Conditioning Prices on Purchase History

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Introduction

- 1988: cost of a gigabyte of hard disk storage was about $11,500
- 2000: cost was $13, roughly 900 times cheaper.
- It is now possible to save, analyze, and use information about individual customers.
  - Loyalty programs for airlines, hotels, supermarkets.
  - Cookies, logins, credit card numbers for online purchases.
- But buyers can take defensive measures.
- How do these effects work themselves out?

Example of Netscape cookies

```
.yahoo.com      TRUE    /       FALSE   2060279446
   B       99uerc0teitt0&b=2
.yahoo.com      TRUE    /       FALSE   1271361534
   Y v=1&n=9p40tt0kndtpl&l=7l0h80d/o&p=m1f2sg02010205
www.weather.com FALSE   /       FALSE   1006221546
   footprint       1%7Chomegarden_garden
.amazon.com     TRUE    /       FALSE   1011859195
   session-id      104-4960085-2200764
.amazon.com     TRUE    /       FALSE   1011859195
   session-id-time 1011859200
   Wed%20Oct%2024%2015:40:02%20EDT%202001%200.1921455979
```

The model

- One profit-maximizing seller with zero MC.
- Two-periods; seller can commit to price plan.
- Seller has way to remember behavior of customers, e.g., cookies.
- Consumers want at most one unit per period.
- Two types of consumers with wtp v_H and v_L, with fraction π having high value.
- Consumer indifference resolved in favor of seller.

Pricing strategy

- Flat pricing
  - Sell only to high, makes profit $2\pi v_H$.
  - Sell to all, makes profit $2v_L$.
- Price conditioning: an example
  - Set high price first period
  - Sell at high price second period to those who bought first period
  - Sell at low price to others second period.

All consumers myopic

- Myopic consumers don't recognize that their choices today affect prices they are offered tomorrow.
- Conditioning strategy results in 2 units sold to high value type at v_H, one unit sold to low-value type at v_L
- Profit is

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

- Note: need cookie-like technology to recognize high-value buyers

When is this profitable?

- Conditioning is always better than selling only to high-value consumers; better than selling to entire population when

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

- Hence there is a range of values determined by

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

  where seller would sell to everyone if it couldn't condition, but chooses to condition if possible.

All consumers sophisticated

- Sophisticated consumers recognize that the future pricing depends on their initial choices.
- Can delete cookies or delay purchase.
- Let p_H, p_L be the present value (sum) of prices charged to high- and low-value types.
- Let x_H, x_L be the total amount consumed over the two periods.

Profit-maximization problem

$$\begin{aligned}
\max_{x_H, x_L, p_H, p_L} \quad & \pi p_H x_H + (1-\pi) p_L x_L \\
v_H x_H - p_H &\geq v_H x_L - p_L \\
v_H x_H - p_H &\geq 0 \\
v_L x_L - p_L &\geq v_L x_H - p_H \\
v_L x_L - p_L &\geq 0.
\end{aligned}$$

Here x_H and x_L can take on values 0,1, or 2. Can examine the $2^3 = 8$ cases.

Possible cases

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.

Price conditioning

Last 3 cases are only interesting ones. Case (2,0) is sell only to high-value, case (2,2) is sell to both, case (2,1) is the conditioning case. Self-selection constraints for conditioning case are:

$$\begin{aligned} 2v_H - p_H &\geq v_H - p_L \\ 2v_H - p_H &\geq 0 \\ v_L - p_L &\geq 2v_L - p_H \\ v_L - p_L &\geq 0. \end{aligned}$$

See graph next slide.

Self-selection constraints

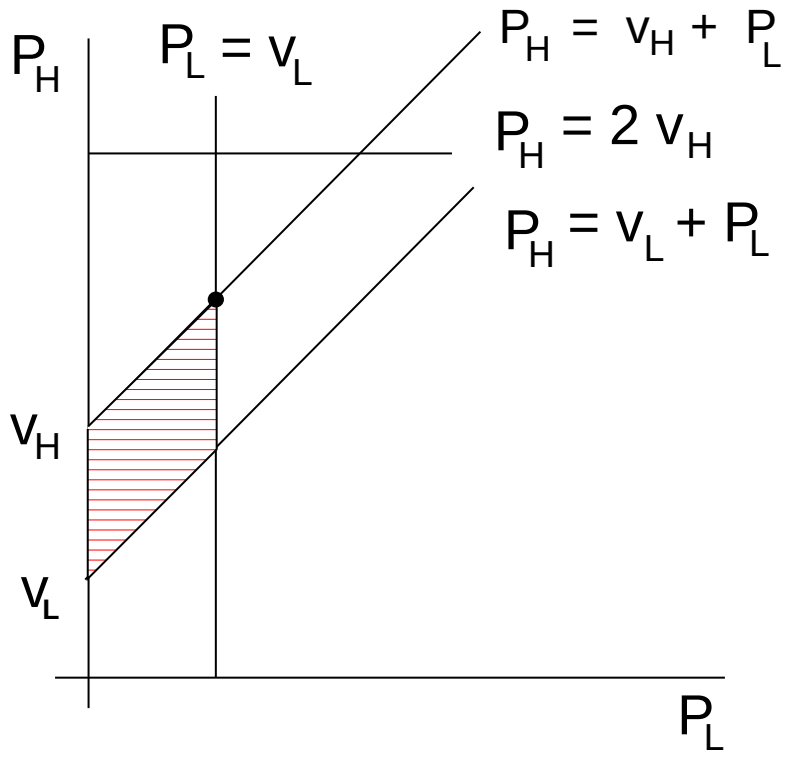

Figure 1: Self-selection constraints.

Conditioning solution

- Solution is $p_L = v_L$ and $p_H = v_H + v_L$.
- Profit is $\pi v_H + v_L$.
- When does this dominate flat pricing? That is, when is:

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

Conditioning profitable?

Answer: never! Why? Need to have:

$$\begin{aligned} \pi v_H + v_L &> 2\pi v_H \\ \pi v_H + v_L &> 2v_L. \end{aligned}$$

Add these together to get contradiction.

Graphical argument

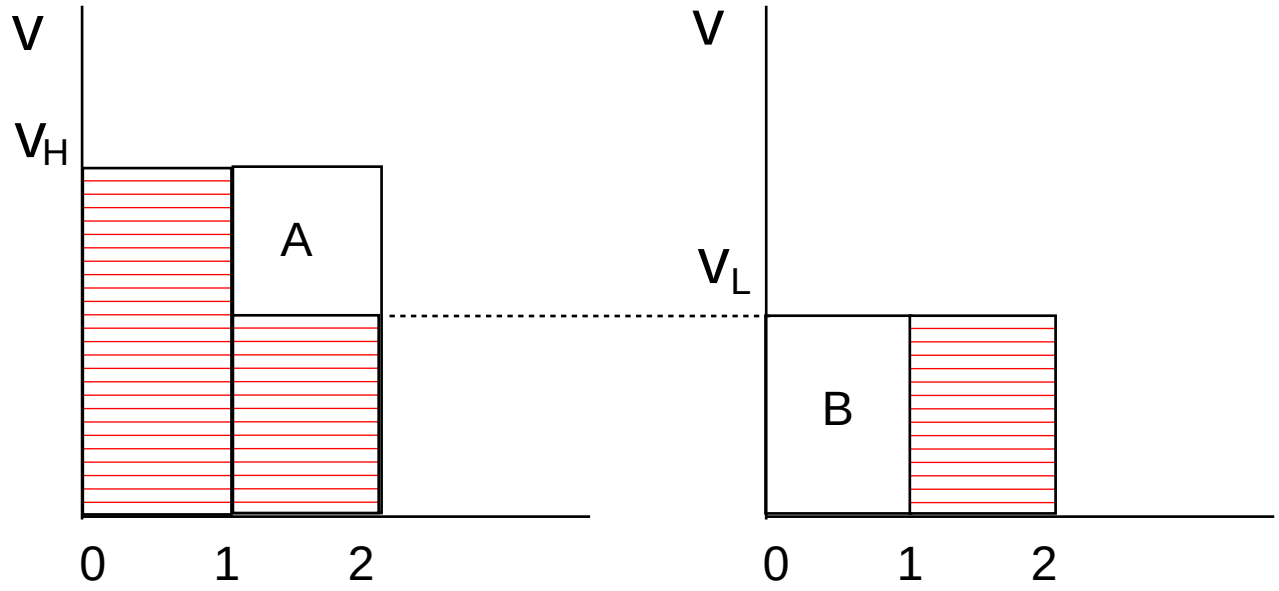

Figure 2: Demand curves, 2 consumers, shaded area is revenue.

Literature

- Stokey (1979) “Intertemporal Price Discrimination”
  - Intertemporal PD not profitable
  - Unless different discount rates, or costs change
- Salant (1989)
  - Result is due to linearity
  - Relates to Mussa-Rosen-Spence quality discrimination
- Acquisti and Varian (2001)
  - New feature: conditioning on individual behavior
  - But “reduced form” of problem is the same due to revelation principle

Possible resolution

- Different costs or interest rates (Stokey).
- Only a fraction of the population is sophisticated (Obvious but realistic.)
- Value of second-period consumption is different from first-period.
  - Less: diminishing MU (done in quality discrimination literature)
  - More: enhanced service such as one-click shopping, coupons, recommendations. Very natural in our application.

Fraction of population myopic

- A fraction m of the population is myopic
- Seller charges a high price to everyone, then a low price to those who did not purchase. Low-value consumers and sophisticated high-value consumers wait, so seller gets revenue $2m\pi v_H + (1 - m\pi)v_L$.
- Note that seller must be able to identify buyers for this to work (via cookie-like technology)
- Better than flat pricing when m is large. Specifically:

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

Enhanced services

- v_{H1}, v_{H2} denotes value of the first and second units for high-value
- v_{L1}, v_{L2} for low value.
- Several cases, relevant one is:

$$\begin{aligned} v_{H1} + v_{H2} - p_H &\geq v_{H1} - p_L \\ v_{H1} + v_{H2} - p_H &\geq 0 \\ v_{L1} - p_L &\geq v_{L1} + v_{L2} - p_H \\ v_{L1} - p_L &\geq 0, \end{aligned}$$

Better service in second period induces high-value consumer to reveal type.

Conditioning profitable?

- For conditioning to be profitable

$$\begin{aligned} \pi v_{H2} + v_{L1} &> \pi v_{H1} + \pi v_{H2} \\ \pi v_{H2} + v_{L1} &> v_{L1} + v_{L2}. \end{aligned}$$

- Rearrange:

$$\begin{aligned} v_{L1} &> \pi v_{H1} \\ \pi v_{H2} &> v_{L2}. \end{aligned}$$

- First-period inequality: would sell to both first period
- Second-period inequality: would sell only to high-value second period

Differential value of service

For these constraints to be satisfied, consumers must place different value on services. Assume not:

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

Add necessary inequalities on previous slide together:

$$\pi\left(v_{H2} - v_{H1}\right) > v_{L2} - v_{L1}.$$

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

$$\pi e > e.$$

Timing

- Think of overlapping generations model where consumers shop twice
- Customers arrive and are given price
  - p_0 if they have no cookie.
  - p_b if they bought before at p_0.
  - p_n if they didn't buy before when faced price p_0.
- If high-value customers can "delay," then can offer prices in any order as long as present value ends up as p_H or p_L.
- If high-value customers can "delete" then seller has to offer high price first (otherwise customers would delete and return).

Welfare effect of conditioning

How does conditioning compare to flat pricing wrt consumer plus producer surplus?

- Sell only to high-value: $\pi[v_{H1} + v_{H2}]$
- Conditioning: $\pi[v_{H1} + v_{H2}] + (1 - \pi)v_{L1}$
- Sell to both $\pi[v_{H1} + v_{H2}] + (1 - \pi)[v_{L1} + v_{L2}]$
- So conditioning can make consumers better off when the monopoly solution would prevail otherwise: $v_{L1} + v_{L2} < \pi(v_{H1} + v_{H2})$.

Restricting enhanced service

- A strategy: Offer a high price and a low price first period. If the consumer buys at the high price, offer a personalized enhanced service second period. If the consumer buys at the low price, then offer standard service next time.
- This requires offering a menu price/quality packages first period, unlike previous strategies.
- Example: Airline offers a high-price ticket and a low-price ticket. If the consumer buys the high-price ticket, next time he gets a first-class upgrade.

Analysis of restricted service

- Assume $v_{H2} - v_{H1} > v_{L2} - v_{L1}$.
- Solution is:

$$\begin{aligned} p_H &= v_{H2} - v_{H1} + 2v_{L1} \\ p_L &= 2v_{L1}. \end{aligned}$$

- More profitable than flat pricing when:

$$\begin{aligned} v_{L1} &> \pi v_{H1} \\ v_{H2} &> v_{L1} \end{aligned}$$

- More profitable than offering service to everyone when

$$\pi\left[v_{H2} - v_{H1}\right] > v_{L2} - v_{L1}.$$

- (Basically just PD wrt enhanced service.)

No commitment

No-enhanced service. Flat pricing optimal, but seller is worse off.

Enhanced service. Depends on whether customers can "delete" or "delay."

Delay purchase: Same equilibrium as with commitment.

Delete cookies: Can't offer low price first period, since consumers can delete. Can't offer high price first period, since can't commit to low price second period. So flat pricing is the only equilibrium.

What makes sellers worse off without commitment?

- As usual, lack of commitment makes sellers worse off. How?
- Answer: without commitment, buyers will pursue a mixed strategy
  - Suppose the HV type accepts any first-visit price less than p_H with probability 1. Then if the seller observes a rejection, it must be a LV type. Then seller will offer a low value on second visit. But then HV type wouldn't want to always accept.
  - Similar argument shows HV type won't reject a price less than p_H with probability 1.
- See Fudenberg and Tirole, chapter 10.2.2 and/or Curtis Taylor (2002)

Competition

- Arbitrary number of firms and consumers, no commitment, positive marginal costs c.
- Symmetric equilibrium involves: consumers optimally determining whether to stay or switch, firms choosing prices to maximize profit, profit being driven to zero.
- Define incremental value of enhanced service:

$$\begin{aligned} e_H &= v_{H2} - v_{H1} \\ e_L &= v_{L2} - v_{L1}. \end{aligned}$$

and assume $e_L < e_H$.

Summary of possible equilibria

- All charge flat price? No, since raising price for 2nd visit pays.
- All customers loyal in equilibrium:

$$\begin{aligned} p_0 &= c - \frac{e_L}{2} \\ p_b &= c + \frac{e_L}{2}. \end{aligned}$$

- Only high-value customers loyal in equilibrium:

$$\begin{aligned} p_0 &= c - \frac{\pi e_H}{2} \\ p_b &= c + \frac{(2-\pi)e_H}{2}. \end{aligned}$$

Details for all-loyal case

- Consumer optimization:

$$\begin{aligned} v_{H2} - p_b &\geq v_{H1} - p_0 \\ v_{L2} - p_b &\geq v_{L1} - p_0 \end{aligned}$$

- Rewrite:

$$\begin{aligned} p_b &\leq p_0 + e_H \\ p_b &\leq p_0 + e_L. \end{aligned}$$

- Zero profit:

$$p_0 + p_b = 2c.$$

Will firms deviate?

- Solution is $p_0 = c - e_L/2$ and $p_b = c + e_L/2$.
- Consider a firm that raises p_b to $p_0 + e_H$
  - Low-value customers will switch
  - High-value customers pay more
- This will *not* be profitable when:

$$\begin{aligned} p_0 &+ \pi(p_0 + e_H) + (1-\pi)p_0 < \\ p_0 &+ p_b = 2p_0 + e_L, \end{aligned}$$

- Reduces to

$$\pi e_H < e_L.$$

- Note this is likely when $e_L \approx e_H$.

Details for high-value loyal case

- Consumer optimization:

$$\begin{aligned} p_b &\leq p_0 + e_H \\ p_b &\geq p_0 + e_L. \end{aligned}$$

- Profits come from everyone buying at p_0 and high-value types buying at p_b. Zero profit implies:

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

- Deviation: will a firm cut its price to keep low-value customers? Won't pay when $e_L < \pi e_H$.
- This is "CD club equilibrium." HV types are loyal, LV types keep switching. Loyal HV type pays more due to LV disloyalty.

Lock-in equilibrium

- These are “lock-in equilibria”
  - Consumers benefit from personalized service only if they visit same vendor second time
  - So there is a “switching cost”
  - Firms compete to get loyal customers
  - Competition prices down first for first visit, up for second
- Second-visit consumers always subsidize first-visit consumers
- In case where low-value customers switch, the high-value type subsidizes the low-value type

Conclusion

- Conditioning is profitable if there are enough myopic consumers.
- Conditioning is profitable if the seller can provide an enhanced service that has different value to high- and low-value consumers.
- Conditioning is profitable if seller can differentially provide access to enhanced service.
- Competition can create lock-in equilibrium in which neither type switches or only the low-value type switches.