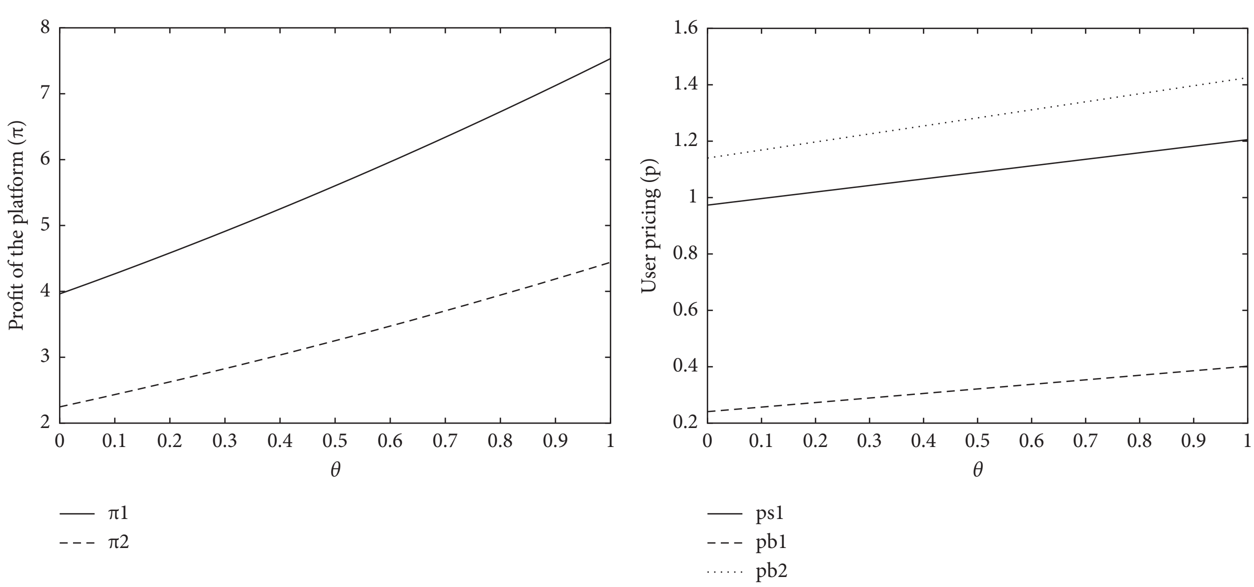

Figure 6: The impact of consumer content quality sensitivity on profits and pricing.

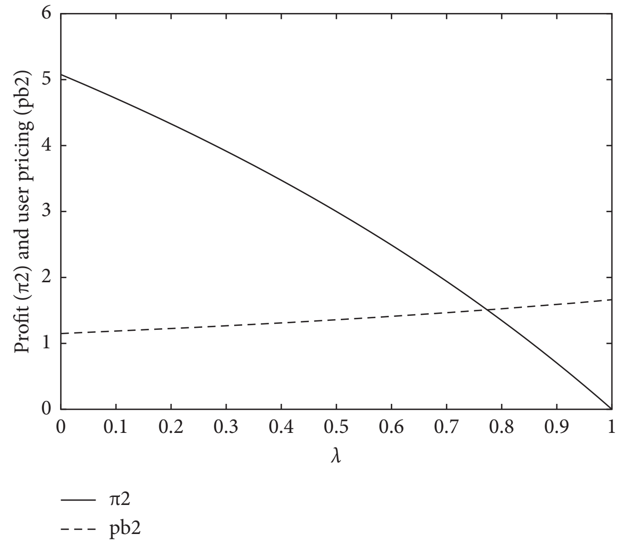

Figure 7: The impact of transaction share ratio on platform profit and user pricing.

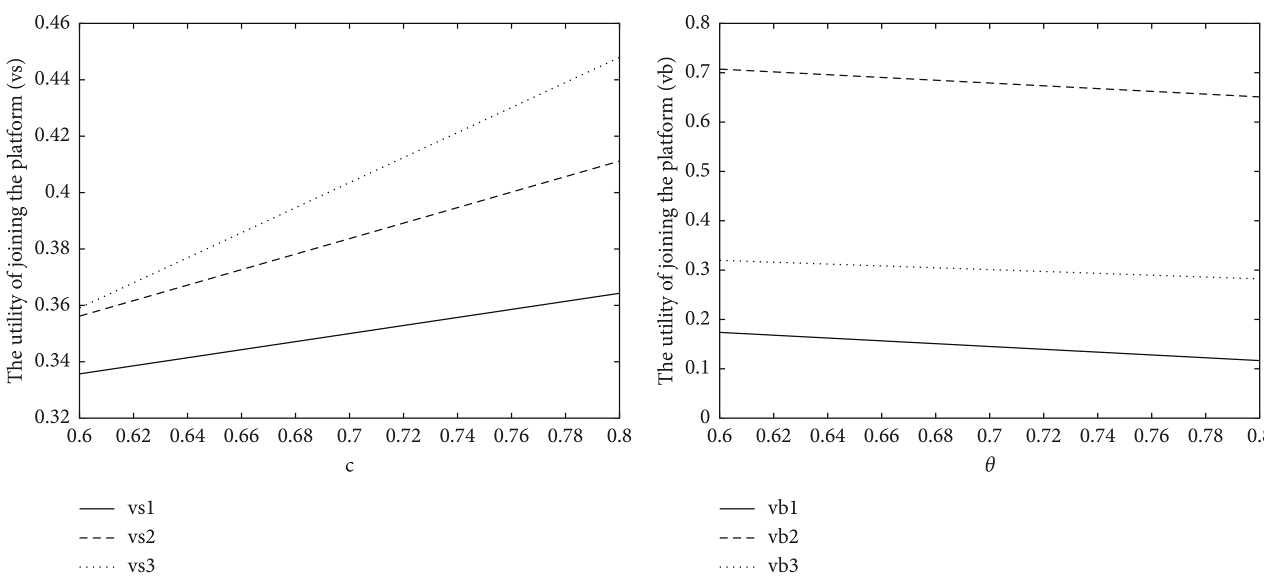

Figure 8: The impact of cost and consumer's sensitivity on user utility.

under the registration system. Under the transaction system, the platform charges consumers less. This is consistent with Proposition 3.

4.4. Impact of Platform Content Qualities. Assign the parameters $\beta_s = 0.7$, $\beta_b = 0.8$, $\alpha_s = 0.6$, $\alpha_b = 0.4$, $\theta = \{0.1, 0.7\}$, $c = 0.5$, and $\lambda = 0.4$. Parameters $q \in [0, 1]$. Figure 5 shows that when consumers are less sensitive to content quality, as content quality improves, platform profits will decrease, and the registration fees charged to content producers and transaction fees charged to consumers will decrease. When consumers are more sensitive to content quality, with the improvement of content quality, the profit of the platform will increase, and the registration fees charged to content producers and transaction fees charged to consumers will increase, which is consistent with Proposition 4.

4.5. Impact of Consumer Content Quality Sensitivities. Assign the parameters $\alpha_s = 0.6$, $\alpha_b = 0.4$, $\beta_s = 0.3$, $\beta_b = 0.7$, $q = 0.5$, $c = 0.5$, and$\lambda = 0.4$. Parameters $q \in [0, 1]$. Figure 6 shows that as consumers' quality sensitivity increases, platform profits and user pricing increase, which is consistent with Proposition 5.

4.6. Impact of Transaction Share Ratios. Assign the parameters $\alpha_s = 0.6$, $\alpha_b = 0.4$, $\beta_s = 0.3$, $\beta_b = 0.7$, $q = 0.5$, $c = 0.5$, and $\theta = 0.6$. Parameters $\lambda \in [0, 1]$. Figure 7 shows that as the proportion of transaction sharing increases, platform profits will decrease, and transaction fees charged to consumers will increase, which is consistent with Proposition 6.

4.7. Comparison of User Utilities. According to the previous assumptions, assign specific values to each parameter and calculate the values of user utility joining the platform. As shown in Figure 8, from the perspective of content producers, the user utility under the multiple transaction system is higher than that under the single transaction system and registration system. From the perspective of consumers, the user utility under the single transaction system is higher than that under the multiple transaction system and registration system.

5. Conclusion

This paper establishes a two-sided market consisting of a single monopoly live broadcast platform, content producers, and consumers. Under the registration system and the transaction system, the influence of intergroup network externality, intragroup network externality, the quality of platform content, and consumer content quality sensitivity on the scale of users, pricing, and profit is discussed. The results are shown as follows:

(1) The scale and profit of platform users are positively correlated with the intergroup network externality coefficient on both sides, positively correlated with the consumers' intragroup network externality coefficient, and negatively correlated with the content producers' intragroup network externality coefficient.

(2) The profit of platform under the two models is negatively correlated with content production cost. When consumers are more sensitive to content quality, it is positively correlated with content quality and positively related to user content quality sensitivity.

(3) The registration fee charged by the platform to content producers is negatively correlated with the content production cost. When consumers are more sensitive to content quality, they are positively correlated with content quality and positively correlated with consumers' content quality sensitivity.

(4) The registration fee charged by the platform to consumers is positively correlated with content production cost, negatively correlated with the level of content quality, and positively correlated with the sensitivity of consumers' content quality.

(5) The transaction fees charged by the platform to consumers are negatively correlated with content production cost. When consumers are more sensitive to content quality, it is positively correlated with the level of content quality and consumers' sensitivity to content quality.

(6) The revenue of the live broadcast platform under the multiple transaction systems is higher than that under the registration and single transaction systems. In terms of the utility of joining the platform, content producers and consumers prefer the transaction system.

The above conclusions have specific management implications for the development of the live broadcast industry and platform economy. Firstly, the live broadcast platform is an industry with significant network effects. The user scale and revenue are closely related to the intergroup and intragroup network externality. The platform should implement an active marketing strategy to increase the user scale. Secondly, when the platform attracts content producers to join the platform, the influence of network externalities within the content producer group should be considered. The platform should set the corresponding entry threshold in order to improve the content quality level of the platform and reduce the resource competition between content producers. Finally, the platform should continuously upgrade the platform's technology and value-added service to expand the platform's membership user scale and increase the platform's membership income.

This paper certainly has its limitations. Only monopolistic live broadcast platform pricing mechanisms are considered. In the future, we can study the pricing mechanism of competitive live broadcast platforms in two-sided markets. When establishing multiple transaction system mode, it is very difficult to find an equilibrium solution. Therefore, in the future, it is possible to establish a more reasonable model in order to find an equilibrium solution and analyze the influence of factors such as transaction matching probability on the pricing strategy of the platform.

Data Availability

No data were used to support this study.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

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