PRICING STRATEGY OF A TWO-SIDED PLATFORM UNDER CONSUMER CATEGORIZATION

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ABSTRACT

Many two-sided platforms categorize consumers into distinct groups according to their levels of activity. This study investigates a platform's pricing strategy when consumers are categorized into two distinct groups. By modeling a per-transaction fee in the platform's profit-maximizing objective, equilibrium results are derived for scenarios with and without consumer categorization. Then, the two scenarios are compared to explore the impact of categorizing consumers on the fees charged to users on both sides and the platform's profit. It is shown that, under consumer categorization, although sellers are charged a higher per-transaction fee, the expected profit is enlarged, and both the market scale and platform profit increase. The incremental profit of the platform first increases and then decreases in relation to the proportion of active consumers, and the benefit of categorizing consumers is maximized when active consumers are more than a half of the total.

Keywords: Consumer categorization; Optimal pricing; Two-sided platform; Indirect network externality

1. Introduction

Two-sided platforms connect consumers and sellers and enable interaction or transactions between them [Schiff 2007]. Given the enormous increase in internet-based commerce and online consumer interaction in recent years, numerous industries have chosen to operate via two-sided platforms. As a new form of market organization, they have become increasingly crucial [Hagiu 2009]. E-commerce platforms such as Amazon, eBay, iTunes, and Alibaba are

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typical two-sided platforms where sellers and buyers are connected to make transactions online, and individuals can buy products and/or services without having to travel to retail outlets [Bigne et al., 2005]. With the development of these platforms, E-commerce has become nearly ubiquitous. Among others, Windows, Apple's iPhone OS, and Google's Android are two-sided operating platforms for computers and cell phones, enabling consumers to download and use thousands of applications from third-party developers. Additionally, Sony's PlayStation, Microsoft's Xbox, and Nintendo's Wii are well-known two-sided game consoles through which players access numerous online games provided by third-party developers.

Two-sided platforms are special, because they exhibit positive indirect network externality between the two sides. That is, users on the two sides are correlated and they mutually influence the demand or the benefit of each other. For example, as for Amazon.com, buyers' utility from accessing the platform gets improved when there are more online sellers in the sense that a larger number of sellers indicate a higher level of product diversity, providing buyers more purchasing choices. In turn, more buyers indicate a higher selling potential thus higher expected income for sells. Then, on account of the network externality, the operational strategy the platform employs towards one side influences the strategy towards the other side [Rochet and Tirole, 2003; Filistrucchi et al., 2014].

In practice, consumers often have different preferences and loyalties toward E-commerce platforms. Thus, some consumers conduct most of their transactions on a single platform, whereas others make relatively fewer transactions over time on different platforms. For example, a buyer may transact via Amazon or eBay 10 times per month, while another buyer may just purchase twice a month without platform loyalty. Specifically, consumers whose interactions with the other-side users exceed a certain level could be considered "active," whereas the rest are "non-active." Often, preferential policies are often created for active consumers, which helps improve consumer loyalty and satisfaction and the long-term growth of E-commerce businesses [Eid, 2011]. For example, the E-commerce platform Tmall classifies buyers into groups T1, T2, T3, and T4. Consumers belonging to T2 have the privilege of obtaining a refund as soon as they return a purchase. With JD.com, a PLUS member system was established wherein preferential policies were offered to PLUS members, who can enjoy a 90% discount for clothes, a 95% discount for famous brands, and they can return merchandise for free.

As is shown in the economic research [Narasimhan, 1984; Shepard, 1991; Aguirre et al., 2010; Cosguner et al., 2017], price discrimination can be used to enhance a firm's profit. Given the properties of different types of consumers on an E-commerce platform, if the platform ignores those differences, the opportunity of obtaining higher profits may be lost. However, indirect network externalities exist in the platform because of the two-sidedness. Then, the pricing strategies designed for the two groups of consumers influence the pricing strategies for the sellers, which means that the active consumers, non-active consumers, and sellers influence one another mutually. Furthermore, because active consumers generally contribute more profit and utility to sellers, their impact should be greater. Thus, we still need to explore the role of the indirect network externality in influencing the pricing strategy on the seller side when the prices for active or non-active consumers change, and how to charge the three groups to enhance profitability.

In this paper, we explore the pricing strategy of a two-sided platform when buyers are characterized into two different groups. Specifically, we seek answers to the following research questions: 1) "From the platform's perspective, how pricing should be set for different groups of users to maximize the platform's profit?" 2) "What will the results be when price discrimination toward distinct consumer groups is applied in a two-sided platform?" 3) "Does charging the groups differently necessarily benefit the platform when the pricing strategy for the other side users changes because of the indirect network externality?"

To answer these questions, a profit-maximizing problem is modeled from the platform's perspective. We not only consider users on both sides to be heterogeneous in terms of the utility gained from using the platform, but also categorize consumers into two distinct groups in terms of their activity levels. Considering the mathematical tractability and to unveil the basic implications of consumer categorization, we categorize consumers into two groups. In our analysis, the pricing policies with and without consumer categorization are derived separately, and the equilibrium results are compared from different perspectives to investigate the effects of consumer categorization on user surplus on both sides, as well as the platform's profit. Sensitivity analyses are also undertaken to explore other management insights.

The remainder of this paper is organized as follows. Section 2 reviews the related literature. In Section 3, a basic model is formulated to describe users' surplus when they access a two-sided platform. In Sections 3.1 and Section 3.2, the equilibrium results of scenarios with and without consumer categorization are derived, respectively. Section 4 gives detailed comparisons about the equilibrium results between the two scenarios. Finally, Section 5 summarizes the results and offers suggestions for future research. All proofs are given in the Appendix.

2. Literature Review

Pioneered by Caillaud and Jullien (2003), Rochet and Tirole (2003, 2004), Hagiu (2004), and Armstrong (2006), literature about two-sided platforms, including the E-commerce platforms, (e.g., Pei and Paswan 2018, Zhang et al. 2018, Xu et al. 2018), or the platforms such as Airbnb and Xiaozhu in sharing economy (e.g. Chen and Wang 2019) has flourished. Among the literature, many studies take platform pricing as the main decision variable to allow for the characteristics of indirect network externalities.

Chandra and Collard–Wexler (2009) present an economic model of the newspaper market. They show that a monopolist will not necessarily choose to set higher prices on both sides of the market but may choose to raise prices on one side and lower them on the other side. To illustrate key principles that drive pricing in two-sided markets, Schiff (2007) illustrates basic pricing issues in two-sided markets using some simple linear models based on Rochet and Tirole (2006) and Armstrong (2006). Jeon and Rochet (2010) build a model of an academic journal that fulfills the double role of certification and dissemination of knowledge and study the pricing from a two-sided market perspective. Hagiu and Spulber (2013) introduce first-party content, which can be used as a strategic instrument in addition to pricing. Filistrucchi and Klein (2013) present a general model of a two-sided market with heterogeneous consumers. They show how one can account for the feedback loops that arise when there are two network effects between the two sides of the market. Kung and Zhong (2017) study a two-sided platform's pricing problem for grocery delivery services. In their analysis, membership pricing, transaction pricing, and cross subsidization are compared. They find that membership pricing collects revenues soonest and maximizes order frequency. Considering the investing resource constraint, Dou and He (2017) explore the value-added service investing and pricing strategies for a two-sided platform, where the two-side users need to pay a participation fee. Tang et al. (2013) study the pricing by platform in two-sided market when it offers differentiated services (i.e., matching and value-added services). They show that the platform can get extra users and profits by offering differentiated services. Using a canonical principal-agent model, Jeon et al. (2015) study the price discrimination by a monopoly two-sided platform who mediates interactions between two different groups of agents. Gao (2018) develop a general model for mixed two-sided platforms, finding that a monopolist platform's incentive to bundle and its optimal pricing strategy are determined by simple and testable formulas using familiar price elasticities of demand. Li et al. (2011), Yoo et al. (2007), Weyl (2010), etc. are among several other researchers exploring pricing policies for two-sided markets.

A key insight in the literature above suggests that pricing decisions of two-sided markets are novel compared with traditional markets; the network externality plays a key role in determining the pricing policy. Additionally, service improvements, first-party content, and other factors can be critical in shaping pricing strategy. To obtain optimal pricing solutions, the literature generally considers the users on each side to be of the same type, or they consider them to be heterogeneous from a certain dimension (e.g., utility derived from using the fundamental services of the platform). However, in these studies, users on the same side of the platform are not categorized as different types from other dimensions. In contrast, we not only consider the heterogeneity of consumers, but also classify them into different groups in terms of their activity levels.

Some studies investigate optimal pricing policies by considering factors of competition. Rochet and Tirole (2003) build a model of platform competition with two-sided markets, unveiling the determinants of pricing and end-user surplus for different governance structures. Additionally, they compare outcomes with those under an integrated monopolist and a Ramsey planner. Armstrong (2006) presents three different models of two-sided markets on a monopoly platform, on competing platforms where clients join a single platform, and in "competitive bottlenecks" where one group joins all platforms. For each model, determinants of equilibrium prices are explored. Schiff (2003) analyzes the behavior of platforms with two-sided networks where there are no intrinsic benefits to consumers other than network effects. Three different market structures, a monopoly and duopolies with and without compatibility, are considered in this paper. Furthermore, comparisons of prices, profits, consumer surplus, and welfare are made across the three scenarios. Belleflamme and Peitz (2010) investigate seller investment incentives on a two-sided platform in competing environment. They show that for-profit intermediation may lead to overinvestment when free access would lead to underinvestment. Cheng et al. (2018) examines the optimal pricing decisions for an online video platform by considering the customer's choice behavior, both a monopoly and two duopolistic platforms are considered. They show that the pricing for the two-side users change differently with the degree of audiences' disutility for advertisements. Dou et al. (2018) study the pricing strategy of a two-sided platform when competition among selling-side users exists. They find that fiercer competition leads the platform to make less of an effort to improve the service level for sellers. Zennyo (2016) investigates the competition between vertically differentiated platforms in two-sided markets. It is found that despite the existence of quality differences, the decisions by the platforms about royalty rates are symmetric and only hardware pricing is asymmetric. Belleflamme and Toulemonde (2018) explore the price competition between taxed two-sided platforms, where the tax incidence on price, participations and profits are discussed. Other studies, including Lee and Mendelson (2008), Lin et al. (2011), Jones and Mendelson (2011), and Evans (2003) also consider the competition factor in two-sided platform pricing.

The literature incorporating competition in a two-sided platform unveils that decisions are differentiated from a monopoly platform, and some of the factors (e.g., royalty rates and audiences' disutility for advertisements) impact platform decisions in different ways when there is competition. Nonetheless, users are generally considered to be of the same type on each side, except that they are heterogeneous from a certain dimension. To explore the platform pricing when there are different types of consumers on the same side of the platform, we categorize the buying-side users into two groups.

To the best of our knowledge, the only study allowing for consumer categorization is Chao (2013), which analyzes mixed bundling in two-sided markets where installed base effects are present. It illustrates that the pricing structure deviates from traditional bundling pricing and in the standard two-sided markets literature. In the analysis, consumers are categorized into two groups, with one as a preexisting group and the other as potential consumers yet to buy access to the platform. In contrast, in our paper, consumers are categorized into two different groups according to their activity levels. Both groups of consumers have access to the platform, with one group of "active" consumers and the other group of "non-active" ones.

3. The Model

In this part, we set up a model where the platform categorizes consumers into an active group and a non-active group. Similar to Rochet and Tirole (2003), a per-transaction fee charged by the platform for each user is modeled. The notations in the modeling setup are summarized in the table below.

Notation: variables and explanations.

Table 1. Variables and explanations

Variable	Explanation
θ	the proportion of active consumers, $0<\theta<1$
n_i	the number of consumers who trade with sellers, $i=v,c$
β	the utility that each seller brings to each consumer
u_i	the per-transaction gross utility associated with a consumer who trades with sellers
p_i	the per-transaction fee charged by the platform for each group of consumers
p_s	the per-transaction fee charged by the platform for the sellers
α	the utility of each consumer in using the fundamental service of the platform platform
γ_i	the seller's expected profit from a consumer, $0<\gamma_i<1$, $i=v,c$
f	the seller's cost of supplying a product or service to consumers on the platform
π_s	the profit per-transaction associated with a seller
Π_1, Π_2	the profit of the platform when categorizing and not categorizing consumers
$\tilde{p}_b$, $\tilde{p}_s$	the per-transaction fee for consumers and sellers without consumer categorization
$\tilde{n}_b$, $\tilde{n}_s$	the number of consumers and sellers when consumers are not categorized
γ	the expected profit for a seller when consumers are not categorized
$\tilde{\pi}_s$	the profit per-transaction for a seller when consumers are not categorized

Without loss of generality, the total size of consumers on the platform is normalized to 1, in which the proportion of active consumers (v) is θ ($\theta \in (0,1)$), and the non-active consumers (c) is $1-\theta$[1]. In both groups, the number of consumers trading with sellers is assumed to be n_i ($i=v,c$). Next, we characterize the consumer's utility and seller's expected profit.

Assuming that each seller brings utility β ($\beta \in (0,1)$) to each consumer, it can be interpreted as the indirect network externality as it represents the utility that a consumer gains with an extra seller joining the platform [Rasch 2013). Following Armstrong (2006), to focus on how the indirect network externality influences the user scale on the

[1] Similar assumptions can be found in Prasad et al. (2015), Hu et al. (2019) and Lin (2018).

two sides, the direct network externality on the same side is not allowed for. The per-transaction gross utility associated with a consumer who trades with sellers can be formulated as

$$u_i = \alpha + \beta n_s - p_i n_s, \quad (i = v, c) \tag{1}$$

In Equation (1), α measures the usage benefit each consumer obtains from accessing and using the fundamental service of the platform (e.g. browsing and buying products on eBay, communicating with online sellers for more details of products), which is assumed to be uniformly distributed over the interval [0,1] [Rochet and Tirole 2006, Dou and He 2017]; βn_s stands for the utility contributed by indirect network externality; $p_i n_s$ is the per-transaction fee charged by the platform where p_i is the per-transaction fee that each consumer pays to the platform [Rochet and Tirole 2003, Reisinger 2014, Kung and Zhong 2017]. For example, American Express provides a discount to the merchant, and a caller is charged a per-minute calling fee and the receiver is charged a per-minute reception fee in a telecom network. Much of the literature assumes that transaction volume is a multiplied result of the user numbers on the two sides i.e., $n_i n_s$ [Rochet and Tirole 2006]. More generally, the real transaction volume occurring in practice should be a proportion of $n_i n_s$ (i.e., $\xi n_i n_s$, $0 < \xi < 1$). For example, a cardholder typically patronizes a proportion of all available stores cooperating with the credit card company. However, though the analytical results will be different with $\xi n_i n_s$, the main conclusions derived from the results will not be affected because ξ is an exogenous parameter. Thus, for the ease of analysis, we assume the transaction volume to be $n_i n_s$, as is done by Rochet and Tirole (2006), Kung and Zhong (2017).

Likewise, the total size of sellers is also normalized to 1, and they are charged on a per-transaction basis. The profit per-transaction associated with a seller can be formulated as

$$\pi_s = \gamma_v n_v + \gamma_c n_c - p_s(n_c + n_v) - f \tag{2}$$

where $0 < \gamma_i < 1$, ($i = v, c$) represents the expected profit from a consumer [Rasch 2013]; f represents the seller's cost of supplying a product or service (e.g., the wholesale price for a product or the labor cost for supply the service) to consumers and is also assumed to be uniformly distributed on the interval [0,1]; p_s measures the per-transaction fee each seller pays to the platform for each consumer. Given that an active consumer brings higher expected profits for sellers, we assume $\gamma_v > \gamma_c$ to distinguish an active consumer from a non-active consumer rather than assuming the transaction volume from an active consumer is larger than that from a non-active consumer and that the expected profits from the two groups of consumers are the same. The reasons for this assumption are: 1) active consumers are more valuable thus the expected profit from an active consumer should be higher than that from a non-active consumer; 2) the different expected profits from the two types of consumers measure the indirect network externalities; 3) it is not necessary to model different expected profits and different volumes of transactions simultaneously because the two aspects emphasize the same fact that an active consumer is more valuable to sellers than a non-active consumer.

3.1. The Scenario with Consumer Categorization

Transactions are made when a consumer's gross utility per-transaction is non-negative; i.e., $u_i > 0$. Let $\bar{\alpha}$ be the usage benefit that makes a consumer indifferent between trading and not trading with sellers when $u_i = 0$; then $\bar{\alpha} = (p_i - \beta)n_s$. Therefore, a consumer whose usage benefit lies in the region $[\bar{\alpha}, 1]$ will make the transaction, and the size of the two groups of consumers can be formulated as

$$\begin{cases} n_v = \theta[1 + (\beta - p_v)n_s] \\ n_c = (1-\theta)[1 + (\beta - p_c)n_s] \end{cases} \tag{3}$$

Likewise, an individual seller will make a transaction with a non-negative expected profit; i.e. $\pi_s \geq 0$. Let $\bar{f}$ be the cost that makes a seller indifferent between trading and not trading when $\pi_s = 0$, we can derive that $\bar{f} = (\gamma_v - p_s)n_v + (\gamma_c - p_s)n_c$. Therefore, a seller whose cost lies in the region $[0, \bar{f}]$ will trade with consumers. Then, the size of sellers is

$$n_s = (\gamma_v - p_s)n_v + (\gamma_c - p_s)n_c \tag{4}$$

Following Armstrong (2006), by assuming that fees are charged on a per-transaction basis for both consumers and sellers, the platform's profit-maximizing problem under consumer categorization can be formulated as

$$\max \Pi_1 = \max\{n_v p_v n_s + n_c p_c n_s + n_s (n_v + n_c) p_s\} \quad (5)$$

Maximizing Eq. (5) with Eqs. (3) and (4), we can obtain the following theorem.

Theorem 1. Let $X = \theta(\gamma_v + \beta) + (1-\theta)(\gamma_c + \beta)$, the optimal per-transaction fees that maximize the platform's profit are given by:

$$\begin{cases} p_c^* = [4 - 2\theta\gamma_v(\gamma_v + \beta) - (1-\theta)(\gamma_c + \beta)(\gamma_c + \gamma_v)]/2X \\ p_v^* = [4 - 2\gamma_c(1-\theta)(\gamma_c + \beta) - \theta(\gamma_v + \beta)(\gamma_c + \gamma_v)]/2X \\ p_s^* = [\theta\beta(1-\theta)(\gamma_v - \gamma_c)^2 + 2\theta(\gamma_v - \beta) + 2(1-\theta)(\gamma_c - \beta)]/[4 - \theta(1-\theta)(\gamma_v - \gamma_c)^2] \end{cases}$$

Based on the optimal pricing strategy shown in Theorem 1, we derive some characteristics of the optimal pricing strategy, which are presented in the following two propositions.

Proposition 1.

(1) *Let* $\bar{\beta} = 2[\theta\gamma_v + (1-\theta)\gamma_c]/[2 - \theta(1-\theta)(\gamma_v - \gamma_c)^2]$ *; the optimal per-transaction fees for sellers decreases in the utility the consumer gains from an extra seller; i.e.,* $\frac{\partial p_s^*}{\partial \beta} < 0$ *, and*

(a) *when* $0 < \beta < \bar{\beta}$ *, the platform charges the sellers.*

(b) *when* $\beta = \bar{\beta}$ *, the platform neither charges sellers nor subsidizes them.*

(c) *when* $\bar{\beta} < \beta < 1$ *, the platform subsidizes sellers.*

(2) *The optimal per-transaction fee for sellers increases in the expected profit and the proportion of active consumers.*

This proposition illustrates that sellers could either be charged or subsidized. Sellers are charged less when a consumer gains more utility from an extra seller and are charged more when they gain higher expected profits from one consumer, or when there are more active consumers.

When more utility can be gained from an additional seller pre-transaction, more consumers transact. When they are charged a lower per-transaction fee, more sellers access the platform, and the consumer scale increases accordingly because of the indirect network externality. Therefore, platform profit can be increased when the scale of the overall market increases. With the further utility increase that a consumer gains from an extra seller, the sellers become more attractive and more valuable for the platform. Thus, the transaction fee charged to sellers may decrease to zero. When that utility is relatively large, the platform should subsidize sellers to attract more sellers and consumers, to enhance profitability. With a higher expected profit per consumer, or with a larger scale of active consumers, sellers' profits increase, thus the seller scale increases. Then, higher platform profits can be achieved by charging sellers a higher per-transaction fee.

Proposition 2. *The following results hold:*

(1) *Consumers are always charged rather than subsidized.*

(2) *The optimal per-transaction fee for consumers* p_i^* *decreases in the expected profit* γ_i *, the proportion of the active consumers* θ *, and the utility that an extra seller brings to a consumer* β *,* $i = v, c$ *.*

This proposition indicates that platform profits can increase even when consumers are charged lower transaction fees. The reason is that when the profit a consumer is expected to contribute to sellers increases, consumers become more attractive to sellers. When they are charged less, the number of consumers increases, and a much larger number of sellers can be realized, generating higher profits for the platform. Therefore, with a larger γ_v and θ, active consumers are charged a lower per-transaction fee, or with a larger γ_c, non-active consumers are charged a lower per-transaction fee.

The results also show that common (active) consumers would be charged less when the active consumer scale increases (when a common consumer offers a higher expected profit for sellers). When the active consumer scale increases, the seller scale can be enlarged, because having more active consumers increases expected profits for the platform. On the other hand, the common consumer scale is smaller when there are more active consumers. The common consumer scale becomes smaller if the platform charges them a higher per-transaction fee. Therefore, to enhance non-active consumers' utility and maintain the scale, a lower per-transaction fee should be charged to non-active consumers.

When a seller provides more utility to consumers, contrary to the intuition that consumers should be charged more as they obtain a higher gross utility because of the indirect network externality, they should instead be charged a lower per-transaction fee. The logic behind this is that charging a lower per-transaction fee to consumers enlarges the consumers' total utility. Thus, the consumer scale increases. Because of the indirect network externality, the seller scale becomes correspondingly larger, which can be of great benefit to the platform because having more sellers is attractive for consumers. Although a lower per-transaction fee is charged, higher total platform profits can be achieved by increasing the overall size of the market. If the platform charges consumers higher transaction fees, consumers derive less utility from the platform. Thus, fewer consumers are able to enjoy the higher utility offered by sellers.

Additionally, from the optimal pricing in Theorem 1, it is easy to see that $p_c^* - p_v^* = (\gamma_v - \gamma_c)/2$. Recall the assumption that $\gamma_v > \gamma_c$, then $p_v^* < p_c^*$ holds. This result is consistent with our common belief that active consumers should be charged less compared with non-active consumers. The reason is straightforward: active consumers are more important because they provide greater utility to sellers. When they are charged less, the scale of active consumers increases, which in turn attracts more sellers to the platform. Consequently, though active consumers are charged lower transaction fees, the platform's profits can be improved by increasing the total market on both sides.

3.2. The Scenario without Consumer Categorization

In this section, a model in which consumers are not categorized into distinct groups, but only differentiated in terms of their usage utility when they access the platform is constructed. Denoted by p_b the per-transaction fee that a consumer is charged, the gross utility of a consumer is

$$u_b = \alpha_b + \beta\tilde{n}_s - \tilde{p}_b\tilde{n}_s \tag{6}$$

where α_b is the usage utility from accessing and using the fundamental service of the platform, it is also assumed uniformly distributed on the interval $[0,1]$; $\beta\tilde{n}_s$ measures the utility that the consumer gains from the indirect network externality.

Assume the expected profit from each consumer for each seller is γ, $\gamma \in (0,1)$. Compared with the former situation, γ equals the average value of the expected profit provided by both active and non-active consumers; i.e., $\gamma = \theta\gamma_v + (1-\theta)\gamma_c$, $\gamma_c < \gamma < \gamma_v$. Assume that a seller is charged $\tilde{p}_s$ per-transaction for each consumer, and the cost for supplying a product or service is f, which is uniformly distributed over the interval $[0,1]$. Denoted by $\tilde{n}_b$ the consumer scale, the profit per-transaction that a seller obtains is

$$\tilde{\pi}_s = \gamma\tilde{n}_b + \tilde{p}_s\tilde{n}_b - f \tag{7}$$

Consumers and sellers transact when $u_b \geq 0$ and $\tilde{\pi}_s \geq 0$. Denoted by $\bar{\alpha}_b$ ($\bar{\pi}_s$) the usage benefit (the expected profit) that makes a consumer (seller) indifferent between trading and not trading. Thus, from $u_b = 0, \tilde{\pi}_s = 0$, we have $\bar{\alpha}_b = (p_b - \beta)\tilde{n}_s$; $\bar{\pi}_s = (\gamma - \tilde{p}_s)\tilde{n}_b$. That is, a consumer or a seller makes the transaction when the usage benefit or the cost lies in the interval $[(p_b - \beta)\tilde{n}_s, 1]$ and $[0, (\gamma - \tilde{p}_s)\tilde{n}_b]$, respectively. Therefore, the scale of consumers and sellers in the scenario without consumer categorization can be formulated as

$$\tilde{n}_b = 1 - (\tilde{p}_b - \beta)\tilde{n}_s, \quad \tilde{n}_s = (\gamma - \tilde{p}_s)\tilde{n}_b \tag{8}$$

Likewise, on a per-transaction fee basis, the optimal profit of the platform without consumer categorization Π_2 can be formulated as

$$\max \Pi_2 = \max\{\tilde{n}_b\tilde{n}_s\tilde{p}_b + \tilde{n}_s\tilde{n}_b\tilde{p}_s\} \tag{9}$$

By solving the profit function, the optimal user scale and the optimal per-transaction fees that the platform should charge the two sides can be derived in the following theorem.

Theorem 2. In the case without consumer categorization:

(1) The optimal user scales are: $\tilde{n}_b^* = 2/[4-(\beta+\gamma)^2]$, $\tilde{n}_s^* = (\gamma+\beta)/[4-(\beta+\gamma)^2]$.

(2) The optimal per-transaction fees that sellers and consumers should be charged can be given by, $\tilde{p}_s^* = (\gamma-\beta)/2$, $\tilde{p}_b^* = [2-\gamma(\beta-\gamma)]/(\beta+\gamma)$.

From the equilibrium results, it is easy to find that the platform should always charge consumers and should subsidize sellers when $\beta > \gamma$. They should charge sellers when $\beta < \gamma$, and neither charge nor subsidize sellers when $\beta = \gamma$. The condition $\beta < \gamma$ suggests that an additional consumer attracts more sellers because the expected profit from a consumer is larger. Charging sellers higher fees enables the platform to make more profit. Otherwise, more consumers would be attracted by an additional seller because of the larger utility. Consequently, the scale of the overall market is enlarged and a higher profit can be achieved.

From Theorem 2, we also find that the optimal per-transaction fee for sellers (consumers) $\tilde{p}_s^*$ ($\tilde{p}_b^*$) increases (decreases) in the expected profit from a consumer γ and decreases in the utility that a seller provides to a consumer β.

More sellers access the platform when consumers bring larger expected profits, and charging sellers a higher per-transaction fee increases the platform's profitability. Conversely, when a consumer gains more utility from a seller, sellers are more important because they are more attractive to consumers. Charging sellers lower fees increases their expected profit thus enlarges the user scale on both sides, from which a higher platform profit can be achieved.

Likewise, when more sellers are attracted by an extra consumer offering a larger expected profit, charging consumers lower transaction fees enlarges the total number of both consumers and sellers, and the platform profit. However, when a seller brings more utility to consumers, consumers should be charged lower fees, as explained above in Proposition 2. Charging non-active consumers lower fees enlarges the number of consumers. Therefore, more consumers benefit from the higher utility provided by sellers.

4. Comparisons

In this section, we compare scenarios with and without consumer categorization. To begin with, we present the result of pricing comparison as follows:

Proposition 3. *The following results hold:*

(1) *Sellers are charged a higher per-transaction fee under consumer categorization.*

(2) *Let* $\tilde{\theta} = (\gamma_v - 2\gamma_c - \beta)/2(\gamma_v - \gamma_c)$, *then when* $0 < \theta \le \tilde{\theta}$, $\tilde{p}_b^* \ge p_c^*$; *when* $\tilde{\theta} < \theta < 1$,. $\tilde{p}_b^* < p_c^*$.

(3) *Active consumers are charged a lower per-transaction fee under consumer categorization.*

Under consumer categorization, the expected profit that can be gained from active consumers is higher. That is, sellers benefit more from the platform. As a result, the seller scale increases because of higher expected profits. For the platform, higher profits can be made by charging sellers a higher per-transaction fee.

Recall that Proposition 4 illustrated that active consumers should always be charged with a lower per-transaction fee under consumer categorization. However, for non-active consumers, this is not necessarily the case.

When the scale of active consumers is relatively small, the size of both markets would be enlarged slightly under consumer categorization. However, because the scale of non-active consumers is large, the size of both markets can be increased more when non-active consumers are charged a lower per-transaction fee. Therefore, charging non-active consumers a lower per-transaction fee benefits the platform more. When the scale of active consumers is relatively large, the market size of both sides can be significantly enlarged under consumer categorization and the platform can make higher profits. Also, in this situation, since the scale of non-active consumers is small, a lower per-transaction fee for non-active consumers cannot effectively increase the whole market. Therefore, a higher per-transaction fee for non-active consumers in this situation leads to higher platform profits.

Because active consumers provide greater utility for sellers, they are the more important users for the platform. Thus, setting a lower per-transaction fee for them enlarges the entire market and realizes higher platform profit.

Combing Propositions 2 and 3, it shows that sometimes the platform subsidizes sellers but charges consumers. It seems that this can rarely happen in practice. However, in certain conditions, the platform may choose to subsidize the seller but charge consumers. For example, when a credit card issuing bank cooperates with a popular merchant, they may offer a discount (e.g., 20% off) to cardholders. Then, to compensate the discounted cost, the bank would offer a subsidy (e.g., 30%) to the merchants. Meanwhile, the bank still levies a certain proportion of the transaction fee which is paid by consumers. Thus, as a matter of fact, consumers are charged a per-transaction fee. Additionally, when we download a paid application through apple store, 30% of the profit gained by the application developers would be levied by the platform. It seems that consumers haven't pay to the platform, however, all the 30% of the sellers' profits gained by the platform comes from consumers.

Next, we compare the strategy of subsidizing or charging in the two scenarios. The proposition below summarizes the results:

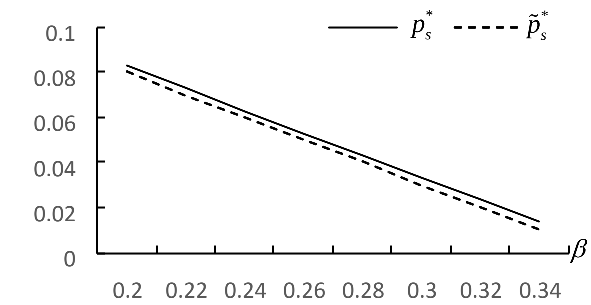
Proposition 4. *The following results hold:*

(1) *If* $\gamma_c < \beta < \gamma$, *sellers are charged in both scenarios and are charged a higher per-transaction fee under consumer categorization.*

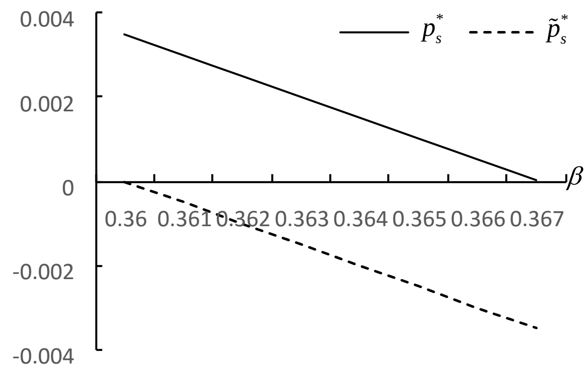
(2) *If* $\gamma < \beta < \overline{\beta}$, *sellers are charged under consumer categorization but are subsidized without consumer categorization.*

(3) *If* $\overline{\beta} < \beta < \gamma_v$, *sellers are subsidized in both scenarios, and the subsidy is smaller under consumer categorization.*

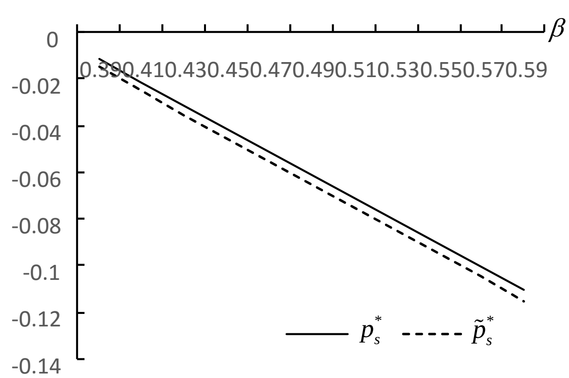
Proposition 4 implies that under the same conditions, sellers can either be subsidized or be charged in cases with or without consumer categorization. For a better illustration, we conduct a numerical example, where $\gamma_c = 0.2, \gamma_v = 0.6, \theta = 0.4$, Figure 1 shows the result.



(1) $\gamma_c < \beta < \gamma$



(2) $\gamma < \beta < \bar{\beta}$



(3) $\bar{\beta} < \beta < \gamma_v$

Figure 1: The Result of Charging or Subsidizing Sellers in the Two Cases

It is indicated that a consumer provides more utility for a seller when $\gamma_c < \beta < \gamma$ in the scenario without consumer categorization. As discussed above, charging sellers when they obtain higher cross-market utility (i.e., the utility from the indirect network externality) generates more profit for the platform. When consumers are categorized, sellers' gross utility further increases as active consumers provide more cross-market utility. Thus, sellers are charged more in this situation.

When a seller brings more utility to a consumer, subsidizing sellers effectively enlarges the entire user scale and can be more profitable than when consumers are not categorized. However, when consumers are categorized, active consumers provide more utility for sellers, and charging sellers can be beneficial to the platform.

As β increases ($\beta > \overline{\beta}$), sellers are more important for the platform, because they create higher utility for consumers. Therefore, subsidizing sellers enlarges the overall user scale and improves the platform's profit. Under consumer categorization, sellers obtain more utility because of active consumers. Thus, the subsidy decreases.

Next, we compare the user scale, expected profit for sellers, and the optimal platform profit in the two scenarios. The results are summarized in the following proposition.

Proposition 5. *The following results hold:*

(1) *The optimal scales of both sides are enlarged under consumer categorization.*
(2) *The expected profit of sellers increases under consumer categorization even though they are charged with a higher per-transaction fee.*
(3) *The platform profit becomes higher under consumer categorization.*

The scale of active consumers increases when they are charged a lower per-transaction fee. As a result, more sellers will access the platform under consumer categorization because of the indirect network externality. Therefore, the size of both markets becomes larger when the platform categorizes consumers. Recall that sellers are charged a higher per-transaction fee or subsidized with a lower per-transaction fee under consumer categorization, the platform benefits more from the seller side.

Although they are charged a higher per-transaction fee, the expected profit of the seller is enlarged. Under consumer categorization, active consumers bring more expected profit for sellers. In addition, the active consumer scale increases when they are charged lower transaction fees. As a result, sellers' profits increase.

It can be observed that the optimal profit is larger under consumer categorization. Categorizing consumers into two groups enlarges the total market size on both sides, from which the platform achieves higher profit. This is probably the reason why consumers are categorized into different types in practice.

By comparing the optimal profits in the two scenarios, we analyze the monotonicity of the profit increment with respect to θ. The result is presented as follows:

Proposition 6. *Denote by* $\Delta\Pi$ *the profit increment after consumer categorization; then* $\Delta\Pi$ *increases in* θ *when* $\theta \in (0, 0.5]$, *and there exists* $\tilde{\theta} \in (0.5, 1)$ *at which* $\Delta\Pi$ *arrives at its maximum.*

The result shows that the profit increment under consumer categorization is non-monotonic in relation to the scale of active consumers. Additionally, we use an example to illustrate, the parameters are set to be $\gamma_c = 0.2, \gamma_v = 0.6, \beta = 0.3$. Figure 2 presents the result.

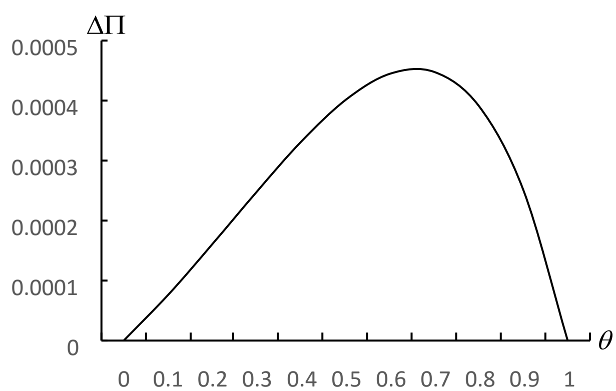


Figure 2: The Profit Increment under Consumer Categorization in Relation to θ

Intuitively, the scale of active consumers (or VIP consumers) is usually relatively small for most traditional one-sided markets. Our result reveals that for two-sided platforms, the benefit of consumer categorization is maximized when active consumers are more than a half of the total. This indicates that the positive effect of the cross-market network externality creates the biggest benefit for two-sided platforms when they categorize a large enough proportion of active consumers. This may explain the real-world practice that many two-sided platforms (e.g., Tmall) designate a large percentage of their consumers as star members, for whom preferential strategies are formulated.

5. Robustness test: Membership fees

In this section, we consider two scenarios similar as Section 3. We replaced the transaction fees with one-time membership fees. In addition, we assume that the platform charges different membership fees for active and non-active consumers. That is, the platform charges active consumers for p_v, and charges non-active consumers for p_c. According to Section 3, we change the model to

$$u_i = \alpha + \beta n_s - p_i, \quad (i = v, c) \tag{10}$$

$$\pi_s = \gamma_v n_v + \gamma_c n_c - p_s - f \tag{11}$$

where p_s denotes the one-time membership fee each seller pays to the platform.

5.1. Scenario with Consumer Categorization

Similar with Section 3.1, the user scale when consumers are categorized into two groups can be given as

$$\begin{cases} n_v = \theta[1 + (\beta - p_v)n_s] \\ n_c = (1-\theta)[1 + (\beta - p_c)n_s] \\ n_s = (\gamma_v - p_s)n_v + (\gamma_c - p_s)n_c \end{cases} \tag{12}$$

The platform's profit-maximizing problem under consumer categorization can be formulated as

$$\max \Pi_1 = \max\{n_v p_v + n_c p_c + n_s p_s\} \tag{13}$$

Theorem 3. Let $Y = [4 - \theta(\gamma_v + \beta)^2 - (1-\theta)(\gamma_c + \beta)^2]$, the optimal membership fees that maximize the platform's profit are given by:

$$\begin{cases} p_c^* = [4 - 2\theta\gamma_v(\gamma_v + \beta) - (1-\theta)(\gamma_c + \beta)(\gamma_c + \gamma_v)] / 2Y \\ p_v^* = [4 - 2\gamma_c(1-\theta)(\gamma_c + \beta) - \theta(\gamma_v + \beta)(\gamma_c + \gamma_v)] / 2Y \\ p_s^* = [\theta\beta(1-\theta)(\gamma_v - \gamma_c)^2 + 2\theta(\gamma_v - \beta) + 2(1-\theta)(\gamma_c - \beta)] / 2Y \end{cases}$$

5.2. Scenario without Consumer Categorization

According to Section 3, we change the utility of a consumer and the expected profit of a seller as:

$$u_b = \alpha_b + \beta\tilde{n}_s - \tilde{p}_b \tag{14}$$

$$\tilde{\pi}_s = \gamma\tilde{n}_b - \tilde{p}_s - f \tag{15}$$

where $\gamma = [\theta\gamma_v + (1-\theta)\gamma_c]$, $\gamma_c < \gamma < \gamma_v$.

Then, the optimal user scale given the membership fee can be obtained as:

$$\tilde{n}_b = 1 - \tilde{p}_b + \beta\tilde{n}_s, \quad \tilde{n}_s = \gamma\tilde{n}_b - \tilde{p}_s \tag{16}$$

Likewise, on a membership fee basis, the optimal profit of the platform without consumer categorization Π_2 can be formulated as:

$$\max \Pi_2 = \max\{\tilde{n}_b\tilde{p}_b + \tilde{n}_s\tilde{p}_s\} \tag{17}$$

By solving the profit function, the optimal user scale and the optimal membership fees can be given in the following theorem.

Theorem 4. In the case without consumer categorization:

(1) The optimal user scales are: $\tilde{n}_b = 2/[4 - (\beta + \gamma)^2]$, $\tilde{n}_s = (\gamma + \beta)/[4 - (\beta + \gamma)^2]$.

(2) The optimal membership fees that sellers and consumers should be charged can be given by $\tilde{p}_s^* = (\gamma - \beta)/[4 - (\beta + \gamma)^2]$, $\tilde{p}_b^* = [2 - \gamma(\beta - \gamma)]/[4 - (\beta + \gamma)^2]$.

Comparing Theorem 3 (4) with Theorem 1 (2), we can find that in each scenario (i.e., with and without consumer categorization), the denominator of the optimal pricing strategies in the transaction fee context are the same as the membership fee context, though the denominators are different. Therefore, we can easily obtain that the main conclusions still hold when the platform charges a membership fee that: 1) the sellers can either be charged or be subsidized while consumers are charged; 2) sellers are charged a higher membership fee under consumer categorization, active consumers are charged a lower membership fee while the non-active consumers can either be charged a higher or a lower membership fee; 3) the optimal scales of both sides and the platform profit are enlarged under consumer categorization, also, the expected profit of sellers increases under consumer categorization even though they are charged with a higher membership fee; 4) if $\gamma_c < \beta < \gamma$, sellers are charged in both scenarios and are charged a higher membership fee under consumer categorization; if $\gamma < \beta < \bar{\beta}$, sellers are charged under consumer categorization but are subsidized without consumer categorization; if $\bar{\beta} < \beta < \gamma_v$, sellers are subsidized in both scenarios, and the subsidy is smaller under consumer categorization.

Notably, the optimal pricing strategies in the per-transaction fee context generate the same optimal platform profit as in a membership fee context. We summarize this result in the following proposition.

Proposition 7. The optimal profits of the platform remain the same when the platform charges a per-transaction fee and a membership fee in both the scenarios with and without consumer categorization.

This proposition demonstrates that the charging strategies (i.e., membership or per-transaction fee) are indifferent for the platform, which proves the robustness of our model. Based on this result, it is easy to obtain the same profit difference between the scenarios with and without consumer categorization as in the per-transaction fee context. Thus, we reach the same conclusion presented in Proposition 6.

6. Conclusion

This paper investigates the effect of consumer categorization on a two-sided platform, where consumers from the buying side of the platform are classified into two distinct groups according to their activity level. Optimal pricing strategies with and without consumer categorization are derived, and comparisons are made from different perspectives. Also, to explore the impact of the pricing policy on the platform, we conduct the robustness test where the membership fees are charged. The equilibrium results show that sellers on the platform can either be charged or subsidized, whereas consumers will always be charged. Under consumer categorization, sellers will be charged a higher per-transaction fee, whereas active consumers will be charged a lower fee, and the non-active consumers will be charged a lower (higher) per-transaction fee when the scale of the active consumers is relatively small (large). The expected profit of sellers is enlarged though they are charged higher. In addition, the platform's profit is increased when consumers are categorized into two distinct groups, and the incremental profit is maximized when more than a half of the consumers are categorized as active ones. From the robustness test, we show that both the membership fee and the per-transaction fee lead to the same profit for the platform, the main conclusions obtained under the per-transaction fee still hold when the platform charges membership fees.

Our results reveal that categorizing users into different groups is beneficial for two-sided platforms. For users who are categorized as active ones, the pricing can be lowered to enlarge the entire user scale. With a larger user base, the effect of the network externality gets strengthened. Therefore, compared with the scenario where consumers are not categorized as different types, the platform derives more profit when the consumers are distinguished. However, the profit increment does not always increase with more active users. The biggest benefit can be achieved when more than a half proportion of the users are categorized as active by the platform. Counter to the conventional wisdom that the VIP consumers are usually a small proportion of the entire consumer scale, we reveal that for platforms exhibiting indirect network externality, a much larger scale of consumers should be treated as important ones to make the most profit. This differs from traditional industries as users of the platform are on two sides. They are connected to each other that when the user scale increases on one side, more users can be attracted to join the platform on the other side.

The managerial implications of this paper can be summarized as follows. First, for two-sided platforms, such as the E-commerce platforms (e.g., Amazon, Meituan), or the platforms in the sharing economy (e.g., Uber, Airbnb), one of the most important operations is to identify consumers' characteristics to differentiate the valuable ones. Second, a differentiated pricing strategy should be made by utilizing the network externality to enlarge the entire user base. Third, rather than keep a small fraction of VIP consumers in the traditional market, supplying preferential services to a larger proportion of consumers (e.g., more than 50%) on one side helps extract the largest benefit from pricing discrimination. Fourth, practitioners should pay more attention to the differentiated pricing strategy towards different groups of consumers, rather than the pricing strategies itself (i.e., the per-transaction fee or the membership fee).

Our setting and results hold when the proportions of the active and non-active consumer are relatively stable, which means that our results are particularly useful for practitioners when a two-sided platform grows to a relative mature stage that the active or non-active consumers can be characterized, and the scale of each group becomes relatively stable.

This paper explores the effect of categorizing consumers on the buying side of a two-sided platform into two distinct groups. Several limitations exist in this paper, which can be the subjects of future research. First, we categorize consumers according to their level of activity, or the frequency of their interactions with the other side (sellers). Other dimensions could be used to classify consumers, and different findings might be derived. It is also possible that the consumers could be categorized into more than two groups and could be charged differently. Additionally, rather than assuming a certain proportion of active and non-active consumers, it might be better to incorporate the incentive compatibility constraint in the modeling setup to show which group the consumers will join when the platform implements consumer categorization. Other extensions could incorporate the network externality between two groups from the same side of the platform, of which the existence has already been illustrated by some research.

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