SHOULD A SHARING PLATFORM INVEST IN SELF-FULFILLMENT PRODUCTS?

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ABSTRACT

The emergence of a sharing economy increases the utilization of existing products/services and reduces the consumption of new resources. We develop an analytical model to study whether a sharing platform should invest in self-fulfillment products or not and that the platform how to choose from three business modes. We consider two factors (i.e. consumers' type and product's cost) that effect the outcomes. We find that when the proportion of high-type consumers is high enough, B2P (i.e. fully self-fulfillment mode) is the optimal mode for the sharing platform; when the proportion of two types of consumers is approximately equivalent, B2P and P2P (i.e. fully collaborative consumption among consumers) are the optional optimal modes: when the product cost is low or high, P2P is the optimal mode, when the product cost is moderate, B2P is the optimal mode; When the proportion of high-type consumers is low, B2P and hybrid mode are the optional optimal modes: when the product cost is low or high, hybrid mode is the optimal mode, when the product cost is moderate, B2P is the optimal model. Our research enriches the theory of sharing economy and offers some guidelines for the sharing platforms in practice. For sharing platforms that provide instant services, the openness of the platform and whether to provide self-fulfillment products can be determined according to the preference of consumers and the product cost.

Keywords: Sharing platform; Business mode; Self-fulfillment products

1. Introduction

In e-commerce retailers, it is very common for platforms to provide self-fulfillment products. For example, Amazon sells a large amount of products through its self-fulfillment mode (amazonbasics). However, for a sharing platform, it seems that the platform does not need to provide self-fulfillment products. Because the sharing platform was originally created to allow consumers to share idle products other than buy new products. Until now, in almost all transactions, Uber does not use its own cars, and Airbnb does not use its own houses. But in recent years, we have been surprised to find that some sharing platforms are beginning to offer self-fulfillment products. For example, in car sharing field, on February 22, 2019, German auto giants BMW and Daimler jointly announced that they would jointly invest 1 billion euros to establish five travel joint ventures to challenge Uber, Waymo, Didi and other car sharing platforms. Actually, BMW's sharing car program 'DriveNow' already used self-fulfillment cars. In addition, Toyota plans to invest in a similar sharing program and the program will use Toyota cars. What's more interesting is that, in

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2018, Uber invested in electric scooter project 'Lime' and all the electric scooters in the platform are self-fulfillment products. In reality, almost all the sharing bikes are products purchased by the platform itself such as Lyft's Citi Bike program in New York City and Jersey City and Uber's e-bike program 'JUMP'.

Schor [2014] proposes that the sharing platform should be classified according to two dimensions which are 'market orientation' and 'market structure'. These two dimensions reflect the business mode of the sharing platform. He divides the sharing platform into two types according to their orientation: profitable and non-profit platforms. He also divides the sharing platform into two types according to their structure: P2P (person to person) and B2P (business to person) platforms. According to Schor's classification, we have four types of sharing platform, i.e. (P2P, non-profit platform), (P2P, profitable platform), (B2P, non-profit platform), (B2P, profitable platform). For example, the first type of platform is represented by NeighborGoods which is a P2P platform for sharing daily necessities. Product owners can obtain rental income, while the platform doesn't extract commission fees. Uber, RelayRides and Spinlister are representative *companies* for second type of platforms; Maker Space is one of the third type of platform which provides the workspace for people who are connected with common interests (usually computers, mechanics, technology, science, digital art, or electronics) to get together, socialize and collaborate. Mobike and Zipcar are representative enterprises for fourth type of platforms, they adopt self-fulfillment mode to make consumers enjoy more convenience, although the initial investment is expensive. In view of the diversity of the above sharing platforms, we want to explore whether the sharing platform should to invest in self-fulfillment products or not. Therefore, we address the following research questions:

RQ1: Under what conditions is the self-fulfillment mode (B2P) profitable for a sharing platform?

RQ2: What percentage of self-fulfillment products should the sharing platform invest in?

RQ3: What business mode should the sharing platform choose? (P2P, B2P or hybrid mode)

Now although the patterns of sharing platforms are classified, there are few studies on how to choose the appropriate mode for the platform. To answer these questions, we consider a market with a sharing platform, and consumers who can either purchase the product directly from the manufacturer or transact in the sharing platform. We build a economic model to analyze the optimal mode chosen by the sharing platform. If B2P mode is selected, the platform adopts the self-fulfillment mode, which means that the platform purchases the products from the manufacturer and leases them to consumers. If P2P business model is selected, the platform adopts the mode of sharing between consumers. If the platform take B2P and P2P hybrid business mode, the platform provide a proportion of products itself, some consumers buy products from manufacturers, and platform can buy a quantity of products from product manufacturers and leases them to the other consumers. The platform benefit from both its self-fulfillment products and commission fees from transactions between consumers.

From the perspective of two-sided markets, the emergence of the sharing platforms is beneficial to both providers and consumers. For providers, the emergence of platforms allows them to obtain additional benefits during the idle time of the products; for consumers, the sharing market provides them with instant services and allows them to obtain short-term urgently services at any time and any place. For example, we have the sharing bicycles, sharing cars, sharing houses, etc. They are different from traditional leasing. The individual use time of consumers is very short, but the overall use frequency of the sharing products is very high. This article focuses on this type of the sharing market. In a fully self-fulfillment market, we have considered three possible cases in which someone leases products from the platform. In the sharing market, the sharing platform only serves as an intermediate platform to provide services. In the hybrid model, the platform supplements the market with homogeneous products. In different models, market equilibrium conditions determine the final rental price which is consistent with Jiang [2018]. In the research of this article, we temporarily do not consider the platform can provide higher quality self-fulfillment products which account for a small part of the platform's self-fulfillment products.

We find that when the proportion of high-type consumers is high enough, B2P is the optimal mode for the sharing platform; when the proportion of two types of consumers is approximately equivalent, B2P and P2P are the optional optimal modes: when the product cost is low or high, P2P is the optimal mode, when the product cost is moderate, B2P is the optimal model; When the proportion of high-type consumers is low, B2P and hybrid mode are the optional optimal modes: when the product cost is low or high, hybrid mode is the optimal mode, when the product cost is moderate, B2P is the optimal model. With the heterogeneity of consumers increases, the possibility of choosing B2P model for sharing platform will increase, and the possibility of choosing P2P model will decrease.

This study provides three contributions. First, to the best of our knowledge, our study is first in-depth analysis of business mode selections for a sharing platform. There are only some conceptual studies about the classification of sharing platforms in the existing literature, we found three factors that influence the choice of platform business modes.

Second, our study contributes to the existing online platform strategy. Though, self-fulfillment mode is very common in e-commerce platforms, our study finds that the self-fulfillment mode (B2P) can be profitable for a sharing platform in certain conditions.

Third, our study contributes to the existing theory of sharing economy. Traditional collaborative consumption mode may be not always fit for a sharing platform and we find that it is beneficial for a sharing platform to adopt a certain percentage of self-fulfillment products in certain conditions. Our research extends the framework of the sharing economy especially related with self-fulfillment products.

The remainder of the paper is organized as follows. In section 2, we review the related literature. Section 3 discusses the B2P mode. We analyze the P2P and hybrid modes in section 4. In section 5, we compare three business modes. Section 6 extends our paper and section 7 concludes the paper.

2. Literature review

In this section, we review the literature from three streams: online platform strategy, two-sided market and sharing economy.

2.1. Online platform strategy

In recent years, the platform business model has been the focus of scholars in different fields. There are two types of tactics for intermediaries such as Alibaba and Amazon as follow: one is to provide the buyers and sellers with trading channels as the marketplace (e.g., online travel agency [Zheng et al. 2015]), and the other is similar to a reseller, which buys a product or service from a provider before selling it to the consumer. Hagiu and Wright [2014] argue that the most significant difference between the two modes is the distribution of control; the control of the first model (including pricing, advertising and customer service, etc.) lies with the supplier, while the retailer model's control lies entirely with the retailer. From the pricing point of view, these two strategies are the agency model and the wholesale model. Abhishek et al. [2015] find that agency selling is more efficient than reselling and leads to lower retail prices; sales in the electronic channel lead to a negative effect on demand in the traditional channel; additionally, e-tailers prefer agency selling. Kwark et al. [2013] study the impact of agency and wholesale models on online retailers' profit when online retailers provide product reviews. They find that the agency model and the wholesale model have potential impacts on online retailers' profits but with opposite effects. Hao and Fan [2014] study the agency model and the wholesale model in the e-book market; they find that the price for e-book readers and social welfare are lower in the agency model than in the wholesale model and that total consumer surplus is slightly higher in the agency model. Sohn et al. [2008] indicate that for the supply chain, information sharing can be beneficial for the participants.

Research on the business model of the platform mainly focuses on the field of e-commerce. However, in sharing economy, the agency and wholesale models can't be applied to a sharing platform's business mode completely. There have been few studies that explore the online sharing platform's strategy or mode and we want to fill the gap.

2.2. The two-sided market

The two-sided market literature mainly studies pricing strategy in platform setting. Rochet and Tirole [2003] study how the price allocation between two sides of the market is affected by various factors, including platform governance, end users' cost of multihoming, platform differentiation, platform's ability to use volume-based pricing, the presence of same-side externalities, and platform compatibility. The authors further provide a road map to the two-sided market literature and present new results [Rochet and Tirole, 2006]. Parker and Van Alstyne [2005] study strategic information product pricing and design issues characterizing the two-sided network externalities. Economides and Katsamakas [2006] study the optimal two-sided pricing strategy for the technology platforms. Chou et al. [2012] study the pricing of a platform to jointly determine the selling price of the platforms (hardware) sold to consumers and the royalty charged to content developers for content (software). Recent studies extend platform research to a broad setting. Hagiu and Spulber [2013] introduce investment in first-party content as a strategic variable for two-sided platforms and show the interplay with platforms' pricing strategies. Hao et al. [2017] develop a two-sided market model to analyze the platform owner's optimal advertising revenue-sharing (agency) contract with an app developer. Dou et al. [2017] study the pricing strategy of a two-sided platform under consumer categorization and Choi et al. [2019] study the pricing staategy and bunding on the game platforms.

The net neutrality debate is also discussed as an economic issue from the perspective of two-sided market. Economides and Tag [2012] develop a model of two-sided market to assess the effects of the Internet departing from net neutrality. Cheng and Bandyopadhyay [2011] specifically discuss who are gainers and losers of abandoning net neutrality. Guo et al. [2012] find that although abandoning net neutrality sometimes increases consumer surplus and broadband market cove, it reduces innovation. Guo et al. [2013] explore a complete spectrum of broadband network management options based on the supply and demand sides of the market. Guo and Easley [2016] examine the link between network neutrality and content innovation on the Internet. Cai et al. [2012] investigate the joint impact of exclusive channels and revenue sharing on suppliers and retailers in a complementary goods market, where the suppliers sell products and the retailers sell complementary goods/services simultaneously.

Although the sharing platform is also essentially a two-sided market, the mode of the sharimg platform is different from that of the traditional two-sided market. Meanwhile, little is know about whether to use self-fulfillment products when the sharing platform faces three business modes (B2P, P2P and hybrid modes).

2.3. The sharing economy

The sharing economy has drawn much attention in practice and academic research. Most of the studies on P2P sharing introduce this phenomenon at the conceptual level (e.g., Botsman and Rogers [2010], Belk [2010]); Cullen and Farronato [2014] establish a matching model in the P2P labor market through using TaskRabbit data and find that when demand doubles, sellers work almost twice as hard, prices hardly increase and the probability of requested tasks being matched only slightly falls. Hall and Krueger [2015] analyze the details of the average wage received by the drivers who provide transportation on the P2P platform Uber and find that Uber driver-partners earn at least as much as taxi drivers and chauffeurs, and in many cases, they even earn more, indicating that the change in the supply of drivers will not significantly affect the average wage level. Fraiberger and Sundararajan [2017] use the US car industry data and Getaround's P2P car rental data to study the welfare and distribution role of the P2P leasing market, they find improvements in consumer welfare due to the availability of the sharing marketplace and significantly higher improvements for the below-median income segment. Bai et al. [2018] uses queuing theory to study the supply and demand coordination of an on-demand P2P service platform. The research shows that when the potential customer demand increases, the optimal strategy of the platform is to increase the price and payout ratio. Haider et al. [2018] uses a heuristic approach to rebalance the bicycle sharing system. Zervas et al. [2016] uses the Airbnb data from Texas to estimate Airbnb's impact on the pricing and revenue of existing hotels, and they find that the impacts are distributed unevenly across the industry, where lower-end hotels and hotels not catering to business travelers are the most affected. Weber [2014] finds that when the lender and the lessee are risk-neutral, the sharing agency can eliminate the moral hazard problem by providing the lender with the best insurance contract and the best incentives for the lessee. Jiang and Tian [2016] study the impact of P2P product sharing. They indicate that when a monopoly manufacturer sells products directly to consumers, the manufacturer's unit costs and the transaction costs (moral hazard costs and platform charges) play crucial roles in the sharing market. They find that when the marginal cost is relatively high, consumers and manufacturers will achieve a win-win situation. However, when the marginal cost is very low, consumers and manufacturers will both suffer. For manufacturers, the optimal product quality and price will be increased due to the sharing among consumers. Jiang and Tian [2018] study the impact of product sharing on distribution channels. They find that a sharing market will increase the retailers' share of gross margin, and companies can profit from higher capacity-building costs, but it is more likely to increase the retailers' profits than the manufacturers' profits, i.e., product sharing sometimes sacrifices upstream manufacturers' profits to balance the downstream retailers' profit. Benjaafar et al. [2018] study a similar product sharing model where product owners will lend their products through a sharing platform and they find that the product's ownership and usage will be higher in equilibrium collaborative consumption. Weber [2016] indicates that in the sharing market, the price of the product will increase, the high cost product will benefit the enterprise and the consumer; additionally, the introduction of a peer-to-peer economy increases both the consumer surplus and social welfare.

The existing literatures on the sharing economy assumes that collaborative consumption mode among consumers (P2P) is adopted by the sharing platform. There are few studies in the literature that focus on other possible business modes adopted by the platform in reality. And our study takes it into consideration.

3. Fully self-fulfillment model (B2P mode)

Considering a profitable sharing platform, there are three business modes to choose from. If the B2P mode is selected, the platform adopts the self-fulfillment mode, which means that the platform purchases the products from the manufacturer and leases them to consumers.

From the perspective of the platform, we assume that the cost of products purchased by some consumers or the sharing platform remains unchanged, which can also be understood as the manufacturer's exogenous pricing of products. Our study does not consider the manufacturer's product pricing decisions, and assumes that the price is an exogenous variable. The meanings of the symbols are shown in table 1.

For the convenience of comparison, we denote $j \in \{B, P, H\}$ to stand for the B2P mode, P2P mode and the hybrid mode respectively.

Table 1: The main variables and parameters in the paper.

Notations	Implications (i $\in \{H, L\}$, j $\in \{B, P, H\}$, $\alpha \in [0,1]$)
t_i	Product consumption time t for consumers i
v_i	Consumer i's utility from consuming the product;
r	Market clean rental price;
${\pi_i}^j$	Consumer i's decision problem in mode j;
D^j	Product demand in mode j;
n	The amount of the sharing platform's self-fulfillment products;
β^j	The sharing platform's commission rate in mode j;
γ	Rental price when the platform chooses B2P business model;
c	Product's unit purchasing cost;
θ_i	Consumer i's preference for the product;
α	Proportion of high-typed consumers.

We consider a sharing market which adopts the B2P mode. We assume that the size of consumers in the market is 1. Consumers are differentiated by their preference towards the products as follows, High-type consumers means that their preference towards the product is relatively high and low-type consumers means that their preference towards the product is relatively low. A proportion of α high-type consumers whose preference towards the product is θ_H, and a proportion of $(1-\alpha)$ low-type consumers, whose preference towards the product is θ_L. The consumers' utility from consuming the product comes from the time they consume it (Becker 1965). Assume that the life span of the product is 1. Let $t \in [0,1]$ denote the time that consumers consume the product. Then, a consumer who consumes the product for a period of time t obtains a benefit of $\theta_i t$, where $i \in \{H, L\}$, and incurs an opportunity cost of $\frac{t^2}{2}$ which is less than the consumption benefit when $t < 2\theta_i$, the opportunity cost is an important factor affecting product consumption (Fred [1973], Shaw [1992]). Therefore, we can write the consumer's utility function as $v_i(t) = \theta_i t - \frac{t^2}{2}$.

We denote r as the rental fee. (1) If both two types of consumers choose to use products leased from the platform, the total utility denoted as U_i for two types of consumers are as follows:

$$\max_{t \in [0,1]} U_i(t) = \theta_i t - \frac{t^2}{2} - tr.$$

The optimal consumption time and maximum value from consuming the product are then as follows:

$$t_i^* = \theta_i - r,\ v_i^* = \frac{1}{2}(\theta_i - r)^2.$$

(2) If consumers choose to buy products from manufacturers, the decision problem is:

$$\max_{t \in [0,1]} U_i(t) = \theta_i t - \frac{t^2}{2} - c.$$

The optimal consumption time and value are as follows:

$$t_i^* = \theta_i,\ v_i^* = \frac{\theta_i^2}{2} - c.$$

If the platform adopts the B2P model, it will be profitable only if consumers are willing to participate in the B2P market and choose to lease products. We assume that when high-type consumers can afford the sharing products, low-type consumers have three possibilities: (1) buying products (2) leasing products (3) not participating; when high-type consumers lease the sharing products, low-type consumers have two possibilities: (1) renting products (2) not participating; when high-type consumers are not participating, low-type consumers are also not participating. We find that there are three potential market cases: (1) both types of consumers choose to lease products from the platform rather than buy products from the manufacturer; (2) high-type consumers choose to lease products from the platform, while low-type consumers choose not to lease; (3) high-type consumers choose to buy products, while low-type consumers choose to lease products from the platform. We analyze the above three cases as follows:

3.1. Case one in fully self-fulfillment model

When both types of consumers choose to lease products from the platform rather than buy products from the manufacturer, the decision problem of the platform is as follows:

$$\begin{cases}\max\limits_{r}\pi_p(r) = [\alpha(\theta_H - r) + (1-\alpha)(\theta_L - r)](r-c) \\ \qquad s.t. \quad \frac{1}{2}(\theta_H - r)^2 \geq \frac{1}{2}{\theta_H}^2 - c, \frac{1}{2}(\theta_L - r)^2 \geq \frac{1}{2}{\theta_L}^2 - c, \theta_H - r \geq 0, \theta_L - r \geq 0\end{cases}$$

These first two conditions ($\frac{1}{2}(\theta_H - r)^2 \geq \frac{1}{2}{\theta_H}^2 - c, \frac{1}{2}(\theta_L - r)^2 > \frac{1}{2}{\theta_L}^2 - c$) guarantees that for both types of consumers, leasing is better than buying products. And the other conditions ($\theta_H - r \geq 0, \theta_L - r \geq 0$) guarantees that the leasing time is not negative.

Solving this problem, we have the following lemma one as follows:

Lemma 1: When both types of consumers choose to lease products from the platform rather than buy products from the manufacturer in the *B2P mode, the equilibrium commission rate and profit of the platform are shown in table 2.*

Table 2: The equilibrium commission rate and profit of the platform in case one.

Product's unit purchasing cost	Commission rate	Platform's profit
${c_1}^1 < c < {c_2}^2$	$r^B = \frac{\alpha\theta_H + (1-\alpha)\theta_L + c}{2}$	${\pi_P}^* = \frac{(\alpha(\theta_H - \theta_L) + \theta_L - c)^2}{4}$
$c < min\{c_1, {c_3}^3\}$ or $\theta_H < \frac{\theta_L(4+\theta_L)}{2(1+\theta_L)}$ and $c < c_1$	$r^B = \theta_H - \sqrt{{\theta_H}^2 - 2c}$	${\pi_P}^* = \left[\alpha(\theta_H - \theta_L) + \theta_L + \sqrt{{\theta_H}^2 - 2c} - \theta_H\right] * \left(\theta_H - \sqrt{{\theta_H}^2 - 2c} - c\right)$

3.2. Case two in fully self-fulfillment model

When high-type consumers choose to lease products from the platform, while low-type consumers choose not to lease, the decision problem of the platform is as follows:

$$\begin{cases}\max\limits_{r}\pi_p(r) = \alpha(\theta_H - r)(r-c) \\ \qquad s.t. \frac{1}{2}(\theta_H - r)^2 \geq \frac{1}{2}{\theta_H}^2 - c, \theta_L - r \leq 0, \theta_H - r \geq 0\end{cases}$$

These first conditions ($\frac{1}{2}(\theta_H - r)^2 \geq \frac{1}{2}{\theta_H}^2 - c$) guarantees that for high-type consumers, leasing is better than buying products. And the other conditions ($\theta_H - r \geq 0, \theta_L - r \leq 0$) guarantees that the leasing time of high-type consumers is not negtive and low-type consumers choose not to lease.

Solving this problem, we have the following lemma two as follows:

Lemma 2: When *high-type consumers choose to lease products from the platform, while low-type consumers choose not to lease or buy the products, the equilibrium commission rate and profit of the platform are shown in table 3.*

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[1] $c_1 = 2\sqrt{(2-\theta_H)^2 + 2\theta_H\alpha + 2\theta_L(1-\alpha)} + \theta_H(2-\alpha) - \theta_L(1-\alpha) - 4$

[2] $c_2 = \theta_L - \alpha(\theta_H - \theta_L)$

[3] $c_3 = \theta_H\theta_L - \frac{{\theta_L}^2}{2}$

Table 3: The equilibrium commission rate and profit of the platform in case two.

Product's unit purchasing cost	Commission rate	Platform's profit
$\theta_H > \frac{\theta_L(4+\theta_L)}{2(1+\theta_L)}$ and c_4[4] $< c < \theta_H$ or $\theta_H < \frac{\theta_L(4+\theta_L)}{2(1+\theta_L)}$ and $2\theta_L - \theta_H < c < \theta_H$	$r^B = \frac{\theta_H + c}{2}$	$\pi_P{}^* = \frac{\alpha(\theta_H - c)^2}{4}$
$\theta_H > \frac{\theta_L(4+\theta_L)}{2(1+\theta_L)}$ and $c_3 < c < c_4$	$r^B = \theta_H - \sqrt{\theta_H{}^2 - 2c}$	$\pi_P{}^* = \alpha\sqrt{\theta_H{}^2 - 2c}\left(\theta_H - \sqrt{\theta_H{}^2 - 2c} - c\right)$
$\theta_H < \frac{\theta_L(4+\theta_L)}{2(1+\theta_L)}$ and $c_3 < c < 2\theta_L - \theta_H$	$r^B = \theta_L$	$\pi_P{}^* = \alpha(\theta_H - \theta_L)(\theta_L - c)$

3.3. Case three in fully self-fulfillment model

When high-type consumers choose to buy products, while low-type consumers choose to lease products from the platform, the decision problem of the platform is as follows:

$$\begin{cases} \max_r \pi_p(r) = (1-\alpha)(\theta_L - r)(r - c) \\ s.t. \frac{1}{2}(\theta_H - r)^2 \leq \frac{1}{2}\theta_H{}^2 - c, \frac{1}{2}(\theta_L - r)^2 \geq \frac{1}{2}\theta_L{}^2 - c, \theta_L - r \geq 0 \end{cases}$$

These first two conditions ($\frac{1}{2}(\theta_H - r)^2 \leq \frac{1}{2}\theta_H{}^2 - c, \frac{1}{2}(\theta_L - r)^2 \geq \frac{1}{2}\theta_L{}^2 - c$) guarantees that for high-type consumers, buying is better than leasing products and for low-type consumers, leasing is better than buying products. And the other condition ($\theta_L - r \geq 0$) guarantees that the leasing time of low-type consumers is not negative.

Solving this problem, we have the following lemma three:

Lemma 3: When high-type consumers choose to buy products, while low-type consumers choose to lease products from the platform, the equilibrium commission rate and profit of the platform are shown in table 4.

Table 4. The equilibrium commission rate and profit of the platform in case three.

Product's unit purchasing cost	Commission rate	Platform's profit
c_5[5] $< c < c_6$[6]	$r^B = \frac{\theta_L + c}{2}$	$\pi_P{}^* = \frac{(1-\alpha)(\theta_L - c)^2}{4}$
$c < c_5$	$r^B = \theta_L - \sqrt{\theta_L{}^2 - 2c}$	$\pi_P{}^* = (1-\alpha)\sqrt{\theta_L{}^2 - 2c}\left(\theta_L - \sqrt{\theta_L{}^2 - 2c} - c\right)$

Comparing the equilibrium profit of the platform in three cases, we can get the optimal decision of the platform under the B2P model as follows:

Proposition 1: for the platform,

(1) Case one is optimal when the product cost and proportion of high-type consumers is relatively high;

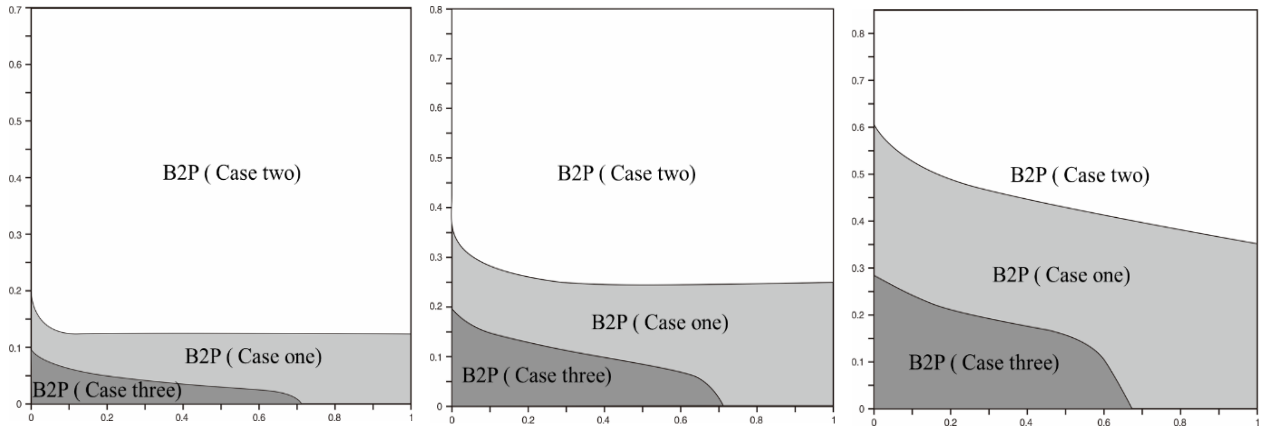
(2) Case two is optimal when the product cost and proportion of high-type consumers is high;

(3) Case three is optimal when the product cost and proportion of high-type consumers is low.

[4] $c_4 = 2\sqrt{\theta_H{}^2 - 2\theta_H + 4} + \theta_H - 4$

[5] $c_5 = 2\sqrt{\theta_L{}^2 - 2\theta_L + 4} + \theta_L - 4$

[6] $c_6 = 2\sqrt{(\theta_H - 2)^2 + 2\theta_L} + 2\theta_H - \theta_L - 4$



（a） $\theta_H = 0.7, \theta_L = 0.2$ （b） $\theta_H = 0.8, \theta_L = 0.4$ （c） $\theta_H = 0.85, \theta_L = 0.6$

Figure 1. Optimal case for a sharing platform (the abscissa represents the proportion of the high-type consumers and the ordinate represents the cost of the product.)

Proposition 1 reveals the strategic choice of a sharing platform which adopts B2P model in different market cases. In B2P business model, two types of consumers ether buy or lease the product, when product's purchase cost is low, high-type consumer will choose to buy the product, and the low-type consumers will choose lease the product from platform. The platform will set a lower rental price to make the low-type consumers participate in the sharing market. The platform pays for the cost of purchasing the product while benefiting from the consumer (case three). When product purchase cost is higher, high-type consumers will switch from buying the product into leasing from the platform. The platform will set a higher rental price to make up for the cost of purchasing cost, two types of consumers both participate in the sharing market (see case 1). In order to ensure that both types of consumers can participate, the cost of the product needs to meet some constraints, and the constraint needs to change with the market share consumers. When purchase cost is high enough, the platform will set a higher rental price to make up for the high cost. Low-type consumers will not afford the sharing product, only high-type consumer participate in the sharing market. In this case, the rental price will be higher, and the platform will only benefit from the high-type consumers (case two). Figure 1(a) shows that when two types of consumers have highly different evaluations of products, case two is the optimal one under most market conditions. Figure 1(b) shows that when the difference between the two types of consumers' evaluation of products is reletively small, the market scope of case one and two are dominant, while the case three is narrowing. Figure 1(c) shows that the difference between the two types of consumers in the product evaluation is small enough, the market scopes in which case one and case three are dominant are greater, and the market scopes in case one and case two are equivalent.

4. Fully open model (P2P) and partial self-fulfillment model (hybrid)

The platform which adopts hybrid model has not only the function of connecting two types of consumers. The platform also has self-fulfillment products to put on the market. The conditions for the existence of hybrid model are: high-type consumers buy products; low-type consumers do not buy products; high-type consumers lease products to low-type consumers; the platform can lease self-fulfillment products to low-type consumers.

The decision problems of two types consumers are as follows:

$$\begin{cases} \max\limits_{\mathrm{t_H}} \pi_H(t) = \theta_H \mathrm{t_H} - \dfrac{\mathrm{t_H}^2}{2} + (1-\mathrm{t_H}) r (1-\beta) - c \\ s.t. 0 \le \mathrm{t_H} < 1, \pi_H(\mathrm{t_H}) > 0, \pi_H(\mathrm{t_H}) > \dfrac{1}{2}\theta_H{}^2 - c \end{cases}$$

$$\begin{cases} \max\limits_{\mathrm{t_L}} \pi_L(\mathrm{t_L}) = \theta_L \mathrm{t_L} - \dfrac{\mathrm{t_L}^2}{2} - \mathrm{t_L} r \\ s.t. 0 < \mathrm{t_L} \le 1, \pi_L(\mathrm{t_L}) > 0, \pi_L(\mathrm{t_L}) > \dfrac{1}{2}\theta_L{}^2 - c \end{cases}$$

The condition for the existence of the product sharing market is: $\theta_L > r$. The equilibrium consumption time for the high-type and low-type consumers are, respectively, as follows: $t_H^* = \theta_H - r(1-\beta)$, $t_L^* = \theta_L - r$. In equilibrium, when the total supply of products is larger than the demand: $\alpha(1-t_H^*) \ge (1-\alpha)t_L^*$, the platform does not need to invest in self-fulfillment products; when the total supply of products is less than the demand: $\alpha(1-t_H^*) < (1-\alpha)t_L^*$, the platform will have the motivation to provide the self-fulfillment quantity n_p, if this is profitable. At this time, the market equilibrium condition is $\alpha(1-t_H^*) + n_p = (1-\alpha)t_L^*$.

Solving this problem, we have the following lemma four:

Lemma 4: In the sharing market, when $\alpha < \frac{\theta_L - n_p}{1-\theta_H+\theta_L}$*, there exists an optimal equilibrium rental price:* $r^* = \frac{\theta_L - \alpha(1-\theta_H+\theta_L) - n_p}{1-\alpha\beta}$.

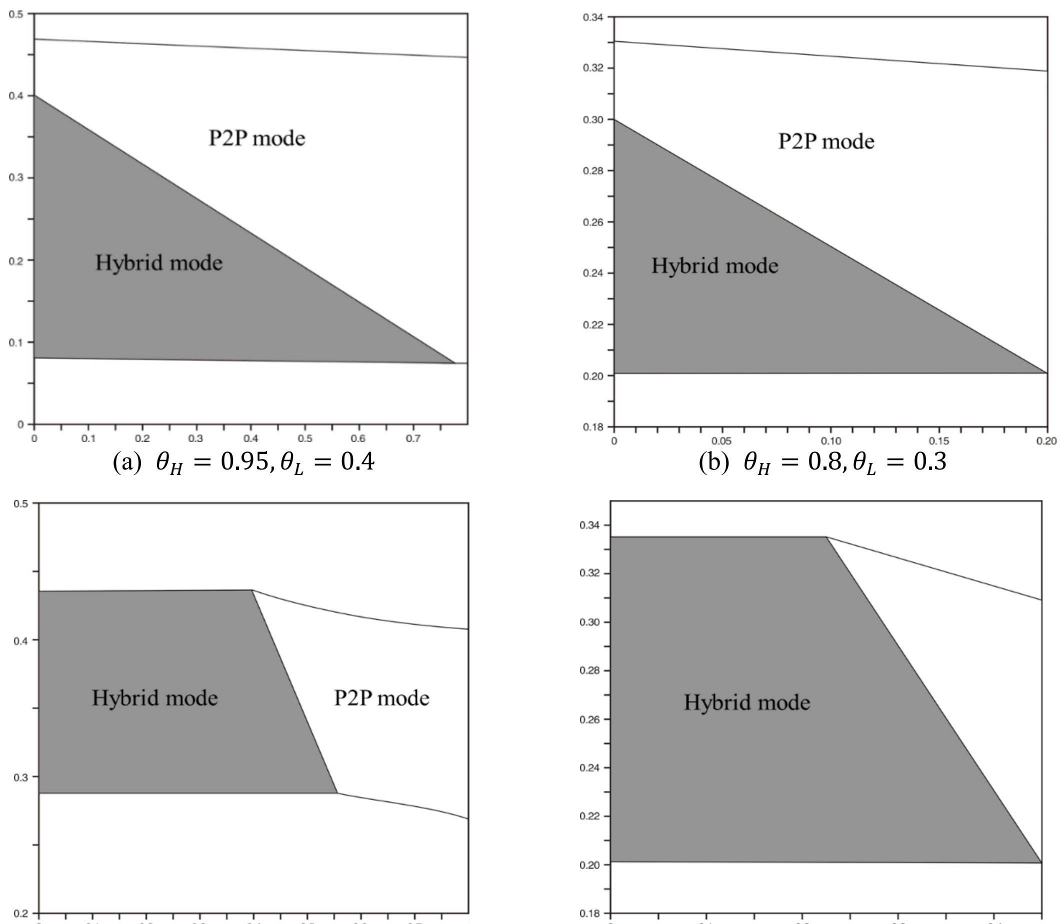
Especially, the proportion of high-type consumers should not be too high, otherwise, the total supply of products is larger than the demand, and the rental price will decrease. When the rental price drops to 0, the product owner will exit the sharing market.The decision problem of the sharing platform can be obtained by substituting r^* and t_H^* into the profit function of the sharing platform as follows:

$$\begin{cases} \max\limits_{\beta,n_p} \pi_p(\beta,n_p) = \big(\alpha(1-t_H^*)\beta + n_p\big)r - n_p c \\ s.t.\, \pi_p\big(\beta,n_p\big) > 0, n_p \geq 0, 0 < \beta < 1 \end{cases}$$

Solving this problem, we have the following:

Proposition 2 when the sharing platform adopts the hybrid business model (P2P business model), the optimal commission rate and the optimal quantity of products purchased by the platform are respectively:

$$\begin{cases} \boldsymbol{\beta^H = \frac{1-\theta_H+\theta_L}{\theta_L+c}} \\ \boldsymbol{{n_p}^H = \frac{\theta_L-c-\alpha(1-\theta_H+\theta_L)}{2}} \end{cases} \text{(hybrid } \textbf{\textit{mode) and}} \begin{cases} \boldsymbol{\beta^P = \frac{1-\theta_H+\theta_L}{2\theta_L-\alpha(1-\theta_H+\theta_L)}} \\ \boldsymbol{{n_p}^P = 0} \end{cases} \textbf{\textit{(P2P mode)}}$$



(a) $\theta_H = 0.95, \theta_L = 0.4$ (b) $\theta_H = 0.8, \theta_L = 0.3$

(c) $\theta_H = 0.9, \theta_L = 0.8$ (d) $\theta_H = 0.8, \theta_L = 0.5$

Figure 2. The optimal mode of a sharing platform (the abscissa represents the proportion of the high-type consumers and the ordinate represents the cost of the product.)

Proposition 2 reveals that the sharing platform how to choose the hybrid mode and P2P mode under different market structures.When platform adopt hybrid mode, high-type consumers will buy products and lease them out to low-type consumers when the products are idle, and the platform also buy a certain amount of products for consumers to use. When platform adopts P2P mode, the platform will not buy any products and just charge commission fees from the transactions between high-type and low-type consumers. When the cost of the product is low, the platform can buy the product with a low cost. When the proportion of high-type consumer is small, if the platform not buy a certain amount of products, market supply and demand will not match. There are two factors that influence the mode selection of the platform. When the proportion of high-type consumers is large, the sharing platform tends to adopt the P2P mode because of the enough market supply. When the proportion of high-type consumers is small, the sharing platform tends to adopt the hybrid mode to supplementary market supply. When the cost of the product is low, the platform tends to adopt the hybrid mode, when the cost of the product is high, the platform tends to adopt the P2P mode because of the large initial fixed investment cost. Figure 2 (a) & (b) shows that when high-type consumers have a high evaluation of the product, while low-type consumers have a low evaluation of the product, and when the proportion of high-type consumers is high or the product cost is large, the platform will adopt the P2P mode. Figure 2 (c) shows that when both types of consumers have a high evaluation of the product, and when the proportion of high-type consumers is high, the platform will adopt P2P mode. Figure 2(d) shows that when both types of consumers evaluate products high, the platform will change from hybrid mode to P2P mode as the proportion of high-type consumers or product cost increases.

5. Comparison of three business models

In the paper, three business models have been analyzed before, and the market conditions of each business model are found. The three cases of B2P mode are compared and analyzed, and the optimal strategy under different market conditions based on B2P mode is found. The hybrid mode and P2P mode are analyzed to find the optimal business model under different market conditions. This section will comprehensively analyze the three business models of B2P, P2P and hybrid, mainly analyzing the B2P business model and P2P under the same market conditions. We study that the sharing platform how to choose business models, and how to choose when both B2P business model and hybrid business model exist under the same market conditions.

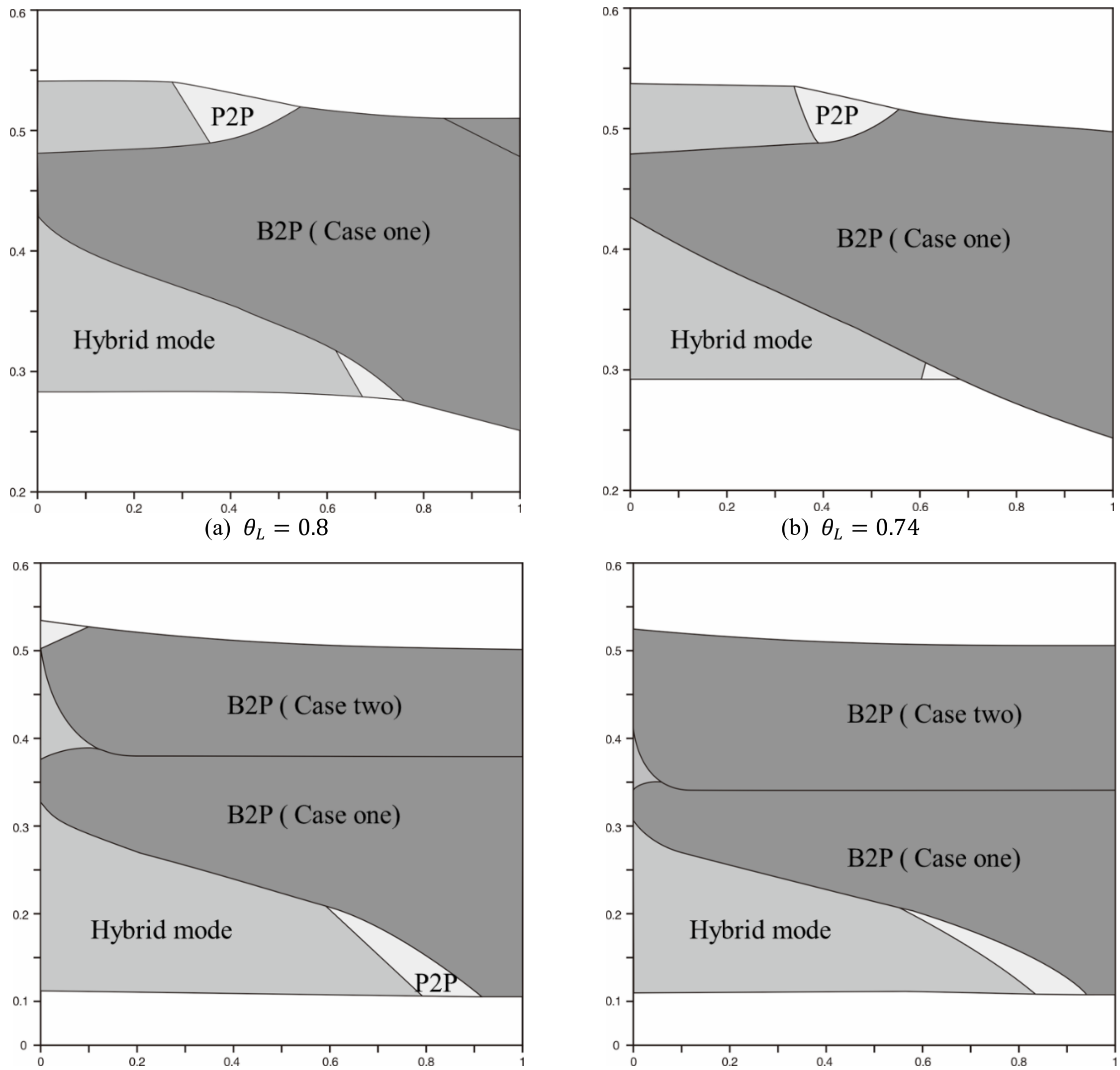
In order to simplify the analysis, we let $\theta_H = 1,\ 0 < \theta_L < 1$ (Without loss of generality), we compare the platform profits of the three business models under different market conditions, and proposition 3 and proposition 4 are obtained as follows:

Proposition 3: Among the three different business models, the platform makes decisions according to different market conditions, as follows:

(1) When the proportion of high-type consumers is high enough, B2P is the optimal mode: when the product cost is low, B2P (case one) is the optimal mode; when the product cost is high, B2P (case two) is the optimal mode;

(2) When the proportion of two types of consumers is equivalent, B2P and P2P mode are the optional optimal modes: when the product cost is low or high, P2P is the optimal mode; when the product cost is moderate, B2P is the optimal mode;

(3) When the proportion of high-type consumers is low, the hybrid mode and B2P mode are the optional optimal modes; when the product cost is low or high, the hybrid mode is the optimal mode; when the product cost is moderate, B2P is the optimal mode.



(a) $\theta_L = 0.8$ (b) $\theta_L = 0.74$

(c) $\theta_L = 0.5$ (d) $\theta_L = 0.4$

Figure 3. Business model selection of the sharing platform (the abscissa represents the proportion of the high-type consumers and the ordinate represents the cost of the product.)

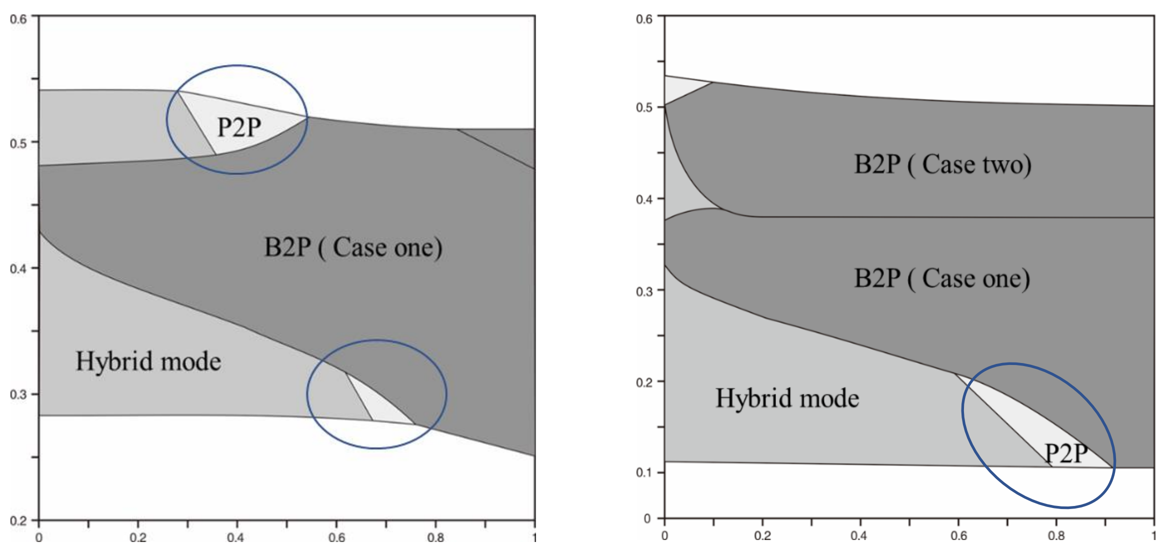
Propositions 3 and 4 reveal how the platform chooses between three business models (B2P, P2P, and hybrid) under different market conditions.The market conditions of our study are composed of three factors: the market share of two types of consumers, the heterogeneity of product evaluation by two types of consumers and the cost of the purchasing the product. Among them, two types of consumers have an impact on supply and demand as well as the rental price in the P2P mode and the hybrid mode.

When the proportion of high-type consumer is too high, if the platform adopts P2P mode, supply will be greater than the demand, leading the market clearing rental price is too low. In this case, the commission fees are limitted for the sharing platform. If the sharing platform adopts the hybrid mode, the situation will get worse. Therefore, When the proportion of high-type consumer is too high, the P2P and hybrid modes are both not the optimal modes. In the B2P mode, the platform can lease products to two types of consumers or high-type consumers who occupy the majority of the market. The rental price is not affected by market supply and demand, and the platform can decide the quantity of products purchased by itself, so the B2P mode is optimal.

When the proportion of two types of consumers is equivalent, product supply and demand can reach equilibrium level in P2P mode, the platform can get higher commission fees from high-type consumer because of the higher market clear rental price, in this case the P2P mode whether become the optimal mode mainly depends on the product cost. The influence of product cost mainly have two aspects, including the platform’s purchasing cost in B2P and hybrid moded and high-type consumers purchasing cost in P2P and hybrid modes. When the product cost is low, the two types of consumers's willingness to buy the product is high, the sharing platform in the B2P mode need to make low rental price to ensure that two types of consumers to participate in the market. The platform' pruchaing cost is low, but the former negetive factor on profit is greater than the low purchasing cost, overall profit of the platform is not high. In the P2P mode, the platform don't have to pay costs for purchasing products, the rental price is high under matching product supply and demand. The platform can get high commission fees from high-type consumers, so the P2P is the optimal mode. As the product cost increases, two types of consumers' willingness to buy the product will be reduced, When the platform adopts the B2P model, it can set a higher rental price to allow two types of consumers to participate. Although the cost of purchasing products on the platform increases, the former has a greater impact on the platform profit than the latter, and the B2P model will become the optimal mode. When the product cost is large enough, the latter will have a greater impact on the platform profit than the former, and P2P mode will become the optimal mode again.

When the proportion of high-type consumers is low, the supply of products in the P2P mode will be less than the demand. The platform can only obtain commissions from high-type consumers who occupy the minority. In order to increase profit, the platform has the motivation to make up for the supply (supply self-fulfillment products) by purchasing products to make the the supply and demand of products matched. When the cost of the product is low or high, the hybrid mode is optimal. When the cost of the product is at the intermediate level, the B2P mode is optimal, and the analysis logic is similar to the previous one.

Proposition 4: As the heterogeneity of product preference $(\theta_H - \theta_L)$ between the two types of consumers increases, the possibility of B2P mode dominants in the market increases, while the possibility of P2P mode dominants in the market decreases.



(a) $\theta_H - \theta_L = 0.2$ (b) $\theta_H - \theta_L = 0.5$

Figure 4. Business model selection of the sharing platform (the abscissa represents the proportion of the high-type consumers and the ordinate represents the cost of the product.)

With the heterogeneity between two types of consumers's evaluation on products (from figure 3 (a) to figure 3 (d), heterogeneity increases in turn), B2P (case two indicates that high-type consumers participate in the market, low-type consumer don't participate in the market) gradually become the dominant business model, consumers' product evaluation have an impact on the consumption time of the product as well as the supply and demand for products. When the heterogeneity between two types of consumers is large, that is, when the low-type consumer evaluates the product low, the demand for the product in the hybrid mode and the P2P mode will be reduced, the supply is greater than the demand, and the rental price of the product is low. The platform has limited profitability. At the same time, in B2P mode (case one means that both types of consumers are involved in the market), the platform will be forced to set lower rental prices in order to ensure that low-type consumers participate in the market, resulting in lower platform profits. And in this case the platform has incentives to set a higher rental price and force low-type consumers to exit the market, in order to obtain higher profit.

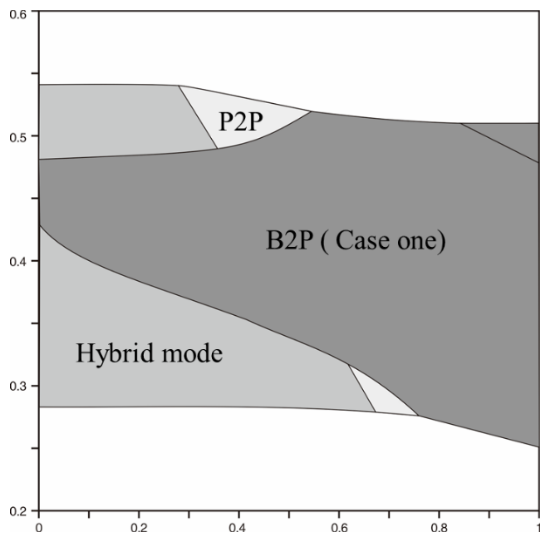
6. Some extensions to our study

6.1. Extension one : Different purchase cost for consumers and the platform

The previous study assumes the purchase cost is the same for consumers and platform. However, in the sharing market, the platform can buy bulk products at a lower price. Therefore, in this part, we will expand to a more general situation.

The impact on the previous study has the following two main aspects: (1) Since the lower purchase cost for the platform, the sharing platform has move motivation to invest in the self-fulfillment products. (2) Since the higher purchase price for consumers, people may be more willing to lease products for use. We assume the purchase cost for consumers is 1, and the purchase cost c for the platform remains the same. The analysis process is similar to the previous study. This section analyzes how should the sharing platform choose from three different business models.

Figure 5 depicts the case when the sharing platform can purchase the product in a discount price.



$\theta_L = 0.5$

Figure 5. Business model selection of the sharing platform under different market conditions

We can get the proposition 5 as follow:

Proposition 5: when the sharing platform can purchase the product in a discount price, the possibility of B2P mode dominants in the market increases, while the possibility of P2P mode dominants in the market decreases.

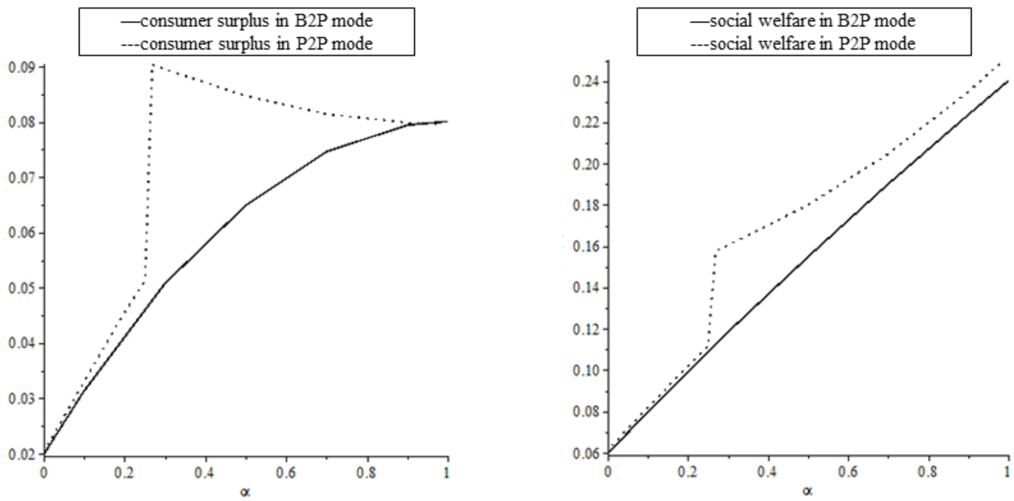
Proposition 5 reveals that a sharing platform with a cost-of-purchase advantage will be more motivated to invest in self-fulfillment products. Because of the large number of purchase agreements with the platform, some bicycle manufacturers will earn an average of less than $2 for each sharing bicycle in reality. When the cost of the sharing product is relatively low, such as bicycles and electric scooters, the quantity discount effect is more significant; when the cost of the sharing product is higher, such as cars and housing, the quantity discount is relatively slight.

Then we consider that if the platform can resell the products to high-type consumers. We denote price difference is β: products purchased on the platform are cheaper than those purchased by consumers. And we assume that the resell cost of the platform is τ. If $\tau > \beta$, the result remains the same as before, at this time, the profit of reselling products is negative, and the platform does not need to resell the products. If $\tau < \beta$, then high-type consumers who previously bought products from manufacturers will turn to the platform to buy, and this part of the revenue will be transferred from the manufacturer to the platform. In other words, the platform's revenue will increase at this time. The increased profit of the platform is $(\beta - \tau)n^H$. And n^H is the number of high-type consumers who buy the product in each case. In general, when the purchase costs are not the same, if we allow the platform to resell products to compete with manufacturers. Only when the resale cost is less than the price difference, the platform will obtain additional profits, and at the same time, the purchase cost of high-type consumers will be smaller, but the other main conclusions will remain the same.

6.2. Extension two: Consumer surplus and social welfare in P2P and B2P modes

In the previous study, we focus on comparing the profit of the platform in different modes. In this part, we will study the consumer surplus and social welfare when the platform provides self-fulfillment goods or not.

When the sharing platform only provides self-fulfillment goods, it may hurt consumers in two aspects: (1) the platform can completely determine the rental price; (2) when the cost of the product is too high, the sharing platform has less motivation to invest in self-fulfillment products, however consumers can benefit from P2P mode.



$\theta_H = 0.8, \theta_L = 0.4$

Figure 6. Consumer surplus and social welfare in P2P and B2P modes

From figure 6, consumer surplus and social welfare is larger in P2P mode than those in B2P mode. Complete B2P model does not benefit consumers as well as the society. Howerer, in hybrid mode, consumer can benefit from the the advantage of B2P mode from two aspects: (1) when the demand of the sharing product is larger than the supply, consumers can benefit from the platform' self-fulfillment products; (2) when the product of the sharing product is reletively high, consumers' willingness to buy is not strong, the platform's self-fulfillment products match the potential demand of consumers.

6.3. Extension three: Manufacturer participates in the sharing platform's cooperation

In the sharing economy, the business mode is changing. In reality, the BMW and Toyota have been extended to the automotive sharing field. For example, the BMW Group has launched the DriveNow car sharing program for the development of the car rental and sharing market, which has achieved initial success internationally. It is foreseeable that the future convergence of manufacturing and service will become increasingly prominent. Take this into consideration, in this part, we will explore the possibility of cooperation between a manufacturer and the sharing platform through strategic alliances.

When the manufacturer and the sharing platform collaborate to make centralized decisions, we denote that the revenue sharing ratio between the manufacturer and the shared platform is w and π_M is the profit of the manufacturer. The decision problems for them are as follows: (d denoted as transaction cost)

$$\begin{cases} \max_{\beta} \pi_M + \pi_P = \alpha(\theta_H t_H^* - \frac{{t_H^*}^2}{2} + (1 - t_H^*)(r^* - d)) \\ s.t. \pi_M + \pi_P(\beta) > 0, 0 \le \beta < 1 \end{cases}$$

The condition for cooperation between the manufacturer and the sharing platform through strategic alliances is that the total revenue of them in centralized decision-making is greater than the total revenue in decentralized decision-making, and the respective profit of them after cooperation are greater than those of non-cooperative profit. After comparison, the *proposition* is as follows:

Proposition 6: In the sharing market, there is a proportional interval $w \in (w_1, w_2)$ ***between the manufacturer and the sharing platform to achieve Pareto improvement. Otherwise they will not cooperate. (***$w_1 = \frac{\pi_P}{\pi_p + \pi_M}$, $w_2 = 1 - \frac{\pi_p}{\pi_p + \pi_M}$***)***

Proposition 6 illustrates that when the manufacturer and the sharing platform agree on the revenue sharing ratio, the strategic cooperation can be beneficial to them. When the sharing ratio is too high or too low, one party will choose not to continue because it is lower than the non-cooperative profit.

7. Conclusion

From the perspective of a sharing platform, our study focuses on how to choose a optimal business model (from B2P, P2P and hybrid modes). The market conditions in our study include three factors: the market share of two types of consumers, the heterogeneity of their product evaluation and the cost of the purchasing the product. When the platform adopts B2P mode, we find that: the optimal strategy is case three (high-type consumers choose to buy products, low-type consumers choose to lease products from platforms) when product cost and the proportion of high-type consumers are low; the optimal strategy is case one (both types of consumers lease products from the platform) when product cost and the proportion of high-type consumers are high; the optimal strategy is case two (high-type consumers lease products from the platform, low-type consumers are not lease any products) when product costs and high-type consumers are high enough.

When the platform adopts the hybrid business mode (P2P mode), we find that when the proportion of high-type consumers is large, the sharing platform tend to adopt the P2P mode because of the enough market supply. When the proportion of high-type consumers is small, the sharing platform tend to adopt the hybrid mode to supplementary market supply. When the cost of the product is low, the platform tend to adopt the hybrid mode, when the cost of the product is high, the platform tend to adopt the P2P mode because of the large initial fixed investment cost.

Finally, the comparison of the three business models shows that when the proportion of high-type consumers is high enough, B2P is the optimal model: when the product cost is low, B2P (case one) is the optimal model; when the product cost is high, B2P (case two) is the optimal model. When the proportion of two types of consumers is equivalent, B2P and P2P modes are the optional optimal modes: when the product cost is low or high, P2P mode is the optimal; when the product cost is moderate, B2P mode is the optimal. When the proportion of high-type consumers is low, the hybrid mode and B2P are the optional optimal modes: when the product cost is low or high, the hybrid mode is the optimal; when the product cost is moderate, B2P mode is the optimal. As the heterogeneity of product evaluation between the two types of consumers increases, the possibility of B2P mode dominants in the market increases, while the possibility of P2P mode dominants in the market decreases.

From the perspective of management implications, our findings offer insights for sharing platforms, consumers and governments. For a sharing platform, when the cost of the product is high and there are many high-type consumers, such as housing demand in many big cities, it is better to adopt the self-fulfillment model. When the cost of the product is medium, such as a car, the platform can adopt a hybrid mode. When the cost of the product is small and fragmented, such as the sharing of skills, the platform can adopt P2P mode. For consumers, it is better to decide which type of person they belong to. If the product is not so important to them (belong to the low-type), then leasing from the platform is a good choice. For the government, different types of platforms should adopt different management methods. For example, some low-cost products, some sharing platforms uncontrollably expand their self-fulfillment products, which ultimately led to the failure of these platforms, such as some sharing bicycle platforms.

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Appendix

Proof of lemma 1:

The profit function of platform is as follow:

$$L = [\alpha(\theta_H - r) + (1-\alpha)(\theta_L - r)](r - c) + \lambda\left(c - \frac{1}{2}r(2\theta_H - r)\right)$$

The optimal solution satisfies the following conditions:

$$\begin{cases} \dfrac{\partial L}{\partial r} = 0 \\ \dfrac{\partial L}{\partial \lambda} \geq 0, \lambda\left(c - \dfrac{1}{2}r(2\theta_H - r)\right) = 0 \\ \lambda \geq 0 \end{cases}$$

Two cases need to be discussed:

(1) $\lambda = 0$, we can prove when $\theta_H > \frac{\theta_L(4+\theta_L)}{2(1+\theta_L)}$ and $\alpha < \frac{\theta_L(2-2\theta_H+\theta_L)}{2(\theta_H-\theta_L)}$ or $\theta_H < \frac{\theta_L(4+\theta_L)}{2(1+\theta_L)}$, $2\sqrt{(2-\theta_H)^2 + 2\theta_H\alpha + 2\theta_L(1-\alpha)} + \theta_H(2-\alpha) - \theta_L(1-\alpha) - 4 < c < \theta_L - \alpha(\theta_H - \theta_L)$, the commission rate the platform charges consumers: $r^B = \frac{\alpha\theta_H + (1-\alpha)\theta_L + c}{2}$, and the platform's profit: $\pi_P{}^* = \frac{(\alpha(\theta_H-\theta_L)+\theta_L-c)^2}{4}$.

(2) $\lambda \neq 0$, we can prove when $\theta_H > \frac{\theta_L(4+\theta_L)}{2(1+\theta_L)}$ and $c < \min\{2\sqrt{(2-\theta_H)^2 + 2\theta_H\alpha + 2\theta_L(1-\alpha)} + \theta_H(2-\alpha) - \theta_L(1-\alpha) - 4, \theta_H\theta_L - \frac{\theta_L{}^2}{2}\}$ or $\theta_H < \frac{\theta_L(4+\theta_L)}{2(1+\theta_L)}$ and $c < 2\sqrt{(2-\theta_H)^2 + 2\theta_H\alpha + 2\theta_L(1-\alpha)} + \theta_H(2-\alpha) - \theta_L(1-\alpha) - 4$, the commission rate charged by the platform to consumers: $r^B = \theta_H - \sqrt{\theta_H{}^2 - 2c}$, the platform's profit: $\pi_P{}^* = \left[\alpha(\theta_H - \theta_L) + \theta_L + \sqrt{\theta_H{}^2 - 2c} - \theta_H\right]\left(\theta_H - \sqrt{\theta_H{}^2 - 2c} - c\right)$. Lemma 1 is proved.

Proof of lemma 2:

The profit function of platform is as follow:

$$L = \alpha(\theta_H - r)(r - c) + \lambda\left(c - \frac{1}{2}r(2\theta_H - r)\right) + \mu(r - \theta_L)$$

The optimal solution satisfies the following conditions:

$$\begin{cases} \dfrac{\partial L}{\partial r} = 0 \\ \dfrac{\partial L}{\partial \lambda} \geq 0, \lambda\left(c - \dfrac{1}{2}r(2\theta_H - r)\right) = 0 \\ \dfrac{\partial L}{\partial \mu} \geq 0, \mu(r - \theta_L) = 0 \\ \lambda \geq 0, \mu \geq 0 \end{cases}$$

Four cases need to be discussed:

(1) $\lambda = 0, \mu = 0$, we can prove when $\theta_H > \frac{\theta_L(4+\theta_L)}{2(1+\theta_L)}$ and $2\sqrt{\theta_H{}^2 - 2\theta_H + 4} + \theta_H - 4 < c < \theta_H$ or $\theta_H < \frac{\theta_L(4+\theta_L)}{2(1+\theta_L)}$ and $2\theta_L - \theta_H < c < \theta_H$, the commission rate charged by the platform to consumers: $r^B = \frac{\theta_H + c}{2}$, the platform's profit: $\pi_P{}^* = \frac{\alpha(\theta_H - c)^2}{4}$.

(2) $\lambda = 0, \mu \neq 0$, we can prove when $\theta_H < \frac{\theta_L(4+\theta_L)}{2(1+\theta_L)}$ and $\theta_H\theta_L - \frac{\theta_L{}^2}{2} < c < 2\theta_L - \theta_H$, the commission rate charged by the platform to consumers: $r^B = \theta_L$, the platform's profit: $\pi_P{}^* = \alpha(\theta_H - \theta_L)(\theta_L - c)$.

(3) $\lambda \neq 0, \mu = 0$, we can prove when $\theta_H > \frac{\theta_L(4+\theta_L)}{2(1+\theta_L)}$ and $\theta_H\theta_L - \frac{\theta_L{}^2}{2} < c < 2\sqrt{\theta_H{}^2 - 2\theta_H + 4} + \theta_H - 4$, the commission rate charged by the platform to consumers: $r^B = \theta_H - \sqrt{\theta_H{}^2 - 2c}$, the platform's profit: $\pi_P{}^* =$

$\alpha\sqrt{{\theta_H}^2-2c}\left(\theta_H-\sqrt{{\theta_H}^2-2c}-c\right)$.

(4) $\lambda \neq 0, \mu \neq 0$, we can prove when $c=\theta_H\theta_L-\frac{{\theta_L}^2}{2}$, $r^B=\theta_L$, ${\pi_P}^*=\alpha(\theta_H-\theta_L)(\theta_L-c)$. Lemma 2 is proved.

Proof of lemma 3:

The profit function of platform is as follow:

$$L=(1-\alpha)(\theta_L-r)(r-c)+\lambda\left(c-\frac{1}{2}r(2\theta_L-r)\right)$$

The optimal solution satisfies the following conditions:

$$\begin{cases} \dfrac{\partial L}{\partial r}=0 \\ \dfrac{\partial L}{\partial \lambda}\geq 0, \lambda\left(c-\dfrac{1}{2}r(2\theta_H-r)\right)=0 \\ \lambda \geq 0 \end{cases}$$

Two cases need to be discussed:

(1) $\lambda=0$, we can prove when $2\sqrt{{\theta_L}^2-2\theta_L+4}+\theta_L-4<c<2\sqrt{(\theta_H-2)^2+2\theta_L}+2\theta_H-\theta_L-4$, $r^B=\frac{\theta_L+c}{2}$, ${\pi_P}^*=\frac{(1-\alpha)(\theta_L-c)^2}{4}$.

(2) $\lambda \neq 0$, we can prove when $c<2\sqrt{{\theta_L}^2-2\theta_L+4}+\theta_L-4$, $r^B=\theta_L-\sqrt{{\theta_L}^2-2c}$, ${\pi_P}^*=(1-\alpha)\sqrt{{\theta_L}^2-2c}\left(\theta_L-\sqrt{{\theta_L}^2-2c}-c\right)$. Lemma 3 is proved.

Proof of proporsition 1:

From $\theta_L=2\sqrt{{\theta_H}^2-2\theta_H+4}+\theta_H-4$, we can get $\theta_H=\frac{2}{3}\sqrt{{\theta_L}^2+6\theta_L}-\frac{1}{3}\theta_L$. When $\theta_H>\frac{2}{3}\sqrt{{\theta_L}^2+6\theta_L}-\frac{1}{3}\theta_L$, it is necessary to compare the profit size in the common area ($\theta_H\theta_L-\frac{{\theta_L}^2}{2}<c<\theta_L-\alpha(\theta_H-\theta_L)$) of case one and case two. Profit in case one is ${\pi_P}^*=\frac{(\alpha(\theta_H-\theta_L)+\theta_L-c)^2}{4}$ and profit in case two is ${\pi_P}^*=\alpha\sqrt{{\theta_H}^2-2c}\left(\theta_H-\sqrt{{\theta_H}^2-2c}-c\right)$. We find that there exists $c*$, when $c>c*$, case two's profit is greater than case one's profit, and vice versa. When $\frac{\theta_L(4+\theta_L)}{2(1+\theta_L)}<\theta_H<\frac{2}{3}\sqrt{{\theta_L}^2+6\theta_L}-\frac{1}{3}\theta_L$, it is necessary to compare the profit size in the common area ($\theta_H\theta_L-\frac{{\theta_L}^2}{2}<c<\min\{\theta_L-\alpha(\theta_H-\theta_L), 2\sqrt{{\theta_H}^2-2\theta_H+4}+\theta_H-4\}$ and $2\sqrt{{\theta_H}^2-2\theta_H+4}+\theta_H-4<c<\theta_L-\alpha(\theta_H-\theta_L)$). In the first common region, We find that there exists $c*$, when $c>c*$, case two's profit is greater than case one's profit, and vice versa. In the second common region, when $c>\theta_L-(\theta_H-\theta_L)\sqrt{\alpha}$, case two's profit is greater than case one's profit, and vice versa. When $\theta_H<\frac{\theta_L(4+\theta_L)}{2(1+\theta_L)}$, it is necessary to compare the profit size in the common area ($\theta_H\theta_L-\frac{{\theta_L}^2}{2}<c<2\theta_L-\theta_H$ and $2\theta_L-\theta_H<c<\theta_L-\alpha(\theta_H-\theta_L)$). In the first common region, we can prove case one's profit is greater than case two's profit. In the second common region, when $c>\theta_L-(\theta_H-\theta_L)\sqrt{\alpha}$, case two's profit is greater than case one's profit, and vice versa. In the comparison of the profit of case one and case three, there exists $c*$, when $c>c*$, case one's profit is greater than case three's profit, and vice versa. Propositions 1 is proved.

Proof of proporsition 2:

The profit function of platform is as follow:

$$L = \left(\alpha(1 - x_H^*)\beta + n_p\right)r - n_p c + \lambda n_p$$

The optimal solution satisfies the following conditions:

$$\begin{cases} \dfrac{\partial L}{\partial \beta} = 0, \dfrac{\partial L}{\partial n_p} = 0 \\ \dfrac{\partial L}{\partial \lambda} \geq 0, \lambda n_p = 0 \\ \lambda \geq 0 \end{cases}$$

There are two cases to discuss:

The first case: when $\lambda = 0$, from the simultaneous solving, we can get $\beta^* = \frac{1-\theta_H+\theta_L}{\theta_L+c}$, and ${n_p}^* = \frac{\theta_L - c - \alpha(1-\theta_H+\theta_L)}{2}$. From $\frac{\partial L}{\partial \lambda} \geq 0$, $\lambda n_p = 0$, we need $c < \theta_L - \alpha(1 - \theta_H + \theta_L)$. Next, we need to find other constraints, and the main constraints are as follows:

From $0 < \beta < 1$, we get $1 - \theta_H < c$, and $\pi_H(x) \geq \frac{1}{2}{\theta_H}^2 - c$ is a constant establishment. From $\pi_H(x) > 0$, we get $c < \theta_H + 3 - 2\sqrt{3}$, from $\pi_L(x) > \frac{1}{2}{\theta_L}^2 - c$, we get $2\sqrt{{\theta_L}^2 - 2\theta_L + 4} + \theta_L - 4 < c$. And after testing, in the optimal solution, $\pi_p > 0$ is established. From $1 - \theta_H < 2\sqrt{{\theta_L}^2 - 2\theta_L + 4} + \theta_L - 4$, we can get $5 - \theta_L - 2\sqrt{{\theta_L}^2 - 2\theta_L + 4} < \theta_H$. From $\theta_L - \alpha(1 - \theta_H + \theta_L) < \theta_H + 3 - 2\sqrt{3}$, we can get $\theta_L - 3 + 2\sqrt{3} < \theta_H$ or $\theta_L - 3 + 2\sqrt{3} > \theta_H$ and $\alpha > \frac{\theta_L - \theta_H - 3 + 2\sqrt{3}}{1-\theta_H+\theta_L}$.

According to those, four cases are discussed:

(1) The condition that the equation $2\sqrt{{\theta_L}^2 - 2\theta_L + 4} + \theta_L - 4 < c < \theta_L - \alpha(1 - \theta_H + \theta_L)$ is satisfied :

(a) $\theta_H > \max\{\theta_{H1}, \theta_{H2}\}$ and $\alpha < \frac{4 - 2\sqrt{{\theta_L}^2 - 2\theta_L + 4}}{1-\theta_H+\theta_L}$;

(b) $\theta_{H1} < \theta_H < \theta_{H2}$ and $\frac{\theta_L - \theta_H - 3 + 2\sqrt{3}}{1-\theta_H+\theta_L} < \alpha < \frac{4 - 2\sqrt{{\theta_L}^2 - 2\theta_L + 4}}{1-\theta_H+\theta_L}$.

(2) The condition that the equation $1 - \theta_H < c < \theta_L - \alpha(1 - \theta_H + \theta_L)$ is satisfied :

(a) $\theta_{H2} < \theta_H < \theta_{H1}$, $0 < \theta_H + \theta_L - 1$, $0 < \alpha < \frac{\theta_L + \theta_H - 1}{1-\theta_H+\theta_L}$.

(b) $\min\{\theta_{H1}, \theta_{H2}\} > \theta_H > \sqrt{3} - 1$ and $\frac{\theta_L - \theta_H - 3 + 2\sqrt{3}}{1-\theta_H+\theta_L} < \alpha < \frac{\theta_L + \theta_H - 1}{1-\theta_H+\theta_L}$.

(3) The condition that the equation $2\sqrt{{\theta_L}^2 - 2\theta_L + 4} + \theta_L - 4 < c < \theta_H + 3 - 2\sqrt{3}$ is satisfied :

$\theta_{H1} < \theta_H < \theta_{H2}$ and $\alpha < \frac{\theta_L - \theta_H - 3 + 2\sqrt{3}}{1-\theta_H+\theta_L}$.

(4) The condition that the equation $1 - \theta_H < c < \theta_H + 3 - 2\sqrt{3}$ is satisfied : $\min\{\theta_{H1}, \theta_{H2}\} > \theta_H > \sqrt{3} - 1$ and $\alpha < \frac{\theta_L - \theta_H - 3 + 2\sqrt{3}}{1-\theta_H+\theta_L}$.

The second case: $\lambda > 0$

$\beta^* = \frac{1-\theta_H+\theta_L}{2\theta_L - \alpha(1-\theta_H+\theta_L)}$, ${n_p}^* = 0$

From $\lambda > 0$, we can get $c > \theta_L - \alpha(1 - \theta_H + \theta_L)$. Next, we need to find other constraints, and the main constraints are as follows:

From $0 < \beta < 1$, we can get $\theta_H + \theta_L > 1$, $0 < \theta_H + \theta_L - 1$, $0 < \alpha < \frac{\theta_L + \theta_H - 1}{1-\theta_H+\theta_L}$.

After testing, when $\theta_H + \theta_L > 1$, $0 < \theta_H + \theta_L - 1$, $0 < \alpha < \frac{\theta_L + \theta_H - 1}{1-\theta_H+\theta_L}$, $\pi_H(x) \geq \frac{1}{2}{\theta_H}^2 - c$ is always established. From $\pi_H(x) > 0$, we can get $c < \frac{1}{8}(1 - \theta_H + \theta_L)^2(1 - \alpha)^2 + \theta_H - \frac{1}{2}$. From $\pi_L(x) > \frac{1}{2}{\theta_L}^2 - c$, we can get $\frac{1}{2}{\theta_L}^2 - \frac{1}{8}(1 - \theta_H + \theta_L)^2\alpha^2 < c$, $\pi_L(x) > 0$ are always established. When $\theta_H + \theta_L > 1$, $0 < \theta_H + \theta_L - 1$, $0 < \alpha < \frac{\theta_L + \theta_H - 1}{1-\theta_H+\theta_L}$, $\frac{1}{2}{\theta_L}^2 - \frac{1}{8}(1 - \theta_H + \theta_L)^2\alpha^2 < \frac{1}{8}(1 - \theta_H + \theta_L)^2(1 - \alpha)^2 + \theta_H - \frac{1}{2}$ is always established.

Further, when $\alpha < \frac{\theta_L-\theta_H-3+2\sqrt{3}}{1-\theta_H+\theta_L}$, $\frac{1}{8}(1-\theta_H+\theta_L)^2(1-\alpha)^2+\theta_H-\frac{1}{2} < \theta_L-\alpha(1-\theta_H+\theta_L)$; when $\frac{\theta_L-\theta_H-3+2\sqrt{3}}{1-\theta_H+\theta_L} < \alpha < \frac{\theta_L+\theta_H-1}{1-\theta_H+\theta_L}$, $\frac{1}{8}(1-\theta_H+\theta_L)^2(1-\alpha)^2+\theta_H-\frac{1}{2} > \theta_L-\alpha(1-\theta_H+\theta_L)$; when $5-\theta_L-2\sqrt{{\theta_L}^2-2\theta_L+4} < \theta_H$ and $\alpha < \frac{4-2\sqrt{{\theta_L}^2-2\theta_L+4}}{1-\theta_H+\theta_L}$ or $5-\theta_L-2\sqrt{{\theta_L}^2-2\theta_L+4} > \theta_H$, $\frac{1}{2}{\theta_L}^2-\frac{1}{8}(1-\theta_H+\theta_L)^2\alpha^2 < \theta_L-\alpha(1-\theta_H+\theta_L)$; when $5-\theta_L-2\sqrt{{\theta_L}^2-2\theta_L+4} < \theta_H$ and $\frac{\theta_L+\theta_H-1}{1-\theta_H+\theta_L} > \alpha > \frac{4-2\sqrt{{\theta_L}^2-2\theta_L+4}}{1-\theta_H+\theta_L}$, $\frac{1}{2}{\theta_L}^2-\frac{1}{8}(1-\theta_H+\theta_L)^2\alpha^2 > \theta_L-\alpha(1-\theta_H+\theta_L)$.

Next, we need to test whether the objective function is concave at the optimal solution. First, from the first derivative condition $\frac{\partial\pi_p}{\partial\beta}=0$. The static point of the function must satisfy the following conditions: $n_p = \frac{\beta(2\theta_L-\alpha(1-\theta_H+\theta_L))-(1-\theta_H+\theta_L)}{2\beta}$.

Then we test the Hessian matrix of the objective function at the static point:

$\frac{\partial^2\pi_p}{\partial {n_p}^2} = -\frac{2(1-\alpha\beta(2-\beta))}{(1-\alpha\beta)^2}$,

$\frac{\partial^2\pi_p}{\partial\beta^2} = \frac{1}{(1-\alpha\beta)^4}\left(2\alpha(1-\alpha)\left(\theta_L-\alpha(1-\theta_H+\theta_L)-n_p\right)\left(\alpha(2+\alpha\beta)(1-\theta_H+\theta_L)+(n_p-\theta_L)(1+2\alpha\beta)\right)\right)$,

$\frac{\partial^2\pi_p}{\partial\beta\,\partial n_p} = \frac{\alpha(1-\alpha)\left((3\alpha\beta+1)(1-\theta_H+\theta_L)+4\beta(n_p-\theta_L)\right)}{(1-\alpha\beta)^3}$.

The Hessian matrix is: $\begin{bmatrix} \frac{\partial^2\pi_p}{\partial {n_p}^2} & \frac{\partial^2\pi_p}{\partial\beta\,\partial n_p} \\ \frac{\partial^2\pi_p}{\partial\beta\,\partial n_p} & \frac{\partial^2\pi_p}{\partial\beta^2} \end{bmatrix}$, among them, $|H_1| = -\frac{2(1-\alpha\beta(2-\beta))}{(1-\alpha\beta)^2} < 0$,

$$|H_2| = -\frac{2(1-\alpha\beta(2-\beta))}{(1-\alpha\beta)^2}\frac{1}{(1-\alpha\beta)^4}\left(2\alpha(1-\alpha)\left(\theta_L-\alpha(1-\theta_H+\theta_L)-n_p\right)\begin{pmatrix}\alpha(2+\alpha\beta)(1-\theta_H+\theta_L)\\+(n_p-\theta_L)(1+2\alpha\beta)\end{pmatrix}\right) - \left(\frac{\alpha(1-\alpha)\left((3\alpha\beta+1)(1-\theta_H+\theta_L)+4\beta(n_p-\theta_L)\right)}{(1-\alpha\beta)^3}\right)^2 = \frac{\alpha(1-\alpha)(1-\theta_H+\theta_L)^2}{(1-\alpha\beta)^2\beta^2} > 0,$$

Hessian matrix is negative semidefinite, so the optimal solution is the maximum. Proposition 2 is proved.

Proof of proporsition 3:

From $\theta_H = \frac{\theta_L(4+\theta_L)}{2(1+\theta_L)} = 1$, we can get $\theta_L = \sqrt{3}-1$, from $\theta_H = \theta_L-3+2\sqrt{3} = 1$, we get $\theta_L = 4-2\sqrt{3}$, from $\theta_H = \frac{2}{3}\sqrt{{\theta_L}^2+6\theta_L}-\frac{1}{3}\theta_L = 1$, we can get $\theta_L = 2\sqrt{3}-3$. Therefore, we can get the simplified range $0 < 2\sqrt{3}-3 < 4-2\sqrt{3} < \sqrt{3}-1 < 1$, accordingly, four cases will be discussed.

The first case, as shown in figure 3 (a), it is easy to prove that the market conditions in which three business models exist simultaneously are divided into multiple regions. When $\alpha = 1$, from $\theta_L-(1-\theta_L)\sqrt{\alpha} = 2\theta_L-1 = \frac{1}{2}$, we get $\theta_L = \frac{3}{4}$. Therefore, when $\frac{3}{4} < \theta_L < 1$, the market conditions for the existence of three types of business model at the same time is divided into five areas. When $\sqrt{3}-1 < \theta_L < \frac{3}{4}$, the market conditions for the existence of three types of business model at the same time is divided into six regions. In area one, the platform has two options: case one of B2P mode and hybrid mode, we can prove that when $c > \frac{1}{2}-\frac{1}{2}(1-\alpha)(1-\theta_L)^2$, the hybrid mode is better than that of B2P mode, and vice versa. In area two, the platform has two options: case one of B2P mode and P2P mode, we can prove that when $c > \theta_L+(1-\theta_L)\alpha-\theta_L\sqrt{(1-\alpha)\alpha}$, the P2P mode is better than B2P mode, and vice versa. In the area three, platform has two options, case three of B2P mode and hybrid mode, because

$$\frac{1}{4}c^2-\frac{1}{2}\left(\theta_L-\alpha(1-\theta_H+\theta_L)\right)c+\frac{1}{4}\left({\theta_H}^2-{\theta_L}^2\right)\alpha-\frac{1}{2}\left(\theta_H-\frac{1}{2}\right)\alpha+\frac{1}{4}{\theta_L}^2-\frac{(1-\alpha)(\theta_L-c)^2}{4} = \frac{\alpha(1-\theta_H+c)^2}{4} > 0,$$

The hybrid mode is superior to the P2P mode. and we find that that in area four and area five, there respectively exist c_1* and c_2*. When $c > c_1*$, B2P mode is superior to the hybrid mode, and vice versa. When $c > c_2*$, B2P mode is superior to the P2P mode. When $\sqrt{3}-1<\theta_L<\frac{3}{4}$, the area six adds on. There are two choices for the platform: case two of B2P mode and P2P mode. It is easy to prove that case two of B2P mode is superior to P2P mode. When $4-2\sqrt{3}<\theta_L<\sqrt{3}-1$, $2\sqrt{3}-3<\theta_L<4-2\sqrt{3}$, and $0<\theta_L<2\sqrt{3}-3$, analyses are similar to the previous one. Among them, when $c>\theta_L-\alpha(1-\theta_H+\theta_L)$, $\frac{1}{4}\alpha(1-\alpha)(1-\theta_H+\theta_L)^2-\frac{(1-\alpha)(\theta_L-c)^2}{4}=\frac{(1-\alpha)\left({\theta_L}^2\alpha-(\theta_L-c)^2\right)}{4}>\frac{(1-\alpha)^2{\theta_L}^2\alpha}{4}\geq 0$. Proposition 3 is proved.