Conditioning Prices on Purchase History

Alessandro Acquisti
Hal R. Varian*
University of California, Berkeley

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Abstract

Many transactions are now computer mediated, making it possible for sellers to condition their pricing on the history of interactions with individual consumers. This paper investigates conditions under which price conditioning will or will not be used. Our simplest model involves rational consumers with constant valuations for the good being sold and a monopoly seller who can commit to a pricing policy. In this framework, the seller will not find it profitable to condition pricing on past behavior.

We consider various generalizations of this model, such as allowing the seller to offer enhanced services to previous customers, making the seller unable to commit to a pricing policy, and allowing competition

*Research support from NSF grant 9979852 is gratefully acknowledged. Email: {acquisti,hal}@sims.berkeley.edu.

in the marketplace. All of these generalizations have equilibria with price conditioning.

1 Introduction

In 1988 the cost of a gigabyte of hard disk storage was about $11,500. By 2000 that cost was $13, roughly 900 times cheaper. Today, a gigabyte of storage costs about a dollar. This remarkable reduction of the cost of storing information has led firms to capture, save, and analyze much more information about transactions with their customers.

Supermarkets, airlines, credit cards and other industries have compiled vast databases of individual consumer transactions. Sellers in these industries routinely offer price promotions, prizes, and other sorts of inducements to individual customers based on their analyses of purchase behavior.

Collecting and analyzing such information is even easier in the online world. Though the HTTP protocol used by Web servers is stateless, browsers typically accept "cookies" from servers that contain information about the current transaction. These cookies persist after the session has ended, so that the next time the user accesses the server (using the same account) the server can retrieve identification which can be matched with details of past interactions. See Schartz [2001] for a history of Web cookies and an overview of how they work.

Even without cookies, static IP addresses, credit card numbers, direct user authentication, and a variety of other mechanisms can be used to identify individual users.

Since more and more transactions are mediated by computers, both online and offline, sellers can easily condition the price offers that they make today on past behavior. With computer mediated transactions, price discrimination on an individual basis becomes quite feasible. See Bailey [1998], Economist [2001] and Landesberg and Zeisser [2001] for discussion of how companies can use tracking tools to refine marketing strategies.

Of course, consumers can take defensive measures. No one is forced to join a loyalty program, and it is easy to set one's browser to reject cookies or to erase them after a session is over. One can even use a variety of credit cards or anonymous payment technologies to make purchases hard to trace.

In short, with today's technology, sellers can post prices, observe choices, and condition future prices on observed behavior. But buyers can also hide the fact that they bought previously. Hence, it is likely that sellers will have to offer buyers some benefits in order to induce them to reveal their identity.

In this paper, we develop some models of these strategic interactions among buyers and sellers in which sellers can condition price on purchase history. Our results are surprising. We find that in the simplest model, where consumers' valuations of the good being sold are constant, sellers do not want to condition current price offers on past behavior. However, we subsequently find that if the consumer's value for the good changes as he or she makes more purchases, the seller will find it profitable to condition prices on past behavior.

The seller can induce such a change in value by offering enhanced services to prior users, such as discount coupons (common in supermarket loyalty clubs), prizes or awards (common with airlines and credit cards), lowered transactions costs (such as one-click shopping), or personalized services (such as recommendations.)

2 Previous literature

Our analysis combines different areas of research. It is of interest to the literature on inter-temporal price-discrimination, to the literature on behavior-based targeted pricing, to the literature on the economic aspects of privacy, and to the empirical literature on the value of purchase histories and customer information.

With respect to the price-discrimination literature, we extend Mussa and Rosen [1978], Stokey [1979], Riley and Zeckhauser [1983], and Salant [1989]'s results on the conditions under which price discrimination is or is not optimal for a seller who can commit to a pricing policy.

We also relate our results to the more recent literature on customer recognition and targeted pricing (such as Hart and Tirole [1988], Villas-Boas [1999], Villas-Boas [2001], Fudenberg and Tirole [1998], Fudenberg and Tirole [2000], Chen and Zhang [2001], and Taylor [2002]). These papers generally assume that the monopoly seller is unable to commit to a pricing policy.

We also contribute to the literature on the economic aspects of consumer privacy (e.g., Posner [1981], Calzolari and Pavan [2001]) by examining not only when sellers will want to condition prices, but also what the impact of such conditioning will be.

We analyze both the cases of a monopolistic seller and competitive sellers, with and without commitment, and we focus on understanding the advantages and disadvantages that customers can gain from revealing personal information to sellers. Our model reinforces the empirical literature on marketing and customer information, such as Rossi and Allenby [1996] and Rossi and Allenby [1999].

3 The model

We begin with a simple model of a single profit-maximizing seller of a good that can be provided at zero marginal cost.

The seller has a mechanism for recording purchase history of customers. This could be based on technologies such as loyalty programs, credit card numbers, static Internet addresses, or other such devices, but we will refer to it as a "cookie."

New customers come to the seller and are offered a price. Their decision about whether to purchase at this price is observed. The second time they come to the seller the price they are offered can be conditioned on their earlier behavior. The following list summarizes the possible actions the seller can take depending on whether or not a cookie is present and what it indicates about prior behavior.

No cookie. The seller offers a price and records whether or not the customer purchases. It sets a cookie indicating whether or not purchase took place at the offered price.

Cookie shows customer bought before at price offered. The seller offers a price which may depend on the details of the previous purchase.

Cookie shows customer did not buy before at price offered. The seller offers a possibly different price.

We approach this problem from the perspective of mechanism design. For simplicity we restrict ourselves to two types and two periods. Let v_H be high-value type's willingness to pay for one unit of consumption, and let v_L be the low-value type's willingness to pay for one unit of consumption. Let π indicate the fraction of the population that has the high value.

We will assume that if the consumer is indifferent, he will act in the manner preferred by the seller, since the seller could always cut a price by a penny if it were profitable to do so. For simplicity, we also assume a zero discount rate.

If the seller sets a flat price of v_H each period, it will make a profit of $2\pi v_H$ and if it sets a flat price of v_L each period, it will make a profit of $2v_L$. The maximum profit available from flat pricing is therefore $\max\{2\pi v_H, 2v_L\}$.

We are interested in whether the seller can do better by some form of conditioning that will allow price discrimination so that the high-value person pays more than the low-value person.

4 All consumers myopic

Myopic consumers are those who base their purchase decision on the price that they see today. They do not recognize that the price they face on the next purchase may depend on today's behavior.

In this case the seller can offer a price of v_H in the first meeting with the consumer. If the consumer does not purchase at this price, the seller can offer a price of v_L the second time.

This strategy results in sales of 2 units to the high-value population and 1 unit to the low-value population, yielding revenues of

$$2\pi v_H + (1-\pi)v_L.$$

How does price conditioning affect overall welfare? There are two cases.

Case 1. $\pi v_H > v_L$. If conditioning were not possible, the seller would sell only to the high-value consumers. Allowing conditioning doesn't change the price the high-value consumers face. Low-value consumers purchase the good, but get zero surplus from the purchase. Hence overall welfare (producer plus consumer surplus) rises, but this is entirely due to the increased profit received by the seller.

Case 2. $\pi v_H < v_L$. If conditioning were not possible, the seller would sell to everyone at price v_L. When conditioning is possible, it will be profitable when

$$\pi > \frac{v_L}{v_H}\left(\frac{1}{2 - v_L/v_H}\right).$$

Hence there will be a set of values of π determined by

$$\frac{v_L}{v_H} > \pi > \frac{v_L}{v_H}\left(\frac{2}{1 - v_L/v_H}\right),$$

for which the seller would sell to everyone if it didn't have a way to condition, but chooses to restrict output when a conditioning technology is available. The high-value consumers loose under conditioning, the low-value consumers are no worse off (though they consume in one period rather than two.) The seller is better off due to selling at a higher price to the high-value consumers but worse off from losing one period of revenue from the low-value consumers. If the seller voluntarily chooses to condition, it must be better off, but overall welfare declines.

5 All consumers sophisticated

Consumer may eventually come to recognize that purchasing at a high price is not the best strategy, since it guarantees that they will face a high price in the future. Let us suppose now that consumers can delete cookies, use an anonymous payment system, or take some other steps to avoid establishing a purchase history.

Initially, we suppose that all consumers are sophisticated and see through the seller's strategy.

Let p_H be the present value (in this case, the sum) of the prices charged to the high-value person, and p_L the present value of the prices charged to the low-value person. Let x_H be the total amount consumed by the high-value type and x_L the total amount consumed by the low-value type.

The optimization problem facing the seller is:

$$\max_{x_H, x_L, p_H, p_L} \quad \pi p_H + (1-\pi) p_L \tag{1}$$

$$v_H x_H - p_H \geq v_H x_L - p_L \tag{2}$$

$$v_H x_H - p_H \geq 0 \tag{3}$$

$$v_L x_L - p_L \geq v_L x_H - p_H \tag{4}$$

$$v_L x_L - p_L \geq 0. \tag{5}$$

It is clear that due to the linearity of the problem x_L and x_H can only take on the values $\{0, 1, 2\}$. Table 1 lists the maximum revenue associated with the eight possible cases.

Note that the last three cases dominate the others, so that there are relatively few interesting cases. We will examine two of the cases in the table to get a flavor for the analysis.

Consider case $(x_H, x_L) = (1, 2)$. Among the self-selection constraints are

$$v_H - p_H \geq 2v_H - p_L \tag{6}$$

$$2v_L - p_L \geq v_L - p_H. \tag{7}$$

x_H	x_L	Maximum revenue
0	0	0
0	1	Not incentive compatible
0	2	Not incentive compatible
1	0	πv_H
1	1	v_L
1	2	Not incentive compatible
2	0	$2\pi v_H$
2	1	$\pi v_H + v_L$
2	2	$2v_L$

Table 1: Payoffs and profits.

Rearranging these inequalities gives us the contradiction

$$v_L \geq p_L - p_H \geq v_H. \tag{8}$$

Now consider case $(x_H, x_L) = (2, 1)$. The self-selection constraints are

$$2v_H - p_H \geq v_H - p_L \tag{9}$$

$$2v_H - p_H \geq 0 \tag{10}$$

$$v_L - p_L \geq 2v_L - p_H \tag{11}$$

$$v_L - p_L \geq 0. \tag{12}$$

It is easily seen that the solution to these inequalities is $p_L = v_L$ and $p_H = v_H + v_L$, which yields a profit of $\pi v_H + v_L$. When does this exceed the profit from flat pricing? That is, when do we have

$$\pi v_H + v_L > \max\{2\pi v_H, 2v_L\}? \tag{13}$$

The following result shows the answer is "never."

Fact 1 (Conditioning is not optimal.) *It is never optimal for the seller to condition prices on past behavior when consumers are sophisticated.*

Proof. Writing out the necessary inequalities in 13 we have

$$\pi v_H + v_L > 2\pi v_H \tag{14}$$

$$\pi v_H + v_L > 2v_L. \tag{15}$$

Adding these together gives a contradiction. □

The result that price discrimination is not optimal in this context is closely related to Stokey [1979] and Salant [1989]. Stokey [1979] shows that intertemporal price discrimination (with commitment to the posted prices) is never optimal. Salant [1989] extends Stokey's result to the case of multiple types and shows that it follows from the linearity of the constraints in the problem.[1] He also relates Stokey's problem to the Mussa and Rosen [1978] quality-discrimination results.

[1] Riley and Zeckhauser [1983]'s "no haggling" result is also related to linearity and is related to the Stokey-Salant results, as well as the analysis of this paper.

In our model, we allow the seller to identify individual buyers and condition pricing on purchase history of individual consumers, a feature not considered in the Stokey-Salant models. However, we find that with sophisticated consumers, our model has the same "reduced form" as the Stokey model. This is basically a consequence of the revelation principle: both the Stokey-Salant model and the model we examine are equivalent to the same mechanism design problem.

6 A geometric treatment

The most interesting case of price conditioning in the previous section was case (2,1), in which the high-value type consumed both periods and the low-value type consumed only in the second period.

The self-selection constraints for this case are given in inequalities 9-12, which can be written as

$$v_H + p_L \geq p_H \tag{16}$$

$$2v_H \geq p_H \tag{17}$$

$$p_H \geq v_L + p_L \tag{18}$$

$$v_L \geq p_L. \tag{19}$$

We have plotted these inequalities in Figure 1. It is clear by inspection that $(p_H, p_L) = (v_H + v_L, v_L)$ is the only candidate for profit-maximization;

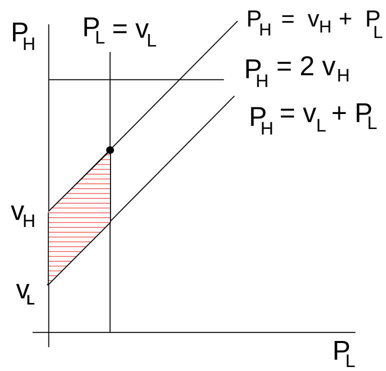

Figure 1: Self-selection constraints.

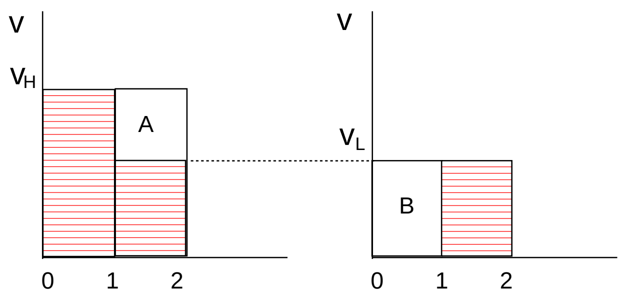

Figure 2: Demand curves, with shaded area indicating revenue.

this is the point illustrated by the black dot.

But does this solution dominate flat pricing? Refer to Figure 2 where we have plotted the demand curve for total consumption for two groups of consumers. The shaded part of the curve equals the revenue extracted by the seller under these prices. It is easy to see that if $A > B$, charging only v_H yields more revenue, and if $B > A$ charging the v_L yields more revenue. Hence one of these two flat pricing strategies must dominate differential pricing.

Intuitively, if selling to the high-value customers is more profitable than selling to both high- and low-value customers, then the seller wants to always sell to those customers. There is no advantage to cutting its price to sell to the low-value customers.

This result is somewhat disconcerting since sellers have invested many millions of dollars in computer systems to allow them to collect customer history to enable them to condition pricing on purchase behavior. Though experimentation with such systems has only gone on for a few years in the online world, loyalty programs for airlines travelers and supermarket shoppers have been around for years. Such programs commonly offer special prices to consumers with different purchase histories. But the results described above show that, at least in the simplest model, such behavior is not profitable. What is missing from this model?

One answer is that it that not all of the population is sophisticated. We examine this in the next section.

Another answer is customer resistance. However, frequent flyer programs and supermarket loyalty cards have been extremely popular. No one likes to think that they have been charged more than anyone else, but everyone likes to get a price break. Structuring a personalized pricing program in a palatable way is important, but the airline and supermarket examples show that it can be done.

Another approach is suggested by inspection of Figure 2. The geometric argument for no conditioning depended heavily on the fact that the value of the first purchase was the same as the value of the second purchase. It appears likely that price discrimination could be optimal when the value of the second unit of consumption has a different value than the first.

We could, for example, assume that marginal utility of consumption is decreasing so that the value of the second unit of consumption is less than that of the first. This is equivalent to the standard analysis of quality or quantity discrimination, in which utility is assumed to be a concave function of quality/quantity. See Mussa and Rosen [1978] and Maskin and Riley [1984] for early treatments and Tirole [1988] and Varian [1992] for textbook analysis. Salant [1989] establishes conditions for price discrimination to dominate flat pricing in his related model.

A more interesting assumption, in our context, is to examine the case where the second unit of consumption is *more* valuable than the first. This could arise because the second visit to the merchant is more efficient or pleasant than the first one, which might occur because the seller offered enhanced services of some form, which could be enabled by the information the customer has revealed during the first purchase. Examples could be targeted recommendations, personalized service or content, one-click shopping, prizes, or a variety of other enhanced services. This case has not been examined in the previous literature, but is relatively easy to handle in our discrete framework.

7 Some consumers are myopic

Suppose that a fraction m of each type is myopic, with a fraction $1-m$ being sophisticated. This case is undoubtedly realistic, but relatively straightforward in terms of analysis, so we will conduct only a cursory examination.

Assume that the seller conditions prices on purchase history by first charging a high price to everyone and then offering a low price to those who did not purchase.

The low-value consumers and the sophisticated high-value customers will wait for second period to buy at the low price. The myopic high-value consumers pay the high price each period. The revenue the seller receives is therefore

$$2m\pi v_H + (1 - m\pi)v_L.$$

This will exceed the revenue from flat pricing when

$$m\pi > \max\left\{\frac{2\pi v_H - v_L}{2v_H - v_L}, \frac{v_L}{2v_H - v_L}\right\}.$$

Hence if the fraction of myopic consumers is large enough, the seller will want to condition prices on purchase history.

Of course, the myopic consumers could just be consumers who had a particularly high cost of deleting cookies, or engaging in other sorts of anonymizing behavior.

Note that, as usual, the presence of unsophisticated consumers can ex-

High type	Low type	Maximum revenue
$v_{H1} + v_{H2}$	$v_{L1} + v_{L2}$	$v_{L1} + v_{L2}$
$v_{H1} + v_{H2}$	v_{L1}	$v_{L1} + \pi v_{L2}$
$v_{H1} + v_{H2}$	0	$\pi(v_{H1} + v_{H2})$
v_{H1}	$v_{L1} + v_{L2}$	Not incentive compatible
v_{H1}	v_{L1}	v_{L1}
v_{H1}	0	πv_{H1}
0	$v_{L1} + v_{L2}$	Not incentive compatible
0	v_{L1}	Not incentive compatible

Table 2: Payoffs and profits for multiple consumption case.

ert a negative externality on the sophisticated consumers, by creating an equilibrium that makes the sophisticated consumers worse off.

8 Enhanced services

Let v_{H1} represents the value of the first unit of consumption for the high-value consumer, and v_{H2} the value of the second unit of consumption. Define v_{L1} and v_{L2} similarly. Of course, we assume that

$$v_{H1} > v_{L1} \tag{20}$$

Utility for the high-value consumer can take on 3 values, $(0, v_{H1}, v_{H1} + v_{H2})$ and likewise for the low-value consumer. Note that it is, by definition, impossible to receive a utility of v_{H2}. Thus there are 2^3 cases, which are summarized in Table 2.

The only interesting case is where the high-value type consumes twice and the low-value type consumes once, so we spell that one out.

The self-selection constraints for the conditioning solution in this case are

$$\begin{aligned} v_{H1} + v_{H2} - p_H &\geq v_{H1} - p_L && (21) \\ v_{H1} + v_{H2} - p_H &\geq 0 && (22) \\ v_{L1} - p_L &\geq v_{L1} + v_{L2} - p_H && (23) \\ v_{L1} - p_L &\geq 0, && (24) \end{aligned}$$

which can be transformed to

$$\begin{aligned} v_{H2} + p_L &\geq p_H && (25) \\ v_{H1} + v_{H2} &\geq p_H && (26) \\ p_H &\geq v_{L2} + p_L && (27) \\ v_{L1} &\geq p_L. && (28) \end{aligned}$$

These inequalities are plotted in Figure 3. The optimum is determined by $p_H = v_{H2} + v_{L1}$ and $p_L = v_{L1}$. We need to verify that the horizontal line determined by $p_H = v_{H1} + v_{H2}$ passes above this optimum. Algebraically, this requires:

$$v_{H1} + v_{H2} > v_{H2} + v_{L1}, \qquad (29)$$

Making the cancellation we see that this condition reduces to assumption (20).

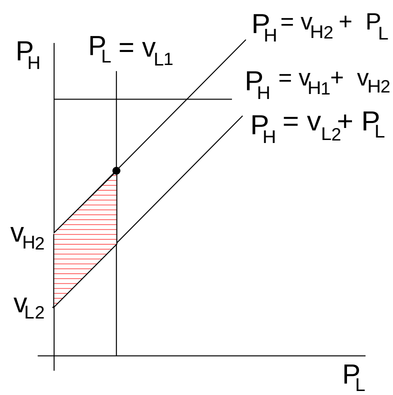

Figure 3: Self-selection constraints.

The revenue from price conditioning exceeds the revenue from flat pricing when

$$\pi v_{H2} + v_{L1} > \pi v_{H1} + \pi v_{H2} \quad (30)$$

$$\pi v_{H2} + v_{L1} > v_{L1} + v_{L2}. \quad (31)$$

Making the obvious cancellations gives us the following result.

Fact 2 (When is conditioning profitable?) *Conditioning prices will be profitable when*

$$v_{L1} > \pi v_{H1}$$

$$\pi v_{H2} > v_{L2}.$$

in which case $p_H = v_{H2} + v_{L1}$ *and* $p_L = v_{L1}$.

Note that the second inequality is more likely to hold when the seller can offer an enhanced service that is worth relatively more to the high-value type than to the low-value type. For example, one-click shopping may be more valuable to those who consume more frequently, or to those who have a higher value of time. Similarly, personalized coupons for baby food might be more valuable to consumers who have previously purchased diapers.

Indeed, if both types have the same value for the enhanced service, the necessary inequalities cannot both be satisfied. To see this, assume the contrary:

$$v_{H2} - v_{H1} = v_{L2} - v_{L1} = e > 0. \tag{32}$$

Now subtract the second inequality from the first in Fact 2, to find

$$\pi(v_{H2} - v_{H1}) > v_{L2} - v_{L1}. \tag{33}$$

Substituting, and recalling that $\pi < 1$, we have the contradiction

$$\pi e > e. \tag{34}$$

It is also worth noting that we have never needed to assume that $v_{H2} > v_{H1}$ or $v_{L2} > v_{H1}$. Hence Fact 2 applies in the classic case of "diminishing marginal utility" just as well as it does in the "enhanced service" case in our application.

9 Timing

We have seen that the seller will condition prices on purchase history when it is able to provide an enhanced service that has differential value to the consumers. We have seen that the present value of the payments will be

$$p_H = v_{H2} + v_{L1} \tag{35}$$

$$p_L = v_{L1}. \tag{36}$$

Since we are assuming that the seller can commit to price plans, it appears that this present value can be divided between the two periods in a variety of ways. However, whether or not that is the case depends on the tools that the high-value buyer has to defend himself against the price discrimination.

Let us return to the setup in the introduction and consider an overlapping generations model where consumers visit an online store at most twice. If they have no cookie indicating a prior visit, they are charged p_0. If they have a cookie indicating that they bought on a prior visit, they are charged p_b. If they have a cookie indicating that they did not buy on their earlier visit, they are charged p_n.

One way to implement the pricing system described in equations (35-36) is to charge

$$p_0 = v_{H1} \tag{37}$$

$$p_b = v_{L1} + v_{H2} - v_{H1} \tag{38}$$

$$p_n = v_{L1}. \tag{39}$$

In the second visit the high type pays v_{L1} plus a premium equal to the incremental value of the enhanced service. This strategy is commonly implemented by special offers to "new customers only," with repeat customers paying the "standard" price.

But another way to implement the same present value is to charge

$$p_0 = v_{L1} \tag{40}$$

$$p_b = v_{H2} \tag{41}$$

$$p_n = v_{L1}. \tag{42}$$

Here everyone is charged a low price on first visit and a high price on the second visit. Essentially, the seller is collecting information on the first visit which is then used to provide the enhanced service that only the high-value people are willing to pay for on the second visit. For example, an online merchant learns billing information and shipping address on the first visit. On the second visit, the merchant can offer, for example, "one-click shopping," a service that frequent purchasers, or those with high time value, might find particularly valuable.[2]

Which of these two pricing patterns might we expect? The answer de-

[2]Below we describe some empirical results from Goolsbee and Chevalier [2002] that show that Amazon customers are much less price sensitive that Barnes and Nobel customers, possibly because of the enhanced services that Amazon offers.

pends on the nature of the technology at the buyer's disposal. If the only way that the high-value consumer can imitate the low-value consumer is to delay purchase when faced with a high-price during the first visit to a store, then these two price profiles are equivalent.

But if the high-value consumer can delete his cookies, and return to the seller appearing to be a consumer who never bought before, the profile that involves charging $p_0 = v_{L1}$ cannot be an equilibrium. For if this profile were offered, the high-value consumer would buy on its first visit (taking the "low introductory offer for new consumers"), delete his cookie, and then return to buy again at the same price. True, he would not get the enhanced service, but his payoff would be $2v_{H1} - 2v_{L1}$, which is larger than $v_{H1} - v_{L1}$, the payoff from pricing plan (35-36).

Hence the only equilibrium price plan when "delete cookies" (or, more generally, anonymous shopping) is possible is to charge the high price first.

10 Welfare effect of conditioning

How does price conditioning affect social welfare? The appropriate surplus calculations are shown in Table 3. Note that in terms of total welfare, conditioning fits between the two other cases. Conditioning dominates flat pricing when the alternative is selling only to the high-value type, but not when the alternative is selling to both types.

More specifically, if $v_{L1} + v_{L2} < \pi(v_{H1} + v_{H2})$, and the inequalities in Fact

Case	Consumer Surplus	Producer Surplus	Total Surplus
Sell only to high-value	0	$\pi[v_{H1} + v_{H2}]$	$\pi[v_{H1} + v_{H2}]$
Condition prices	$\pi[v_{H1} - v_{L1}]$	$\pi v_{H2} + v_{L1}$	$\pi[v_{H1} + v_{H2}] + (1 - \pi)v_{L1}$
Sell to both	$\pi[v_{H1} + v_{H2} - v_{L1} - v_{L2}]$	$v_{L2} + v_{L1}$	$\pi[v_{H1} + v_{H2}] + (1 - \pi)[v_{L1} + v_{L2}]$

Table 3: Surplus calculations.

2 are satisfied, allowing firms to use cookies makes the society as a whole better off. The welfare ordering of the outcomes is the same as the ordering of total quantity sold, which is consistent with the welfare analysis in Varian [1985].

11 No commitment

What happens when the seller cannot commit to its second period behavior?

Let us return to the baseline model described in Section 1. If the most profitable strategy is to sell at the low price, the inability to commit doesn't affect the outcome.

However, when the most profitable strategy is to charge the high price to all, the inability to commit leave the door open to the high type to emulate the strategy of the low-value type, hoping that the seller will then cut the price in the second period.

Since this case is analyzed in Fudenberg and Tirole [1991], pp. 402-405, and in Taylor [2002], we only present the intuition of the argument.

Suppose the high-value type accepts any first-visit price less than v_H with probability 1. Then if the seller observes a rejection, it must be a low-value type. This means that the seller will offer a low value on second visit. But then high-value type wouldn't want to always accept with probability 1 since rejecting would get him a lower price. A similar argument shows that the high-value type won't reject a price less than v_H with probability 1.

It follows that the high-value type will pursue a mixed strategy in equilibrium. In equilibrium, the seller will charge the same prices as in the case with full commitment, but will make less profit due to the randomized strategy of the high-value type.[3]

Turning now to the case of enhanced services, we ask: "Can price conditioning be an equilibrium when sellers cannot commit to future pricing?" The answer is "yes," but there is a subtlety. When commitment is not possible, we have to worry about the sequencing of price offers.

Any first period price in which the high-value and low-value types behave differently will allow the seller to enforce a separating equilibrium second period. Hence the equilibrium in which the seller conditions must be interpreted as one in which the seller offers to the same price to everyone first period, v_{L1} and offers a price of v_{H2} second period.

However, we saw in section 9 that offering the low price first period is an equilibrium only when the high-value buyer cannot delete cookies; that is, the only way the high-value consumer has to imitate the low-value consumer

[3] Because profit is reduced due to randomization, there may be conditioning solutions that yield more profit than the flat price outcome when the discount rate is greater than one. We are greatful to Curtis Taylor for pointing this out to us, as well as explaining some of the intricacies of the no-committment problem.

is to delay purchase.

In practice, this is a case in which a seller is able to offer a coupon to new users only, in the hope of converting them into second-period customers. Of course, if anyone can pretend to be a new customer, this strategy is not effective in enforcing price discrimination. (We examine a competitive equilibrium of this sort in a later section.). If the high-value consumer can "delete" rather than just "delay," being unable to commit imposes a cost on the seller, in that it will not be able to implement a price conditioning solution.

In addition, if the value of the enhanced service is such that price discrimination is not optimal, and flat-pricing at the high price is better than flat pricing at the low price, the lack of a commitment device might force the seller to adopt a mixed strategy in the first period just as in the baseline case.

One way for the seller to commit to flat pricing is to publicly post prices. This is common in both supermarkets and online shopping, where most price discounting takes place via coupons of one sort or another.

This analysis thus far depends the fact that the model terminates after two periods. It would be desirable to examine a no-commitment model with several periods, but such an extension brings up several additional issues. See Villas-Boas [1999], Villas-Boas [2001], Fudenberg and Tirole [1998] and Fudenberg and Tirole [2000] for models of this type.

12 Competition and conditioning

Up until now we have been considering a monopoly seller. In this section we examine what happens when identical sellers compete for customers. We assume that these sellers cannot commit to future prices, and cannot tell whether customers have bought before from other firms.

As before, we assume each seller sets prices of p_0 if the customer has no cookie, p_b if a cookie shows customer bought at p_0, and p_n if the cookie shows that the consumer did not buy at p_0.

We also assume that the good can be provided at constant marginal cost of $c \geq 0$. To avoid trivial cases we also assume $v_{H1} > c$. Since we normalize the population size to 1, the cost of selling one unit to a fraction π of the population is πc. We also assume that the enhanced service can be provided at zero marginal cost; this makes no difference as long as the consumers' valuations of the enhanced service exceed its marginal cost.

There are several conceivable equilibria. Consumers could make their first purchase from a firm and then stay with it in order to receive enhanced services on the next purchase. Some consumers could switch to a competitor or delete their cookies in order to receive the "introductory" price of p_0. Or, possibly, everyone could switch sellers every period.

We use the notation introduced earlier for the incremental value of the enhanced service:

$$e_H = v_{H2} - v_{H1}$$

$$e_L = v_{L2} - v_{L1}.$$

We will spell out the analysis for the case where the Spence-Mirrlees condition holds,

$$e_L < e_H,$$

and simply state the results for the reverse inequality, since the analysis is completely parallel.

There are three equilibrium conditions that must be satisfied:

1. Consumers must be make optimal choices, which will impose a set of inequalities.

2. Profits are driven to zero, which is an equality.

3. Firms are profit maximizing, which requires comparing their price choices to alternative choices they might make.

Case 1. We first show that it is not an equilibrium for all firms to charge a flat price p at which all consumers purchase. The zero profit condition requires $p = c$. Consider a single firm that raises its price by any amount less than $\min\{e_H, e_L\}$ and provides the (free) enhanced service. This will be an attractive option for some or all consumers, thereby increasing profit, showing that charging flat prices is not an equilibrium.

Case 2. All customers shop at the same store twice rather than switch.

Consumer optimization requires

$$v_{H2} - p_b \geq v_{H1} - p_0 \quad (43)$$

$$v_{L2} - p_b \geq v_{L1} - p_0, \quad (44)$$

or

$$p_b \leq p_0 + e_H \quad (45)$$

$$p_b \leq p_0 + e_L. \quad (46)$$

Profit maximization will drive p_b to satisfy

$$p_b = p_0 + e_L,$$

and competition ensures profits are driven to zero, which means

$$p_0 + p_b = 2c.$$

Solving these two equations in two unknowns we have

$$p_0 = c - \frac{e_L}{2} \quad (47)$$

$$p_b = c + \frac{e_L}{2}. \quad (48)$$

In order to show that this is an equilibrium, we need to show that no single firm can increase its profit by changing its behavior.

Clearly no firm will want to lower its price. Will a single firm want to raise its price? By raising p_b to $p_0 + e_H$ the deviating firm will induce its low-value customers to switch to the competition, or delete their cookies, in order to purchase at price p_0. On the other hand the high-value customers will choose to pay the higher price. The profit from this pricing deviation will be less than the profit from the presumed equilibrium when

$$p_0 + \pi(p_0 + e_H) + (1 - \pi)p_0 < p_0 + p_b = 2p_0 + e_L,$$

which reduces to

$$\pi e_H < e_L.$$

Note that this is a "lock-in" equilibrium: consumers face a cost of switching second period, because they would lose the enhanced service. Firms respond by charging low prices first period, then high prices second period, as described in Klemperer [1989, 1995].

Case 3. The low-value type switches to another seller or deletes its cookie, the high-value type remains.

This requires

$$p_b \leq p_0 + e_H \quad (49)$$

$$p_b \geq p_0 + e_L. \quad (50)$$

$$(51)$$

Profit maximization now implies $p_b = p_0 + e_H$. Profits come from everyone buying at p_0 during the first visit, and high-value types buying at p_b and low-value types buying at p_0 during their second visit. Competition ensures that profits are driven to zero, implying

$$p_0 + \pi(p_0 + e_H) + (1 - \pi)p_0 = 2c,$$

or

$$2p_0 + \pi e_H = 2c.$$

Solving for equilibrium we have

$$p_0 = c - \frac{\pi e_H}{2} \quad (52)$$

$$p_b = c + \frac{(2 - \pi)e_H}{2}. \quad (53)$$

$$(54)$$

For this to be an equilibrium no single firm can deviate from these prices and make a profit. If a single firm lowers p_b to $p_0 + e_L$, it will keep its low-value customers but make less revenue on the high-value customers. This will not be profitable when

$$p_0 + p_b = p_0 + (p_0 + e_L) < p_0 + (p_0 + \pi e_H),$$

which is to say when

$$e_L < \pi e_H.$$

This is a "partial lock-in" equilibrium, as only the low-value types find it attractive to switch. The firms find it more profitable to let them go than to keep them, since keeping them would require cutting the price to the high-value types.

Case 4. The high-value type switches sellers, and the low-value type remains. This requires

$$p_b \geq p_0 + e_H \quad (55)$$

$$p_b \leq p_0 + e_L, \quad (56)$$

$$(57)$$

which implies

$$p_0 + e_L \geq p_b \geq p_0 + e_H$$

Hence this case cannot occur when $e_H > e_L$.

Here is a summary of the results.

Fact 3 (Equilibria with competition.) *With identical competing firms we have*

- *It is never an equilibrium for all firms to charge a flat price.*
- *If $e_L < e_H$, then in equilibrium*

  - *No consumers will switch when* $e_L > \pi e_H$.
  - *Low-value consumers will switch when* $e_L < \pi e_H$.
  - *High-value consumers will never switch.*

- *If* $e_L > e_H$, *then in equilibrium*
  - *No consumers will switch when* $e_H > (1 - \pi)e_L$.
  - *High-value consumers will switch when* $e_H < (1 - \pi)e_L$.
  - *Low-value consumers will never switch.*

These outcomes exhibit a form of "customer poaching," a term introduced by Fudenberg and Tirole [2000]. They analyze a duopoly in which some consumers remain loyal and others defect to the competitor. In their model switching costs are zero, firms offer partial substitutes a la Hotelling, services are not personalized, and firms can tell which firms consumers bought from previously. Their baseline case is long distance telecommunications service, which is quite different from our situation, due to the undifferentiated nature of the good being sold.

In our situation, the seller can able to provide a *personalized* service that is valuable to at least some of the consumers. This creates switching costs for the consumers, since they would then have to rebuild the relationship with the seller.

In some cases these switching costs may be relatively small—e.g., entering credit card information—but even relatively small switching costs can matter. Goolsbee and Chevalier [2002] estimate demand elasticities facing Amazon and barnesandnoble.com. They find that the demand curve facing Amazon is much more inelastic than that facing barnesandnoble.com, an effect that may be due to the more personalized environment offered by Amazon. If this hypothesis is correct, it may be that Amazon's investment in "enhanced services" may be a significant contribution to its competitive advantage. Note that offering such services required large expenditures in fixed cost to implement the system, but have very small marginal costs to service each customer.

13 Summary

In this paper we have investigated the conditions under which price conditioning will be optimal for a seller when the history of interactions with individual consumers can be tracked.

In our baseline case, with constant values for the product being sold, the seller will not find it profitable to condition prices on past customer behavior. If enough customers are myopic, or the costs of using anonymous technologies are too high, the seller will want to condition pricing on purchase history.

If the seller can offer enhanced services to returning customers due to the information it has received from them during previous transactions, it will also often be profitable to condition.

We have extended this analysis to consider scenarios where the seller cannot commit to prices and where the seller faces competition. In these cases there may be mixed strategy equilibria and lock-in equilibria.

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