

Optimal Registration Price and Expected Revenue Study of C2C Second-Hand Trading Platforms

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ABSTRACT

This paper establishes a dynamic pricing model for C2C second-hand trading platforms under the influence of the utility of second-hand goods, analyzes and solves the model, and obtains the optimal registration price and optimal expected revenue of the second-hand platform. The research results show that in an oligopoly market, the optimal expected revenue of C2C second-hand platforms first decreases with the increase of the utility of goods. After the utility of goods increases to a certain value, the expected revenue of the second-hand platform increases with the increase of the utility of goods, and regardless of the utility of goods, the optimal expected revenue of the platform is always greater than zero. In addition, the size of the utility of goods has different impacts on the optimal seller registration fee and the optimal buyer registration fee. Therefore, this paper proposes suggestions such as adding distance ranking function and setting different transaction subsidies for different utility of goods to continuously improve the utility of second-hand goods traded on the platform.

KEYWORDS

C2C Second-hand Trading Platform; Dynamic Pricing Model; Utility of Goods; Optimal Expected Revenue.

1. INTRODUCTION

In recent years, with the change in consumer attitudes and the advancement of internet technology, more and more people are choosing to shop online. Fueled by the trend of online shopping, the volume of purchases is gradually increasing, leading to a continuous accumulation of idle goods. Consequently, second-hand trading platforms are gradually emerging. People now prioritize obtaining the highest utility from goods at the lowest possible price over owning the items themselves. According to a comprehensive analysis of the panorama of China's sharing economy released by iResearch, the transaction volume and growth rate of China's second-hand goods market from 2017Q1 to 2019Q1 are illustrated in Fig.1. The transaction volume of China's second-hand goods market increased from 131.67 billion yuan in 2017Q1 to 202.54 billion yuan in 2019Q1. The fastest growth rate was recorded in 2018Q2, with a year-on-year growth rate of up to 10.7%. Although the transaction volume and scale of second-hand trading platforms are gradually increasing, the current main source of profit for these platforms relies on the turnover investment of retained funds during transactions between buyers and sellers. This single source of revenue prompts consideration of adopting a membership fee-based model, similar to other sharing economy platforms, to charge fees to users on both sides of the transaction.

Generally, the sharing economy consists of three components: idle resources, sharing platforms, and supply and demand sides[1]. As second-hand trading platforms often allow sellers to set prices based

on the utility of their idle goods, exploring the impact of goods' utility on the platform's profitability holds significant practical significance.



Fig. 1 Trend of Transaction Volume and Growth Rate of China's Second-Hand Goods Market from 2017Q1 to 2019Q1

1.1. Literature Review

The research on pricing strategies in two-sided markets currently focuses on three main directions: Consumer behavior research, which primarily explores user belonging behavior and differences in preferences for product diversity; platform behavior research, which mainly investigates platform's exclusionary behavior and issues related to price commitments; and research on other factors influencing platform pricing, such as price elasticity of both sides of users and platform differentiation [2].Xue Rongna et al. [3] suggested that the quality of goods or services can impact platform pricing and proposed recommendations such as encouraging consumers to report misinformation about products and improving after-sales service mechanisms.Armstrong [4] found that the size of cross-network externalities, charging models, and user multi-belonging behavior all have significant impacts on equilibrium prices. Wang Shuangya et al. [5] considered the influence of within-network externalities on pricing models in two-sided markets. They established and studied three types of two-sided market models under different conditions: both sides of users equally single-belonging, one side single-belonging while the other side partially multi-belonging, and both sides partially multi-belonging.

In the realm of transactions, goods play a crucial role, with research often focusing on the impact of goods' quality on profits. There is limited research on the utility of goods obtained by both buyers and sellers. This paper combines the Hotelling model, considering factors such as platform service costs, transportation costs for buyers and sellers, to construct a pricing model for C2C second-hand platforms under oligopoly conditions influenced by the utility of goods. The model is then analyzed and validated.

2. MODELING OF C2C SECOND-HAND PLATFORM PRICING

2.1. Basic Assumptions

This paper primarily investigates the pricing strategy of C2C second-hand platforms during the early stages of development, where a one-time registration fee is charged to both buyers and sellers who intend to conduct transactions on the platform. Considering the platform's utilization of dynamic pricing to balance user quantity and registration fees, we further analyze the impact of factors such as utility of second-hand goods and service quality on the pricing of registration fees and expected

revenue for the service platform. The ultimate goal is to optimize the expected revenue of C2C second-hand platforms. The following assumptions are proposed:

Assumption 1: There is only one C2C second-hand trading platform in the market, without considering the presence of multiple competing platforms.

Assumption 2: For the platform, the input cost mainly includes the construction investment in the early stage and the service operation cost in the later stage. To simplify the model and the platform construction cost belonging to sunk cost, the platform construction cost is ignored in this model, and only the later service operation cost c is studied, $c = \gamma l^2$. where $\gamma > 0, l > 0$, denote the service cost coefficient and the service quality provided by the platform to users, respectively.

Assumption 3: Let $\varepsilon > 1$, denote the coefficient between the transaction volume and the users in the platform, since a single transaction is reached by both buyers and sellers, the total transaction volume of the platform is $\frac{\varepsilon(n_s + n_b)}{2}$ [6].

Assumption 4: t_b, t_s denote the unit transportation costs of individual buyers and individual sellers, respectively, both of which are greater than 0. Under oligopoly conditions t_b and t_s denote the difference between whether a user transacts on the platform or not. The number of individual buyers and individual sellers owned in the platform are n_b and n_s and, respectively. buyers and sellers need to pay the registration fee to the platform before the first transaction are P_b and P_s , respectively. And let $\min(t_b, t_s) > \max(\alpha_b, \alpha_s)$ [3].

Assumption 5: Considering that second-hand goods pricing is mainly determined by sellers, sellers may overestimate the utility of the goods to price the second-hand goods, and buyers spend some cost to select and purchase the goods on the platform. Therefore, θ is used to denote the proportion of the utility of the good to the buyer, and m is used to denote the actual utility of the good.

Assumption 6: Assume that buyers and sellers make only one transaction after paying the registration fee on the platform. Considering that almost no one is willing to spend a registration fee greater than the value of the good to transact on the platform, it should satisfy $\theta m > p_b$ and $m > p_s$.

Assumption 7: Considering that the C2C platform has intergroup network externality, the utility of buyers and sellers on the platform will be affected by the size of each other's quantity, and there is a positive correlation, and the coefficients of the intergroup network externality for individual buyers and sellers are denoted by α_b and α_s , which are affected by $\alpha_b n_s$ and $\alpha_s n_b$ respectively.

Table 1. Symbols and abbreviations

α_s	Intergroup Network Externality System for Individual Sellers	α_b	Intergroup network externality coefficients for individual buyers
n_s	Size of number of individual sellers	n_b	Size of number of individual buyers
P_s	Registration fees paid by individual sellers to the platform	P_b	Registration fees paid by individual buyers to the platform
v	Second-hand value of goods	a	Difficulty of trading commodities
θ	the coefficient of proportionality of the utility of the good to the individual buyer. $\theta \in [0, 1]$	m	Commodity utility of second-hand goods
t_s	Unit transportation costs for individual sellers	t_b	Unit transportation costs for individual buyers
x	the spatial location of individual sellers in a linear city $x \in [0, 1]$	y	Spatial location of individual buyers on a linear city, $y \in [0, 1]$
ε	coefficients between transaction volumes and users in the platform, $\varepsilon > 1$	c	marginal cost
π	Platform Profit	γ	Cost-of-service factor
l	Quality of services provided by the Platform to users		

Specific symbols are shown in Table 1.

2.2. Model Construction

Under a monopoly market, individual buyers receive the following utility:

$$u_b = \alpha_b n_s + \theta m - p_b - t_b y \quad (1)$$

Under a monopoly market, individual sellers receive the following utility:

$$u_s = \alpha_s n_b + m - p_s - t_s x \quad (2)$$

Under the oligopoly market, C2C second-hand platforms gain profits as follows:

$$\Pi = p_b n_b + p_s n_s - \frac{(n_b + n_s)}{2} \varepsilon c = p_b n_b + p_s n_s - \frac{(n_b + n_s)}{2} \varepsilon \gamma^2 \quad (3)$$

For a buyer and a seller to trade when and only when both get utility greater than 0, the following system of equations is obtained based on equations (1) and (2):

$$\begin{cases} n_b = y^* = \frac{\alpha_b n_s + \theta m - p_b}{t_b} \\ n_s = x^* = \frac{\alpha_s n_b + m - p_s}{t_s} \end{cases} \quad (4)$$

Following the method of backward reasoning, solving the system of equations (4) yields the following respective quantities for the buyer and seller users when utility is greater than zero:

$$\begin{cases} n_b = \frac{(\theta m - p_b)t_s + (m - p_s)\alpha_b}{t_s t_b - \alpha_s \alpha_b} \\ n_s = \frac{(\theta m - p_b)\alpha_s + (m - p_s)t_b}{t_s t_b - \alpha_s \alpha_b} \end{cases} \quad (5)$$

It is known that t_b , t_s , α_b , α_s , n_s , n_b are all greater than 0 and satisfy Assumption 6, which leads to $t_s t_b - \alpha_s \alpha_b > 0$.

Substitute the (5)'s back into the platform profit function (3) equation to get the platform profit function after determining the number of individual buyers and individual sellers, and take the second-order derivatives of P_b and P_s therein to get the Hessian matrix of the profit function with respect to P_b and P_s as follows:

$$\left| \begin{array}{cc} 2t_b & \alpha_s + \alpha_b \\ \alpha_b \alpha_s - t_b t_s & \alpha_b \alpha_s - t_b t_s \\ \alpha_s + \alpha_b & 2t_s \\ \alpha_b \alpha_s - t_b t_s & \alpha_b \alpha_s - t_b t_s \end{array} \right| = \frac{4t_b t_s - (\alpha_b + \alpha_s)^2}{(t_b t_s - \alpha_b \alpha_s)^2} \quad (6)$$

The first-order sequential principal subequation of this Hessian matrix is greater than 0 ($\frac{2t_b}{\alpha_b \alpha_s - t_b t_s} < 0$), according to Assumption 4: $\min(t_b, t_s) > \max(\alpha_b, \alpha_s)$, It can be obtained that the

second order sequential principal subequation is greater than 0 ($\frac{4t_b t_s - (\alpha_b + \alpha_s)^2}{(t_b t_s - \alpha_b \alpha_s)^2} > 0$). Therefore, since

the Hessian matrix is negative definite, there exists an optimal registration fee that allows the C2C second-hand platform to maximize profit. By setting the first-order derivatives of the registration fees for both buyers and sellers to zero and solving simultaneously, the optimal registration fees that the platform should charge to both buyers and sellers can be obtained as equations (7) and (8). Substituting these optimal registration fees back into the platform profit function yields the optimal profit equation (9) for the C2C second-hand platform at that time.

$$p_b^* = \frac{\gamma^2 \varepsilon (2t_b t_s - t_b \alpha_b + t_b \alpha_s - \alpha_b^2 - \alpha_b \alpha_s) + 2mt_b (\alpha_b - \alpha_s) + 2m\theta (2t_b t_s - \alpha_b \alpha_s - \alpha_s^2)}{2(4t_b t_s - (\alpha_b + \alpha_s)^2)} \quad (7)$$

$$p_s^* = \frac{\gamma^2 \varepsilon (2t_b t_s + t_s \alpha_b - t_s \alpha_s - \alpha_s^2 - \alpha_b \alpha_s) + 2m(2t_s t_b - \alpha_s \alpha_b - \alpha_b^2) + 2m\theta (2\alpha_s t_s - \alpha_b t_s)}{2(4t_b t_s - (\alpha_b + \alpha_s)^2)} \quad (8)$$

$$\Pi^* = \frac{\gamma^2 l^4 \varepsilon^2 (t_s + t_b + \alpha_s + \alpha_b) + \gamma l^2 \varepsilon \theta m (4t_s - 2\alpha_s - 2\alpha_b) + 4m^2 \theta^2 t_s + 4m^2 \theta (\alpha_b + \alpha_s) + 4m^2 t_b - 2\gamma l^2 \varepsilon m (2t_b + \alpha_s + \alpha_b)}{4(4t_b t_s - (\alpha_b + \alpha_s)^2)} \quad (9)$$

2.3. Decomposition of the Model

(1) The impact of the utility of second-hand goods, denoted as m , on the expected profit Π of the C2C second-hand platform. In equation (9), the first-order and second-order derivatives of platform profit with respect to the utility of goods are calculated as follows: $\frac{\partial^2 \Pi}{\partial m^2} = \frac{2(t_s \theta^2 + \theta \alpha_b + \theta \alpha_s + t_b)}{4t_b t_s - (\alpha_b + \alpha_s)^2} > 0$. Therefore,

there exists a utility value m of second-hand goods that minimizes the platform profit Π . Let $\frac{\partial \Pi}{\partial m} = 0$,

When the first derivative is equal to 0, $m = \frac{\gamma^2 \varepsilon (2t_s \theta + \theta \alpha_b + \theta \alpha_s + 2t_b + \alpha_b + \alpha_s)}{4\theta(t_s \theta + \alpha_b + \alpha_s) + 4t_b} > 0$, the minimum profit at

this point: $\Pi = \frac{\varepsilon^2 \gamma^2 l^4 (\theta - 1)^2}{16(t_s \theta^2 + \theta \alpha_b + \alpha_s \theta + t_b)} > 0$. when the utility of second-hand goods satisfies the following

inequality: $m > \frac{\gamma^2 \varepsilon (2t_s \theta + \theta \alpha_b + \theta \alpha_s + 2t_b + \alpha_b + \alpha_s)}{4\theta(t_s \theta + \alpha_b + \alpha_s) + 4t_b}$, The platform profit increases as the utility of the goods increases.

(2) The impact of the service cost coefficient γ on the expected profit Π of the C2C second-hand platform. In equation (9), the first-order derivative and the second-order derivative of platform profit

with respect to the service cost coefficient are obtained: $\frac{\partial \Pi^*}{\partial \gamma} = \frac{\gamma \varepsilon^2 l^4 (\theta - 1)^2}{8(t_s \theta^2 + \alpha_b \theta + \alpha_s \theta + t_b)} > 0$,

$\frac{\partial^2 \Pi^*}{\partial \gamma^2} = \frac{\varepsilon^2 l^4 (\theta - 1)^2}{8(t_s \theta^2 + \alpha_b \theta + \alpha_s \theta + t_b)} > 0$. From this, it can be seen that the platform's expected profit increases with the increase of the service cost coefficient, and the marginal expected profit of the platform also increases with the increase of the service cost coefficient. From the perspective of maximizing the optimal profit of C2C second-hand platforms, under unchanged conditions, increasing the service cost coefficient can enable the platform to obtain greater profits, and the growth rate shows an increasing trend. Platforms should strive to provide the highest quality services at the lowest cost possible to achieve greater profits.

3. SIMULATION AND ANALYSIS OF PRICING MODELS FOR C2C SECOND-HAND PLATFORMS: CONSIDERING PRODUCT UTILITY FACTORS

The analysis of various constraints in this paper, based on relevant research and experience, sets the following parameters: $\gamma=1.9$, $l=0.9$, $t_b=0.6$, $t_s=0.45$, $\varepsilon=10$, $\alpha_b=0.1$, $\alpha_s=0.3$, $\theta=0.8$. Using Maple 2008 for plotting, the function of C2C second-hand platform profit with respect to product utility is depicted in Fig. 2.

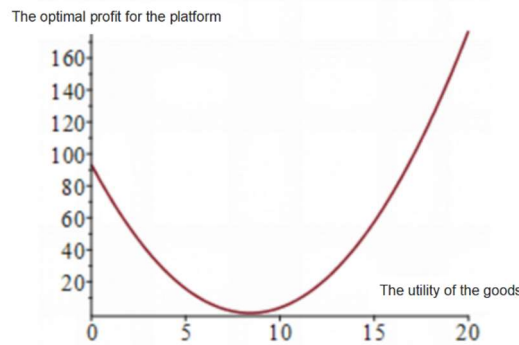


Fig. 2 Function of Second-hand Platform Profit with Respect to Product Utility

From Fig. 2, it can be observed that the optimal profit of the C2C second-hand platform exhibits a trend of initially decreasing and then increasing with the increase in product utility. Additionally, regardless of how product utility changes, the platform's optimal profit remains greater than 0. From the trend depicted in the graph, under unchanged conditions, the platform should strive to enhance the utility of second-hand goods to achieve greater benefits.

Further analysis of the relationship between product utility and the optimal buyer registration fee and optimal seller registration fee is illustrated in Fig.3, as shown below.



Fig. 3 Platform's Optimal Pricing Function with Respect to Product Utility

From Fig. 3, it can be observed that both the optimal seller registration fee and the optimal buyer registration fee exhibit a gradually linear growth trend with the increase in product utility. Specifically, the seller registration fee is more significantly influenced by the increase in product utility compared to the buyer registration fee. However, before reaching the critical value where the optimal seller registration fee equals the optimal buyer registration fee due to the growth of product utility, the platform should charge buyers a higher registration fee than sellers. This is because products with initially low utility have inherently lower value, even if a successful transaction occurs, the total utility that the seller can obtain is relatively low. At this stage, if a high registration fee is charged to sellers to sell their second-hand goods on the platform, the total utility obtained by the seller would only be slightly higher or even lower than the utility of the second-hand goods themselves.

4. CONCLUSION AND RECOMMENDATIONS

This paper focuses on the early development stage of C2C second-hand platforms, where there exists a monopoly market with only one platform. A dynamic pricing model based on product utility is constructed. The study demonstrates that product utility has a significant impact on the profit of C2C second-hand platforms. When product utility is below a certain threshold, platform profit decreases with increasing product utility. Conversely, when product utility exceeds a certain threshold, platform profit increases with utility. However, the impact of product utility on the optimal seller registration fee and optimal buyer registration fee differs. The seller's registration fee is more affected.

Based on the research findings, the following recommendations are proposed:

- (1) Before sellers upload second-hand goods for trading, detailed product information should be collected from them. Based on this information, an estimation of product utility can be made. For goods with high utility, platforms can consider offering rebates or subsidies to encourage transactions of high utility goods.
- (2) Implement a feature that sorts second-hand goods by distance to increase the transaction success rate. Buyers can use this feature to select sellers with the lowest transportation costs, especially for goods with high utility. Buyers and sellers in close proximity can choose offline transactions, which can also increase the transaction success rate of goods with high utility.

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