Impact of Online In-store Referrals

Ling-Chieh Kung*

In 2006, Amazon launched a new form of marketplace to allow third-party merchants, including other online retailers, to use its platform to sell their products. The products of these third-party merchants were listed on the same search result listing page along with Amazon's own products. This strategy introduces competitors' products to its platform and results in a more competitive environment. At the same time, it diversifies the products on the platforms and brings a wider selection to customers. This strategy turned out to be one of the key reasons for Amazon to become the largest online retailer in the United States. Mulpuru et al. (2012) show that more customers search on Amazon (30%) than on Google (13%) before they make an online purchase. In a more recent survey, Marvin (2015) shows that the percentage for Amazon has grown to 44%, while that for all the search engines was only 34%. In fact, third-party sellers account for over 45% of the total sales quantity on Amazon in the third quarter of 2015 (Rao, 2016). Beside benefiting from customers brought in by the wide selection, Amazon charges a 6% to 25% referral fee depending on the product category to generate revenues from referrals.[1]

A more interesting type of online referrals was adopted by Sears, a leading United States online retailer. When one searches for products on Sears, the products on the result listing page may be from not only Sears but also other online retailers, e.g., Kmart. Sears only notifies customers by putting a small logo of the competing retailers under the products. If we click into one product to see its detailed information and description, there is no additional information about the true seller. Sears deliberately camouflaged the product from competing retailers as its own, providing the competitors its existing customer base, order system, and payment solutions. In short, unlike Amazon, who refers customers to third-party sellers who may not have their own channels, Sears refers customers to competing retailers who also sells their products through their own channels. According to Cai and Chen (2011), these activities among competing online retailers are called in-store referrals. While a referral may be one-way (A refers B's product

*Department of Information Management, National Taiwan University; lckung@ntu.edu.tw.

[1]For a complete list of categories and referral fees, see "Amazon.com Help: Fees and Pricing," available on `https://www.amazon.com/gp/help/customer/display.html?nodeId=1161240`.

but not the other way), it may also be mutual (both A and B refer the other's product). For example, one may also find Kmart referring its customers to Sears' products.

Why would an online retailer be willing to sell its competitors' products on its own website? While there are clearly multiple reasons, Cai and Chen (2011) identify a few. The direct benefit obtained by collecting referral fees is of course one driving force. More interestingly, they demonstrate that referrals may be beneficial by allowing retailers to together expand the market. While they obtain this conclusion by analyzing the interaction among retailers selling horizontally differentiated products, an analysis for products of vertical differentiation is still missing in the literature. It is conceivable that vertical differentiation will give online retailers new challenges about in-store referrals. For example, should a retailer refer its customers to a superior or inferior product? In either case (if possible), what is the incentive for that? What is the impact of quality difference on the retailers' referral strategies? Finally, how do the quality difference and referral fees jointly determine the market equilibrium?

Please try to study the impact of a referral relationship among competing online retailers selling products with quality difference. You may want to model two competing retailers selling one kind of product of vertical quality differentiation. Before referrals, customers are aware of only one platform. This gives the retailers a direct incentive to form a referral relationship for market expansion. Once the referral relationship is established, the referred retailer may pay a fixed fee or share a portion of its revenue as referral fees to the referring retailer. Let's ignore one-way referrals and focus on mutual referrals. If we may analytically derive the equilibrium prices and profits under no referral and mutual referral, we may compare them to address the above research questions.

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Pricing Strategy of a Two-sided Grocery Delivery Platform

Ling-Chieh Kung*

Traditionally, a delivery service provider delivers goods from self-owned warehouses to its consumers using its own trucks and employees. In the grocery delivery industry, companies like AmazonFresh adopt this operation model. Owing to the advances in technology, however, different types of delivery services spring up in recent years. In particular, some companies build Internet platforms for consumers to order groceries and food materials online. Instead of building a centralized logistics system, the platform assigns these consumer orders to independent contractors, often called shoppers in this business model, for them to buy the ordered goods from independent brick-and-mortar retailers and ship to consumers. As the central service enabler is the two-sided Internet platform connecting consumers and shoppers, we call it *platform delivery* in this study.

As of 2016, one of the most successful platform deliverer is Instacart, a San Francisco-based startup founded in 2012.[1] Valued more than two billion dollars, Instacart was listed as top one in *Forbes America's most promising companies list* in 2015 (Soloman, 2015). Besides startups, big companies also enter this industry in the same way. For example, Google founded Google Express to be another platform for grocery delivery service. An obvious advantage of this model is that the delivery service can be provided without owning any warehouse, trucks, and full-time shoppers. A huge initial investment can then be saved. Nevertheless, because the shoppers are not full-time employees, sufficient incentives must be provided to prevent shortage of shoppers. This is a key issue faced by all platform owners in the sharing economy.

In general, the success of a platform delivery company (and most multi-sided Internet platforms) relies on its installed base, and the benefit of joining the platform at one side increases as the number of users at the opposite side raises up. This feature is documented as the positive cross-side network externality. Obviously, more shoppers attract more consumers, as it will become easier and faster for a consumer to find a shopper to complete the delivery. Similarly,

*Department of Information Management, National Taiwan University; lckung@ntu.edu.tw

[1] A Taiwanese startup Honestbee is doing the same business. Similarly, Foodpanda adopts the same model to deliver meals from restaurants to consumers.

more consumers attract more shoppers, as it will be more likely to get assigned an order. Providing enough incentives for both sides to be large enough is the most critical problem faced by a platform owner. Pricing of course cannot be ignored in the design of the incentive system. The most challenging part of this problem is that, even though the platform faces two sides of users, the pricing problems for the two sides are never independent due to the cross-side network effect. The two pricing problems must be considered together to optimally provide incentives for shoppers and consumers to stay connected to the platform. This brings new challenges and a great potential values to the investigation of platform pricing.

While in theory there can be all kinds of pricing plans, complicated policies are hard to execute and incurs implicit management costs. Therefore, in industry some simple strategies are popular. If a company adopts the *membership-based pricing* strategy, the platform sustains losses in every transaction but charges every consumer a fixed membership fee at the beginning of each membership period. On the opposite, the platform may charge a per-transaction fee but no fixed fee. This is the *transaction-based pricing* strategy. Note that, at least for the platform delivery business, it is less natural to subsidize a shopper a fixed fee before she/he provides any services. However, whether it is more profitable to charge membership fees, transaction fees, or both from consumers is not so clear. In either case, the platform needs to decide the amount paid to the shopper in each transaction. This introduces the third strategy, which we call it the *cross-subsidization* strategy, under which the platform simply subsidizes the shopper exactly the amount collected from the consumer in each transaction. It is worthwhile to investigate which pricing strategy may generate the highest profit for the platform.

Please try to construct a game-theoretic model featuring sharing economy and network externality to examine a grocery delivery platform's two-sided pricing strategy. There should be at least three types of players in the market: a platform, a group of potential consumers, and a group of potential shoppers. One major purpose may be to study the profitability of the three pricing strategies mentioned above, whether any of them can be globally optimal, and figure out factors that affect their profitability. On one hand, maybe we can theoretically explain the economic rationale behind these pricing mechanisms popularly adopted in practice. On the other hand, it would also be great to provide a good reference for platform owners in industry to design their pricing plans to efficiently incentivize users to join the platform.

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Modeling Product Pricing by Considering Consumers' Decisions Based on Utility Maximization

Ling-Chieh Kung*

In previous lectures, we have investigated a few game-theoretic models about a firm's profit maximization problem. However, most of these models do not have a role played by consumers. In particular, while the firm has a utility function (which is typically her profit function or expected profit function) and acts to maximize her utility function, the sales outcome is directly assumed to be a function of the firm's decision (e.g., $a - bp$ where p is the retail price or $\mathbb{E}[\min\{q, D\}]$ where q is the inventory level). In this note, we will introduce some models that explicitly models the consumers' decisions based on utility maximization. In each model, we will see that consumers' have their utility functions, and each of them make a decision that maximizes his utility function. Being able to model consumers' decisions will enrich our model and allow us to tackle more research questions.

1 The first model

Consider the following monopoly pricing problem (which has been introduced in the first lecture). A seller sells a product to a market. For consumers in the market, their willingness-to-pay θ uniformly spread within 0 and 1. Note that this is saying that consumers are *heterogeneous* on their willingness-to-pay for the product. Whenever we have a group of heterogeneous consumers, we call the attribute(s) that differentiates these consumers their *type*. In this example, we call the willingness-to-pay θ as a consumers' type. Let p be the retail price chosen by the seller. For the type-θ consumer, his utility function is

$$u(\theta) = \theta - p$$

if he purchases the product and 0 otherwise. We say that his *reservation price* is 0. Each consumer decides whether to buy the product by considering the product price and his own

*Department of Information Management, National Taiwan University; lckung@ntu.edu.tw.

willingness-to-pay θ. The unit production cost of the product is c. The seller chooses p to maximize her profit.

To solve the seller's problem, we first try to derive the demand function. Given a price p, a consumer buys the product if and only if his willingness-to-pay $\theta \geq p$. Therefore, the group of consumers are divided into two *segments*: The *high segment* of consumers whose $\theta \in [p, 1]$, and the *low segment* of consumers whose $\theta \in [0, p)$. We sometimes call them *high-end consumers* and *low-end consumers*, respectively. The intuition is clear: One buys the product if and only if he sufficiently likes the product. The market segmentation then implies that the demand volume is

$$D(p) = 1 - p,$$

and the seller's profit-maximization problem is

$$\max_{p} \ (p - c)(1 - p).$$

Obviously, the optimal price is $p^* = \frac{1+c}{2}$. The equilibrium profit is $\pi^* = \frac{(1-c)^2}{4}$.

Note that we are not assuming the demand function is like this or like that; we *derive* the demand function based on our model setting. Also note that the assumption of uniformly distributed willingness-to-pay provides a justification to the widely adopted linear demand setting. Finally, note that the consumer of type p is *indifferent* between buying and not buying. As θ is continuous, it does not matter whether we include him in the high-end or low-end segment.

2 Exogenous product quality

Sometimes we want to model the impact of product quality. In particular, may we modify the previous model to include a parameter q as the product quality so that the equilibrium price and profit will increase in q?

To do so, let's say the type θ is now a consumer's willingness-to-pay *for a unit of quality*. Therefore, the type-θ consumer's utility function becomes

$$u(\theta) = \theta q - p$$

if he purchases a product of quality q and 0 otherwise. Note that this setting captures three intuitive features. First, one gets happier when the quality becomes higher. Second, one gets happier when the price becomes lower. Finally, when the quality becomes higher, those of higher θ will have a larger increase than those of lower θ. After all, those of higher θ are willing to pay more for a high quality product, so increasing the product quality has a higher impact on them. Let's assume that q is exogenous, and the seller may choose p to maximize her profit. All other settings are the same.

To solve the seller's problem, again we need to first derive the demand function. Given a price p, again the market will be divided into two segments (why?), and all we need to do is to find the indifferent consumer's type θ. In other words, we need to find θ_0 that satisfies

$$u(\theta_0) = \theta_0 q - p = 0,$$

which implies that $\theta_0 = \frac{p}{q}$. All the consumers whose type $\theta \geq \theta_0$ will buy the product (as their utility of buying the product is nonnegative) while all others will not. Therefore, the high segment is $\theta \in [\frac{p}{q}, 1]$ while the low segment is $\theta \in [0, \frac{p}{q}]$. Therefore, the demand function is

$$D(p) = 1 - \frac{p}{q},$$

and the seller's problem is

$$\max_p \; (p - c)\left(1 - \frac{p}{q}\right).$$

It is still straightforward to solve this problem and obtain the optimal price $p^* = \frac{q+c}{2}$. The equilibrium profit is $\pi^* = \frac{(q-c)^2}{4}$. Indeed this model represents the desired fact that both p^* and π^* increases in q.

3 Endogenous product quality

What if the product quality q is also a decision variable? In this case, typically there should be some cost to increase q (otherwise the seller should always set q to its highest possible value). For example, the profit function may become

$$(p - C(q))\left(1 - \frac{p}{q}\right),$$

where the unit production cost $c(q)$ increases in q. Common choices of $C(q)$ include cq (so the cost is linear to quality) and cq^2 (so the cost is convex to quality) for some $c > 0$. Another choice is to consider a profit function

$$(p - c)\left(1 - \frac{p}{q}\right) - C(q).$$

In this model, $C(q)$ is the one-time R&D cost. In any case, note that the seller's problem's (joint) concavity needs to be verified. Moreover, the problem becomes two-dimensional, i.e. having two decision variables. In general more advanced techniques are needed to solve multi-dimensional constrained problem. Let's ignore this at this moment.

An easier model may be obtained by switching from a continuous-type setting to a binary-type setting. Instead of letting θ be uniformly distributed between 0 and 1, let θ follows a Bernoulli distribution of two possible values θ_L and θ_H, where $\theta_L < \theta_H$ and

$$\Pr(\theta = \theta_L) = \beta = 1 - \Pr(\theta = \theta_H).$$

In other words, we are saying that there are two types of consumers, high-end consumers (of type θ_H) and low-end consumers (of type θ_L), and the proportion of low-end consumers is β. Let's say the unit production cost is $C(q) = \frac{cq^2}{2}$. All other settings are the same.

To derive the demand function, note that there are only three possible outcomes: All consumers buy the product, only high-end consumers buy the product, and on consumers buy the product. The seller may adjust p and q to induce one of these to be the equilibrium outcome. As the last option is obviously not good, let's compare the first two strategies.

To induce all consumers to buy the product, we have

$$\begin{aligned} \max_{p,q} \quad & 1 \cdot \left(p - \frac{cq^2}{2}\right) \\ \text{s.t.} \quad & \theta_L q - p \geq 0. \end{aligned}$$

The constraint $\theta_L q - p \geq 0$ ensures that all low-end consumers are willing to buy the product. Obviously, high-end consumers will also buy the product, and thus all consumers will buy the product. The demand is then $\beta + (1 - \beta) = 1$. For each consumer, the seller earns $p - \frac{cq^2}{2}$. To solve this problem, note that the constraint must be binding at any optimal solution (otherwise the seller may increase p to make herself better off). Therefore, for any optimal solution, we have $\theta_L q = p$. If we replace p in the objective function by $\theta_L q$, we reduce the problem to

$$\max_{q} \ \theta_L q - \frac{cq^2}{2}.$$

The optimal quality level is $q^{\text{all}} = \frac{\theta_L}{c}$. The equilibrium profit is $\pi^{\text{all}} = \frac{\theta_L^2}{2c}$.

Similarly, to induce only the high-end consumers to buy the product, we have

$$\begin{aligned} \max_{p,q} \quad & (1 - \beta)\left(p - \frac{cq^2}{2}\right) \\ \text{s.t.} \quad & \theta_H q - p \geq 0. \end{aligned}$$

Again, the constraint must be binding at any optimal solution, and we may reduce the problem to

$$\max_{q} \ (1 - \beta)\left(\theta_H q - \frac{cq^2}{2}\right)$$

The optimal quality level is $q^{\text{high}} = \frac{\theta_H}{c}$. The equilibrium profit is $\pi^{\text{high}} = (1 - \beta)\frac{\theta_H^2}{2c}$. Note that when the sellers decides to serve only high-end consumers, the optimal product quality gets higher ($q^{\text{high}} > q^{\text{all}}$). This is reasonable: As your target consumers are willing to pay more for quality, increasing the quality is a good idea. We may verify that the optimal price is also higher under the high-end-only strategy.

Lastly, we need to compare the two equilibrium profits. Serving all consumers is better than serving only the high segment if and only if

$$\pi^{\text{all}} = \frac{\theta_L^2}{2c} > (1-\beta)\frac{\theta_H^2}{2c} = \pi^{\text{high}},$$

i.e., $\frac{\theta_L}{\theta_H} > \sqrt{1-\beta}$. In other words, what matter are the two willingness-to-pay levels and the relative size of the two groups of consumers. If θ_L is quite low compared to θ_H, serving the low segment would require the seller to cut down the price by a huge amount. It is then better to serve only the high segment. If β is low, which means that the size of low segment is small, it is also the seller's best interest to serve only the high segment.

4 Two products

Let's ignore endogenous quality and go back to the exogenous quality setting. What if the seller now has two products, each of quality q_1 and q_2? Without loss of generality, let's assume that $q_1 > q_2$, so products 1 and 2 are the high- and low-quality products, respectively. The unit production costs of products 1 and 2 are c_1 and c_2, respectively. How to price these two products for profit maximization?

Given the prices p_1 and p_2 for products 1 and 2, respectively, each consumer has three options: buying product 1, buying product 2, or buying nothing. By buying product 1, a type-θ consumer's utility is $\theta q_1 - p_1$. He will be willing to buy product 1 (compared to buying nothing) if and only if $\theta \geq \frac{p_1}{q_1}$. Similarly, he will be willing to buy product 2 if and only if $\theta \geq \frac{p_2}{q_2}$. Now, if a consumer is only willing to buy one of the two products, he will buy it; if he is willing to buy both, he will choose the one that gives him a higher utility. In this case, he prefers product 1 if and only if

$$\theta q_1 - p_1 \geq \theta q_2 - p_2 \quad \Leftrightarrow \quad \theta \geq \frac{p_1 - p_2}{q_1 - q_2}.$$

Let $\theta_1 = \frac{p_1}{q_1}$, $\theta_2 = \frac{p_2}{q_2}$, and $\bar{\theta} = \frac{p_1-p_2}{q_1-q_2}$, the relationship among the three cutoff values determines the equilibrium market segmentation.

Suppose that $\bar{\theta} > \theta_2$, i.e., $p_1 q_2 > q_1 p_2$. In this case, the market will be divided into three segments: the high segment $\theta \in [\frac{p_1-p_2}{q_1-q_2}, 1]$ of consumers who buy product 1, the middle segment $\theta \in [\frac{p_2}{q_2}, \frac{p_1-p_2}{q_1-q_2}]$ of consumers who buy product 2, and the low segment $\theta \in [0, \frac{p_2}{q_2}]$ of consumers who buy nothing. The seller's profit function is

$$(p_1 - c_1)\left(1 - \frac{p_1 - p_2}{q_1 - q_2}\right) + (p_2 - c_2)\left(\frac{p_1 - p_2}{q_1 - q_2} - \frac{p_2}{q_2}\right).$$

On the contrary, if $\bar{\theta} < \theta_2$, i.e., $p_1 q_2 < q_1 p_2$, the middle segment degenerates and the market will be divided to only two segments: the high segment $\theta \in [\frac{p_1}{q_1}, 1]$ of consumers who buy product 1, and the low segment $\theta \in [0, \frac{p_1}{q_1}]$ of consumers who buy nothing. The seller's profit function is

$$(p_1 - c_1)\left(1 - \frac{p_1}{q_1}\right).$$

It is the seller's discretion to set p_1 and p_2 to induce either equilibrium. For example, he may set an extremely high p_2 to satisfy $p_1 q_2 < q_1 p_2$. In this case, no one prefers product 2, and we will have the two-segment equilibrium. As the seller's profit function is different under the two market segmentation strategy, to find the seller's optimal prices, we need to solve two subproblems, one for each strategy. In the first subproblem, we solve for p_1 and p_2 under the three-segment equilibrium, i.e, we solve

$$\begin{aligned} \pi^{\text{three}} = \max_{p_1, p_2} \quad & (p_1 - c_1)\left(1 - \frac{p_1 - p_2}{q_1 - q_2}\right) + (p_2 - c_2)\left(\frac{p_1 - p_2}{q_1 - q_2} - \frac{p_2}{q_2}\right) \\ \text{s.t.} \quad & p_1 q_2 \geq q_1 p_2. \end{aligned}$$

In other words, the seller restricts herself by asking "if I want to have three segments, what are the optimal prices?" After π^{three} is found, the seller should proceed to solve the second subproblem

$$\begin{aligned} \pi^{\text{two}} = \max_{p_1, p_2} \quad & (p_1 - c_1)\left(1 - \frac{p_1}{q_1}\right) \\ \text{s.t.} \quad & p_1 q_2 \leq q_1 p_2. \end{aligned}$$

By comparing π^{three} and π^{two}, the seller may find her optimal strategy. This is called the *product line design* problem in the marketing literature.

Up to now, if you understand the formulation and the concepts of market segmentation and strategy selection, it is great. Unfortunately, even though the above subproblems are not really complicated, we have not taught you in this course how to analytically solve these multi-dimensional constrained problems. If you really want to solve them, please study the KKT condition by yourself or discuss with the instructor.