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How Does Free Riding on Customer Service Affect Competition?

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The free-riding problem occurs if the presales activities needed to sell a product can be conducted separately from the actual sale of the product. Intuitively, free riding should hurt the retailer that provides that service, but the author shows analytically that free riding benefits not only the free-riding retailer, but also the retailer that provides the service when customers are heterogeneous in terms of their opportunity costs for shopping. The service-providing retailer has a postservice advantage, because customers who have resolved their matching uncertainty through sales service incur zero marginal shopping cost if they purchase from the service-providing retailer rather than the free-riding retailer. Moreover, allowing free riding gives the free rider less incentive to compete with the service provider on price, because many customers eventually will switch to it due to their own free riding. In turn, this induced soft strategic response enables the service provider to charge a higher price and enjoy the strictly positive profit that otherwise would have been wiped away by head-to-head price competition. Therefore, allowing free riding can be regarded as a necessary mechanism that prevents an aggressive response from another retailer and reduces the intensity of price competition.

Key words: free riding; sales service; selling cost; channel conflict; retail competition; competitive strategy; game theory
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1. Introduction

Imagine a college student planning to purchase some audio equipment. Not knowing precisely which product fits her needs best, she might visit a Tweeter store, recognized for its high level of customer service, and ask for the assistance of knowledgeable salespeople. The salespeople expend time and effort to help the college student by listening to her situation carefully, letting her try many different products, and finally identifying the product that fits her needs best. Because Tweeter must incur all these selling costs, they will be reflected in the price of the audio equipment. Knowing this, the student goes to a local discount audio store, which does not offer any sales service, and purchases the same audio equipment that Tweeter recommended, but at a lower price.

What this frugal college student has done is "free ride" off of Tweeter's selling effort, or service, to resolve the matching problem between her needs and the available audio products.[1] She enjoyed the opportunity to try some equipment and Tweeter's expert advice, an experience most discount retailers cannot offer, and then obtained the discount retailer's lower price. This free-riding problem can occur whenever the presales activities needed to sell a product, such as providing informed sales advice to consumers, can be conducted separately from the actual sale of the product. Therefore, it is possible for one retail store to engage in the presales activity necessary to sell the product, but for a different, lower-priced store to make the final sale. As the selling costs incurred for such presales service have grown increasingly significant, the free-riding problem has become more and more substantial for many retailers.[2]

Conventionally, free riding in a retail market should hurt the profit of the retailer that provides the service (for a survey in a distribution channel environment, see Antia et al. 2004, Coughlan et al. 2001; also see Carlton and Chevalier 2001). The cost of free riding for the retailer that offers presales service is clear, but its benefits, if any, may be more difficult to discern.

Traditionally, retail stores have used various devices to keep consumers from free riding, such as territorial restrictions or exclusive dealership agreements for a certain manufacturer (Coughlan et al. 2001). The idea behind these devices is that free riding hurts retail profits; therefore, retailers must make it harder for customers to compare products and prices from

[1] The situation in which sales assistance is optimal has been analyzed by Wernerfelt (1994b).

[2] One-third of customers who came to Tweeter to shop enjoyed free riding by switching to competitors that offered the product at a lower price (see Gourville and Wu 1996).

different retail outlets to reduce the amount of free riding. Also, the main focus of existing literature has been the negative impact of free riding on a retailer's incentive to offer service and the way retailers and manufacturers prevent free riding (for general references, see Carlton and Perloff 2000). However, those tactics to prevent free riding can be implemented only through channel coordination with manufacturers, and without upstream channel coordination, most retailers are vulnerable to the free-riding problem. To prevent free riding, retailers try to lower their prices, but many are limited in their ability to do so because of the costs of offering presales service. Therefore, such retailers would have to eliminate their sales service (Carlton and Chevalier 2001). Nonetheless, many retailers still continue to provide sales service and thrive despite the free-riding problem. Are they simply doomed to vanish in the near future? How can they cope with the threat of free riding and still provide costly service? This article tries to offer some answers to these questions.

An interesting insight gained from this analysis is that both free-riding and service-providing retailers can benefit from free riding. The basis for this counterintuitive result is that the service provider can use its service offer to attract many people to the store and effectively lock in some customers because visiting another retailer would entail additional shopping costs. This argument is appealing, yet incomplete. If a retailer could lock in all customers who visit the store, all retailers would engage in intense price competition upfront to attract more customers. However, by allowing free riding, a retailer that provides service can induce free-riding competitors to avoid competing severely on price. That is, the competitor (free rider) has less incentive to compete with the service-providing retailer on price because many customers who visit the service provider eventually will switch to the free rider to enjoy its lower price. This induced soft strategic response enables the service provider to charge a higher price. Allowing free riding can therefore be regarded as a necessary mechanism by the service provider to prevent an aggressive response from another retailer.

Before offering a formal rationale for this argument with a simple model, we briefly review some associated literature. The free-riding retailing problem has been studied and is well understood in standard economics and marketing literature (e.g., Carlton and Chevalier 2001, Carlton and Perloff 2000). Telser (1960) and Singley and Williams (1995) suggest that free riding increases the price disparity between the service-providing retailer and the free rider. As a consequence, more customers free ride off one retailer's service and buy the product from the other retailer, who charges a lower price. Free riding thereby can dissuade retailers from offering sales service. Several studies in channel conflict literature also suggest that free riding decreases the levels of retail service, such as presale service, customer education about product attributes, and salesperson training, in a multichannel distribution setting (see Antia et al. 2004 for a survey about free riding in multichannel conflicts).[3]

The work of Wu et al. (2004) is a notable exception, which shows analytically that retailers might benefit from providing service even in the presence of the painful free-riding problem. Two segments of customers exist: one with a positive search cost and another with zero search cost. A retailer needs to establish itself as a service provider to make a positive profit by attracting customers and locking in all the customers who have a positive search cost, even if the zero-search-cost customer segment engages in free riding.[4] However, these authors focus on the negative impacts of free riding and regard it as a pure cost to be managed; they do not recognize its benefit to the retailer. In contrast, this article focuses on the strategic role of free riding in reducing the intensity of price competition and evaluates its benefit to the service-providing retailer.

The current work also relates to sales management literature (Churchill et al. 1999, Godes 2003, Wernerfelt 1994a). We follow Wernerfelt's (1994a) conception that sales assistance improves the quality of the match between a customer's need and a product. In markets in which the customer's situation determines his or her needs but the number of possible situations is very large, the map that identifies the best match between the customer's situation and a product might be known only to the salesperson. In the opening vignette, the college student does not know precisely what to buy among so many alternatives; should she buy a single-crystal silver Silway MK II or the Orca limited MK II for her new JVS FS-D5 audio system?[5] In this context, more than 140 different items

[3] See Arya and Mittendorf (2006) and Raju and Zhang (2005) for the interesting strategic implication of channel conflict and channel coordination.

[4] They do not need a mechanism to prevent a cut-throat competition because the customers always need sales service irrespective of the price difference between retailers, and the amount of free riding is exogenously determined (i.e., the portion of zero search cost customers). In contrast, we allow that customers may forgo the sales service if the price benefit can compensate their risky purchase (i.e., purchasing without resolving matching uncertainty). Hence, the amount of free riding is endogenous from price decisions, and therefore the mechanism for softening price competition is necessary.

[5] Both are the highest-quality audio cables, priced around $200 (www.audioweb.com). If the customer considers only product descriptions, she would have a difficult time determining which cable is better for her particular audio system. The Silway is the better fit for the JVS FS-D5 system, but this is not always the case.

are available for audio cable alone, which makes it very difficult to find the best matching product without knowledgeable sales advice.

The structure of this article is as follows. We present a formal model of free riding in §2. We analyze the free-riding model in §3 and compare it with a benchmark model without free riding, which leads to the main results in §4. In §5, we endogenize sales service and extend the model to the case of multiple free riders in §6. The conclusions appear in §7.

2. Model

Customers

Customers are assumed to purchase either one or zero units of a product. All customers receive the same utility v if the product is a good match with their situation; otherwise, they receive $\underline{v}$ utility. For simplicity, we set utility $\underline{v}$ equal to zero. Also, v is common and known to customers, but whether the product fits their situation or specific needs is unknown (Wernerfelt 1994a).

The total market size is normalized to one, and there are two segments of customers: informed and uninformed. Informed customers (α) have sufficient knowledge about the product and know precisely whether it fits their situation or specific needs. In contrast, the uninformed fraction $(1-\alpha)$ is not sure about the match between the product specification and their situation, and therefore needs the retailer's sales service to resolve this matching uncertainty.[6] The relative size of each segment is common knowledge among both customers and retailers. However, it is important to note that the results we obtain herein do not rely on this two-segment assumption. That is, we do not exclude the $\alpha = 0$ case, which would imply that there are only uninformed customers.[7] We return to this point subsequently.

Customers incur shopping costs when they visit the store. Within each segment, customers are heterogeneous in terms of their shopping cost, $t \sim U[\underline{t}, \bar{t}]$, where $\underline{t} \geq 0$ and $\bar{t} = \underline{t} + 1$, and the density is 1. These shopping costs, which are private information to customers, represent a disutility or opportunity cost for the customer's time spent shopping. Even though customers may incur the same amount of time or cost to visit the store, the opportunity cost for the time varies according to the customer's income level (Narasimhan 1984). In general, as a customer's income level increases, the value attached to successive units of time becomes higher.

Retailers

Two retailers indexed by $i \in \{1, 2\}$ compete for the same customers. Both retailers sell the same product A at prices p_1 and p_2, and the unit cost of the product, $c > 0$, is the same for both retailers. The product A is a good match with a customer's situation with the probability m (<1). The matching probability m is common knowledge to customers and assumed to be strictly less than one. Therefore, it is possible that the product will not match the customer's situation even after sales service is incurred.[8]

The model also includes two crucial features about the role of the selling effort and the asymmetry of retailers in terms of their service provision. First, uninformed customers must consult a service-providing retailer if they want to resolve their matching uncertainty before they purchase. In line with Wernerfelt (1994a), customers need expert service to identify the best match between their situation and a product or must physically inspect the product before they purchase it.

Second, only one retailer (Retailer 2) offers sales service; the other (Retailer 1) does not (we subsequently endogenize this sales service choice). This assumption implies that only Retailer 2 incurs a selling cost, equal to k, for each customer who visits the store. Specifically, we model the cost of free riding as the selling costs that a retailer incurs to serve a customer who may or may not purchase a product (Shin 2005). For example, a local audio store must expend time and effort to help customers identify the product that best fits their needs, irrespective of whether they buy the product. It incurs a conventional variable cost only if a product is sold, but the selling cost can be incurred without an actual sale, as in a free-riding situation. A key feature of selling cost is that it is not a function

For example, the 48 Bose system fits better with Orca's product (based on a discussion with an independent audio dealer).

[6] Wernerfelt (1994a) analyzes the truthfulness of sales service; we impose an honesty condition by assuming that the retailer offers a guarantee on its advice if customers buy.

[7] We assume two segments to model customer dynamics or learning. Uninformed customers become informed after they receive sales service; that is, their knowledge differs before and after they receive sales service.

[8] This one-product setting can be extended easily to a multiple products case, which is more consistent with many real-world situations. The situation can be generalized as follows. Retailers sell two products (A and B) in their assortments and may sell one of either product or nothing. The unit cost of both A and B is c for both retailers. Customers find a good match between their needs and a product with probability η, which is the same for both products A and B and independent. Therefore, there are four potential situations: (1) product A is a good match (probability $\eta(1-\eta)$); (2) product B is a good match (probability $\eta(1-\eta)$); (3) both products A and B are good matches (probability η^2); and (4) neither product A nor B is a good match (probability $1-2\eta(1-\eta)-\eta^2$). Because η is common knowledge to customers, they have prior beliefs of matching $m = 2\eta(1-\eta)+\eta^2$ (<1) for all $\eta \in [0, 1)$. The problem therefore can be simplified to the case in which retailers sell only one product, and the probability of a match for that product is m.

Table 1 Summary of Customer Behaviors

Segments	Product matching	Visiting decision	Purchase decision	Portion
Informed customers (α)	No ($1-m$)	Don't visit any store	No purchase	$(1-m)\times\alpha$
	Yes (m)	Visit Retailer 1	Purchase at Retailer 1	$m\times\alpha$
Uninformed customers ($1-\alpha$)	No ($1-m$)	Visit Retailer 2	No purchase	$(1-m)\times(1-\alpha)$
	Yes (m)	Visit Retailer 2	Purchase a product at Retailer 1 if $t\le\frac{(\bar{t}+\underline{t})}{3}-\frac{\alpha}{3(1-\alpha)}$; purchase at Retailer 2 otherwise.	$m\times(1-\alpha)$

of the number of products sold, but of the number of customers who visit the store, including those who free ride off the store's selling effort. Selling costs also differ from fixed costs, because they are still a function of the firm's strategic decisions, such as advertising and level of service, that affect the number of customers who visit the store.

Shin (2005) offers other examples of selling costs. Real estate agents spend effort to transport customers to multiple prospective homes, and auto retailers expend time and effort during customers' test drives. These sales efforts occur without any guarantee of actual sales. Alternatively, selling costs can result from opportunity costs. If a store is crowded with customers who might not buy a product, potential buyers may not bother to come into the congested store. By serving the wrong customers (free riders), the store gives up its opportunity to make another sale. Therefore, the retailer that does not provide such service enjoys a lower price position than the retailer that provides ancillary services because of its lower selling costs.

Game

The game consists of three main stages. In Stage 0, retailers decide the level of their prices and services (whether to offer selling service or not), and post them. Customers observe the announced price and service levels.

In Stage 1, customers decide which store to visit. When consumers visit a store, they incur shopping cost t. Therefore, customers compare the expected utility of visiting each store and visit the store that gives them the greatest expected utility (which must be nonzero, otherwise customers would not participate in the market). Informed customers, who have no uncertainty about the product match, visit the store that offers the product at the lower price. The previous cost asymmetry assumption between two retailers suggests that Retailer 1 charges a lower price. Thus, we assume that Retailer 1 is the lower-priced retailer in this game; we subsequently check that this assumption is indeed satisfied in the solution. The expected utility for uninformed customers if they visit Retailer 1 is $mv-p_1-t$. Because they cannot determine the match of a product prior to their purchase without sales service, they simply make a purchase, which might result in v utility with probability m, and pay p_1. In other words, uninformed customers cannot make a purchase decision conditional on whether or not there is a match.[9] The expected utility for uninformed customers if they visit Retailer 2 is $m\max\{v-p_1-t, v-p_2\}-t$. With the help of Retailer 2's sales service, customers can determine whether the product matches their needs before they make a purchase decision.

In Stage 2, uninformed customers who visit Retailer 2 know whether the product matches their needs. If it does not, they decide not to buy. If it fits, they must then choose where to buy (depending on t). Customers can either purchase a product from Retailer 2 (stay) or switch to Retailer 1 (free ride), depending on their shopping costs and the prices that Retailers 1 and 2 charge. When uninformed customers learn that a product fits their needs (with probability m), customers with $t<p_2-p_1$ $(=\Delta p)$ switch to Retailer 1 to buy the product, and others stay and purchase from Retailer 2. All customers who visit Retailer 1 during Stage 1 purchase a product; otherwise, they would not have visited the store.[10]

Table 1 summarizes the customer behavior of each segment, and the order of decisions for uninformed customers appears in Figure 1.

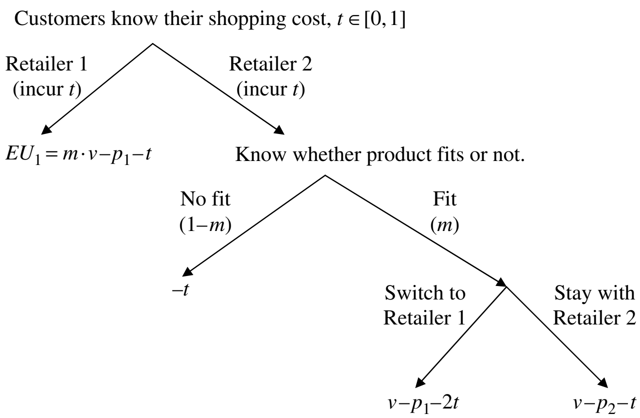
3. Free-Riding Pricing Game

To solve the customer's visiting decision, the problem must be solved backward. At Stage 2, all uninformed

[9] Without service, the product is an experience good. The author thanks the area editor for this clarification.

[10] At Stage 1, all customers need to incur the shopping cost, irrespective of their types. However, only some uninformed customers incur additional shopping costs in Stage 2; this shopping cost matters in the model because customers either stay or switch to another retailer according to these shopping costs. The Stage 1 shopping costs can be interpreted as pure traveling costs and omitted from the analysis, but those in Stage 2 can be interpreted as informational costs. The service also might transfer imperfectly because the other supplier has slightly different products. We thank the area editor and an anonymous reviewer for this suggestion.

Figure 1 Uninformed Customers' Decision Tree



customers who visit Retailer 2 prefer to (1) switch to Retailer 1 (free ride) if and only if their shopping costs are low relative to the price difference, $t \leq \Delta p = p_2 - p_1$; or (2) purchase a product from Retailer 2 if and only if their shopping cost is relatively high, $t > \Delta p = p_2 - p_1$.[11] In contrast, all informed customers visit Retailer 1 during Stage 1 if the product fits their need. Again, we later verify this condition that Retailer 1's price is lower than that of Retailer 2.

Knowing customers' purchase decisions in Stage 2, we can calculate uninformed customers' visiting decisions during Stage 1 as follows: All uninformed customers with $t > \Delta p$ visit Retailer 2 if and only if their expected utility (EU) from visiting Retailer 2 is greater than that from visiting Retailer 1,

$$\begin{aligned} EU_1 &= mv - p_1 - t \\ &< EU_2 = (1-m)(-t) + m(v - p_2 - t) \\ &\Leftrightarrow \quad mp_2 < p_1. \end{aligned} \tag{1}$$

All uninformed customers with $t \leq \Delta p$ visit Retailer 2 if and only if their expected utility from visiting Retailer 2 is greater than that from visiting Retailer 1,

$$\begin{aligned} EU_1 &= mv - p_1 - t \\ &< EU_2 = (1-m)(-t) + m(v - p_1 - 2t) \\ &\Leftrightarrow t < \left(\frac{1-m}{m}\right) p_1. \end{aligned} \tag{2}$$

In addition, $mp_2 < p_1$ implies $t < ((1-m)/m)p_1$ for all uninformed customers with $t \leq \Delta p$, because $\Delta p < ((1-m)/m)p_1 \Leftrightarrow mp_2 < p_1$. Therefore, the condition $mp_2 < p_1$ guarantees that all uninformed customers (those with both $t > \Delta p$ and $t \leq \Delta p$) visit Retailer 2.

There are two cases that we need to consider: $mp_2 \geq p_1$ and $mp_2 < p_1$. If $mp_2 \geq p_1$, nobody visits Retailer 2 because all uninformed and informed customers receive greater expected utility by visiting Retailer 1. The free-riding problem thus becomes trivial because it never occurs. Retailer 2 always benefits by lowering its price to the point at which $mp_2 < p_1$, and it receives positive demand from uninformed customers. In response, Retailer 1 has two possible options: Accept the situation $mp_2 < p_1$ and optimize its profit within the situation, which reverts the case to $mp_2 < p_1$, or lower its price to just below mp_2 to cause all customers to prefer to purchase from it. In turn, Retailer 2 would further lower its price, and so on. A price war between retailers thus ensues.

The following assumption guarantees that, in equilibrium, the matching probability is low enough that all uninformed customers find it better to resolve the uncertainty than to buy a product at a lower price with the higher risk of it not matching their needs (uncertainty aversion) at Retailer 1. Therefore, all uninformed customers visit Retailer 2, and the free-riding problem becomes nontrivial.

Assumption 1. *The matching probability is low that* $m \leq m^*$, *where* $m^* = (\alpha + 3(1-\alpha)c + (1-\alpha)(1-\underline{t}))/(\alpha + 3(1-\alpha)c + (1-\alpha)(2+\underline{t}))$, *and* $0 < m^* < 1$ *for all* $\alpha \in (0,1)$.

Now we focus on the case $mp_2 < p_1$; we subsequently verify that it is satisfied in equilibrium and that Retailer 1 never wants to deviate by lowering its price.

For the moment, we make the following two assumptions.

Assumption 2. $\bar{t} \geq 2\underline{t}$.

That is, the market is big enough that the amount of customer heterogeneity is sufficient for both retailers to survive.

Assumption 3. v *is sufficiently large that* $mv \geq 2\alpha/(3(1-\alpha)) - 2(2\bar{t} - \underline{t})/3 + c$, which ensures that in equilibrium, v is sufficiently large that every customer wants to buy a product if the product fits his or her situation. Hence, the market demand elasticity is zero.

Now consider Retailer 1's demand. All informed customers who find a good match between their needs and a product ($\alpha \times m$) purchase the product from Retailer 1. Uninformed customers with $t < \Delta p$ who find that the product fits their situation also purchase from Retailer 1 ($(1-\alpha) \times m \times (\Delta p - \underline{t})$). In contrast, uninformed customers with $t \geq \Delta p$ who find that the product fits their situation purchase from Retailer 2 ($(1-\alpha) \times m \times (\bar{t} - \Delta p)$). Note that all

[11] If a customer is indifferent about purchasing, we assume she purchases at Retailer 1; if she is indifferent about visiting, we assume she visits Retailer 1. The marginal preference of Retailer 1 results from the lack of salesperson interaction, which might be considered a hassle, at Retailer 1 or because Retailer 1 always can provide $p_1 - \varepsilon$. This tiebreak assumption does not affect the main results.

uninformed customers first visit Retailer 2, so the selling costs Retailer 2 incurs are $k \times (1-\alpha)$.

The profit functions for Retailers 1 and 2, thus, are as follows:

$$\begin{aligned} \pi^1 &= m[\alpha + (1-\alpha)(\Delta p - \underline{t})](p_1 - c), \\ \pi^2 &= m(1-\alpha)(\bar{t} - \Delta p)(p_2 - c) - k(1-\alpha). \end{aligned} \tag{3}$$

From the first-order condition, it follows that $p_1 = (p_2 + c - \underline{t})/2 + \alpha/(2(1-\alpha))$ and $p_2 = (\bar{t} + p_1 + c)/2$. Thus, the optimal prices are $p_1^* = 2\alpha/(3(1-\alpha)) + c + (\bar{t} - 2\underline{t})/3$, $p_2^* = \alpha/(3(1-\alpha)) + c + (2\bar{t} - \underline{t})/3$, and $p_1^* \le p_2^*$ if $\alpha \le 3/4$.[12] Also, $mp_2 < p_1$ for $\forall\, m \le m^*$, where $m^* = (\alpha + 3(1-\alpha)c + (1-\alpha)(1-\underline{t}))/(\alpha + 3(1-\alpha)c + (1-\alpha)(2+\underline{t}))$. Therefore, the profits are

$$\pi_1^* = \frac{m}{1-\alpha}\left[\frac{\alpha 2 + (1-\alpha)(\bar{t} - 2\underline{t})}{3}\right]^2, \quad \text{and}$$

$$\pi_2^* = \frac{m}{1-\alpha}\left[\frac{\alpha + (1-\alpha)(2\bar{t} - \underline{t})}{3}\right]^2 - k(1-\alpha).$$

Assumption 2 guarantees that both Retailer 1 and Retailer 2 charge a price $p_i > c$ for all α, and thus make positive profits in the market if the selling cost k is not too high:

$$\frac{m}{1-\alpha}\left[\alpha\frac{1}{3} + (1-\alpha)\left(\frac{2\bar{t} - \underline{t}}{3}\right)\right]^2 - k(1-\alpha) \ge 0$$

$$\Leftrightarrow \quad \frac{m[\alpha + (1-\alpha)(2\bar{t} - \underline{t})]^2}{9(1-\alpha)^2} \ge k.$$

Let $\bar{k} = m[\alpha + (1-\alpha)(2\bar{t} - \underline{t})]^2/9(1-\alpha)^2$; then, Retailer 2 earns positive profits as long as the selling cost is less than $k \le \bar{k}$. Therefore, both retailers' participation constraints are satisfied. Also by Assumption 3, even the customer with the highest shopping cost receives a positive utility from buying a product when it fits his or her needs; thus, the participation constraint for all customers is satisfied.

Next, we verify that any deviation strategy from the pricing p_1^*, p_2^* cannot be profitable for retailers. Small deviations in the neighborhood of p_i^* are always dominated by p_i^* from the first-order condition, so the only possible deviations are the nonlocal deviations caused by a significant change in demand (Equation (3)), which is based on the premises that (1) the market is fully covered and therefore total demand is fixed, and (2) both retailers have a positive demand, and furthermore, $p_1 \le p_2$.

First, we verify that retailers do not deviate by charging high prices, such that some customers decide not to purchase. Second, we check the other possible deviations caused by a nonlinear change in demand. For example, a nonlinear jump in demand in Equation (3) occurs when the order of the two prices is reversed because the informed customers who were supposed to go to Retailer 1, by the premise that $p_1 \le p_2$, switch to Retailer 2 when the order of the two prices is reversed, $p_2 < p_1$. Similarly, another nonlinear jump in demand might occur if Retailer 1 lowers its price just below mp_2 because all uninformed customers receive higher expected utility by purchasing a product at Retailer 1 rather than at Retailer 2, where they could resolve their matching uncertainty. In summary, the following equilibrium conditions must be satisfied:

$$\pi_1^* \ge \pi_1^d = \max_{p_1} \pi_1(p_1 \mid p_1 \le mp_2^*) \quad \text{and} \tag{IC-1}$$

$$\pi_2^* \ge \pi_2^d = \max_{p_2} \pi_2(p_2 \mid p_2 \le p_1^*). \tag{IC-2}$$

Also, it is important to show that there is no holdup problem, such that Retailer 2, which promises to offer sales service, will refuse to do so when customers visit the store. Retailer 2 can hold up uninformed customers through sunken shopping costs. Retailers announce the levels of their price and service at Stage 0. Whereas announcing the price level is a strong commitment (consumers can easily verify the breach), service, by its nature, is hard to describe and verify if retailers breach their vague promises (e.g., "You will get the best service!" "Service satisfaction guaranteed!"). Such a service holdup strategy is tempting in two ways. First, it enables Retailer 2 to save its selling costs. Second, it might increase demand by $1-m$ because customers who realize that the product is not a good match and decide not to buy might instead purchase a product because of their positive expected utility under uncertainty. Therefore, we also verify that there is no holdup in equilibrium.

Proposition 1 (Free-Riding Pricing Game Equilibrium). *Suppose that $k \le \bar{k}$. If there exist sufficient uninformed customers that $\alpha < (9-\sqrt{45})/4$, and the matching probability m is sufficiently low,*

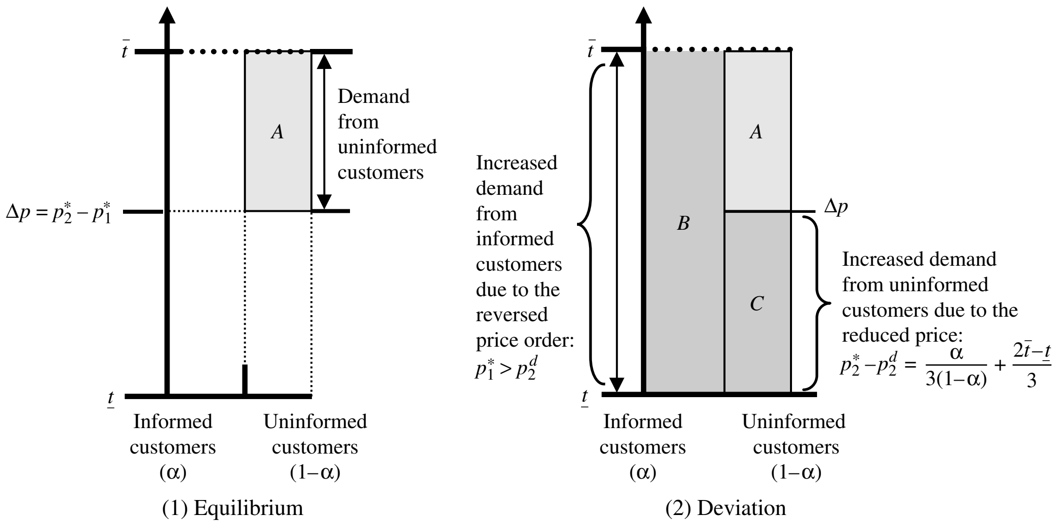
$$m \le \min\left\{\frac{1}{v}\left(\frac{\alpha}{3(1-\alpha)} + c + \frac{2\bar{t} - \underline{t}}{3}\right), \frac{3c(1-\alpha)}{\alpha + (1-\alpha)(2+\underline{t})}\right\},$$

then:

(E1) *There exists an unique pure-strategy Nash equilibrium for the free-riding pricing game, both retailers charge prices p_1^*, p_2^*. All uninformed customers visit Retailer* 2 *and receive selling service to resolve their matching uncertainty. When a product fits their situations, uninformed customers always prefer to* (1) *switch to Retailer* 1 (*free ride*) *and buy if and only if $t \le (\bar{t} + \underline{t})/3 - \alpha/(3(1-\alpha))$, or* (2) *purchase the product from Retailer* 2 *if and only if $t > (\bar{t} + \underline{t})/3 - \alpha/(3(1-\alpha))$. All informed customers who find a good match with a product both visit, and purchase from, Retailer* 1.

[12] $\Delta p = (2\underline{t}+1)/3 - \alpha/(3(1-\alpha)) > 0 \Leftrightarrow \alpha < (1+2\underline{t})/(2(1+\underline{t}))$. According to Assumption 2, $0 \le \underline{t} \le 1$. It is straightforward that $(1+2\underline{t})/(2(1+\underline{t})) \le 3/4$ for all $\underline{t} \in [0,1]$. Hence, $\Delta p = p_2^* - p_1^* \ge 0$ when $\alpha \le 3/4$.

Figure 2 Demand for Retailer 2 (Service Provider)



(E2) *Furthermore, Retailer* 2 *will not hold up customers who have already incurred shopping costs* (*no service holdup*).[13]

Proof. See the appendix.

As the proof in the appendix shows, various possible nonlocal deviations do not increase a retailer's profits. The most interesting and plausible case is the nonlocal deviation in which Retailer 2 (service provider) reduces its price to just below the equilibrium price level of Retailer 1 ($p_2^d \le p_1^*$), and thereby encounters a nonlinear jump in its demand function by garnering all the demand from the informed customers as well. The moment the price drops lower than the competitor's price, all informed customers (α) switch to Retailer 2. In this situation, Retailer 2 maximizes its profit by charging the same price as the equilibrium price of Retailer 1, so that $p_2^d = \arg\max_p \pi_2^d(p \mid p \le p_1^*) = p_1^*$ (see the appendix), which implies that Retailer 2 must sacrifice its profit margin by $p_2^* - p_2^d$.

Retailer 2 can attract more people than in the equilibrium scenario (area $B + C$ in Figure 2), which increases the sales of the product by $m \times Area\ (B+C)$. However, this strategy entails the great expenses of a reduced unit price ($p_2^* - p_2^d = \alpha/(3(1-\alpha)) + (2\bar{t} - \underline{t})/3$) for all customers, including those who would have purchased the product at a higher price (*Area A*). Furthermore, this strategy draws some unwanted people from whom the retailer incurs unintended extra selling costs by serving, but not earning a profit from, them (no match case: $(1 - m) \times Area\ C$). Therefore, if the matching probability m is low, the benefit of the increased demand from the reduced price becomes marginal, whereas the cost of increasing demand, which is a sure sacrifice of the profit margin $p_2^* - p_2^d$, becomes more salient, especially when α is small ($\alpha < (9 - \sqrt{45})/4$).

Retailer 1 also can deviate and steal all the uninformed customers from Retailer 2 by lowering its price below mp_2^*, such that all uninformed customers purchase a product even without resolving their matching uncertainty. However, this deviation is again dominated by the equilibrium price when the matching probability m is low ($m \le 3c(1-\alpha)/(\alpha + (1-\alpha)(2+\underline{t}))$), such that the benefit of the increased demand is more than offset by the sacrifice of its profit margin decrease, $p_1^* - mp_2^*$.

Furthermore, if Retailer 2 decides not to offer any service to uninformed customers who visit the store, it can save its selling cost. However, if the matching probability is small, such that $m < (1/v)(\alpha/(3(1-\alpha)) + c + (2\bar{t} - \underline{t})/3)$, the uninformed customers' expected utility is $mv - p_2 = mv - \{\alpha/(3(1-\alpha)) + c + (2\bar{t} - \underline{t})/3\} < 0$. Thus, all customers who visit Retailer 2 find it better not to purchase a product, which prevents Retailer 2 from holding up customers' shopping costs by not offering service. Thus, service holdup cannot be a profitable deviation for Retailer 2.

The proposition also states that when there are many uninformed customers and matching probability is low, such that sales service is important, some customers will free ride off the retailer's sales service, but the retailers (both service provider and free rider) will charge prices above their marginal costs and obtain positive profits as long as the selling costs are not exorbitantly high. Proposition 1 holds even when only uninformed customers exist ($\alpha = 0$ case).

This positive profit result for a service-providing retailer, despite the presence of annoying free riding,

[13] For example, $\alpha = 0.5$, $m = 0.008$, $v = 10$, $\underline{t} = 0.5$, $c = 0.001$, and $k = 0.001$ satisfies all conditions (including Assumptions 1, 2, and 3) for Propositions 1 and 2.

is interesting. The costs of free riding are apparent, and free riding seems like a nuisance for retailers, whereas its benefits, if any, are harder to perceive. We continue to investigate the strategic role of free riding in the next section.

4. Benchmark Model: No-Free-Riding Case

To illustrate the role of free riding, a comparison of the preceding scenario with a benchmark scenario is helpful. In the benchmark case, two retailers compete with each other for the same market (again, only one provides a service), but free riding is prohibited because customers are not allowed to visit a different store during Stage 2 (in other words, the service and product are not separable).

The constraint that customers cannot switch after they visit one store is a device to rule out free riding under duopoly competition to demonstrate the pure impact of free riding. In practice, some retailers start to provide a service only after the actual purchase occurs to bundle their service with the actual product sales; for example, many real estate agents ask customers to sign a contract, which states they must purchase through the sales agent who helps them find the house that fits their needs before they incur any selling effort. Customers do not need to purchase a house through the agent if it does not fit their needs, but if they want to purchase a particular house that the agent has shown them, they must purchase only through that agent.[14] There still exists the matching uncertainty that might make customers decide not to purchase.

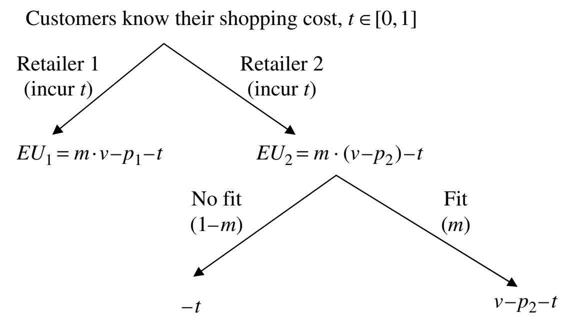
The order of decisions made in the benchmark model appears in Figure 3.

As in the free-riding game, we assume that Retailer 1 is the lower-priced retailer and verify that this assumption holds in equilibrium. During Stage 0, retailers charge prices, and customers know these prices. Similar to the free-riding pricing game, customers decide whether, and which retailer, to visit in Stage 1.

Informed customers who find a good match with a product (probability m) visit Retailer 1 if $v - p_1 \geq t$.

[14] This simple contract alleviates the concern of free riding to some degree for real estate agents who must incur enormous selling costs. Real estate agents spend a lot of time and effort to take customers to several places to find their desired houses, and it usually takes more than a few trips for customers to finalize their purchase decision. As a result, the fear of free riding is very high in this industry. However, even such a contract does not eliminate agents' entire concern about high selling costs because many customers still use the service and do not purchase; that is, the no-matching case (or low m).

Figure 3 Customers' Decision Trees (Without Free Riding)



The number of customers who visit Retailer 1 is

$$N_1(p_1) = \begin{cases} \alpha m & \text{if } p_1 \leq v - \bar{t}, \\ \alpha m(v - p_1 - \underline{t}) & \text{if } p_1 > v - \bar{t}. \end{cases} \tag{4}$$

Uninformed customers find it better to visit Retailer 2 because $mp_2 \leq p_1$. Therefore, uninformed customers visit Retailer 2 if and only if their expected utility from visiting Retailer 2 is greater than 0, $EU_2 = (1-m)\cdot(-t) + m\cdot(v-p-t) \geq 0 \Leftrightarrow t \leq m(v-p)$. The number of customers who visit Retailer 2 is

$$N_2(p_2) = \begin{cases} (1-\alpha) & \text{if } p_2 \leq v - \dfrac{\bar{t}}{m}, \\ (1-\alpha)\{m(v-p_2) - \underline{t}\} & \text{if } p_2 > v - \dfrac{\bar{t}}{m}. \end{cases} \tag{5}$$

In Stage 2, customers decide whether to buy. All informed customers who visit the store purchase a product, whereas uninformed customers who visit the store purchase only if the product is a good match. Thus, the profit functions for each retailer are as follows:

$$\pi_1(p_1, p_2 \mid mp_2 \leq p_1 \leq p_2) = \begin{cases} \alpha m(p_1 - c), & \text{if } p_1 \leq v - \bar{t}, \\ \alpha m\{v - p_1 - \underline{t}\}(p_1 - c), & \text{if } p_1 > v - \bar{t}. \end{cases} \tag{6}$$

$$\begin{aligned} \pi_2(p_1, p_2 \mid mp_2 \leq p_1 \leq p_2) &= mN_2(p_2)(p_2 - c) - k\cdot N_2(p_2) \\ &= \begin{cases} (1-\alpha)m(p_2 - c) - k(1-\alpha), & \text{if } p_2 \leq v - \dfrac{\bar{t}}{m}, \\ (1-\alpha)\{m(v-p_2) - \underline{t}\}(p_2 - c) \\ \quad - k(1-\alpha)\{(v-p_2) - \underline{t}\}, & \text{if } p_2 > v - \dfrac{\bar{t}}{m}. \end{cases} \end{aligned} \tag{7}$$

Both retailers maximize these profit functions subject to the constraint that $p_1 \leq p_2$. The optimizing prices that retailers charge are $p_1^o = p_2^o = (v+c)/2 - \underline{t}/(2m)$ (see the appendix).

However, these prices do not constitute equilibrium. Unlike the free-riding pricing game, limit-pricing behavior occurs. For example, Retailer 2 always finds it profitable to lower its price slightly by ε below p_1, which increases its profits because it can steal all informed customers' demand without sacrificing much. In response, Retailer 1 lowers its price slightly by 2ε to increase its demand and profit, and so on. Thus, a price war arises, and we arrive at the following proposition:

Proposition 2. *Suppose that the difference between the marginal cost and the selling cost is small, such that $c(1-m) \le k$. When there exists a sufficient number of uninformed customers, such that $\alpha \le (mc+k-c)/(2mc+2k-c-mk-m^2c)$, there exists the unique pure-strategy equilibrium of the no-free-riding game in which retailers charge $p_1^e = m(c+k/m)$, $p_2^e = c+k/m$, and Retailer 2 gets zero profit.*

Proof. See the appendix.

Collectively, Propositions 1 and 2 suggest an important point: Without free riding, both retailers would engage in intense price competition to attract more customers. By allowing free riding, the service-providing retailer can induce a soft strategic response from the free riding retailer that could have charged a much lower price. Hence, both retailers enjoy positive profits that otherwise would have been eliminated by head-to-head price competition.

Put differently and more precisely, without free riding, the free rider cannot help being aggressive on price to attract customers when it knows that all customers will be locked in to the store they visit in Stage 1. Particularly, a free-riding retailer cannot charge a price higher than the marginal cost of the service provider (i.e., $c+k/m$), because the service provider always has an incentive to undercut its price and take over all the informed customers by giving up a little margin whenever it can. Hence, the profit margin that a free-riding retailer can attain from the informed customers over whom it enjoys monopoly power is limited and much smaller than the case when free riding is allowed. Given this limited profit margin, the free rider has an incentive to charge a price that lands just below the price (mp_2^e) that makes uninformed customers indifferent between purchasing a product at Retailer 2 or Retailer 1 when there exists a sufficient number of uninformed customers ($\alpha \le (mc+k-c)/(2mc+2k-c-mk-m^2c)$). The benefit of the increased demand from the uninformed customers offsets the reduced profit margin. Lowering its price below mp_2^* is not a profitable deviation in the free-riding game because it must sacrifice too much profit margin.

However, this scenario does not occur when free riding is allowed because many customers will end up switching to the free rider in the end, and the service provider has less incentive to be aggressive. In effect, the service-providing retailer may welcome customer free riding to induce a higher price from the free rider. In this sense, free riding is a necessary mechanism to limit severe price competition, which induces a softer reaction from the competitor that now enjoys free riding. This induced soft strategic response again enables the service provider to charge a higher price and enjoy positive profits.

We also find a direct result of the profit comparison between the free-riding game and the benchmark case that indicates both free riders and service-providing retailers could benefit from free riding.

Proposition 3. *When $(1-\underline{t})^2 \ge 9c$, both retailers earn more profits with free riding than without; $\pi_1^{FR} \ge \pi_1^{NF}$, and $\pi_2^{FR} \ge \pi_2^{NF}$.*

Proof. See the appendix.

5. Endogenous Sales Service

Consider a case in which retailers can choose whether to offer sales service before they determine their pricing. In the preceding analysis, we treated this sales service decision as a given, such that retailers are exogenously differentiated and know the other retailer's sales service decision when they set prices. Recall that there is a cost k associated with offering sales service on top of the marginal product cost c, whereas the free rider's cost involves only the marginal product cost c.

It cannot be an equilibrium strategy for both retailers to offer sales service because then either firm benefits from deviating and deciding to free ride off the other competitor's sales service. This deviating strategy has the benefits of both lowering costs and softening competition through service differentiation. As a result, one retailer will not offer sales service (without loss of generality, we assume it is Retailer 1) in equilibrium, and the other competitor (Retailer 2) might offer sales service or not, depending on the parameters of the model. Also, it cannot be an equilibrium strategy that neither offers sales service, because then neither firm can make a positive profit because of Bertrand competition. Moreover, any retailer can benefit from deviating and offering service as long as the selling cost is not exorbitantly high ($k \le \bar{k}$).

The current model does not predict which of two ex ante identical retailers will provide costly sales service. However, if firms enter the market sequentially, the first entrant (Firm 1) can decide whether to offer service in full anticipation of the effect of its service choice on the second entrant (Firm 2). If Firm 1 chooses to offer service, Firm 2 will find that taking a free-rider role is more profitable, and vice versa. Firm 2 always wants to position itself such that it can differentiate itself from Firm 1 to avoid undifferentiated, head-to-head price competition.

Proposition 4. *The firm that enters the market first will choose to provide service, and the firm that follows into the market will choose not to if the selling cost is sufficiently small, such that*

$$k \le k^*, \quad \textit{where } k^* = \frac{m[(1-\alpha)(\bar{t}+\underline{t})-\alpha]}{3(1-\alpha)^2}.$$

Otherwise, the first entrant will not provide service, and the second entrant will provide service.

Proposition 4 suggests that Firm 1 chooses its store style on the basis of the level of selling costs. One important implication is that a retailer sometimes offers a service even if it fully recognizes the potential costs of free riding by the competitor, because the retailer still might be better off incurring selling costs for all customers than it would be as a free rider. In other words, $\pi_2^* \ge \pi_1^*$ when $k \le k^*$, where $k^* = m[(1-\alpha)(\bar{t}+\underline{t})-\alpha]/(3(1-\alpha)^2)$. Also, note that the participation constraint for a service-providing retailer is satisfied, $\bar{k} \ge k^*$, because $((1-\alpha)\bar{t}+1)^2 \ge (2(1-\alpha)\bar{t}-1)$ for all $\alpha \in [0,1]$, and $\bar{t} > 1$ ($\bar{t} = 1+\underline{t}$).

Moreover, the threshold level of the selling cost (k^*) increases as the average customer's shopping cost increases ($\partial k^*/\partial(\bar{t}+\underline{t}) > 0$). However, the threshold level increases only with respect to the matching probability (m) and the size of the informed customers (α), and only if the average customer's shopping cost is relatively large or there are many uninformed customers in the market ($(1+\bar{t}+\underline{t})(1-\alpha) \ge 2$).

Proposition 5. *The threshold level of selling cost* (k^*) *monotonically increases*

$$\frac{\partial k^*}{\partial(\tilde{t})} > 0, \quad \textit{for all } \tilde{t} > 0, \ \textit{where } \tilde{t} = \frac{\bar{t}+\underline{t}}{2}.$$

Also, it has a different sign according to the size of the set of informed customers (α) *and the matching probability, depending on the range of* $(1+\bar{t}+\underline{t})(1-\alpha)$,

$$\begin{aligned}
&\frac{\partial k^*}{\partial \alpha} > 0, \quad \frac{\partial k^*}{\partial m} > 0, \qquad \textit{if } (1+\bar{t}+\underline{t})(1-\alpha) \ge 2,\\
&\frac{\partial k^*}{\partial \alpha} < 0, \quad \frac{\partial k^*}{\partial m} > 0, \qquad \textit{if } 1 \le (1+\bar{t}+\underline{t})(1-\alpha) < 2,\\
&\frac{\partial k^*}{\partial \alpha} < 0, \quad \frac{\partial k^*}{\partial m} < 0, \qquad \textit{if } (1+\bar{t}+\underline{t})(1-\alpha) < 1.
\end{aligned}$$

Proposition 5 thus suggests that when the market condition is $(1+\bar{t}+\underline{t}) \cdot (1-\alpha) \ge 2$, Firm 1 tends to offer a service if its product is standardized and appeals to the largest number of customers (high m) or is well known (large α). The service-providing retailer can benefit from the increased demand by customers through the increased matching probability when the market conditions are favorable for the service provider, due to the high average shopping cost of customers. It appears counterintuitive that a large α benefits the service-providing retailer, but the market condition ($(1+\bar{t}+\underline{t})(1-\alpha) \ge 2$) also imposes a restriction on the average shopping cost, such that it must get larger as α increases. As long as the condition holds, the increased α implies an increased average shopping cost, and thus the preceding argument applies.

However, when the market condition is different, such as when $(1+\bar{t}+\underline{t})(1-\alpha) < 1$, Firm 1 tends to offer a service only if its product is specialized and targeted at a niche market (small m), or is new (small α).

6. The Case of Multiple Free Riders

We now extend our model to the case in which multiple free riders exist and compete. The key question is how the introduction of competition among free riders will affect the previous finding that free riding can soften price competition between the service provider and free riders. Consider the preceding setup with a free-entry version of n free-riding retailers (Singh et al. 2006). Entry occurs until the (expected) profits of free-riding retailers are driven to zero, which results in n free-riding retailers in the market.[15] Let p_s be the price charged by the service-providing retailer and $p_1, p_2, \ldots, p_n$ be the prices charged by n free-riding retailers. We assume that only informed customers know the whole distribution of prices, whereas uninformed customers know the prices of the service provider and the one free rider located closest to them. Unlike the previous results, the existence of informed customers is a necessary condition for the multiple free-riders case, and the result depends on the two-segment assumption. We assume that all free-riding retailers are evenly located on a circular city while the service provider if located in the center of the circle and therefore that they have the same symmetric demand of $1/n$ uninformed customers (Balasubramanian 1998). Informed customers visit the retailer that offers the lowest of the $n+1$ prices. The profit functions for each free-riding retailer $i \in 1, 2, \ldots, n$ and the service-providing retailer s are as follows:

$$\pi_i(p_1,\ldots,p_n,p_s) = \begin{cases} (p_i-c)\left\{D_I(p_i)+\dfrac{1}{n}D_U(p_i,p_s)\right\} \\ \qquad \text{if } p_i = \min(p_1,\ldots,p_n), \\ (p_i-c)\left\{\dfrac{1}{n}D_U(p_i,p_s)\right\} \\ \qquad \text{if } p_i > \min(p_1,\ldots,p_n), \end{cases} \tag{8}$$

[15] We can also consider the model with a fixed number of firms. In this case, the expected profits for the free riders can be positive, unlike the free-entry version (Varian 1980). See also Footnote 22 for more detail.

where $D_I(p_i) = m\alpha$ and $D_U(p_i, p_s) = m(1-\alpha)(p_s - p_i - \underline{t})$ for all $i \in \{1, 2, \ldots, n\}$,

$$\pi_s(p_1, \ldots, p_n, p_s) = m\left\{\sum_{i=1}^{n} \frac{(1-\alpha)}{n}(\bar{t} - p_s + p_i)(p_s - c)\right\} - k(1-\alpha). \quad (9)$$

The game has no pure-strategy equilibrium, as the model considered by Varian (1980) does.[16] We focus instead on the mixed-strategy equilibrium, in which retailers randomize their price strategies. We take the set of mixed strategies for each free-riding retailer to be the set $\underline{F}$ of cumulative distribution functions on $[c, c+L]$, where L is the length of support. If $\widetilde{F} = (F_1, \ldots, F_n)$ is a mixed-strategy combination, retailer i's expected payoff is $E_i(\widetilde{F}) = \int_c^{c+\bar{t}} \cdots \int_c^{c+\bar{t}} \pi_i \, dF_1 \ldots dF_n$.

Proposition 6. *The symmetric equilibrium cumulative distribution function for n free-riding retailers are implicitly defined by the following,*

$$F(p) = \begin{cases} 1 - \left(\dfrac{(1-\alpha)(1+c+\bar{p}-\underline{t}-2p)}{2n\alpha}\right)^{1/(n-1)} & \text{for } c \le p \le c+L \\ 0 & \text{for } p < c \\ 1 & \text{for } p > c+L. \end{cases}$$

The service-providing retailer charges a price $p_s^* = (c + \bar{t} + \bar{p})/2$, where $\bar{p} = \int_c^{c+L} pf(p)\,dp$. Then, $F^* = (F_1, \ldots, F_n)$ and $p_s^* = (c + \bar{t} + \bar{p})/2$ constitute a Nash equilibrium for n free-riding retailers and the service provider. When $\underline{t} = 0$, a closed-form solution for the distribution function is

$$F(p) = \int_0^p f(x)\,dx = \begin{cases} 1 - \left\{\dfrac{(1-p)n - p}{n}\right\}^{1/(n-1)} & \text{for } c \le p \le c + \dfrac{n}{n+1} \\ 0 & \text{for } p < c \\ 1 & \text{for } p > c + \dfrac{n}{n+1}, \end{cases}$$

$\bar{p} = (n-1)/(n+1) + c$, and $p_s^* = (c + \bar{t} + \bar{p})/2 = n/(n+1) + c$ for $n \ge 2$.[17] *Moreover, when the selling cost is not high enough that $k \le \bar{k}$, the expected profit of the service provider is always positive.*

Proof. See the appendix.

Proposition 6 shows that even with multiple free riders, the service-providing retailer always makes a positive profit if the selling cost is not exorbitantly high. In particular, the average price charged by free riders are strictly lower than that of the service-providing retailer when $\underline{t} = 0$. Even the introduction of competition among free riders does not affect the role of free riding to soften price competition between the service provider and free riders. However, this finding holds only when free riders have exclusive access to some customers, which is analogous to the case in which they have local monopoly power or are horizontally differentiated through a positive traveling cost. Even a small traveling cost enables retailers to avoid Bertrand competition (Diamond 1971). Without a mechanism that helps free riders avoid Bertrand competition among themselves, the previous result—that free riding can soften price competition—is of no use because prices are already driven down to the marginal cost. In contrast, when service-providing retailers sell multiple products and each free rider is selling slightly different products—in other words, they are horizontally differentiated—the competition-softening intuition of free riding still persists.

The current model has considered a special type of information structure among customers. Uninformed customers are not only uncertain about their match, but also about price distribution of other free riders but one. However, these two notions of "information" can be totally unrelated to each other. Future research can relax this restriction and look at the more general case of information structure among customers.

7. Conclusion

Free riding often occurs when all the presales activities needed to sell a product can be conducted separately from the actual sale of the product. In such circumstances, revenues from the sale of the product must cover the costs of providing this sales service to customers who might or might not purchase. Retailers that do not provide such services find themselves in a lower cost position than those that must incur the costs of providing ancillary services. As the price disparity between the service provider and the free-riding retailer increases, more customers are likely to free ride off the former retailer's service and enjoy the lower price of the latter. This scenario imposes selling costs involved with offering those ancillary sales services but yields little extra revenue for the service provider. An important feature of selling costs is that they are a function of the number of customers who visit the store, including those who free ride off of the service. These selling costs, together with free riding, should eliminate the retailer's incentive to provide sales service, but many service-providing retailers still exist.

[16] See the proof of Proposition 6 in the appendix for the detail.

[17] In particular, when $n = 2$ and $\underline{t} = 0$, the equilibrium price for the free riders and the service provider are $\bar{p} = c + 1/3$ and $p_s^* = c + 2/3$, respectively.

Intuitively, retailers' free riding should harm those retailers that provide services. In a sense, free riding is analogous to the theft of services in that the customer uses one retailer's resources but provides all the profits to the retailer that makes the actual sale (Carlton and Perloff 2000). Therefore, it is hard to understand how the retailer providing the services benefits from free riding, but this study shows that it does. A service-providing retailer can use its service offer to attract people to the store and obtain a postservice price advantage over other competitors. In other words, customers who have resolved their matching uncertainty through sales service incur zero marginal shopping cost if they purchase from the service-providing retailer rather than free-riding competitors. Furthermore, by allowing free riding, the service-providing retailer can induce a softer reaction from its competitor because many customers eventually will switch to the free rider to enjoy its lower pricing. This induced soft strategic response enables the service provider to charge a higher price than its cost and enjoy the strictly positive profits that otherwise would have been wiped out by head-to-head price competition. Therefore, allowing free riding can be regarded as a necessary mechanism for softening price competition.

We do not claim that free riding is always beneficial to retailers. If the selling cost is very high, the service provider must find a way to reduce customer free riding. However, it also needs to find another safeguard against head-to-head price competition in such a case.[18] Free riding is nonetheless a painful loss for the service provider, in that it has the direct effect of a loss of selling costs. However, it also has the indirect effect of mitigating price competition by preventing a tougher reaction from the competitor.

Various examples of free riding other than sales assistance in the store also exist, such as when one retailer heavily advertises a product that is also carried by another retailer.[19] The first retailer could create demand for the product that benefits both retailers, but the second retailer incurs no costs for attracting customers. A more subtle form of free riding involves fashion trends. For example, certain department stores (e.g., Saks Fifth Avenue, Barney's New York) are viewed as fashion trendsetters, a reputation they have achieved by investing in highly qualified designers. Although only the largest, most prestigious department store chains send their employees to Europe to view current fashion shows, competing retailers can easily visit the fashion trendsetters, mimic their offerings, and carry similar items. These free-riding fashion stores can reap a benefit without incurring a comparable cost.

Furthermore, customers increasingly purchase products from online retailers, which limits their ability to judge the quality of the products they buy. The prevalence of online shopping has made uncertainty about product quality a significant customer concern. Online shoppers therefore might use offline stores to resolve their quality uncertainty by physically touching and inspecting the product. In such environments, the free-riding problem becomes a substantive issue for traditional bricks-and-mortar stores.[20]

A possible extension to the model presented herein is to consider a situation in which shopping costs are asymmetric across retailers. For example, the shopping cost is always lower for online retailers. Such an extension could shed light on the issue of channel conflict between offline and online channels.

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Appendix

Proof of Proposition 1 (Free-Riding Pricing Game Equilibrium).

Proof of (E1). First, we show that retailers do not deviate by charging high prices, such that some customers choose not to purchase. The intuition is that competition between retailers makes it unprofitable to charge a high price such that some customers decide not to buy. In that case, customers switch to the other competitor (which has an incentive to attract them); therefore, a retailer's ability to charge a high price is limited. Suppose Retailer 1 charges p_1, so both informed customers with $t \le v - p_1$ and uninformed customers with $t \le \Delta p$ and $m(v - p_1 - t) - t \ge 0$ visit the store. There are two cases to consider.

Case 1. $\Delta p < m/(1+m)(v-p_1)$. Note that $\Delta p < m/(1+m) \cdot (v - p_1)$ implies that $p_2 - p_1 < m(v - p_2)$. In this case, there are no free-riding customers because they do not find it

[18] In Connecticut, for example, by law a real estate agent's fee cannot be lower than 3%. This boundary serves as a safeguard for real estate agents to avoid Bertrand competition when they prevent free riding by asking customers to sign the contract described previously.

[19] For example, the free-riding issue on generic advertising whose effect is to increase category sales is analyzed in Bass et al. (2005).

[20] The effect of an online retailer on price competition and channel strategies has been studied by several researchers (Ariely and Lynch 2000, Bakos 1997, Bernstein et al. 2007, Lal and Sarvary 1999, Zettelmeyer 2000).

worthwhile to visit the store. It is straightforward that $p_1^d = \arg\max_p m[\alpha(v-p-\underline{t})]\cdot(p-c) = (v-\underline{t}+c)/2$, and $p_2^d = \arg\max_p m[(1-\alpha)\{m(v-p)-\underline{t}\}]\cdot(p-c) = (v+c)/2-\underline{t}/(2m)$. The condition that $p_1 \le p_2$ is binding. Because of the convexity of the profit function of Retailer 1, it will charge the corner solution as long as $p_2 < (v-\underline{t}+c)/2$. Then, $v-p_1-\bar{t} = (v-c)/2-(\underline{t}+2m\bar{t})/(2m) > 0$ under Assumption 3, which is contradictory (Retailer 1 does not charge such high prices).

Case 2. $\Delta p \ge (m/(1+m))(v-p_1)$. The deviation price strategy is relatively straightforward because $p_1^d = \arg\max_p m[\alpha(v-p-s\underline{t}) + (1-\alpha)\beta(v-p-\underline{t})]\cdot(p-c)$ and $p_2^d = \arg\max_p m[(1-\alpha)\{\bar{t}-p+p_1^d\}]\cdot(p-c)$, where $\beta = (m/(1+m))$ and $(1-\beta)p_1 + \beta v \le p_2$ from the condition $(\Delta p \ge (m/(1+m))(v-p_1))$. The optimizing price for Retailer 2 is $p_2' = (\bar{t}+c)/2 + (1/2)p_1$, which must satisfy the following condition: $p_2 > p_1 \Leftrightarrow \bar{t}+c > p_1$.

In this case $(\Delta p \ge (m/(1+m))(v-p_1))$, Retailer 1 will not charge a price that is too high because that price is always dominated by charging the price $\bar{t}+c > p_1$. In turn, Retailer 1 does not charge a price that is too high because Retailer 2 also gets more profit by charging $p_2' = (\bar{t}+c)/2 + (1/2)p_1$. The deviation in which retailers charge higher prices, such that any customer decides not to buy, is not profitable. □

We now verify that the possible nonlocal deviations caused by a nonlinear change in demand do not increase a retailer's profit.

Let $p_1^d = \arg\max_p \pi_1^d(p \mid p \le mp_2^*)$, $p_2^d = \arg\max_p \pi_2^d(p \mid p \le p_1^*)$ denote the prices that Retailers 1 and 2 charge in deviation, respectively. There is a nonlinear jump in demand, and either retailer faces the demand of the entire market. Hence, the profit functions do not follow Equation (3). In these cases, $\pi_1^d = \{m\cdot\alpha + (1-\alpha)\}\cdot(p_1^d - c)$ because all uninformed customers purchase a product at Retailer 1, even without resolving their matching uncertainty, whereas informed customers purchase a product only if it fits their needs. Also, $\pi_2^d = m(p_2^d - c) - \{m\alpha + (1-\alpha)\}\cdot k$ because all uninformed customers visit Retailer 2 and purchase after they receive the sales service, whereas informed customers visit only if the product fits their needs. Hence, Retailer 2 needs to serve all the uninformed customers $(1-\alpha)$ and informed customers whose needs its product fits $(m\alpha)$. Maximum profits are obtained when both retailers choose the corner solution, $p_1^d = mp_2^*$, $p_2^d = p_1^*$. Hence,

$$\pi_1^d = \{m\alpha + (1-\alpha)\}\left[m\left\{\frac{\alpha + (1-\alpha)(2+\underline{t})}{3(1-\alpha)}\right\} - (1-m)c\right]$$

and

$$\pi_2^d = m\left[\frac{2\alpha + (1-\alpha)(1-\underline{t})}{3(1-\alpha)}\right] - \{m\alpha + (1-\alpha)\}k.$$

First, (IC-1) can be rewritten as

$$\pi_1^d = \{m\alpha + (1-\alpha)\}\left[m\left\{\frac{\alpha + (1-\alpha)(2+\underline{t})}{3(1-\alpha)}\right\} - (1-m)c\right] \le \frac{m}{(1-\alpha)}\left[\frac{2\alpha + (1-\alpha)(1-\underline{t})}{3}\right]^2 = \pi_1^*.$$

The inequality (IC-1) is always satisfied if $m \le 3c(1-\alpha)/(\alpha + (1-\alpha)(2+\underline{t}))$.

Now consider (IC-2),

$$\pi_2^d = m\left[\frac{2\alpha + (1-\alpha)(1-\underline{t})}{3(1-\alpha)}\right] - \{m\alpha + (1-\alpha)\}k \le \frac{m}{1-\alpha}\left[\frac{\alpha + (1-\alpha)(2+\underline{t})}{3}\right]^2 - (1-\alpha)k = \pi_2^*.$$

After a few algebraic computations, the inequality can be rewritten as

$$[6\alpha + 3(1-\alpha)(1-\underline{t})] - \{\alpha + (1-\alpha)(2+\underline{t})\}^2 \le 9\alpha(1-\alpha)k.$$

Let $f(\underline{t},\alpha) = [6\alpha + 3(1-\alpha)(1-\underline{t})] - \{\alpha + (1-\alpha)(2+\underline{t})\}^2$. Then, $f(\underline{t},\alpha)$ can be rewritten as $f(\underline{t},\alpha) = -(1-\alpha)^2\underline{t}^2 - (7-2\alpha)(1-\alpha)\underline{t} - (\alpha^2 - 7\alpha + 1)$. Thus, $\partial f/\partial \underline{t} > 0$ for $\underline{t} \in [0,1]$. Furthermore, $f(\underline{t},\alpha) \le f(1,\alpha) = -4\alpha^2 + 18\alpha - 9 \le 0$ for $\forall\, \alpha \le (9-\sqrt{45})/4$. Hence, when $\alpha \le (9-\sqrt{45})/4$, the inequality (IC-2) always holds because (RHS) is positive while (LHS) is negative.

In summary, when $\alpha \le (9-\sqrt{45})/4$ and the matching probability m is sufficiently low that $m \le (3c(1-\alpha))/(\alpha + (1-\alpha)(2+\underline{t}))$, (IC-1) and (IC-2) hold. This completes the proof of (E1) □

Proof of (E2). Suppose that Retailer 2 decides not to offer any service to uninformed customers who visit the store so that it can save the selling cost. Uninformed customers who visit the store then have an expected utility $mv - p_2$ of purchasing from Retailer 2. However, if the matching probability is small, such that $m < (1/v)(\alpha/(3(1-\alpha)) + c + (2\bar{t}-\underline{t})/3)$, the uninformed customers' expected utility is $mv - p_2 = mv - \{\alpha/(3(1-\alpha)) + c + (2\bar{t}-\underline{t})/3\} < 0$. Thus, nobody decides to purchase. This condition prevents Retailer 2 from holding up customers' shopping costs by not offering service. Furthermore, $\alpha \le (9-\sqrt{45})/4$ guarantees the existence of a low matching probability m, which satisfies Assumption 3 at the same time (all informed customers find it better to purchase a product) because $2\alpha/(3(1-\alpha)) + c - 2(2\bar{t}-\underline{t})/3 \le mv$ (Assumption 3) and $mv < \alpha/(3(1-\alpha)) + c + (2\bar{t}-\underline{t})/3$ (Proposition 1) can coexist if $2\alpha/(3(1-\alpha)) + c - 2(2\bar{t}-\underline{t})/3 < \alpha/(3(1-\alpha)) + c + (2\bar{t}-\underline{t})/3 \Leftrightarrow 1/(1-\alpha) < 4\bar{t} + \underline{t}$. The last inequality always holds when $\alpha \le (9-\sqrt{45})/4$ and $\underline{t}+1 = \bar{t}$. This completes the proof of (E2). □

Thus, when there exist sufficient uninformed customers that $\alpha \le (9-\sqrt{45})/4$ and the matching probability $m$is sufficiently low that $m \le \min\{(1/v)(\alpha/(3(1-\alpha)) + c + (2\bar{t}-\underline{t})/3), 3c(1-\alpha)/(\alpha + (1-\alpha)(2+\underline{t}))\}$, (E1) and (E2) are satisfied for all $\underline{t} \in [0,1]$. □

Derivation of Optimizing Prices for the No-Free-Riding Game

Whereas Retailer 1's price is bounded above by the price level of Retailer 2, Retailer 2's price is not bounded above and can reach the point that some customers do not find it worthwhile to visit the store (no matter how large v is). Retailer 2 solves this unconstrained maximization problem and charges the optimizing price $p_2^o = (v+c)/2 - \underline{t}/(2m)$. Also, if $p_1 > v - \bar{t}$, then from the first-order condition, $p_1 = (v-\underline{t}+c)/2$, which implies that $2\bar{t} - \underline{t} > v - c$ (because $(v-\underline{t}+c)/2 > v - \bar{t}$). However, Assumption 3 implies that v is sufficiently large that $2\bar{t} - \underline{t} + c < v$, which is a contradiction. Therefore, p_1 must be $p_1 \le v - \bar{t}$. Retailer 1 now charges the maximum price (corner solution) it can charge under the constraints $p_1 \le p_2 = (v+c)/2 - \underline{t}/(2m)$ and $p_1 \le v - \bar{t}$. Moreover, it is easy to show that $(v+c)/2 - \underline{t}/(2m) \le v - \bar{t}$ with Assumption 3. Hence, the optimizing prices that retailers charge are $p_1^o = p_2^o = (v+c)/2 - \underline{t}/(2m)$. □

Proof of Proposition 2 (No-Free-Riding Game Equilibrium). First, we show that this is indeed a Nash equilibrium. At these prices, both retailers earn $\pi_1^e = \{m \cdot \alpha + (1-\alpha)\} \cdot (p_1^e - c)$, $\pi_2^e = 0$. Retailer 2 cannot gain by raising its price because it will make no sales (thereby still earning zero); by lowering its price below $c + k/m$, it can increase sales but also incurs losses (only m portion of uninformed customers eventually purchase products, but Retailer 2 must serve all of them, and the profit function is $\pi = (1-\alpha)\{m \times (p-c) - k\}$). Similarly, Retailer 1 cannot gain by raising its price above $p_2^e = c + k/m$ because it will make no sales; if it lowers its price below $p_1^e = m(c + k/m)$, where it already has the entire market demand, it only loses price margin. The only possible deviation is $p \in [m(c+k/m), c+k/m]$. Any price below $c + k/m$ is dominated by charging $c + k/m$ in this range, because Retailer 1 faces the same demand at any price in this range (all uninformed customers prefer to visit Retailer 2). Hence, the deviation profit is $\pi_1^d = m\alpha\{(c + k/m) - c\}$. In addition, $\pi_1^e = \{m\alpha + (1-\alpha)\}(mc + k - c) \ge m\alpha \cdot (k/m) = \pi_1^d$ for all $\alpha \le (mc + k - c)/(2mc + 2k - c - mk - m^2c)$ when $k \ge c(1-m)$. Thus, charging $p_1^e = m(c+k/m)$, $p_2^e = c + k/m$ is an equilibrium. □

What remains is to show that there can be no other Nash equilibrium. To show this, we use the following two lemmas.

Lemma A1. *There exists no symmetric pure-strategy equilibrium.*

Proof. There exists no symmetric equilibrium, such that both retailers charge the same price. Suppose both retailers charge $p_1 = p_2 > c + k/m$. Without free riding, Retailer 2 can benefit by lowering its price slightly by ε, which enables it to steal all informed customers from Retailer 1. Thus, this price cannot constitute an equilibrium. Charging a price below $c + k/m$ cannot constitute an equilibrium because Retailer 2 incurs only losses. Also, both retailers could charge $p_1 = p_2 = c + k/m$, in which case Retailer 2 could increase its profit by increasing its price. Retailer 2 still makes all the sales to the uninformed customers, but at a strictly higher price. Again, these price choices cannot constitute an equilibrium. Therefore, there exists no symmetric equilibrium in the game. When there exits an equilibrium, it must be $p_1 \ne p_2$. □

Lemma A2. *When there exists a pure-strategy equilibrium, it must be the case that* $p_1 < p_2 = c + k/m$.

Proof. Retailer 2 cannot charge lower $c + k/m$ because it incurs only losses from sales. Suppose $c + k/m \le p_2 < p_1$. Retailer 1 could benefit from lowering its price below p_2 because it can sell to all informed customers at a strictly positive profit. It is not possible, however, that $c + k/m < p_2$. Suppose $c + k/m \le p_1 < p_2$. Retailer 1 could increase its profit by raising its price to p_2 because it would still sell to all informed customers at a strictly positive profit. This scenario reverts to the case in which $p_1 = p_2 > c + k/m$ and therefore cannot constitute an equilibrium. Finally, suppose $p_1 \le c + k/m < p_2$. Again, Retailer 1 could increase its profit by raising its price to p_2, and the same logic applies. Therefore, $p_1 \le p_2 = c + k/m$, but we also know $p_1 \ne p_2$ by Lemma A1, so we are finished. □

Now we consider two cases for Retailer 1. Suppose that $p_1 < m(c + k/m)$; Retailer 1 would increase its profit by raising its price to $p_1 = m(c + k/m)$ because it is selling to the entire market, but at a strictly higher price. Thus, this price choice could not constitute an equilibrium. Suppose next that $m(c + k/m) < p_1 < c + k/m$. We already discussed that Retailer 1 could benefit by charging $m(c + k/m)$ when $\alpha \le (mc + k - c)/(2mc + 2k - c - mk - m^2c)$, so this price choice is also not an equilibrium.

We thus rule out all possible price configurations other than $p_1^e = m(c + k/m)$, $p_2^e = c + k/m$. This completes the proof of Proposition 2. □

Proof of Proposition 3. Retailer 2 is obvious, and Retailer 1 needs a few algebraic computations: $\pi_1^{NF} = \{m\alpha + (1-\alpha)\}(mc + k - c) \le m/(1-\alpha)\{(2\alpha + (1-\alpha)(1-\underline{t}))/3\}^2 = \pi_1^{FR} \Leftrightarrow 9(1-\alpha)\{m\alpha + (1-\alpha)\}(mc + k - c) \le 9(1-\alpha)\{m\alpha + (1-\alpha)\}(mc) \le m\{2\alpha + (1-\alpha)(1-\underline{t})\}^2 \Leftrightarrow 9(1-\alpha)\{m\alpha + (1-\alpha)\}c \le 9c \le (1-\underline{t})^2 \le \{2\alpha + (1-\alpha)(1-\underline{t})\}^2$, using the condition that $9c \le (1-\underline{t})^2$. Hence, this inequality always satisfies. □

Proof of Proposition 6. Following Varian (1980), there exists no pure-strategy equilibrium among free riders. Suppose not, then all retailers charge a single price p^o. A slight cut in price by one of the retailers would capture all informed customers and lead to positive profit for that retailer. If all retailers charged c, and thus earned zero profit, each would increase its profit by increasing its price and focusing on its local market (i.e., uninformed customers). Hence, there exists no pure-strategy equilibrium. Next, we focus instead on the mixed-strategy equilibrium, where retailers randomize their price strategies. There are exactly two events relevant for free riders. The retailer might be the lowest-price retailer, in which case (good situation) it gets all informed customers and follows the profit function $\pi_g(p) = (p-c)m\{\alpha + (1/n)(1-\alpha)(p_s - p - \underline{t})\}$. Alternatively, the other retailer might charge a lower price, in which case (bad situation) the retailer faces the following profit function: $\pi_b(p) = (1/n)(p-c)m(1-\alpha)(p_s - p - \underline{t})$. All prices charged with positive density must yield the same expected profit.[21] Moreover, this common level of profit must be zero because of free entry. Hence, $\pi_g(p)(1-F(p))^{n-1} + \pi_b(p)[1 - (1-F(p))^{n-1}] = 0$. Rearranging this equation, we get the following cumulative distribution function:

$$F(p) = 1 - \left(\frac{\pi_b(p)}{\pi_g(p) - \pi_b(p)}\right)^{1/(n-1)} = 1 - \left(\frac{(1-\alpha)(p_s - p - \underline{t})}{n\alpha}\right)^{1/(n-1)}. \tag{A1}$$

[21] For the fixed number of firms case, the common level of profit will be $\max_p \pi_b(p) = (1/n)(p-c)m(1-\alpha)(p_s - p - \underline{t})$. From the convexity of the profit function, $p_i^* = \arg\max_p\{\pi_b(p) = (1/n)(p-c)m(1-\alpha)(p_s - p - \underline{t})\} = (p_s + c - \underline{t})/2$. Hence, the common level of profit for the fixed number of firms case will be $(m(1-\alpha)/n)((p_s - c - \underline{t})/2)^2$.

Suppose all free riders follow the symmetric mixed strategies with cumulative distribution function $F(p)$. The expected profit is

$$E\pi_s(p) = m\cdot(1-\alpha)\cdot(p-c)\cdot\left[\bar{t}-p+\sum_{i=1}^{n}E(p_i)\right]-k(1-\alpha),$$

where $E(p_i)=\bar{p}=\int pf(p)\,dp$ for every i. Hence, $E\pi_s(p)=m(1-\alpha)(p-c)(\bar{t}-p+\bar{p})-k(1-\alpha)$. From FOC, $p_s=(c+\bar{t}+\bar{p})/2$. Plugging this into (A1), we get $F(p)=1-((1-\alpha)(1+c+\bar{p}-\underline{t}-2p)/(2n\alpha))^{1/(n-1)}$.

Therefore, we can derive the equilibrium cumulative distribution functions for n free-riding retailers. Let L be the length of the support. Then,

$$F(p)=\begin{cases}1-\left(\dfrac{(1-\alpha)(1+c+\bar{p}-\underline{t}-2p)}{2n\alpha}\right)^{1/(n-1)}\\ \quad\text{for } c\le p\le c+L\\ 0\quad\text{for } p<c\\ 1\quad\text{for } p>c+L.\end{cases}\tag{A2}$$

Thus, $F^*=(F_1,\ldots,F_n)$ and $p_s^*=(c+\bar{t}+\bar{p})/2$ constitute a Nash equilibrium for n free-riding retailers and the service provider.

Now we derive the closed-form solution of this mixed strategy for a special case of $\underline{t}=0$.

Lemma B1. *Let L be the length of the support and f be an integrable function satisfying*

(i) $\displaystyle\int_c^{c+L} f(x)\,dx=1,$

(ii) $\displaystyle\bar{p}=\int_c^{c+L} pf(p)\,dp,$

(iii) $$\int_c^{p} f(x)\,dx=\begin{cases}1-\left(\dfrac{(1-\alpha)(1+c+\bar{p}-2p)}{2n\alpha}\right)^{1/(n-1)}\\ \quad\textit{for } c\le p\le c+L\\ 0\quad\textit{for } p<c\\ 1\quad\textit{for } p>c+L.\end{cases}$$

It is possible to express $f(p)$ in terms of p and constants c, not involving $\bar{p}$.

Proof. Simplify by substituting

$$g(y)=f(y+c),$$
$$\bar{y}=\int_0^L yg(y)dy,$$
$$A=\frac{1-\alpha}{2n\alpha},\quad\text{and}\quad B=\frac{1}{n-1}$$

Then, conditions (i)–(iii) become

(i)′ $\displaystyle\int_0^L g(x)\,dx=1,$

(ii)′ $\displaystyle\bar{y}=\int_0^L yf(y)\,dy$ so that $\displaystyle\bar{p}=\int_0^L (y+c)g(y)\,dy=\bar{y}+c,$

(iii)′ $$\int_0^y g(x)\,dx=\begin{cases}1-\{A(1+\bar{y}-2y)\}^B & \text{for } 0\le y\le L\\ 0 & \text{for } y<0\\ 1 & \text{for } y>L.\end{cases}$$

Using the continuity of $\int_0^y g(x)\,dx$, we obtain the following two conditions:

$$y=0:\quad 0=1-(A(1+\bar{y}))^B,\quad\text{hence, } 1+\bar{y}=1/A,$$
$$y=L:\quad 1=1-(A(1+\bar{y}-2L))^B,\quad\text{hence, } 1+\bar{y}=2L.$$

Therefore, $A=1/2L$ and $\bar{y}=2L-1$. The condition (iii)′ can now be written as

(iii)′ $$\int_0^y g(x)\,dx=\begin{cases}1-(1-y/L)^B & \text{for } 0\le y\le L\\ 0 & \text{for } y<0\\ 1 & \text{for } y>L.\end{cases}$$

Finally, we apply (ii)′:

$$\begin{aligned}2L-1=\bar{y}&=\int_0^L yg(y)\,\mathrm{d}y\\ &=\left[y\left(1-\left(1-\frac{y}{L}\right)^B\right)\right]_0^L-\int_0^L\left[1-\left(1-\frac{y}{L}\right)^B\right]\mathrm{d}y\\ &=L-\left[y+\frac{L}{B+1}\left(1-\frac{y}{L}\right)^{B+1}\right]_0^L=\frac{L}{B+1}.\end{aligned}$$

Therefore, $B+1=L/(2L-1)$; that is, $B=(1-L)/(2L-1)$. We conclude that

$$F(p)=\int_0^p g(x)\,dx=\begin{cases}1-(1-p/L)^{(1-L)/(2L-1)} & \text{for } 0\le y\le L\\ 0 & \text{for } y<0\\ 1 & \text{for } y>L.\end{cases}\tag{A3}$$

In particular, $L=n/(n+1)$ from $B=(1-L)/(2L-1)$, and $\bar{p}=(n-1)/(n+1)+c$ from $\bar{p}=\bar{y}+c=2L-1+c$. □

By Lemma B1, we know that the equilibrium-pricing strategy for the service provider is $p_s^*=(c+\bar{t}+\bar{p})/2=n/(n+1)+c$. Then, $F^*=(F_1,\ldots,F_n)$ and $p_s^*=n/(n-1)+c$ constitute a Nash equilibrium for n free-riding retailers and the service provider.

Next, we prove the positive profit of the service provider, which is the core of this proposition. Because $\bar{p}>c$ and $k\le m(1+\underline{t})/2$, $p_s^*=(c+\bar{t}+\bar{p})/2>c+(1+\underline{t})/2\ge c+k/m$. The expected profit for the service provider is $E\pi_s(p_s^*)=m(1-\alpha)((1+\underline{t}+\bar{p}-c)/2)^2-k(1-\alpha)>m(1-\alpha)((1+\underline{t})/2)^2-k(1-\alpha)>0$ if and only if $k\le m((1+\underline{t})/2)^2$. Furthermore, $\bar{k}=m\cdot[\alpha+(1-\alpha)\cdot(2\bar{t}-\underline{t})]^2/(9(1-\alpha)^2)\ge m((1+\underline{t})/2)^2$ because $\bar{k}=m\cdot[\alpha+(1-\alpha)\cdot(2\bar{t}-\underline{t})]^2/(9(1-\alpha)^2)\ge m((1+\underline{t})/2))^2\Leftrightarrow(\alpha+(1-\alpha)(2+\underline{t}))/(3(1-\alpha))\ge(1+\underline{t})/2\Leftrightarrow 2\alpha+2(1-\alpha)\cdot(2+\underline{t})\ge 3(1-\alpha)(1+\underline{t})$ for every $\alpha\in[0,1]$. It is now clear that when $k\le\bar{k}$, the expected profit of the service provider is always positive. □

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