When Should Firms Offer Free Trials?

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Abstract

A monopolist can offer free samples or free returns to let consumers try his product. When the cost of offering free trials is negligible, the standard theory (Milgrom 1981, Grossman 1981) predicts unraveling: the monopolist always offers them to reveal his product's quality. I show that when products differ in vertical quality and a horizontal attribute, unraveling may not occur. When consumers know the product's vertical quality, the monopolist offers free trials for a central region of horizontal attributes. He is less likely to offer free trials when quality is higher. Mandating free trials may hurt expected consumer welfare. When consumers do not know the product's vertical quality, the monopolist is more likely to offer free trials when quality is higher. Nevertheless, he may not offer free trials even when his product has the highest possible vertical quality.

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1 Introduction

Many producers offer free samples to consumers. For example, Lever Brothers successfully introduced the detergent Surf by sending out more than 4 million free samples (Kotler 1990). Gillette Company introduced Trac II Razor by sending out 12 million free samples (Assael 1993). Free samples are also offered in the markets of beauty aids, cookies, music CDs, video games, computer software and magazines. Many producers offer free returns, enabling consumers to try the product at a negligible cost. On-site demonstrations and testers serve the same purpose. By trying it out, a consumer learns about the product's characteristics.

Free trials are most relevant for experience goods. Nelson (1970, 1974) defines experience goods as products whose quality can only be ascertained after consumers purchase them.[1] The standard theory (Milgrom 1981, Grossman 1981) predicts that when product quality is uncertain and the producer can credibly and costlessly reveal it, he always does. The logic is straightforward. Suppose no firm reveals product quality, the producer with the highest quality benefits from revealing his quality. Once he reveals his quality, the producer with the second highest quality benefits from revealing *his* quality. Unraveling continues until every quality type is revealed.

The standard theory concerns only one dimension of product quality: the vertical dimension. In this paper, I show that when products differ in not only vertical quality, but also in a horizontal attribute, the standard theory is no longer valid. In fact, unraveling breaks down two-fold: the monopolist may not reveal either the product's vertical quality or its horizontal attribute.

The monopolist produces a single product at constant marginal cost. The product is characterized by its vertical quality and horizontal attribute, both exogenous. The horizontal attribute is distributed on the unit interval. Consumers are uniformly distributed on the same interval. Each consumer incurs disutility from mismatch with the product, defined as the distance between her location and the product's horizontal attribute. Therefore, the product is more popular among consumers when its horizontal

[1] In contrast, the quality of search goods can be learned on observation.

attribute is closer to .5.

I explore three information structures. First, the complete-information benchmark: consumers know the product's vertical quality and horizontal attribute. Second, consumers know the product's vertical quality, but not its horizontal attribute. Third, consumers know neither the product's vertical quality nor its horizontal attribute.

In the complete-information benchmark, the equilibrium price, demand and profit all increase in the product's vertical quality. For a given level of vertical quality, the equilibrium profit and demand increase as the horizontal attribute approaches .5. When the product's vertical quality is high, the equilibrium price also increases as the horizontal attribute approaches .5. When the product's vertical quality is low, the equilibrium price first increases and then decreases as the horizontal attribute approaches .5.

In the second scenario, consumers do not know the product's horizontal attribute. The game hence suits experience goods that have gained some quality reputation. Free trials credibly inform consumers of the product's horizontal attribute. The monopolist in equilibrium offers them only when his product's horizontal attribute is close to .5.

Intuitively, few consumers are interested in a product with horizontal attribute close to 0 or 1. When the monopolist in equilibrium does not offer free trials for many horizontal attributes of the product, consumers are uncertain about their mismatch. This uncertainty can help the monopolist to obtain a higher equilibrium profit.

When the product's vertical quality is high, the monopolist is less likely to offer free trials. Most consumers would buy his product without trying it. Offering trials can drive away some consumers with a bad match. When the product's vertical quality is low, the monopolist gets little demand if he does not offer free trials. Free trials guarantee the demand from consumers with a good match.

I show by an example that mandating free trials may hurt expected consumer welfare. If trials are mandated, although no consumer regrets buying the product, fewer consumers buy it and those who buy have to pay more. When consumers' gain from the improved match cannot compensate their loss due to the higher price, mandating free trials decreases consumer welfare.

In the third scenario, consumers know neither the product's vertical quality nor its horizontal attribute. The game hence suits brand new experience goods. The monopolist in equilibrium is more likely to offer free trials when the vertical quality is high, consistent with the standard theory. He may not offer free trials, however, even when his product has the highest possible vertical quality.

Besides free trials, my paper sheds light on many other forms of strategic information transmission from producers to consumers. For example, some landlords post online pictures of their apartments to attract potential renters, while others do not.[2] As the direct cost of doing so is almost zero, my theory helps to explain the non-posting behavior. For another example, Bordeaux winemakers have recently decided to reveal their wines' horizontal attributes by listing grape varieties on the labels. O'Connell (2006) points out that this change reflects an emerging eagerness for French wine producers to reach out to Americans, who are drinking fewer bottles from France. Under the interpretation that Americans' willingness to pay for French wines has lowered over time, this observation is consistent with my prediction in Proposition 5.

My paper adds to the literature of quality disclosure. Milgrom (1981) and Grossman (1981) establish the standard theory of quality disclosure. They show that unraveling is the unique equilibrium. I compare my results with theirs in Section 5. Seidmann and Winter (1997) generalize Milgrom's result by characterizing conditions for the existence and uniqueness of the unraveling equilibrium. They use the sender-receiver framework. In their paper, the sender does not take any action other than sending messages, while in my model the monopolist also chooses the price.

This paper is also related to the literature of informative advertising, although the focus there is to look at how producers optimally inform consumers of the product's existence and price, rather than quality.[3]

Nelson (1974) first mentions that advertising can "match products to buyers." In the same spirit, Lewis and Sappington (1994) model quality signals that inform con-

[2]See `http://boston.craigslist.org/aap/`, accessed September 2006.
[3]Bagwell (2005) provides a comprehensive review of the advertising literature.

sumers of their match with the product. They examine how a producer chooses the precision of such signals and find that he often chooses the best available signal or the completely uninformative signal. Their producer has no private information. In contrast, Anderson and Renault (2006a) show that a search-good monopolist would reveal only partial information regarding the physical location of his product.

Section 2 analyzes the complete-information benchmark. Section 3 then examines the case in which only the vertical quality is known to consumers. In Section 4, neither the vertical quality nor the horizontal attribute is known to consumers. Section 5 compares my results with the standard theory of unraveling. Section 6 concludes.

2 A Benchmark Model: Complete Information

A profit-maximizing monopolist sells a product at no cost. Both vertical quality and horizontal attribute of the product are exogenous. This can be interpreted in two ways. First, the situation considered here represents a trial-offering subgame in which both vertical quality and horizontal attribute are chosen in earlier stages of an extended game. Second, both vertical quality and horizontal attribute are results of an R&D process which involves experiments with random outcomes. Hereafter, I refer to the vertical quality as "quality," and the horizontal attribute as "location." The monopolist is characterized by his product's quality and location, (v, l), where $v \geq 0$ and $0 \leq l \leq 1$. The monopolist learns (v, l) immediately after they are realized. For example, he can survey small groups of consumers.

Utility-maximizing consumers of mass one are uniformly distributed on $[0, 1]$. If a consumer located at c purchases one unit of the product from monopolist (v, l) at a price p, her utility is,

$$U(c; p; v, l) \equiv v - |c - l| - p. \tag{1}$$

That is, a consumer's utility is the product's quality less its price and her mismatch, defined as the distance between the consumer and the product. If a consumer does not buy the product, her utility is zero regardless of her location. Consumer c buys one

TABLE 1 **Subgame Perfect Equilibrium under Complete Information**

For firm (v,l) with $0 \le l \le \frac{1}{2}$, locate the correct row for quality v from column 1 and then locate the correct row for location l from column 2. For example, when $v = \frac{1}{2}$ and $l = \frac{1}{3}$, locate $0 \le v < \frac{3}{2}$ in column 1, and then $\frac{v}{2} \le l \le \frac{1}{2}$ in column 2. Columns 3-5 give the equilibrium price, demand and profit. Notice that when $1 < v < \frac{3}{2}$, no location l satisfies $\frac{v}{2} \le l \le \frac{1}{2}$; when $v \ge 2$, no location l satisfies $0 \le l < 2 - v$.

v	l	$p^c(v,l)$	$D^c(v,l)$	$\pi^c(v,l)$
$0 \le v < \frac{3}{2}$	$0 \le l < \frac{v}{3}$	$\frac{1}{2}(v+l)$	$\frac{1}{2}(v+l)$	$\frac{1}{4}(v+l)^2$
	$\frac{v}{3} \le l < \frac{v}{2}$	$v-l$	$2l$	$2l(v-l)$
	$\frac{v}{2} \le l \le \frac{1}{2}$	$\frac{1}{2}v$	v	$\frac{1}{2}v^2$
$v \ge \frac{3}{2}$	$0 \le l < 2-v$	$\frac{1}{2}(v+l)$	$\frac{1}{2}(v+l)$	$\frac{1}{4}(v+l)^2$
	$2-v \le l \le \frac{1}{2}$	$v+l-1$	1	$v+l-1$

unit of the product if $U(c;p;v,l) \ge 0$.

In the complete-information benchmark, the vector (v,l) is common knowledge. There is no uncertainty in the game. The monopolist chooses a price for the product, and then each consumer decides whether to buy a unit of the product.

Firm[4] (v,l) has the same equilibrium strategies as firm $(v, 1-l)$, for any possible location l. Hence I characterize the equilibrium only for firms with $l \in [0, \frac{1}{2}]$.

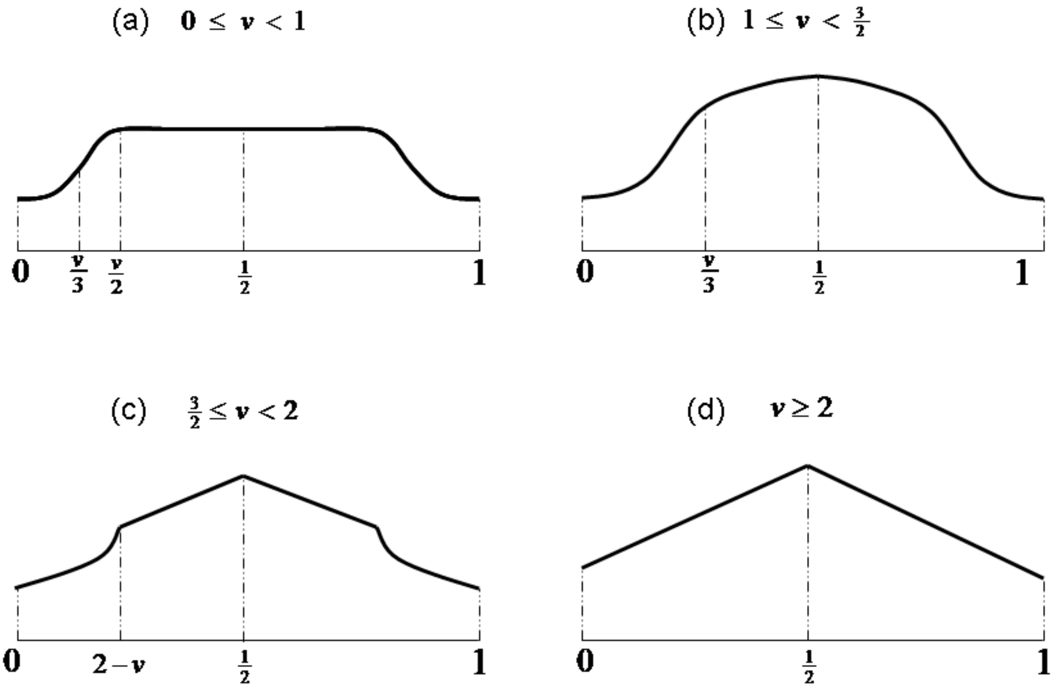
Proposition 1. *Suppose the product's quality and location (v,l) are common knowledge. When $0 \le l \le \frac{1}{2}$, Table 1 shows the Subgame Perfect Equilibrium (SPE) price $p^c(v,l)$, demand $D^c(v,l)$ and profit $\pi^c(v,l)$.*

All proofs are in the appendix. Table 1 shows several features of the Subgame Perfect Equilibrium. First, for a given location, the equilibrium price, demand and

[4]Throughout this paper, a firm refers to one type of monopolist.

FIGURE 1
EQUILIBRIUM PROFIT UNDER COMPLETE INFORMATION

The four pictures correspond to four different ranges of quality. In each picture, the vertical axis is the equilibrium profit, and the horizontal axis is the product's location. All the four profit curves are symmetric around location .5.

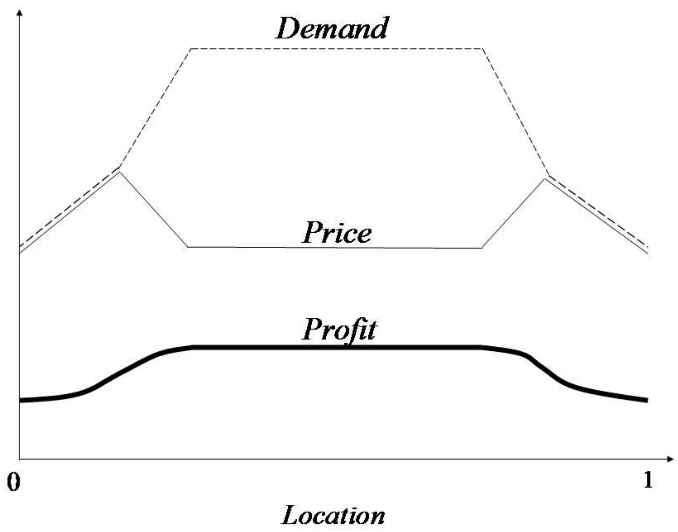


profit all increase in quality. When quality is higher, the monopolist can increase the price without losing any consumers, making a higher profit.

Second, for a given quality, the equilibrium profit and demand both increase as the product's location approaches .5. Intuitively, the product becomes more popular. The monopolist can take advantage of the increased popularity, sell more units of the product, and make a higher profit. Figure 1 illustrates how the monopolist's equilibrium profit changes with location for any given quality level. The equilibrium profit strictly increases when location approaches .5, except when quality is smaller than one and location is between $\frac{v}{2}$ and $1 - \frac{v}{2}$, in which case the equilibrium profit does not change with location.

FIGURE 2
EQUILIBRIUM PRICE, DEMAND AND PROFIT UNDER COMPLETE INFORMATION

$v < 1$ in this figure. The x-axis represents the product's horizontal characteristic space $[0, 1]$. The thin solid line is the monopolist's equilibrium price, the dashed line his equilibrium demand, and the thickened solid line his equilibrium profit. The price curve and the demand curve overlap when location is close to 0 or 1.



Third, if $0 \leq v < \frac{3}{2}$, the equilibrium price first increases and then decreases as location approaches .5. If $v \geq \frac{3}{2}$, the equilibrium price always increases as location approaches .5. Intuitively, when location is close to 0 or 1, the product is not popular. Price has to be low since otherwise the monopolist barely gets any demand. As location moves away from 0 or 1 toward .5, more consumers become interested in the product and the monopolist raises the equilibrium price. When location is close to .5, the product is popular in the market, and two possibilities arise.

If quality is high, the monopolist sells to all consumers by making the consumer with the worst match indifferent. He hence increases the equilibrium price as location approaches .5. If quality is low, he does not try to sell to all consumers, since otherwise the price would be too low. The closer is the product's location to .5, the more units he tries to sell. In order to sell more, he lowers the equilibrium price as location approaches .5.

Figure 2 illustrates the low quality case: it shows how the equilibrium price, demand and profit change with the product's location when quality is at a fixed level strictly lower than 1. The profit curve is the same as in Figure 1 (a). The monopolist in equilibrium never sells to the entire market. As explained, the equilibrium price first increases and then decreases as location approaches .5, and the equilibrium demand and profit both increase.

3 Known Vertical Quality, Unknown Horizontal Attribute

In this section, consumers know the product's quality, but not its location. The Bayesian game under consideration suits experience goods with some quality reputation. For example, when a consumer decides whether to buy a skin care product, she can learn its vertical quality by reading online reviews or asking her friends. She cannot, however, find out her exact match without trying the product.

Free trials credibly reveal the product's location, and I make three assumptions on them. First, they cannot substitute for the full product[5]. Second, if the monopolist decides to offer free trials, he offers them to every consumer. In particular, he does not offer free trials to each consumer with a probability less than one. Neither does he offer free trials selectively based on consumer characteristics.[6] Third, the cost of producing and distributing free trials is zero.

Product quality $v \geq 0$ is common knowledge. The extensive form is as follows.

Stage 1 Nature determines l according to the probability density function $g(l)$. The monopolist knows l; consumers know $g(l)$, but not l.

Stage 2 The monopolist decides whether to offer free trials. If he does, each consumer tries the product and learns l.

Stage 3 The monopolist chooses the price of the product. Each consumer decides whether to buy one unit of the product.

[5]Bawa and Shoemaker (2004) examine the substitution effect.

[6]Rossi, McCulloch, and Allenby (1996) and Grossman and Shapiro (1994) show that knowing consumer characteristics helps the producer target nearby consumers and make more profit.

I look for Perfect Bayesian Equilibria (PBE) in pure strategies. In particular, I categorize them into two groups.

Definition 1. *A* Fully Revealing Equilibrium *is a PBE in which the monopolist always offers free trials. Any other PBE is a* Partially Revealing Equilibrium*.*

Proposition 2. *A Fully Revealing Equilibrium always exists.*

A Fully Revealing Equilibrium is supported by the following off-equilibrium-path belief: consumers believe that the monopolist's product is located at 0 whenever free trials are not offered.

In a Fully Revealing Equilibrium, every consumer learns the product's location from the free trial. The monopolist at every location charges the equilibrium price in the complete-information benchmark and earns the corresponding equilibrium profit.

Next, I turn to discuss Partially Revealing Equilibria. I show that such equilibria always feature a central region of locations for which the monopolist offers free trials. This region is symmetric around .5. Further, it shrinks as quality v increases.

I adopt the following "tie-breaking" rule from Anderson and Renault (2006b): if the monopolist earns the same equilibrium profit in the continuation games whether he offers free trials or not, I assume that he does not offer free trials. This assumption is appropriate as in reality there may be a fixed cost for the monopolist to offer free trials.

Consider a Partially Revealing Equilibrium. If the monopolist in equilibrium offers free trials, he charges his complete-information equilibrium price and earns his complete-information equilibrium profit. If the monopolist in equilibrium does not offer free trials, he must make more than his complete-information profit, otherwise he would choose to offer free trials. Therefore, the monopolist's equilibrium profit is always higher in a Partially Revealing Equilibrium than in a Fully Revealing Equilibrium.

When not offered free trials, consumers infer firms' locations from the equilibrium prices. For any equilibrium price p, let $L(p)$ be the set of locations where firms charge p and do not offer free trials. The consumer located at c, upon observing price p, expects utility

$$EU(c;p;v,l) = v - p - E(|c-l||l \in L(p)), \tag{2}$$

where the last term, $E(|c-l||l \in L(p))$, is her expected mismatch with the product. As before, consumer c buys one unit of the product if $EU(c;p;v,l) \geq 0$.

When firm (v,l) in equilibrium charges price p and does not offer free trials, the demand comes from consumers who expect positive utility from buying the product. Formally, denote by $D^p(p;v,l)$ the equilibrium demand of firm (v,l) who charges equilibrium price p and does not offer free trials, then

$$D^p(p;v,l) = m(\{c|EU(c;p;v,l) \geq 0\}), \tag{3}$$

where the right-hand side is the measure of a set of consumers. The corresponding equilibrium profit is

$$\pi^p(p;v,l) = p \cdot D^p(p;v,l) = p \cdot m(\{c|EU(c;p;v,l) \geq 0\}). \tag{4}$$

Recall that firms with $l \in L(p)$, who in equilibrium charge price p and do not offer free trials. By equation (2) and (3), they get the same equilibrium demand. Consequently, they make the same equilibrium profit. Therefore, whenever two firms that do not offer free trials make different levels of equilibrium profit, they must be charging different equilibrium prices. This observation leads to the following lemma.

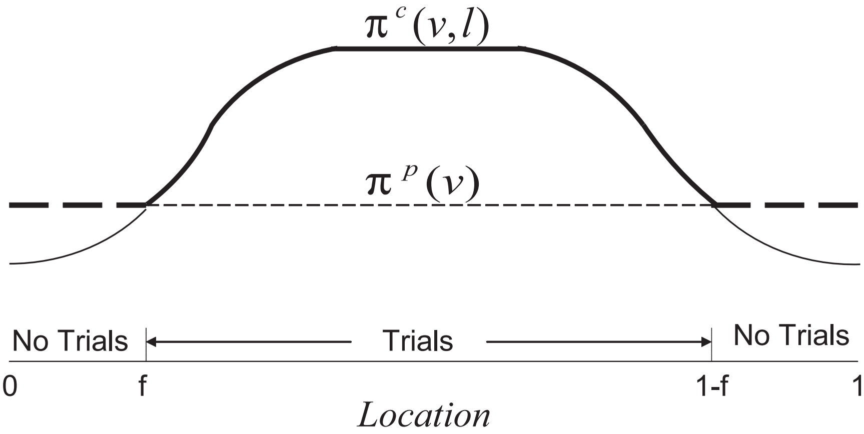
Lemma 1. *In every Partially Revealing Equilibrium, all firms that do not offer free trials make the same profit.*

Although firms that do not offer free trials can charge different equilibrium prices, they must make the same equilibrium profit. Otherwise, suppose two firms that do not offer free trials make different levels of equilibrium profit, the low-profit firm can make a higher profit by deviating to the other firm's equilibrium price.

To sustain a Partially Revealing Equilibrium, all firms that do not offer free trials must make the same equilibrium profit. Denote this profit by π^p. For a given qual-

FIGURE 3
THE MONOPOLIST'S PROFIT IN A PARTIALLY REVEALING EQUILIBRIUM

In this figure, $0 < f < 0.5$. The solid curve is the monopolist's profit under complete information, $\pi^c(v, l)$. The dashed straight line is π^p. The thickened parts of the two lines represent the monopolist's profit in the Partially Revealing Equilibrium.



ity v, there may be more than one Partially Revealing Equilibrium. In each of these equilibria, however, there is only one equilibrium level of π^p. I now discuss this level.

Lemma 2. *In every Partially Revealing Equilibrium,* $\pi^c(v, 0) = \pi^c(v, 1) \leq \pi^p \leq \pi^c(v, 0.5)$.

If the monopolist in equilibrium does not offer free trials, he makes more profit than when he is known to be located at 0 or 1; he makes less profit than when he is known to be located at .5. As a result, he makes the same equilibrium profit as some firm does under complete information, which leads to the following proposition.

Proposition 3. *In every Partially Revealing Equilibrium, there exists a threshold f with $0 \leq f \leq 0.5$ such that the monopolist (v, l) offers free trials if and only if $f < l < 1-f$. Equilibrium profit is $\pi^c(v, l)$ when he offers free trials, and $\pi^c(v, f)$ when he does not offer them.*

Figure 3 illustrates Proposition 3. As shown in Figure 3, f is chosen such that $\pi^c(v, f) = \pi^p$. The monopolist in equilibrium offers free trials if, and only if, his product's location is in a central region: $(f, 1 - f)$. When offering free trials, he makes the same profit as under complete information, $\pi^c(v, l)$. When not offering them, he makes profit π^p.

Now I discuss the intuition of Proposition 3. Under complete information, the monopolist makes a higher profit when his product is located closer to .5. It is therefore natural for firms located close to .5 to offer free trials in equilibrium, as described in Proposition 3. Why, however, do some firms not offer free trials, contradicting the standard argument of unraveling? In particular, why do firms located at f and $1 - f$ in equilibrium offer no free trials?

Given that some firms do not offer free trials, consider an arbitrary firm. If it offers free trials, consumers learn the product's exact location. If it does not offer free trials, consumers are uncertain of the product's location, and form expectations on their match. As long as the the product's location is close enough to 0 or 1, consumers are on average more optimistic about their match if free trials are not offered. As a result, the monopolist keeps the product's location ambiguous by not offering free trials.

Next, I discuss the profit ranking of different Partially Revealing Equilibria.

Corollary 1. *Consider Partially Revealing Equilibria A with threshold f_A and B with threshold f_B. If $f_A > f_B$, equilibrium profit is higher at every location in A than in B.*

The position of the dashed line in Figure 3, π^p, is higher in equilibrium A. Therefore, equilibrium profit of firms that do not offer free trials in A is higher. Furthermore, there are more firms that do not offer free trials in A.

Next, I discuss the existence of a Partially Revealing Equilibrium. The following off-equilibrium-path belief supports all Partially Revealing Equilibria. When a firm deviates to offering no free trials and an off-equilibrium-path price, every consumer believes that he is located at 0. Under this belief, no firm benefits from charging an off-equilibrium-path price. Meanwhile, no firm benefits from changing its trial-offering decision by sequential rationality. Therefore, no firm has any profitable deviation in a Partially Revealing Equilibrium.

In the following proposition, I offer a sufficient condition for the existence of a Partially Revealing Equilibrium. I also discuss the existence of a *Non-Revealing Equilibrium*, a special Partially Revealing Equilibrium in which no firm offers free trials. To keep the condition tractable, assume that the distribution of location is symmetric around .5.

Assumption S. $g(l) = g(1-l)$ *for any* $l \in [0,1]$, *and* $g(0) > 0$.

Proposition 4. *Suppose Assumption S holds. A Partially Revealing Equilibrium exists if* $v > 2 - \sqrt{2}$. *A Non-Revealing Equilibrium exists if* $v \geq 1$.

Intuitively, the existence of a Partially Revealing Equilibrium requires quality to be sufficiently high. When quality is low, the monopolist can hardly get any demand if he does not offer free trials. When quality is higher than one, the monopolist makes the highest profit at every location by never offering free trials. All consumers purchase the product for its high quality.

Proposition 4 suggests that the product's quality can affect the monopolist's decision to offer free trials. I formalize this relationship by focusing on the *Highest Profit Symmetric Equilibrium*.

Definition 2. *The* Highest Profit Symmetric Equilibrium (HPSE) *is the Partially Revealing Equilibrium in which (1) for any equilibrium price* p *charged by some firms that do not offer free trials, if* $l \in L(p)$, *then* $1 - l \in L(p)$, *and (2) the equilibrium profit for every firm is the highest among all Partially Revealing Equilibria that satisfy (1).*

Proposition 5. *Suppose Assumption S holds. When* v *increases,* f *increases in the HPSE.*

Surprisingly, the higher is the product's quality, the *less* likely does the monopolist offer free trials. The argument, however, is intuitive. To the monopolist, offering free trials always has the benefit of attracting consumers nearby at the cost of deterring consumers far away. When quality is high, consumers would buy the product without trying it, and the benefit of offering free trials is outweighed by the cost. On the other hand, when quality is low, consumers would buy the product only if they expect to have a good match. The monopolist can hardly get any demand if he does not offer free trials. Hence the higher is quality, the less likely the monopolist offers free trials.

Some evidence from the magazine industry is consistent with Proposition 5. For the top 100 best-selling magazines from Amazon.com as of November 9, 2006, 49 (49%) offer free trials by providing electronic sample pages or forms on their web sites to request free trial issues. Out of the 100 magazines, 13 have won the National Magazine

Award in General Excellence during 2000-2006, given by the American Society of Magazine Editors.[7] Among these 13 magazines, only 4 (31%) offer free trials. Furthermore, among the 6 magazines that have won the award in the last two years (2005-2006), only 1 (17%) offers free trials.

The percentage of award-winning magazines that offer free trials is lower than that of general top selling magazines. Under the natural interpretation that award-winning magazines have better quality reputation than an average top selling magazine, this observation is consistent with Proposition 5. Furthermore, the more recently a magazine has won the award, the less likely it offers free trials. Under the natural interpretation that a more recent award carries more weight in consumers' quality evaluation, this observation is also consistent with Proposition 5.[8]

Finally, a social planner may consider mandating free trials to improve consumer welfare. The existence of multiple equilibria makes it impossible to characterize general properties of consumer welfare. Nevertheless, I offer the following example in which mandating free trials hurts consumers in the HPSE.

Example 1. *Suppose $v = 1$ and l equals a and $1-a$ with probability .5 each, with $0 \leq a < 0.5$. In the HPSE, the monopolist never offers free trials. Mandating free trials reduces expected consumer welfare when $3-2\sqrt{2} < a < 0.5$ and increases expected consumer welfare otherwise.*

Mandating free trials brings the monopolist into the complete-information benchmark. Compared with this benchmark, price in the HPSE is lower, demand is higher and it is possible that more consumers derive a positive surplus. On the other hand, mandating free trials can protect consumers from regretting their purchase. When a is close to 0 in this example, the second effect is crucial and consumers prefer trials to be mandated. When a is close to .5, consumers have less uncertainty in matching with the product. They pay a lower price in the HPSE and enjoy a higher consumer surplus.

[7]The list of winners is available at `http://www.magazine.org/Editorial/National_Magazine_Awards`, accessed November 2006. The General Excellence category recognizes overall excellence in magazines. Other prestigious awards such as the Investigative Reporters and Editors Award and the Pulitzer Prize often focus on individual articles rather than the overall quality of the magazines.

[8]Past winners are eligible for the same award. For instance, National Geographic has won the General Excellence award four times since 1984.

4 Unknown Vertical Quality and Horizontal Attribute

In the real world, consumers are often uncertain about product quality. Many new firms are registered every day, and even well-established firms change or upgrade their product lines all the time. When consumers face new products with no quality reputation, free trials reveal both the product's quality and its location. When should the monopolist offer free trials in this case? I try to answer this question by examining the following game.

Stage 1 Nature determines the value of v and l with $v \geq 0$ and $0 \leq l \leq 1$. The monopolist knows both v and l; consumers know the distribution of v and l, but they do not know v or l.

Stage 2 The monopolist decides whether to offer free trials. If he does, each consumer learns both v and l.

Stage 3 The monopolist chooses the price of the product. Each consumer decides whether to buy one unit of the product.

Compared with the previous Bayesian game, the only change here is the consumers' information in Stage 1. A Fully Revealing Equilibrium still always exists and is supported by the following off-equilibrium-path belief: whenever a firm deviates to offering no free trials, every consumer believes that its product has quality zero.

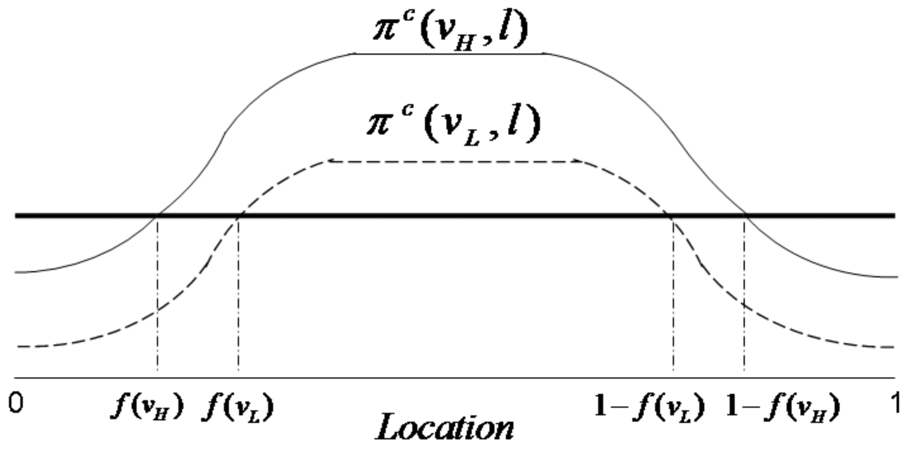
I now characterize a property of all Partially Revealing Equilibria.

Proposition 6. *In every Partially Revealing Equilibrium, there exists a decreasing function $f(v)$ such that the monopolist (v, l) offers free trials if and only if $l \in (f(v), 1 - f(v))$.*

I illustrate Proposition 6 in Figure 4.

FIGURE 4
THE MONOPOLIST'S EQUILIBRIUM PROFIT WITH UNKNOWN QUALITY AND LOCATION

In this figure, $0 \leq v_L < v_H$, and $0 < f(v_H) < f(v_L) < 0.5$. The solid curve is the monopolist's profit under complete information for quality v_H, and the dashed curve for quality v_L. The thickened straight line is the monopolist's profit when he does not offer free trials in equilibrium.



For a given product quality, firms located closer to .5 are more likely to offer free trials. Further, firms with higher product quality offer free trials at more locations. To summarize, firms with higher quality and locations closer to .5 are more likely to offer free trials.

The following off-equilibrium-path belief supports all Partially Revealing Equilibria. First, if a trial-offering firm deviates to offering no free trials and an off-equilibrium-path price, consumers believe that the product has quality zero. Second, if a non-trial-offering firm deviates to an off-equilibrium-path price, consumers believe that the product has quality zero.

I offer an example of a Partially Revealing Equilibrium, in which even firms with the highest quality products do not offer free trials.

Example 2. *v and l are independent random variables. Quality v equals v_H or v_L with probability .5 each, where $0 \leq v_L < v_H$. Location l equals 0 or 1 with probability .5 each. There exists a Non-Revealing Equilibrium when (1) $0 \leq v_H < 2$ and $v_L \geq \frac{v_H^2}{2} - v_H + 1$, or (2) $v_H \geq 2$*

and $v_L \geq v_H - 1$.

In this example, the monopolist with quality v_H does not offer free trials when the difference of v_L and v_H is small. In general, when the distribution of quality is more widely dispersed, high quality firms have a stronger incentive to offer free trials.

5 The Breakdown of Unraveling

In my paper, unraveling corresponds to the Fully Revealing Equilibrium. It still exists but is dominated by any Partially Revealing Equilibrium in terms of the monopolist's equilibrium profit.

In essence, unraveling breaks down two-fold. When the product's vertical quality is known to consumers, the monopolist may not offer free trials for some horizontal attributes. When the product's vertical quality is not known to consumers, the monopolist may not offer free trials for some vertical quality. Simply put, the monopolist does not always reveal his product's vertical quality. He does not always reveal the product's horizontal attribute either.

In Section 3, one may think that the distance from the product's horizontal attribute to .5 resembles the vertical quality and wonder whether equilibrium price can always signal out this distance. This is not the case.

Definition 3. *A* Semi-Separating Equilibrium (SSE) *is a Partially Revealing Equilibrium in which (1) for any equilibrium price* p *charged by some firms that do not offer free trials, if* $l \in L(p)$, *then* $1 - l \in L(p)$, *and (2) if* $l \in L(p)$ *and* $l' \neq 1 - l$, *then* $l' \notin L(p)$.

Proposition 7. *Suppose Assumption S holds and a SSE with threshold* f_s *exists. There exists a Partially Revealing Equilibrium with threshold* f_s *in which all firms that do not offer free trials charge the same equilibrium price.*

Proposition 7 shows that whenever a SSE exists, in which equilibrium price reveals the product's distance from .5, there exists another Partially Revealing Equilibrium in which the signaling rule of price is completely suppressed. Further, the monopolist at every location makes the same profit in the two equilibria.

6 Conclusion and Discussion

The key insights of this paper are Proposition 3 and 4. Proposition 3 describes the monopolist's trial-offering behavior in a Partially Revealing Equilibrium: he offers free trials for horizontal attributes in a central region. Proposition 4 then offers a sufficient condition for a Partially Revealing Equilibrium to exist. In other words, Proposition 4 tells us when the Fully Revealing Equilibrium is not unique.

Proposition 5 is also enlightening. It examines how product quality affects the monopolist's decision to offer free trials. Proposition 6 discusses the same issue in a different information context and draws an opposition conclusion. In the real world, it is most likely that some consumers know the product's quality, and others do not. The two propositions reflect the monopolist's mixed incentive of offering free trials. When product quality is high, he wants to reveal the high vertical quality, but hide the horizontal attribute. When product quality is low, he wants to reveal the horizontal attribute, but hide the low vertical quality. Whether he offers free trials or not would depend on the percentage of informed consumers and the distributions of vertical quality and the horizontal attribute.

To conclude, I discuss some assumptions and implications of the paper.

6.1 Positive Production Cost

I have assumed that the total cost of production is zero. A more general cost structure can be incorporated. For example, suppose the fixed cost and marginal cost of production both increase in product quality v. The monopolist's profit under complete information would change, but it still increases as the product's location approaches .5. As a result, when consumers know the product's vertical quality, but not its horizontal attribute, the monopolist still offers free trials for a central range of horizontal attributes, as in Proposition 3. Proposition 4 would hold with a different threshold.

As long as the marginal cost increases slowly enough in the product's quality, the monopolist's complete-information profit would still increase in product quality, given any horizontal attribute. As a result, Proposition 6 holds.

I have also assumed that the cost of producing and distributing free trials is always zero. This can be relaxed as well. As long as this cost is low enough and does not vary with the product's horizontal attribute, Proposition 3 still holds. Proposition 4 holds with different thresholds. Proposition 6, however, need not be true if this cost sharply increases in the product's vertical quality.

6.2 Marketing Dynamics

I have analyzed three information scenarios in a static model. The dynamics of marketing a product by offering free trials can be learned by linking these scenarios. In the product's early age, it has no quality reputation. Results from Section 4 suggest that the higher the product's quality is, the more likely free trials are offered. Once the product has become familiar to consumers and earned some quality reputation, results from Section 3 suggest that the higher the product's quality is, the less likely the monopolist offers free trials.

As a result, a high quality monopolist may choose to offer free trials in the beginning but not afterwards. He earns more profit later by exploiting his reputation of high quality. On the other hand, a low quality monopolist may choose not to offer free trials in the beginning but switch to offer them afterwards. He earns more in the beginning by not revealing the true quality of his product.

APPENDIX

Proof of Proposition 1. For each possible (v, l), the monopolist chooses a price to maximize his profit. When he charges price p and is located at $l \in [0, \frac{1}{2}]$, the demand is

$$D^c(p; v, l) = \begin{cases} 1, & \text{if } 0 \leq p < v - (1 - l) \\ l + (v - p), & \text{if } v - (1 - l) \leq p < v - l \\ 2(v - p), & \text{if } v - l \leq p < v \\ 0, & \text{if } p > v \end{cases}$$

Correspondingly, the profit is

$$\pi^c(p; v, l) = \begin{cases} p, & \text{if } 0 \le p < v - (1-l) \\ p(l + v - p), & \text{if } v - (1-l) \le p < v - l \\ 2(v-p)p, & \text{if } v - l \le p < v \\ 0, & \text{if } p > v \end{cases}$$

When $0 \le v < \frac{3}{2}$, three possibilities arise.

- If $\frac{v}{2} \le l \le \frac{1}{2}$, which is possible only when $0 \le v \le 1$, the profit is maximized at $p = \frac{v}{2}$, the corresponding demand is v, and the maximum profit is $\frac{v^2}{2}$.
- If $\frac{v}{3} \le l < \frac{v}{2}$, the profit is maximized at $p = v - l$, the corresponding demand is $2l$, and the maximum profit is $2l(v - l)$.
- If $0 \le l \le \frac{v}{3}$, the profit is maximized at $p = \frac{v+l}{2}$, the corresponding demand is $\frac{v+l}{2}$, and the maximal profit is $\frac{(v+l)^2}{4}$.

When $v \ge \frac{3}{2}$, two possibilities arise.

- If $2-v \le l \le \frac{1}{2}$, the profit is maximized at $p = v+l-1$, the corresponding demand is 1, and the maximum profit is $v + l - 1$.
- If $0 \le l < 2 - v$, which is possible only when $v < 2$, the profit is maximized at $p = \frac{v+l}{2}$, the corresponding demand is $\frac{v+l}{2}$, and the maximal profit is $\frac{(v+l)^2}{4}$.

Table 1 summarizes all the possibilities above. □

Proof of Lemma 1. If Lemma 1 is false, there must exist two distinct locations $l_A, l_B \in [0, 1]$ such that in a Partially Revealing Equilibrium (F1) the monopolist does not offer free trials at l_A or l_B, and (F2) he earns a higher profit at l_A than at l_B. Given (F1), if the monopolist charges the same equilibrium price at l_A and l_B, he obtains the same equilibrium demand at l_A and l_B by equation (2) and (3). By equation (4), he makes the same equilibrium profit at l_A and l_B, which contradicts (F2). Therefore, the monopolist must charge different equilibrium prices at l_A and l_B.

If firm l_B deviates to charge firm l_A's equilibrium price, remaining not to offer free trials, he gets firm l_A's equilibrium demand by equation (2) and (3), and therefore gets firm l_A's equilibrium profit by equation (4). By (F2), he makes a higher profit in this deviation, a contradiction. □

Proof of Lemma 2. By definition of a Partially Revealing Equilibrium, there exists a firm (v, l) that does not offer free trials. For this firm,

$$\pi^c(v, 0) = \pi^c(v, 1) \leq \pi^c(v, l) \leq \pi^p,$$

where the first two (in)equalities are from Proposition 1.

Next, I show $\pi^p \leq \pi^c(v, 0.5)$. Consider any equilibrium price p charged by some firm that does not offer no free trials. For any given $c \in [0, 1]$, by Jensen's inequality,

$$|c - E(l|l \in L(p))| \leq E(|c - l||l \in L(p)).$$

Therefore, for any given $c \in [0, 1]$,

$$\begin{aligned} EU(c; p; v, l) &= v - p - E(|c - l||l \in L(p)) \\ &\leq v - p - |c - E(l|l \in L(p))| \\ &= U(c; p; v, E(l|l \in L(p))). \end{aligned} \tag{5}$$

As a result,

$$\begin{aligned} \pi^p &= p \cdot D^p(p; v, l) \\ &= p \cdot m(\{c|EU(c; p; v, l) \geq 0\}) \\ &\leq p \cdot m(\{c|U(c; p; v, E(l|l \in L(p))) \geq 0\}) \\ &= p \cdot D^c(p; v, E(l|l \in L(p))) \\ &\leq \pi^c(v, E(l|l \in E(p))) \\ &\leq \pi^c(v, \frac{1}{2}), \end{aligned} \tag{6}$$

where the third line is from inequality (5), and the sixth from Proposition 1. □

Proof of Proposition 3. In a Partially Revealing Equilibrium, all firms that do not offer free trials earn π^p by Lemma 1. Let

$$L = \{l | g(l) > 0 \; and \; \pi^c(v, l) \leq \pi^p\}.$$

By definition, $L \neq \emptyset$. Suppose $l \in L$ and $g(l') > 0$. If $|l' - \frac{1}{2}| \geq |l - \frac{1}{2}|$, then $\pi^c(v, l') \leq \pi^c(v, l)$ by Proposition 1, and hence $l' \in L$. By Lemma 2, there exists a location $f \in [0, \frac{1}{2}]$ such that $\pi^c(v, f) = \pi^p$ and $L = [0, f] \cup [1 - f, 1]$. □

Proof of Corollary 1. Trial-offering firms make their complete-information profit in both A and B. By Proposition 3, firms that do not offer free trials earn $\pi^c(v, f_A)$ in equilibrium A and $\pi^c(v, f_B)$ in equilibrium B. By Proposition 1, $\pi^c(v, f_B) \leq \pi^c(v, f_A)$. □

Proof of Proposition 4. Consider a uniform-price Partially Revealing Equilibrium in which all firms that do not offer free trials charge the same equilibrium price. I show that such an equilibrium exists if $v \geq 2 - \sqrt{2}$.

When $1 > v \geq 2 - \sqrt{2}$,

$$\pi^c(v, 0) = \frac{v^2}{4} \leq v - \frac{1}{2} < \frac{v^2}{2} = \pi^c(v, \frac{1}{2}).$$

Therefore, there exists $f \in [0, \frac{1}{2}]$ such that

$$v - \frac{1}{2} = \pi^c(v, f).$$

Suppose all firms located in $[0, f]$ or $[1 - f, 1]$ charge the same price. Since $g(0) = g(1) > 0$, there exist at least two such firms. The two consumers located at 0 and 1 expect the highest mismatch, .5. To see this, realize two facts.

First, they expect a mismatch of .5. Recall that L is the set of locations where the monopolist does not offer free trials.

$$E(|0 - l| | l \in L) = E(|1 - l| | l \in L) = E(l | l \in L) = \frac{1}{2}.$$

Second, they have the highest expected mismatch. Let $0 \leq c_1 < c_2 \leq \frac{1}{2}$,

$$\begin{aligned}
& E(|c_2 - l||l \in L) - E(|c_1 - l||l \in L) \\
\leq \; & (c_2 - c_1) \cdot \Pr(l \in [0, c_2)|l \in L) - (c_2 - c_1) \cdot \Pr(l \in [c_2, f] \cup [1 - f, 1]|l \in L) \\
= \; & (c_2 - c_1) \cdot (\Pr(l \in [0, c_2)|l \in L) - \Pr(l \in [c_2, f] \cup [1 - f, 1]|l \in L)) \\
\leq \; & 0.
\end{aligned}$$

Therefore, every consumer buys the product when free trials are not offered and the price is $v - \frac{1}{2}$. The monopolist earns $\pi^p = v - \frac{1}{2}$ and a Partially Revealing Equilibrium exists.

Now consider $v \geq 1$. From Proposition 1, $\pi^c(v, \frac{1}{2}) = v - \frac{1}{2}$. If every firm charges $p = v - \frac{1}{2}$ and does not offer free trials. Every consumer buys the product and the monopolist's profit is $v - \frac{1}{2} = \pi^c(v, \frac{1}{2})$. A Non-Revealing Equilibrium exists. □

Proof of Proposition 5. If $v \geq 1$, $f = \frac{1}{2}$ in the HPSE by Proposition 4. Consider $v < 1$. Denote the HPSE profit of firms not offering free trials by $\pi^p_H(v)$ when quality is v. $\pi^p_H(v) = \pi^c(v, f)$, where f is the trial-offering threshold in the HPSE for quality v. Let $\Delta v > 0$ be an infinitesimal increase in quality and f' the trial-offering threshold in the HPSE when quality is $v + \Delta v$. In order to show $f' \geq f$, I first prove two claims.

Claim 1.

$$D^c(v, f) \leq D^p_H(p; v, l),$$

where the right-hand side is the HPSE demand of any firm (v, l) that charges price p and does not offer free trials.

Since

$$p \cdot D^p_H(p; v, l) = p^c(v, f) \cdot D^c(v, f),$$

it is sufficient to show $p \leq p^c(v, f)$. Consider three cases. First, $f = \frac{1}{2}$. For any price $p' > p^c(v, f) = \frac{v}{2}$,

$$p' \cdot D^p_H(p'; v, l) \leq p' \cdot D^c(p'; v, l) < \pi^c(v, \frac{1}{2}),$$

where the first inequality is from (6). Firm (v, l) hence offers free trials. Therefore, no firm charges p' and offers no free trials in the HPSE.

Second, $f \in [\frac{v}{3}, \frac{v}{2}]$. For any price $p' > p^c(v, f)$,

$$\begin{aligned} p' \cdot D^p(p'; v, l) &\leq p' \cdot D^c(p'; v, E(l|l \in L(p'))) \\ &= p' \cdot D^c(p'; v, \frac{1}{2}) = p' \cdot D^c(p'; v, f) < \pi^c(v, f). \end{aligned}$$

The first line is from (6), the first equality in the second line is from (1) in the definition of HPSE, and the rest are from Proposition 1. Firm (v, f) hence offers free trials. Therefore, no firm charges p' and offers no free trials in the HPSE.

Third, $f \in [0, \frac{v}{3})$. Suppose some firms charge price $p' > p^c(v, f)$ and do not offer free trials in the HPSE. The consumer located at c has an expected mismatch of

$$E(|c-l||l \in L(p')) \begin{cases} \geq |c - E(l|l \in L(p'))| = |c - \frac{1}{2}| \geq \frac{1}{2} - f, & \text{if } c \notin (f, 1-f) \\ = \int_0^f \Pr(l|l \in L(p'))(c - l + 1 - l - c)dl \geq \frac{1}{2} - f, & \text{if } c \in (f, 1-f) \end{cases}$$

where the second line is from $\int_0^f l \Pr(l|l \in L(p'))dl \leq f \int_0^f \Pr(l|l \in L(p'))dl = \frac{1}{2}f$. Therefore, every consumer's expected mismatch is greater than $\frac{1}{2} - f$. As some firm charges p' in the HPSE and gets a positive demand, $v - p' \geq \frac{1}{2} - f$. Since $f \in [\frac{v}{3}, \frac{v}{2}]$, $v - p^c(v, f) = \frac{1}{2}(v - f) > v - p'$ by Proposition 1. As a result, $\frac{1}{2}(v - f) > \frac{1}{2} - f$. When $v \leq \frac{3}{4}$, this cannot be true as

$$\frac{1}{2}(v - f) - (\frac{1}{2} - f) \leq \frac{1}{2}(v + \frac{v}{3} - 1) \leq 0.$$

When $\frac{3}{4} < v < 1$,

$$\pi^c(v, \frac{v}{3}) \leq v - \frac{1}{2} < \frac{v^2}{2} = \pi^c(v, \frac{1}{2}).$$

Hence there exists $f^* \in [\frac{v}{3}, \frac{1}{2}]$ with $v - \frac{1}{2} = \pi^c(v, f^*)$. Therefore, there exists a Partially Revealing Equilibrium with threshold f^*, in which all firms that do not offer free trials charge price $v - \frac{1}{2}$. Hence $f \notin [0, \frac{v}{3})$ in the HPSE. I reach a contradiction.

Claim 2.

$$\pi_H^p(v) + \Delta v \cdot D_H^p(p; v, l) \leq \pi_H^p(v + \Delta v),$$

where the right-hand side is the profit of firms that do not offer free trials in the HPSE when quality is $v + \Delta v$.

Realize that

$$\begin{aligned}
\pi^c(v+\Delta v, f) &= \pi^c(v, f) + \Delta v \cdot D^c(v, f) \\
&\leq (p+\Delta v) \cdot D^p_H(p; v, l) \\
&= \pi^p_H(v) + \Delta v \cdot D^p_H(p; v, l) \qquad (7) \\
&\leq (p+\Delta v) \cdot D^c(p+\Delta v; v+\Delta v, \frac{1}{2}) \\
&\leq \pi^c(v+\Delta v, \frac{1}{2}), \qquad (8)
\end{aligned}$$

where the first and the last last line are from Proposition 1, the second from Claim 1, and the fourth from (6). Given (7) and (8), there exists $f^* \geq f$ such that

$$\pi^p_H(v) + \Delta v \cdot D^p_H(p; v, l) = \pi^c(v+\Delta v, f^*).$$

By (2) in the definition of HPSE, Claim 2 is true if there exists a symmetric Partially Revealing Equilibrium with threshold f^* when quality is $v + \Delta v$. Such an equilibrium obviously exists if $f^* = f$. Consider $f^* > f$. Denote by p_f the equilibrium price of firm (v, l) in the HPSE when quality is v. In the same equilibrium, denote by $L(p_f)$ the set of locations where the monopolist charges p_f and does not offer free trials. Let $L^* = (f, f^*] \cup [1-f^*, 1-f) \cup L(p_f)$. By (1) in the definition of the HPSE,

$$|c-l| + |c-(1-l)| \leq |c-l'| + |c-(1-l')|, \forall l \in L^*, \forall l' \in L(p_f), \forall c \in [0,1],$$

and the inequality is strict for some c. As a result,

$$m(\{c|v - p_f - E(|c-l||l \in L^*) \geq 0\}) \geq m(\{c|v - p_f - E(|c-l||l \in L(p_f)) \geq 0\}), \quad (9)$$

and the equality holds only if both sides equal 1.

When both quality v and price p_f increase by Δv, there exists a price p^* such that

$$p^* \cdot m(\{c|v + \Delta v - p^* - E(|c-l||l \in L^*) \geq 0\}) = (p + \Delta v) \cdot D_H^p(p; v, f). \tag{10}$$

If $p^* \neq p + \Delta v$ for any equilibrium price p charged by some firm that does not offer free trials in the HPSE when quality is v, a symmetric Partially Revealing Equilibrium with threshold f^* exists. In this equilibrium, firms with $l \in L^*$ charge p^* and do not offer free trials, and the other firms that do not offer free trials charge Δv more than their equilibrium price in the HPSE when quality is v.

If $p^* = p' + \Delta v$ for some equilibrium price p', by (10),

$$m(\{c|v + \Delta v - p^* - E(|c-l||l \in L^*) \geq 0\}) = m(\{c|v - p' - E(|c-l||l \in L(p')) \geq 0\}).$$

Following (9), this equation is possible only if both sides equal 1, which implies $p^* = p' + \Delta v = (p' + \Delta v) \cdot D_H^p(p', v, l)$, and

$$p^* \cdot m(\{c|v - p^* - E(|c-l||l \in (L^* \cup L(p'))) \geq 0\}) = p^*.$$

A symmetric Partially Revealing Equilibrium with threshold f^* exists. In this equilibrium, firms with $l \in L^* \cup L(p')$ charge p^* and do not offer free trials, and the other firms that do not offer free trials charge Δv more than their equilibrium price in the HPSE when quality is v. This ends the proof of Claim 2.

By Claim 1 and 2,

$$\begin{aligned}
\pi^c(v + \Delta v, f) &= \pi^c(v, f) + \Delta v \cdot D^c(v, f) \\
&\leq \pi_H^p(v) + \Delta v \cdot D_H^p(p; v, l) \\
&\leq \pi_H^p(v + \Delta v) \\
&= \pi^c(v + \Delta v, f').
\end{aligned}$$

Therefore, $f' \geq f$. □

Proof of Example 1. By Proposition 4, $f = \frac{1}{2}$ in the HPSE when quality $v = 1$. By Lemma 2,

$$\pi^p_H(1) = \pi^c(1, \frac{1}{2}) = \frac{1}{2}. \quad (11)$$

Equilibrium price has to be .5. For any other price p',

$$D^p_H(p'; 1, a) \leq D^c(p'; 1, E(l|l \in \{a, 1-a\})) = D^c(p'; 1, \frac{1}{2}),$$

and

$$\pi^p_H(1) = p' \cdot D^p_H(p'; 1, a) \leq p' \cdot D^c(p'; 1, \frac{1}{2}) < \pi^c(1, \frac{1}{2}) = \frac{1}{2},$$

which contradicts (11). The expected consumer surplus hence is

$$CS^p_H = \frac{1}{2} - (\frac{1}{2}a^2 + \frac{1}{2}(1-a)^2).$$

If $\frac{1}{3} \leq a < \frac{1}{2}$, consumer surplus under complete information equals a^2, which is strictly smaller than CS^p_H. If $0 \leq a < \frac{1}{3}$, consumer surplus under complete information equals $\frac{(1+a)^2}{8} - a^2$, which is smaller than CS^p_H if $3 - 2\sqrt{2} < a < \frac{1}{3}$ and bigger than CS^p_H if $0 \leq a \leq 3 - 2\sqrt{2}$. □

Proof of Proposition 6. Firms that do not offer free trials earn the same equilibrium profit by the proof of Lemma 1. For any given v, there exists a threshold $f(v) \in [0, 0.5]$ such that firm (v, l) offers free trials if and only if $l \in (f(v), 1 - f(v))$, by the proof of Proposition 3.

Suppose $0 \leq v_1 < v_2$, I show $f(v_1) \geq f(v_2)$. If $f(v_1) < f(v_2)$, there exists a location l such that $f(v_1) < l < f(v_2)$. Firm (v_2, l) does not offer free trials in equilibrium while firm (v_1, l) does, which implies $\pi^c(l, v_1) \geq \pi^c(l, v_2)$. By Proposition 1, $\pi^c(v_1, l) < \pi^c(v_2, l)$, and I reach a contradiction. □

Proof of Example 2. If the two firms with quality v_H offer free trials, their equilibrium profit is $\frac{1}{4}v_H^2$ if $0 \leq v_H < 2$, and $v_H - 1$ if $v_H \geq 2$. If every firm charges the same price and does not offer free trials, every consumer expects quality to be $\frac{1}{2}(v_L + v_H)$, and the mismatch to be .5. When (1) $0 \leq v_H < 2$ and $\frac{1}{4}v_H^2 \leq \frac{1}{2}(v_L + v_H) - \frac{1}{2}$, or (2) $v_H \geq 2$ and

$v_H - 1 \leq \frac{1}{2}(v_L + v_H) - \frac{1}{2}$, there exists a Non-Revealing Equilibrium in which every firm charges price $\frac{1}{2}(v_L + v_H) - \frac{1}{2}$. □

Proof of Proposition 7. By Assumption S, $0 \in L$. Denote by $\pi_S^p(v)$ the profit of firms that do not offer free trials in the SSE, and p_0 the equilibrium price of firm $(v, 0)$. By the definition of SSE,

$$\pi_S^p(v) = p_0 \cdot m(\{c|v - p_0 - \frac{1}{2}(|c-0| + |c-1|) \geq 0\}).$$

Realize that

$$\begin{aligned} &\max_p \; p \cdot m(\{c|v - p - E(|c-l||l \in L) \geq 0\}) \\ = &\max_p \; p \cdot m(\{c|v - p - \int_{L\cap[0,\frac{1}{2}]} \Pr(l|l \in (L \cap [0, \frac{1}{2}])) \cdot \frac{1}{2}(|c-l| + |c-(1-l)|)dl \geq 0\}) \\ \geq \; & p_0 \cdot m(\{c|v - p_0 - \frac{1}{2}(|c-0| + |c-1|) \geq 0\}) = \pi_S^p(v). \end{aligned} \tag{12}$$

The inequality comes from the fact

$$|c-l| + |c-(1-l)| \leq |c-0| + |c-1| = 1, \forall l \in L, \forall c \in [0,1].$$

To see this, realize two facts. Consider a given location $l \in L$. First, when $c \in [0, l]$, $|c-l|+|c-(1-l)| = 1-2c \leq 1$. Second, when $c \in (l, \frac{1}{2}]$, $|c-l|+|c-(1-l)| = 1-2l \leq 1$. When $c \in [\frac{1}{2}, 1]$, the argument is similar.

Given inequality (12), there exists a price p^* such that

$$p^* \cdot m(\{c|v - p^* - E(|c-l||l \in L) \geq 0\}) = \pi_s^p(v).$$

Therefore, there exists a Partially Revealing Equilibrium with threshold f_s in which all firms that do not offer free trials charge p^*. □

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