Shaping Consumer Demand through the Use of Contingent Pricing

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Abstract

In this chapter I assert that revenue management techniques like contingent pricing are not merely an optimal response by firms to exogenous conditions of uncertain demand that is spread over time but that sometimes one of the aims of those techniques is to shape consumer demand in such a way as to create the conditions necessary for successful employment of intertemporal price discrimination. In this view, the interaction between a firm's policies and the strategic response of consumers to those policies leads to consumer arrival processes that are the basis of many revenue management techniques. I consider a model with strategic consumers who can decide when to show up in the market and reveal demand. Using the example of contingent pricing, I investigate how consumers' awareness of the use of contingent pricing affects their decisions regarding when to show up in the market and how, in turn, consumers' responses should affect the firm's use of contingent pricing. I identify the conditions under which it is optimal for the firm to use contingent pricing to induce consumers to arrive at different times in the market. Implications for the design and use of contingent pricing and for public policy are explored.

Revenue management methods have been developed to help a firm improve profits when selling a fixed number of units in a market in which consumer demand is spread over a period of time (i.e., not all consumers appear in the market at the same time). The firm is assumed to face some exogenously given, uncertain demand-generating process. A typical example is air travel, for which the typical (simplifying) assumption is that low-fare leisure travelers tend to appear early in the selling period and high-paying business travelers tend to appear late in the selling period (Wollmer 1992). Revenue management is concerned with deriving how the firm can use capacity allocation, dynamic pricing, and intertemporal price discrimination in the face of this demand-generating process to improve the firm's profits.

The assumption that demand is exogenous is, of course, a simplification and researchers have long recognized that consumers are likely to change or adapt their behavior as a result of revenue management efforts by firms. Researchers have long been concerned with practices of diversion and buy-up when customers are buying lower-fare tickets instead of higher-fare ones and vice versa in response to the availability of open-fare classes determined by the revenue management system (Brumelle et al. 1990; Pfeifer 1989). More recently, there has been much interest in the effects of strategic delay by consumers. Su (2007) considered the case in which some consumers may be patient: if prices at the time they show up in the market are too high, they may be willing to wait until prices drop before making a purchase. He shows that the optimal time path for price depends on whether the high-willingness-to-pay or low-willingness-to-pay customers are more patient. Aviv and Pazgal (2007) assumed that the price path exhibits discounting at some point in time and investigated how strategic delay by consumers should affect the

way the seller sets his discount. Koenigsberg, Muller, and Vilcassim (2008) allowed low-willingness-to-pay consumers to strategically delay their purchases and wait for last-minute deals. They showed that EasyJet's "commitment" to increasing prices over time can be an optimal reaction to such behavior and explored when last-minute sales should still be offered. Strategic consumers are likely to learn or anticipate that sellers will offer last-minute deals. Elmaghraby et al. (2009) show that if the amount of bargain hunting consumers is not too high the seller may be better off if consumers were allowed to make an advance reservation to purchase the product if it is still available at the time of the last-minute sale. The volume you are holding in your hand is evidence of the continuing interest in the effects of strategic consumer behavior on revenue management systems.

This chapter extends and complements the work on strategic consumer behavior and revenue management systems by looking at a setting in which consumers can decide when to show up in the market during the selling period,[1] whereas consumers in the previously mentioned papers could delay only the purchase, not decide when to show up. Assuming that consumers can decide when to show up without any restrictions makes the consumer arrival process endogenous and enables exploration of when and how revenue management can be used by firms to shape that process. The underlying motivation is the realization that arrival processes observed in actual situations do not result simply from exogenous factors but also can reflect long-term changes in behavior in response to implementation of various policies by the firm. This raises the possibility that some revenue-management techniques are used not only in response to existing patterns of behavior but may represent an attempt to create or influence strategic consumers.

[1] I use the term "show up" to indicate that consumers are not active in the market all the time and choose when to become active. One can compare this to price skimming models in which consumers are active in the market all the time.

Consider the pattern in which early consumers in a market typically have a low willingness-to-pay and later consumers a high willingness-to-pay, a pattern that is typical for air travel. This pattern is usually thought to result from leisure travelers' tendency to plan their trips well in advance while business travelers often need to change their plans on short notice. However, there is some anecdotal evidence that during the recession of the early 1990s the wide availability of "standby" bookings led many leisure passengers to delay purchase until the last moment and even show up at the airport without a reservation. This suggests that the common pattern of arrival may be only partially exogenous and may also depend on airline pricing. In addition, from a consumer behavior perspective, humans' well-known tendency to procrastinate and delay decisions until the last moment (Ariely and Wertenbroch 2002; Anderson 2003) suggests that leisure travelers would naturally wait unless there is a compelling reason to do otherwise. The nonrefundable nature of lower-price early bookings would exacerbate the tendency to procrastinate by creating financial risk if travel plans change. This is not meant to suggest that exogenous factors are not sometimes at work in the arrival pattern we observe in the airline industry, but the pricing patterns the airlines use appear to be a necessary condition for maintaining that pattern. In other words, it is possible that the revenue management systems the airlines use may have, over time, led to consumers adopting the behavior we see today.

This raises the question of whether revenue management can be used profitably to induce certain arrival patterns by consumers and what the implications of doing so are. In this work I take a stab at answering these questions by looking at one specific method—contingent pricing (see Biyalogorsky and Gerstner (2004))—and considering whether, in

the face of strategic behavior by consumers, it can be profitable for sellers to use such a price mechanism to induce the low-high arrival pattern typical in the airline industry.

Contingent pricing

Contingent pricing mechanisms are arrangements in which a seller agrees to sell a product to a buyer at a somewhat lower price while keeping an option to cancel the sale and instead sell the product to another buyer (Biyalogorsky and Gerstner 2004). Examples of such arrangements include the use of some cancellation clauses in house sales, airlines deliberately overselling a plane's capacity (Biyalogorsky et al. 1999), and underwriting of standby equity rights offerings (Bohern, Eckbo, and Michalsen 1997). Contingent pricing can help a seller mitigate price risks such as losing the opportunity to sell at a low price while waiting in vain for a high-willingness-to-pay consumer to show up or committing to sell to a low-willingness-to-pay buyer and losing potential sales to high-willingness-to-pay buyers. Biyalogorsky and Gerstner (2004) showed that contingent pricing can reduce such risks and increase the seller's expected profit, consumer surplus, and economic efficiency. The applicability and usefulness of such arrangements have been greatly extended in follow-up work on callable products (Gallego, Kou, and Phillips 2008) and probabilistic selling (Fay and Xie 2008).

The idea behind contingent pricing is to find ways to avoid potentially inefficient use of available capacity. Because demand is spread over time and the seller is uncertain how many consumers will show up, *ex ante* pricing and allocation decisions are inefficient. Contingent pricing allows the seller, at a certain cost, to make decisions that

are efficient *ex post.* In the original model by Biyalogorsky and Gerstner (2004), the seller knows the willingness-to-pay of each consumer because the arrival pattern is known and exogenous. However, since the seller is uncertain about whether the high-willingness-to-pay consumer will show up, his optimal decisions may be inefficient *ex post* and contingent pricing provides a solution to this problem.

If consumers are strategic, however, the arrival pattern is no longer exogenous and depends on the seller's price path. As a result, the seller faces the additional problem of identifying which consumers have a high willingness-to-pay and which consumers have a low willingness-to-pay (in addition to the price risks the seller faces in the original model). In the next section I present a model of contingent pricing with strategic consumers to explore how their strategic behavior affects the use of contingent pricing and when it is optimal for a seller to use contingent pricing, not just to avoid inefficient use of capacity but also to induce an arrival pattern that reveals consumers' willingness-to-pay.

Contingent pricing with strategic consumers

In this section I describe a model of the use of contingent pricing with consumers who behave strategically.

A seller has one unit of a product for sale. As is common in the revenue management literature, there is a selling period of some length of time. Consumers can appear in the market at any point during this period and contract with the seller to purchase the unit. At the end of the period, the unit is delivered to the buyer who arranged to purchase it. The unit has no residual value (zero salvage value).

The major departure of this model from traditional revenue management models is that consumers who are active in the market are strategic and decide when to appear during the selling period. Further, I assume that consumers show up only once and disappear from the market and do not return if they do not contract to purchase the unit. This last assumption keeps in the model the risk of losing customers if the seller does not lock them up once they show up. Implicitly, it assumes that there is competition or other substitutes available to consumers in the market.[2]

Accordingly, the sequence of moves in the game has the seller announcing the price path over the selling period. Based on that, consumers decide when to show up and contract with the seller to purchase the unit. At the end of the period, the unit is delivered to the buyer who purchased it.

These assumptions on the strategic behavior of consumers in the market differ from traditional revenue management models, which usually assume that the pattern of consumers showing up in the market is exogenous. Even recent models that allowed for strategic behavior usually assumed that the appearance of a consumer in the market is exogenous and that the consumer can only decide whether to purchase immediately or to wait for a better price later (Koenigsberg et al 2008; Su 2007). The set-up here also differs from models of price skimming (Besanko and Whinston 1990; Jerath et al 2007). In those models, strategic consumers are constantly active in the market so the seller does not face the risk that consumers who show up and are not served will leave the market.

[2] One can also introduce a cost of showing up into the model. To keep things simple, however, I assume that buyers can show up only once, which, in effect, means that the cost of showing up a second time is infinite.

There are two potential customers in the market: A high-valuation customer (v_h) and a low-valuation customer (v_l). The probability of each type of customer being active in the market is given by q_h and q_l respectively. The customers' valuations and probabilities of being active in the market are common knowledge. However, the seller cannot identify which customer is which and does not observe the number of consumers active in the market. Both the seller and the consumers are risk-neutral.

In this paper I explore whether, under this set of conditions, consumers' responses to a contingent pricing mechanism can lead consumers naturally to choose different times during the selling period to appear and whether it therefore benefits the seller to implement such contingent pricing arrangements.

Since there are only two consumers in the market, the contingent pricing arrangement need only have two price points. The specific arrangement I consider has the seller setting a price of p_l in the first part of the selling period and a higher price, p_h, in the second part of the selling period. In addition, the seller reserves the right to cancel the sale at any point prior to the end of the selling period. Thus, the seller can agree to sell the unit at a price of p_l and then later cancel the initial sale if a high-valuation customer appears and sell the unit at the higher price of p_h. A buyer who agrees to purchase the unit for a price of p_l is not guaranteed to receive it. I assume that compensation, h, is needed to convince a buyer to participate in a contingent contract in which receiving the unit is not guaranteed.[3] The compensation provided to the buyer is discounting of the price to p_l. Thus the price pattern considered has the characteristics of a "deep discount"

[3] Biyalogorsky and Gerstner (2004) showed how the required compensation can be derived from the buyer's utility function.

contingent pricing arrangement (see Biyalogorsky and Gerstner (2004)) with an increasing price path over time. The reason I concentrate on this particular price pattern is that it provides the stiffest test to the use of contingent pricing in the face of strategic consumers. Other possible price patterns make the seller's problem in using contingent pricing easier. For example, a "consolation reward" contingent arrangement, which is similar to the way airlines deal with overbooking, leads to less severe incentive constraint compared to the deep discount case;[4] a decreasing price path over time avoids some of the commitment problems engendered by an increasing path.[5]

What the seller wants to achieve with this contingent pricing arrangement is for the low-valuation customer to appear early and the high-valuation customer to appear late, thus providing the seller with, in essence, two selling opportunities and protecting the seller from the risk of losing customers who are active in the market.

The optimal early price, p_l, must be appealing to the low-valuation customer under the contingent pricing arrangement. It is optimal, therefore, for the seller to set $p_l = v_l - h$ (proof of this and all other derivations can be found in the appendix).

If the high-valuation consumer is active in the market and decides to show-up early to take advantage of the early low price, the probability that he will be able to purchase the unit is $1 - \frac{1}{2} q_l$ (assuming that, when the low-valuation consumer shows up, whoever shows up first gets the unit). Therefore, the expected surplus of the high-valuation consumer from showing up early is

$$(1) \qquad Exp.\,Surplus_{\,coming\,early,\,high-valuation} = (v_h - v_l + h)(1 - \tfrac{1}{2} q_l).$$

[4] Biyalogorsky and Gerstner (2004) showed that with risk-neutral, nonstrategic behavior the deep discount and consolation reward arrangements are equivalent, but that equivalence does not hold in the case of strategic consumers.

[5] Details of the solutions for alternative contingent pricing cases are available from the author.

The expected surplus from showing up late is

(2) $$Exp.\,Surplus_{\,from\,coming\,late,\,high-valuation} = v_h - p_h .$$

With the optimal price, p_h, chosen by the seller, the high-valuation consumer will be indifferent about showing up early or late. Therefore, the optimal contingent prices are

(3) $$\begin{aligned} p_h &= (v_l - h)(1 - \tfrac{1}{2} q_l) + \tfrac{1}{2} q_l v_h \\ p_l &= v_l - h \end{aligned} .$$

Given the optimal prices in (3), the expected surplus of the low-valuation consumer from showing up early is

(4) $$Exp.\,Surplus_{\,from\,coming\,early,\,low-valuation} = h .$$

The optimal surplus from showing up late (note that p_h can potentially be lower than v_l and again assuming that if both the high-valuation and the low-valuation consumer show-up late each have the same chance of getting the unit) is

(5) $$\begin{aligned} Exp.\,Surplus_{\,from\,coming\,late,\,low-valuation} &= (v_l - p_h)(1 - \tfrac{1}{2} q_h) \\ &= \left[h(1 - \tfrac{1}{2} q_l) - \tfrac{1}{2} q_l (v_h - v_l) \right] \left[1 - \tfrac{1}{2} q_h \right] \end{aligned} .$$

For the low-valuation consumer who chooses to show up early, the surplus from appearing early has to be at least as great as that for showing up late. This leads to the following condition for the contingent pricing arrangement to induce consumers to show up at different times:

(6) $$v_h - v_l > h \frac{q_h - q_l}{q_l} .$$

Result 1: *Contingent pricing arrangements can induce low-valuation consumers to show up early and high-valuation consumers to show up late in the selling period even when consumers make decisions strategically.*

Result 1 shows that a contingent pricing arrangement can indeed lead to the low-to-high arrival pattern among consumers that was the basis for the original model of Biyalogorsky and Gerstner (2004). Specifically, this paper shows that a deep-discount contingent pricing arrangement with prices as in (3) will cause the low-valuation consumer to show up early and the high-valuation consumer to show up late in the selling period if condition 6 holds. Contingent pricing will lead to the low-high arrival pattern if the difference in valuations between the consumers is sufficiently large and the compensation required by low-valuation consumers to agree to the contingent pricing arrangement is small enough. The threshold level of the difference in valuation that starts leading to separation in consumer arrival increases the higher the probability of the high-valuation consumer being active in the market and decreases the higher the probability of the low-valuation consumer being active in the market.

The seller's expected profit under the contingent pricing arrangement is

$$(7) \qquad \Pi_{contingent} = (v_l - h)q_l(1-q_h) + q_h p_h .$$

Under fixed pricing (no contingent pricing), the seller's expected profit is[6]

$$(8) \qquad \Pi_{fixed} = \begin{Bmatrix} q_h v_h \quad if \quad v_h > v_l(1+\frac{q_l(1-q_h)}{q_h}) \\ (q_h + q_l - q_h q_l)v_l \quad if \quad v_h > v_l(1+\frac{q_l(1-q_h)}{q_h}) \end{Bmatrix}.$$

[6] Without contingent pricing, the seller does not know whether a customer who shows up has a high or low valuation apart from the base rate of the probability of each being active in the market. The seller's optimal strategy is to set the price at either v_l or v_h.

Comparing the expected profits, the conditions under which the seller will implement a contingent pricing arrangement are

$$(9)\qquad \begin{array}{ll} i. & v_h < v_l\left(1+\dfrac{q_l(1-q_h)}{q_h}\right) \\ ii. & v_h - v_l > 2h\dfrac{q_h+q_l-\frac{3}{2}q_hq_l}{q_hq_l} \end{array}.$$

Result 2: *Contingent pricing arrangements are more profitable than fixed pricing for the seller if condition 9 holds.*

Result 2 shows that it can be profitable for a seller to implement a contingent pricing arrangement (specifically, a deep discount arrangement) and induce strategic consumers to show up at different times during the selling season. This shows that it can be profitable for a seller to use contingent pricing arrangements even if all consumers in the market are completely strategic in their behavior.[7] Second, this points to the possibility that firms' pricing arrangements are a factor that, over time, affected consumer behavior and actually created the familiar demand patterns we see in various industries. Thus, the airlines' use of contingent pricing and other revenue management techniques may have led to the low-valuation travelers who reserve flights well ahead of time and higher-valuation consumers who wait (or at least do not make reservations well in advance).

For contingent pricing to be profitable for the seller, the difference in valuations between the high- and low-valuation consumers must be large enough (equation 9, part ii)

[7] Note that the model precludes some sorts of strategic behavior such as collusion. This is not a problem in the airline industry but can be more problematic in other industries.

to justify the cost of implementing the contingent arrangement (lower prices for low-valuation consumers). At the same time, the difference in valuations cannot be so high that the seller finds it optimal to ignore low-valuation consumers and restrict sales to high-valuation consumers (equation 9, part i). If we compare the conditions in equation 9 to the conditions affecting a seller making optimal fixed-pricing decisions (equation 8), we find that:

Result 3: *It is optimal for the seller to implement contingent pricing only if the seller's optimal fixed-pricing approach is to set a low price that appeals to both high-valuation and low-valuation consumers.*

Result 3 shows how strategic behavior by consumers limits the value of contingent pricing, both in terms of the range of conditions under which it is optimal for the seller to use contingent pricing and in terms of the overall societal benefits from using it. The range over which it is optimal for the seller to use contingent pricing with strategic consumers is smaller than the range if consumers are not strategic. In particular, if consumers are not strategic in their behavior, contingent pricing can be optimal even when the best fixed-pricing approach is to set the price high enough to appeal only to the high-valuation consumer (Biyalogorsky and Gerstner 2004). When the best fixed-pricing approach is to serve only high-valuation consumers, there is a risk of not selling the available unit at all, a clear waste of resources and an inefficient outcome. As Biyalogorsky and Gerstner (2004) pointed out, one of the important effects of contingent pricing is that it avoids this potential waste, leading to increases in both profits and

consumer surplus. Strategic behavior by consumers, however, leads sellers to limit the use of contingent pricing in a way that negates much of its potential positive effect.

Contingent pricing as a truth-revealing mechanism

There are two basic issues that a seller tries to address with contingent pricing. First, the seller is uncertain about the number of active consumers in the market. Second, consumers' valuations are private information that is not observable by the seller. Thus, the seller does not know if a consumer who shows up has a high or low valuation for the unit. By inducing consumers to separate their appearances in the market based on their valuations of the unit, contingent pricing allows the seller to ascertain what each consumer's valuation is and price accordingly.

The field of mechanism design is concerned with understanding how one can design mechanisms that induce others to reveal private information (Laffont 1989). In the setting considered in this work, contingent pricing provides one such mechanism whereby buyers reveal their valuations through choice of arrival time. One way to assess contingent pricing is to consider how effective it is as a truth-revealing mechanism. Assuming that the revelation principle holds in our setting,[8] equation 10 gives the best feasible pricing structure that is consistent with consumers truthfully revealing their valuations.

$$(10) \qquad \begin{array}{ll} v_l & \text{if a buyer identifies as a low valution buyer} \\ v_l + \tfrac{1}{2}(v_h - v_l)q_l & \text{if a buyer identifies as a high valution buyer} \end{array}$$

[8] The central result of mechanism design theory is that one can restrict attention to mechanisms under which all players with private information simultaneously and truthfully reveal that information. The conditions under which this holds are specified by the revelation principle. Developing the conditions under which the revelation principle holds in this setting is beyond the scope of this work, though I later discuss issues associated with implementing truth-revealing mechanisms other than contingent pricing.

Equation 10 thus gives the "best" pricing mechanism that can still lead to consumers revealing their valuations and therefore provides an upper-bound benchmark for the potential profits that the seller can achieve. Comparing equation 10 to the contingent pricing mechanism (equation 3), we see that:

Result 4*: As* h *goes to zero, contingent pricing converges to the "best" feasible truth-revealing mechanism.*

Per result 4, as long as the compensation (or cost), h, that is required to convince the low-valuation consumer to agree to a contingent pricing arrangement is relatively small, the contingent pricing arrangement basically implements the best possible truth-revealing mechanism and no alternative mechanism that the seller can implement will do better.[9]

The preceding discussion suggests that in many cases contingent pricing could be a viable approach for a seller to implement a truth-revealing mechanism. I will go one step further and claim that it is not easy to come up with other practical approaches that implement the truth-revealing pricing of equation 10. The basic issue with trying to implement the pricing structure of equation 10 is that in order for that pricing structure to induce truth-telling by buyers they have to reveal their valuations simultaneously. However, the primary problem facing the seller is that buyers can appear at any time

[9] While we do not know enough to determine what compensation consumers will require to agree to a contingent pricing arrangement, it appears that in many cases the compensation is small relative to the potential benefits to the seller. For example, airline travelers who voluntarily agree to be bumped from a flight usually do so in return for in-kind rewards such as a lower price on a future flight. The real cost of such in-kind rewards for the airlines is much smaller than the stated value.

during the selling period. Once the buyers do not reveal their valuation simultaneously, the pricing structure of Equation 10 no longer induces truth telling. Consider a high-valuation consumer who decides to lie and pretend to be a low-valuation consumer. If the real low valuation already appeared in the market and the seller did not sell the unit to that first low-valuation customer, the seller can do no better than to sell the unit to the second consumer (despite the low price of v_l) because there are no other potential consumers in the market. On the other hand, if the low-valuation consumer has not shown up yet, there is no point in waiting to see if another consumer is active in the market—because if the high-valuation consumer pretends to be a low-valuation consumer, the best the seller can achieve, again, is v_l. Therefore, in order to induce truth-telling, the seller must get both buyers to appear at the same time. The most common method to achieve this is to use an auction. Typical auction structures, however, only achieve second best, which in this case, again, is a price of v_l. To implement the price structure of equation 10 through an auction, one would have to use a special form in which bid steps correspond to the price in equation 10. This, for obvious reasons, is probably impossible in practice.

The point of this discussion is not to prove definitively that there is no other mechanism that implements equation 10 but to demonstrate that it is not easy to do so. Therefore, if contingent pricing achieves results that approach those possible using equation 10, it seems reasonable that sellers will use contingent pricing to induce separation and order in the arrival of consumers so they can ascertain the consumers' valuations.

Conclusion

This chapter shows that when consumers are completely strategic in their decisions regarding when to show up during a selling period the use of a contingent pricing arrangement can cause consumers to arrive in a desired order—specifically, low-valuation consumers first, followed by consumers with a high willingness-to-pay. It also demonstrates that inducing such an ordered arrival pattern can be profitable for the seller and that the profit from a contingent price arrangement can approximate the potential profit from the "best" possible truth-revealing mechanism if the consumer compensation required for implementing contingent pricing is small.

These results demonstrate that sellers can use contingent pricing to influence customer arrival patterns in profitable ways. They point to the intriguing possibility that some of the arrival patterns we actually observe were created over the long term by firms using such revenue management approaches. While this paper only looked at contingent pricing, it is quite possible that other revenue management techniques can have similar effects. Cho, Fan, and Zhou (2009) in this volume consider a seller that implements a dynamic pricing approach based on the remaining inventory and time till the end of the selling season. They show that the seller benefits if some consumers are patient and once in the market strategically wait in anticipation of lower prices.

One issue with the optimal contingent arrangement derived is that it requires commitment from the seller to a certain price path over time. Without that commitment, the seller has an incentive to deviate and change p_h (equation 3) to v_h. While this is formally true in the static one-shot model presented, I do not consider this a major issue. In real-life situations, contingent pricing is used through repeated interactions with consumers, making deviation unprofitable for the seller. In addition, extending the model

to capture other common factors may alleviate the commitment problem. For example, the possibility of having last-minute sales (as in Koenigsberg et al. (2008)) will prevent the seller from raising p_h. Airlines usually set prices in advance and only adjust capacity allocations during the selling period, which in effect creates a commitment device in this particular case.

A more fundamental issue is that consumers have to believe or know that the prices in equation 3 will be in effect. If consumers do not believe that that is the case, they will not respond to the prices in the desired way and will not arrive at the anticipated time. In other words, it is crucial that consumers learn what the price path will be. The implication is that a seller who wants strategic consumers to arrive at a particular time must be consistent and transparent in terms of pricing arrangements. This suggests that making it hard for consumers to learn about prices over time, as many airlines appear to do by creating obstacles and obfuscating the pricing structure, may be counterproductive in the long run because it may lead to an unraveling of the arrival patterns on which many of these pricing mechanisms rely.

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Appendix

Proof of $p_l = v_l - h$

First note that the price p_l cannot be higher than $v_l - h$ because of the participation constraint of the low-valuation consumer. Now, consider a feasible contingent pricing arrangement with prices $\hat{p}_l$ and $\hat{p}_h$ such that $\hat{p}_l < v_l$ and $\hat{p}_h < v_h$. Increasing both prices $\hat{p}_l$ and $\hat{p}_h$ by ε does not change the relevant incentive constraints while still satisfying the participation constraints, therefore leading to the same behavior but with higher prices. Therefore, it is optimal to increase the price until the participation constraint is binding at $v_l - h$.

Derivation of fixed-pricing profits

Under a fixed-price policy, the seller keeps the same price throughout the selling period. If the seller sets the price at v_h, he will sell the unit if a high-valuation customer shows up. The expected profit in this case is $q_h v_h$. If the seller sets the price at v_l, he will sell the unit if any customer shows up. The expected profit in this case is $(q_h + q_l - q_h q_l)v_l$. The seller will set the price at v_h if the expected profit from doing this is higher or if $v_h > v_l(1 + \frac{q_l(1-q_h)}{q_h})$.

Derivation of equation 10

The seller announces that the price will be v_l if a buyer indentifies as a low-valuation consumer, and p_{hr} if a buyer identifies as a high-valuation consumer, and, in case of a tie, will use a coin toss to determine which buyer gets the unit.

If $p_{hr} > v_l$, the low-valuation consumer will truthfully identify as having a low valuation. The expected surplus of the high-valuation consumer from truthfully

indentifying is $v_h - p_{hr}$ while the expected surplus from identifying as a low-valuation consumer is $(v_h - v_l)(1 - q_l/2)$. Thus, if $p_{hr} \le v_l + \frac{1}{2}(v_h - v_l)q_l$, the high-valuation consumer will truthfully indentify himself.