31E11100 - Microeconomics: Pricing

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Lecture 9: Topics on dynamic pricing: time-inconsistent buyers
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Introduction

- So far we have assumed that buyers are rational and know what is best to them
- The broad literature on *behavioral economics* seeks to understand situations, where decision makers are boundedly rational, make mistakes, or have otherwise non-standard preferences.
- For example, decision makers may exhibit:
  - self-control problems
  - loss aversion
  - inattention
  - overconfidence
- For pricing, a relevant question is:
  - Can firm's exploit buyers' bounded rationality, and how?
- Of course, one could also analyze biases by firms' managers, but this appears to be less first-order in this context

Pricing with time-inconsistent buyers

- In this lecture we take up one interesting example: buyers with time-inconsistent preferences
  - Preferences change over time
  - Hyperbolic discounting or $\beta - \delta$ preferences as the simplest example
  - Such preferences lead to self-control problems, preference for commitment, procrastination
- How should seller take into account such preferences in pricing?
- To make the question interesting, we think about products, where benefits and costs occur at different times:
  - Investment goods: current costs and future benefits (health clubs, healthy food, ...)
  - Leisure goods: current benefits and future costs (unhelthy food, credit card borrowing, ...)

Standard (geometric) Discounting

- Decision making over time.
  - Denote time periods by $t = 0, 1, 2, ...$
  - Instantaneous utility in period t from action a_t is $u(a_t)$.
  - Geometric discounting: for all s, and $t > s$, the discounted utility in period s from action a_t in period t is $\delta^{t-s}u(a_t)$ for some $0 \leq \delta \leq 1$.
  - No special importance for current period.

Hyperbolic Discounting

- An example of hyperbolic discounting: $\beta - \delta$ preferences.
- Utility in period s from action a_t in period t is $\beta\delta^{t-s}u(a_t)$ for some $\beta < 1$.
- Notice that current period has now a special meaning.
  - Waiting from now until tomorrow is discounted by $\beta\delta$.
  - Waiting from tomorrow until the day after tomorrow is discounted by δ from today's point of view.
  - Notice that tomorrow, the discount rate between tomorrow and the day after tomorrow is $\beta\delta$ and not δ.
  - Hence the preferences between periods change as time goes on.
- Hence we talk about time inconsistent preferences.

Example

- You have money for a single movie ticket.
- Different movies are shown during the next four weeks.
- The instantaneous willingness to pay for these movies is as follows:
  - $v_0 = 2, v_1 = 3, v_2 = 5, v_3 = 9.$
- If you have geometric discounting, you should choose the t that maximizes

$$\delta^t v_t.$$

- Furthermore, if you plan in period $t = 0$ to choose $t = 3$, then waiting until $t = 3$ will be optimal also at $t = 1$ and $t = 2$.

- Consider now $\beta - \delta$ preferences. Let $\beta = \frac{1}{2}$ and $\delta = 1$.
- How will you choose in this case?
  - Suppose you are sophisticated and you understand what your preferences look like.
  - By backward induction, you realize that in $t = 2$, you choose between $v_2 = 5$ and $\beta\delta v_3 = \frac{9}{2} < 5$.
  - Hence you know that if you reach $t = 2$, you will choose $v_2 = 5$.
  - In $t = 1$, you therefore compare $v_1 = 3$ and $\beta\delta v_2 = \frac{5}{2} < 3$ and you choose v_1.
  - So in $t = 0$, you choose $v_0 = 2 > \beta\delta v_1 = \frac{3}{2}$.

- Assume now that you are naive:
  - You think that your preferences for all future periods coincide with your current preferences.
  - Starting in $t = 0$, you compare $v_0 = 2$ to $\max_t \beta\delta^t v_t = \max\{\frac{3}{2}, \frac{5}{2}, \frac{9}{2}\} = \frac{9}{2}$.
  - Hence you decide to wait expecting to wait until $t = 3$.
  - In $t = 1$, you compare $v_1 = 3$ to $\max\{\frac{5}{2}, \frac{9}{2}\} = \frac{9}{2}$ and decide to wait.
  - In $t = 2$, you compare 5 to $\frac{9}{2}$ and therefore you choose v_2.
- Notice that you make a false prediction about your future behavior at $t = 0$.
- Still you gain relative to the sophisticated agent: From first period perspective, your payoff is $\frac{5}{2} > 2$.

Hyperbolic Discounting

- In late 1990's this model became incredibly popular.
- Laibson: For sophisticated agents, too little pension savings because of $\beta - \delta$ preferences.
- It can explain why people sometimes commit (at a cost) to options that restrict future choices.
- Naive agents: Explains procrastination.
- Yields new insights but at a big cost:
  - What about normative economics here? If preferences change, whose preferences should matter?
  - As you can see in the above simple example, the analysis is really the analysis of a game, not a single decision problem.
  - How to select between various equilibria in games where an agent plays against her future selves?

Pricing with Time-Inconsistent Buyers

- Model by DellaVigna and Malmendier, QJE 2004.
- Three periods $t = 0, 1, 2$.
- A monopolist offers a service to be consumed in $t = 2$.
- Setup cost of K per customer, service cost α for providing the service.
- Buyers with $\beta - \delta$ preferences.
- Consumption has immediate cost c and delayed benefits b that occur in $t = 2$.
  - Health club is the leading example in the paper.
  - Also calling plans, credit cards etc.

Pricing with Time-Inconsistent Buyers

- Costs are unknown in $t = 0$ and drawn from the uniform distribution in $t = 1$.
- Buyer and firm are both risk-neutral.
- The benefits are known in advance and $0 < b < 1$.
- Seller proposes a contract of the form (L, p).
  - L is an (unconditional) up-front payment that is paid regardless of whether the service is eventually used.
  - Contract is accepted or rejected in $t = 0$.
  - p is the fee for using the service after learning c in period 2.

Pricing with Time-Inconsistent Buyers

- Summarizing the timing:
  - $t = 0$
    - ★ Firm offers contract, buyer accepts and pays L in $t = 1$ or rejects and just gets reservation utility $\overline{u}$ in period $t = 1$.
    - ★ If agent accepts, firm pays setup cost K in $t = 1$.
  - $t = 1$
    - ★ Buyer learns her cost c.
    - ★ Decides whether to consume the service or not.
    - ★ If yes, pays p and incurs cost c.
  - $t = 2$
    - ★ If buyer consumer, she experiences utility b otherwise 0.

Time-Consistent Buyer

- Start with the benchmark case with $\beta = 1$, i.e. time-consistent buyer.
- Buy if and only if

$$\delta b - c - p \geq 0 \text{ or } c \leq \delta b - p.$$

- Hence expected payoff at $t = 0$ from accepting the contract is

$$U^{TC} = \delta[-L + \int_0^{\delta b - p} (\delta b - p - c)\, dc].$$

- By not consuming, she gets $\delta \overline{u}$.
- The firm makes expected profit $\pi(L, p)$ if the agent accepts:

$$\pi(L, p) = \delta[L - K + \int_0^{\delta b - p} (p - \alpha)\, dc]$$

- Hence firm chooses (L, p) to maximize $\pi(L, p)$ subject to $U^{TC} = \delta \overline{u}$.

Time-Consistent Buyer

- Hence we can write the problem as:

$$\max_p \delta[\int_0^{\delta b - p} (\delta b - \alpha - c)\, dc - K - \overline{u}].$$

- Notice that this is the problem of maximizing the sum of profit and consumer surplus.
- Hence the optimal choice here is:

$$p^{TC} = \alpha.$$

- Since this is a completely standard model, price = MC and lump sum extracting all surplus is optimal.

Sophisticated Time-Inconsistent Buyer

- Now $\beta < 1$.
- Buy iff
$$c \leq \beta\delta b - p.$$
- Ex ante payoff to a sophisticated buyer:
$$U^S = \beta\delta[-L + \int_0^{\beta\delta b - p} (\delta b - p - c)\, dc].$$
- By rejecting, reservation utility is $\beta\delta\overline{u}$.

Sophisticated Time-Inconsistent Buyer

- So the maximization problem for the firm is now:

$$\max_{p} \delta[\int_0^{\beta\delta b - p} (\delta b - \alpha - c)\, dc - K - \overline{u}].$$

- Again, the firm wants to sell whenever it is first-best from the point of view of the firm and the buyer in period $t = 0$.
- But now this implies setting

$$p = \alpha - \delta b\,(1 - \beta)\,.$$

Sophisticated Time-Inconsistent Buyer

- Pricing below marginal cost.
  - This is done to help the agent.
  - Since the agent in period $t = 0$ understands her preferences at $t = 1$, she realizes that she would consume too little at $p = \alpha$.
  - Commitment to a lower price than marginal cost makes corrects the buyers decisions in $t = 1$ from the point of view of the buyer in $t = 0$.
- In effect, the firm is selling a commitment device for period $t = 1$.
- Pricing is efficient in the sense that total surplus of the firm and the period 0 consumer is maximized.

Naive Time-Inconsistent Buyer

- Finally we consider the case where $\beta < 1$ but in $t = 0$, the buyer believes that $\beta = 1$ i.e. that she is time-consistent.
- We assume that the firm knows this naive belief.
  - This assumption makes sense from a descriptive point of view.
  - Firms can learn this feature in the market when dealing with many buyers.
  - At the same time, a major assumption in terms of modeling.
  - Firms know something about the buyers that contradicts their own view. Goes against the usual assumption of consistent priors.

Naive Time-Inconsistent Buyer

- In $t = 1$, the buyer consumes if and only if $c \leq \beta\delta b - p$.
- In $t = 0$, she expects to consume if $c \leq \delta b - p$.
- Hence in $t = 0$, the ex-ante payoff to naive buyer is

$$U^N = \beta\delta[-L + \int_0^{\delta b - p} (\delta b - p - c)\, dc].$$

- Firm's expected profit (knowing that the buyer is naive):

$$\pi(L, p) = \delta[L - K + \int_0^{\beta\delta b - p} (p - \alpha)\, dc]$$

Naive Time-Inconsistent Buyer

- Again, L must be such that $U^N = \beta\delta\overline{u}$.
- Hence we can write the profit maximization problem as:

$$\max_p \delta[\int_0^{\beta\delta b-p} (\delta b - c - \alpha)\, dc + \int_{\beta\delta b-p}^{\delta b-p} (\delta b - c - p)\, dc - K - \overline{u}]$$

- The first integral is the true surplus.
- The second integral is a fictitious surplus that the naive agent believes that she will get.
- It arises only because she believes that she will accept trades that she will not.
- Also here: price below marginal cost

Discussion

- Both versions of the model feature price below marginal cost, but for different reasons
- With sophisticated consumer, low price helps the buyer to commit to more use
- With naive consumer, seller exploits buyer's mistake: buyer is willing to pay a higher up-front payment L since she is overly confident of her probability of consuming
- The same model would apply with some relabeling of variables to the case of leisure goods, but with opposite conclusion:
  - High price of use, low up-front payment
  - Think about credit cards: low fixed fee, high interest rate

Discussion

- Need to distinguish between time-consistency as such and naivete
- Sophisticated (time-incosistent) consumers benefit from the extra commitment that the pricing scheme gives
- But if buyers are also naive, sellers exploit them by setting a too high up-front payment
- What about differentially sophisticated buyers?
- Second-degree price discrimination possible.
- For example Eliaz and Spiegler, REStud 2006 "Contracting with Diversely Naive Agents" takes first steps in this direction.

Further readings

- The model analyzed here is based on DellaVigna and Malmendier (2004): "Contract design and self-control: theory and evidence", Quarterly Journal of Economics. Related empirical evidence here: DellaVigna and Malmendier (2006): "Paying Not to Go to the Gym", American Economic Review.
- For hyperbolic discounting and its application on saving behavior, see Laibson (1997): "Golden Eggs and Hyperbolic Discounting", Quarterly Journal of Economics.
- There is a lot of literature on behavioral econonimcs applied in IO and pricing. For example, for pricing and loss-averse consumers, see Heidhues, P., & Koszegi, B. (2008). Competition and price variation when consumers are loss averse. American Economic Review, or Herweg and Mierendorff (2013): "Uncertain demand, consumer loss aversion, and flat-rate tariffs", Journal of the European Economic Association.

- The book Ran Spiegler (2011): "Bounded Rationality and Industrial Organization", Oxford University Press, is a comprehensive introduction to topics in pricing, IO and behavioral economics.
- A shorter survey on different related topics: Grubb (2015): "Behavioral Consumers in Industrial Organization: An Overview", Review of Industrial Organization.