ANALYSIS OF FREIGHT PLATFORM DISCRIMINATORY PRICING STRATEGY BASED ON GAME THEORY

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Discriminatory pricing based on user behavior is a common pricing strategy used by platform enterprises. Combined with the characteristics of freight platform, a two-stage dynamic pricing model of differentiated platform was built by using Salop model to analyze the impact of discriminatory pricing strategy on corporate profits and market share of freight platform. The results show that the equilibrium pricing in the second stage is related to platform differences, market share in the first stage and network externality. In the second stage, the registration fee charged by the freight platform to new users is lower than that charged to old users, and the profit and equilibrium price are positively correlated with the difference between platforms and negatively correlated with network externality. The profit of freight platform increases with the improvement of platform matching capacity.

Key Words: *freight platform, two-sided market, discriminatory pricing, network externality*

1. INTRODUCTION

Logistics capacity coordination and supply source coordination are dual urgent problems, and the emergence of Internet freight platform can solve this problem well. The freight platform is a two-sided market based on matching the information of the supply and demand sides. For platform enterprises, discriminatory pricing is a common pricing strategy. The common form is to implement low or discounted prices for new users to promote the transfer of consumers from competitors, which is a customer-centered pricing strategy.

As for the research on discriminatory pricing, with the development of information technology, enterprises can classify consumers according to historical purchase information and set different prices for consumers with different purchase information. Talyor[1] calls this pricing method discriminatory pricing based on purchase behavior. Chen[2] analyzed the impact of discriminatory pricing based on purchase behavior on corporate profits by establishing a two-stage competition model for homogeneous products. Fuden-berg[3] analyzed the impact of discriminatory pricing on corporate profits by establishing a two-stage Hotelling model[4]. Subsequently, many scholars[5,6] conducted analysis based on discriminatory pricing. However, existing researches on discriminatory pricing mainly focus on single market, while few focus on two-sided market.

In recent years, the two-sided market theory has become one of the forefront and hot topics in economic research[7]. The two-sided market refers to the platform that connects different users on both sides and facilitates the transaction between the two types of users by providing intermediary services, such as Amazon, which connects buyers and sellers, and YouTube, which connects users and advertisers. Pricing is the core problem of the two-sided market theory[8]. Many researchers have analyzed the influence of factors such as cross-network externality[9,10], intra-group network externality[11], charging method[8,11], and platform differentiation[12] on the platform pricing strategy. But these studies all assume that the platform will have uniform pricing for both users. In two-sided markets, discriminatory pricing is widespread. For example, in 1995 and 1996, several long-distance telephone operators in the United States offered a bonus to new subscribers. Meituan Takeaway website offers a discount of CNY 10 to new registered users when placing an order. IQIYI Video website for the first time to become a VIP member, the purchase of gold package monthly card only CNY 5, old users need CNY 19.

Most of the existing researches are based on the hypothesis of uniform pricing and the Hotelling duopoly model, and researches on discriminatory pricing strategy are mainly one-sided market. However, the freight platform enterprise is a typical two-sided market. At present, there are few researches on freight platform, and most of the pricing models in related research literature[13] are static pricing models. Therefore, combining the characteristics of freight platform, this study uses Salop model[14] to build a two-stage dynamic pricing model of differentiated platform, analyzes the impact of discriminatory pricing strategy on the profit and market share of freight platform enterprises, and provides scientific basis and strategic suggestions for freight platform enterprises to effectively implement pricing strategy.

2. MODEL CONSTRUCTION

(1) Basic assumptions and parameters

It is assumed that there are three incompatible freight platform enterprises in this market, represented by $i(i=1,2,3)$, equidistant and evenly distributed on Salop ring of length 1, located at 0, 1/3, 2/3 respectively. The freight supply side and the freight demand side are expressed as $n(n=s,b)$. Consistent with the hypothesis of the literature[6], user demands at each stage are independent of each other, and in the two-stage competition, users are free to join the freight platform i according to the principle of utility maximization. In order to simplify the calculation, it is assumed that freight two-sided users are single attribution, that is, only connected to one platform enterprise. The total number of users is 1 and evenly distributed on the ring, $d_{bi}^m(d_{si}^m)$ represent the number of two-sided users, where m ($m=1,2$) represents the number of stages. α represents the network externality coefficient, and $\alpha\in[0,1]$.

Freight platforms benefit from charging registration fees for bilateral user access to the platform. The dynamic competition is divided into two stages: the registration fee in the first stage is ; the second stage is discriminatory pricing for new p_{ni}^1 and old users. The registration fee for new users is p_{ni}^{2f}, and the registration fee for old users is p_{ni}^2 (the superscript represents the number of stages, the same is true below). t is the unit transportation cost between users and freight platform enterprises, which is interpreted as the difference between freight platforms in economics. The greater t is, the greater the difference between platforms will be.

λ is the proportion of remuneration paid by the freight platform to the freight supplier for each transaction. k is the cost that the freight demander needs to pay to the platform for each transaction. N_i^m represents the transaction times (matching times) of two-sided users, and $N_i^m=ed_{bi}^m d_{si}^m$, where e is the technical capability of matching between the supply and demand of the freight platform, and $e\in[0,1]$.

Table 1 Parameters description

Parameters	Description
i	freight platform enterprises, $i=1,2,3$
n	the freight supply side and the freight demand side, $n=s,b$
d_{bi}^m, d_{si}^m	the number of two-sided users
m	the number of stages, $m=1,2$
α	the network externality coefficient, $\alpha\in[0,1]$.
p_{ni}^1	the price of the first stage.
p_{ni}^2	the price of the second stage for old users
p_{ni}^{2f}	the price of the second stage for new users
t	the difference between freight platforms
λ	the proportion of remuneration paid by the freight platform to the freight supplier for each transaction, and $\lambda\in[0,1]$
k	the cost that the freight demander needs to pay to the platform for each transaction
N_i^m	the transaction times(matching times) of two-sided users
e	the technical capability of matching between the supply and demand of the platform, and $e\in[0,1]$
v	the base utility that users gets from platforms

(2) Model description

a) The first stage model

On the freight supply side, users located in x_{s12}^1 choose freight platform 1 to get utility $U_{1,s}^1(x_{s12}^1) = v + \alpha d_{b1}^1 + \frac{\lambda k N_1^1}{d_{s1}^1} - p_{s1}^1 - t(x_{s12}^1 - 0)$, choose platform 2 to get utility $U_{2,s}^1(x_{s12}^1) = v + \alpha d_{b2}^1 + \frac{\lambda k N_2^1}{d_{s2}^1} - p_{s2}^1 - t(\frac{1}{3} - x_{s12}^1)$, v is the base utility that users gets from platform , assuming v is large enough that the two-sided user will access at least one freight platform. x_{s12}^1 is no difference in utility, indicating that the user of this point chooses to access platform 1 and platform 2 to obtain the same utility. Located in x_{s23}^1 platform for the users to choose freight platform 2 get utility $U_{2,s}^1(x_{s23}^1) = v + \alpha d_{b2}^1 + \frac{\lambda k N_2^1}{d_{s2}^1} - p_{s2}^1 - t(x_{s23}^1 - \frac{1}{3})$. In a similar way we can get, $U_{3,s}^1(x_{s23}^1)$, $U_{3,s}^1(x_{s31}^1)$, $U_{1,s}^1(x_{s31}^1)$.

On the freight demand side, users located in x_{b12}^1 choose freight platform 1 to gain utility $U_{1,b}^1(x_{b12}^1) = v + \alpha d_{s1}^1 - \frac{k N_1^1}{d_{b1}^1} - p_{b1}^1 - t(x_{b12}^1 - 0)$, choose platform 2 to get utility $U_{2,b}^1(x_{b12}^1) = v + \alpha d_{s2}^1 - \frac{k N_2^1}{d_{b2}^1} - p_{b2}^1 - t(\frac{1}{3} - x_{b12}^1)$. In a similar way we can get $U_{2,b}^1(x_{b23}^1)$, $U_{3,b}^1(x_{b23}^1)$ $U_{3,b}^1(x_{b31}^1)$, $U_{1,b}^1(x_{b31}^1)$.

The profit function of freight platform is

$$\pi_i^1 = \sum_n d_{ni}^1 p_{ni}^1 \qquad (1)$$

b) The second stage model

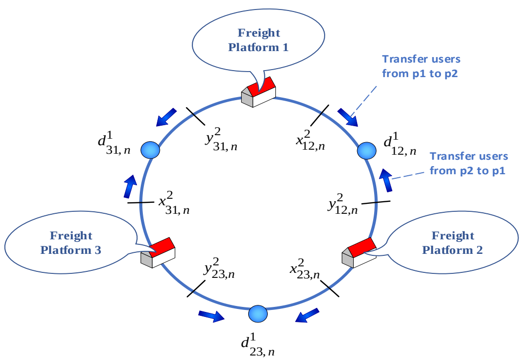

Fig 1. Users distribution in the second stage.

On the freight supply side, since the freight platform adopts the discriminatory pricing strategy for two-sided users, the freight suppliers that choose platform 1 in the first stage will choose again in the second stage, and the old users who continue to choose platform 1 will gain utility $U_{1/1}^2(x_{s12}^2) = v + \alpha d_{b1}^2 + \frac{\lambda k N_1^2}{d_{s1}^2} - p_{s1}^2 - t x_{s12}^1$. Another group of users who move from platform 1 to platform 2 gain utility as new users of platform 2 $U_{1/2}^2(x_{s12}^2) = v + \alpha d_{b2}^2 + \frac{\lambda k N_2^2}{d_{s2}^2} - p_{s2}^{2f} - t(\frac{1}{3} - x_{s12}^2)$. For platform 2, the utility of the old users is $U_{2/2}^2(y_{s12}^2) = v + \alpha d_{b2}^2 + \frac{\lambda k N_2^2}{d_{s2}^2} - p_{s2}^2 - t(\frac{1}{3} - y_{s12}^2)$. The utility of the new user is $U_{2/1}^2(y_{s12}^2) = v + \alpha d_{b1}^2 + \frac{\lambda k N_1^2}{d_{s1}^2} - p_{s1}^{2f} - t y_{s12}^2$. Users transfer between platform 2 and platform 3 and between platform 3 and platform 1 are the same way.

Since the size of the operation cost will not affect the calculation result, to simplify the calculation, it is assumed that both the cost and marginal cost of the freight platform to provide services for both the supplier and the supplier are 0, so the profit function of the second-stage freight platform is:

$$\begin{aligned} \pi_1^2 &= \sum_n d_{n,1/1}^2 p_{n1}^2 + \sum_n (d_{n,2/1}^2 + d_{n,3/1}^2) p_{n1}^{2f} \\ \pi_2^2 &= \sum_n d_{n,2/2}^2 p_{n2}^2 + \sum_n (d_{n,1/2}^2 + d_{n,3/2}^2) p_{n2}^{2f} \\ \pi_3^2 &= \sum_n d_{n,3/3}^2 p_{n3}^2 + \sum_n (d_{n,1/3}^2 + d_{n,2/3}^2) p_{n3}^{2f} \end{aligned} \qquad (2)$$

3. MODEL SOLUTION ANALYSIS

The two stages of access to the freight platform are independent of each other, and the total profit of the platform in the first stage is the profit maximization decision based on the discriminatory pricing strategy in the second stage. Therefore, the backward induction analysis method is adopted to analyze the second stage and solve the sub-game Nash equilibrium.

(1) Second stage equilibrium

We obtain no difference points between freight suppliers:

$$x_{s12}^2=\frac{t+(3\alpha+3ek\lambda)d_{b1}^2-(3\alpha+3ek\lambda)d_{b2}^2-3p_{s1}^2+3p_{s2}^{2f}}{6t}$$
$$y_{s12}^2=\frac{t+(3\alpha+3ek\lambda)d_{b1}^2-(3\alpha+3ek\lambda)d_{b2}^2-3p_{s1}^{2f}+3p_{s2}^2}{6t}$$
$$x_{s23}^2=\frac{t+(\alpha+ek\lambda)d_{b2}^2-(\alpha+ek\lambda)d_{b3}^2-3p_{s2}^2+3p_{s3}^{2f}}{2t} \quad (3)$$
$$y_{s23}^2=\frac{t+(\alpha+ek\lambda)d_{b2}^2-(3\alpha+3ek\lambda)d_{b3}^2-3p_{s2}^{2f}+3p_{s3}^2}{2t}$$
$$x_{s31}^2=\frac{5t-(3\alpha+3ek\lambda)d_{b1}^2+(3\alpha+3ek\lambda)d_{b3}^2+3p_{s1}^{2f}-3p_{s3}^2}{6t}$$
$$y_{s31}^2=\frac{5t-(3\alpha+3ek\lambda)d_{b2}^2+(3\alpha+3ek\lambda)d_{b3}^2+3p_{s1}^2-3p_{s3}^{2f}}{6t}$$

In the second stage, the market shares of platform 1 and platform 2 in the freight supplier are $d_{s12}^2=x_{s12}^2+y_{s12}^2-d_{s12}^1$ and $d_{s21}^2=d_{s12}^1-x_{s12}^2-y_{s12}^2+\frac{1}{3}$. The market shares of platform 2 and platform 3 in the freight supplier are $d_{s23}^2=x_{s23}^2-\frac{1}{3}+y_{s23}^2-d_{s23}^1$ and $d_{s32}^2=d_{s23}^1-x_{s23}^2+\frac{2}{3}-y_{s23}^2$. The market share of platform 3 and platform 1 in the freight supplier are $d_{s31}^2=x_{s31}^2-\frac{2}{3}+y_{s31}^2-d_{s31}^1$ and $d_{s13}^2=d_{s31}^1-x_{s31}^2+1-y_{s31}^2$.

Therefore, in the second stage, the market share of freight platform i are expressed as follows:

$$d_{n1}^2=d_{n12}^2+d_{n13}^2$$
$$d_{n2}^2=d_{n12}^2+d_{n23}^2 \quad (4)$$
$$d_{n3}^2=d_{n23}^2+d_{n31}^2$$

By solving the above equations simultaneously, we can obtain the expressions of the scale of two-sided users of each freight platform only concerning registration fee, network externality coefficient and platform differentiation parameter.

Each freight platform pursues profit maximization through price competition. In the second stage, the first-order condition to be satisfied for the implementation of discriminatory pricing is $\frac{\partial\pi_i^2}{\partial p_{ni}^2}=\frac{\partial\pi_i^2}{\partial p_{ni}^{2f}}=0$, and the optimal pricing strategy for the three freight platforms in the second stage is:

$$p_{bi}^2=\frac{14t+6td_{bi}^1-30(\alpha-ek)}{75}$$
$$p_{bi}^{2f}=\frac{22t-24td_{bi}^1-30(\alpha-ek)}{75} \quad (5)$$
$$p_{si}^2=\frac{8t+6td_{bi}^1-18(\alpha+ek\lambda)}{75}$$
$$p_{si}^{2f}=\frac{13t-24td_{si}^1-18(\alpha+ek\lambda)}{45}$$

Proposition 1. The equilibrium pricing of freight platform in the second stage is related to platform differences, market share in the first stage and network externality. And when $d_{bi}^1>\frac{4}{15}$,there is $p_{bi}^2>p_{bi}^{2f}$. When $d_{si}^1>\frac{1}{6}$, there is $p_{si}^2>p_{si}^{2f}$. At this point, preferential price for new users is the optimal strategy. When $d_{bi}^1<\frac{4}{15}$ and $d_{si}^1<\frac{1}{6}$, Preferential price for old users is the optimal strategy. When $d_{bi}^1=\frac{4}{15}$ and $d_{si}^1<\frac{1}{6}$, the freight platform implements a uniform pricing strategy for bilateral users.

(2) First stage equilibrium

The freight supplier located at x_{s12}^1 satisfies the condition $U_{1,s}^1(x_{s12}^1)=U_{2,s}^1(x_{s12}^1)$, obtained $x_{s12}^1=\frac{(t+3\alpha+3ek\lambda)d_{b1}^1-(3\alpha+3ek\lambda)d_{b2}^1-3p_{s1}^1+3p_{s2}^1}{6t}$. Similarly, we get x_{s23}^1 and x_{s31}^1.

Therefore, in the first stage, the market share of freight platform i in the supply side are:

$$d_{s1}^1=\frac{2t+3(\alpha+ek\lambda)(2d_{b1}^1-d_{b2}^1-d_{b3}^1)-6p_{s1}^1+3p_{s2}^1+3p_{s3}^1}{6t}$$
$$d_{s2}^1=\frac{2t-3(\alpha+ek\lambda)(d_{b1}^1-2d_{b2}^1+d_{b3}^1)+3p_{s1}^1-6p_{s2}^1+3p_{s3}^1}{6t} \quad (6)$$
$$d_{s3}^1=\frac{2t-3(\alpha+ek\lambda)(d_{b1}^1+d_{b2}^1-2d_{b3}^1)+3p_{s1}^1+3p_{s2}^1-6p_{s3}^1}{6t}$$

Similarly, in the first stage, the market share of freight platform i in the demand side are:

$$d_{b1}^1=\frac{2t+6(\alpha-ek)d_{s1}^1+3(ek-\alpha)(d_{s2}^1+d_{s3}^1)-6p_{b1}^1+3p_{b2}^1+3p_{b3}^1}{6t}$$
$$d_{b2}^1=\frac{2t+3(ek-\alpha)(d_{s1}^1-2d_{s2}^1+d_{s3}^1)+3p_{b1}^1-6p_{b2}^1+3p_{b3}^1}{6t} \quad (7)$$
$$d_{b3}^1=\frac{2t+3(ek-\alpha)(d_{s1}^1+d_{s2}^1-2d_{s3}^1)+3p_{b1}^1+3p_{b2}^1-6p_{b3}^1}{6t}$$

By solving the equations in parallel, the result is substituted into the expression of the profit function, let the first derivative of the profit function is equal to 0, and the equilibrium price of the first stage of freight platform i is:

$$p_{bi}^1=\frac{2t-3(\alpha+ek\lambda)}{6} \quad (8)$$
$$p_{si}^1=\frac{2t-3(\alpha-ek)}{6}$$

Lemma 1. In the first stage, the market share of the three freight platforms is 1/3 respectively.

Proposition 2. In order to gain stronger local market monopoly power, all platforms want to be as far away from their competitors as possible, so the final equilibrium result is to position at equal distance from each other.

Then, substituting results of the first stage into (5), in the second stage, the equilibrium pricing of freight platform i can be obtained as:

$$p_{bi}^{2}=\frac{30ek+16t-30\alpha}{75}$$
$$p_{bi}^{2f}=\frac{30ek+14t-30\alpha}{75} \qquad (9)$$
$$p_{si}^{2}=\frac{2t}{9}-\frac{2(\alpha+ek\lambda)}{5}$$
$$p_{si}^{2f}=\frac{t}{9}-\frac{2(\alpha+ek\lambda)}{5}$$

Substituting (9) into (4), in the second stage, the market share of freight platform i for bilateral users can be written as:

$$d_{bi}^{2}=\frac{1}{3}-\frac{t(-3ek+t+3\alpha)}{t^{2}+9(ek-\alpha)(\alpha+ek\lambda)}$$
$$d_{si}^{2}=\frac{5t^{2}+24t(\alpha+ek\lambda)+45(ek-\alpha)(\alpha+ek\lambda)}{t^{2}+9(ek-\alpha)(\alpha+ek\lambda)} \qquad (10)$$

In the second stage, the profit of freight platform i is:

$$\pi_{i}^{2}=\frac{1571t}{5625}+\frac{4\alpha+2ek(\lambda-1)}{15} \qquad (11)$$

Assuming that the interval period between the two stages is short and the discount rate is 1, the total profit of freight platform I in the two stages is:

$$\pi_{i}^{1+2}=\frac{2821t}{5625}-\frac{\alpha}{15}+\frac{ek(\lambda-1)}{30} \qquad (12)$$

Proposition 3. In the second stage, the registration fee charged to new users is lower than that charged to old users, and the profit and equilibrium price increase with the expansion of platform differences and decrease with the increase of network externality.

Proof: $p_{ni}^{2f}-p_{ni}^{2}<0$, $\frac{\partial\pi_{i}^{1+2}}{\partial t}=\frac{2821}{5625}>0$, and $\frac{\partial\pi_{i}^{1+2}}{\partial\alpha}=-\frac{1}{15}<0$; $\frac{\partial p_{ni}^{2}}{\partial t}>0$, $\frac{\partial p_{ni}^{2f}}{\partial t}>0$; $\frac{\partial p_{ni}^{2}}{\partial\alpha}<0$, $\frac{\partial p_{ni}^{2f}}{\partial\alpha}<0$.

Proposition 3 shows that when network externality increase, freight platforms tend to take promotional measures such as reducing registration fees to compete for user scale. At this point, consumer surplus increases and platform profit decreases. When the differences between platforms expand, it means that the market monopoly degree of platform enterprises increases, and platform enterprises have more room to adjust prices, leading to higher prices and profits.

Proposition 4. The profit of freight platform increases with the improvement of platform matching capacity.

Proof: Due to $\lambda\in[0,1]$, $e\geq 0$ and $k\geq 0$, so we get $\frac{\partial\pi_{i}^{1+2}}{\partial e}=\frac{k(\lambda-1)}{30}\geq 0$.

Proposition 4 shows that the freight platform can increase the profit of the platform by improving the technical ability of supply and demand matching. Such as the use of artificial intelligence technology to build a digital vehicle and cargo matching platform to improve efficiency, reduce costs and to occupy absolute advantage in the future market competition.

4. CONCLUSION

For platform enterprises, discriminatory pricing is a common pricing strategy. Based on game theory and combining the characteristics of freight platform, this study uses Salop model to build a two-stage dynamic pricing model of differentiated platform, analyzes the impact of discriminatory pricing strategy on the profit and market share of freight platform enterprises and draws the following conclusions:

a) The equilibrium pricing of freight platform on both sides of freight supply and demand is related to platform differences, first-stage market share and network externality. In the second stage, the registration fee charged by the freight platform to new users is lower than that charged to old users, and the profit and equilibrium price increase with the expansion of platform differences and decrease with the increase of network externality.

b) The profit of freight platform increases with the improvement of platform matching capacity, but decreases with the increase of the proportion of remuneration paid by freight platform to freight supplier.

The research conclusions provide scientific basis and strategic Suggestions for platform enterprises to effectively implement the price strategy:

a) For freight platform enterprises, the size of network externality of two-sided users should be taken into account when adopting discriminatory pricing strategy, so as to judge whether it is feasible and reasonable to implement discriminatory pricing strategy. At the same time, the freight platform can change the difference between platforms to control the market share and stabilize its dominant position in the two-sided market.

b) The freight platform needs to constantly optimize the matching technology, increase the transaction times of bilateral users on the platform and improve the effectiveness of users' joining the platform, so as to enhance the platform's profitability and market competitiveness.

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