Storable goods with time-varying preferences

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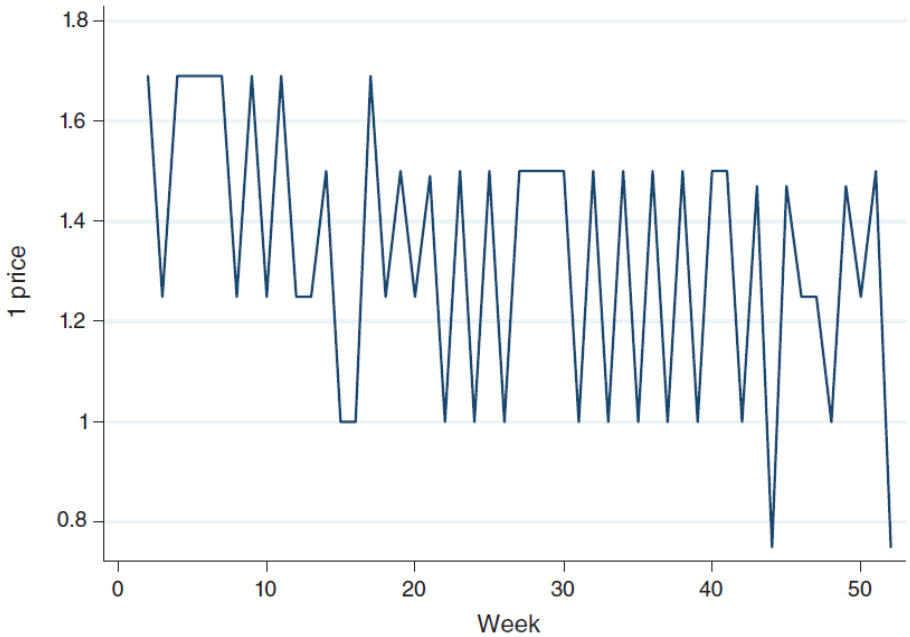
Introduction

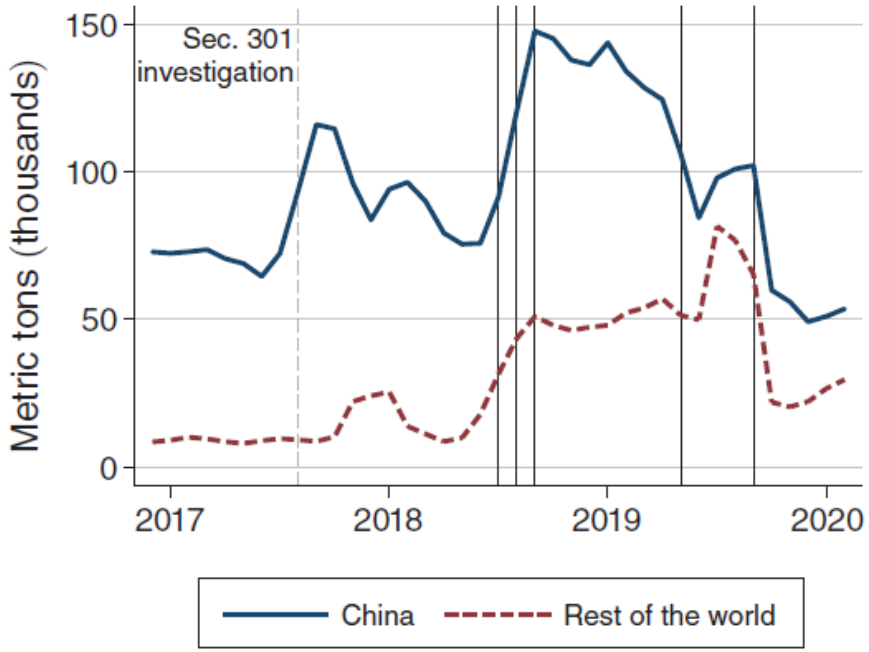
- Many products are perishable but can be stored for future consumption.
  - Beverages, Food, Coffee, Detergents, oil, fuel etc
- Producers and consumers act in an intertemporally optimal manner.
- Do producers and consumers know current and future preferences?
- With constant demand over time there is no reason for buyer to store.
- Why consumers store?
  - Expect higher prices
    - ★ Demand changes, Cost changes, Shocks
- Do producers want consumers storage?
  - Depends
    - ★ Demand (increasing?), Cost (changes?), price discrimination, competition

Introduction

Evidence



Hendel & Nevo (2013; AER)-2 litres Coca-cola



Cavallo et al. (2021;AER Insights)

Introduction

Motivation

- Are preferences constant over time?
  - e.g., Strack and Taubinsky (2022)-No
  - Agents revise their decisions because of changes in preferences, e.g., preference reversal (Ericson and Laibson 2019) or because they are time inconsistent (e.g., Laibson 1997, O'Donoghue and Rabin 1999).

Example

A consumer can purchase a product at day 0 planning to consume it in days 1, 2. An exogenous event results in different tastes of the same consumer in days 1 and 2.

Example

When planning a week in advance, 50% are *optimistic* and choose a healthy over an unhealthy snack, while this fraction drastically falls to 20% when individuals are given a non-anticipated opportunity to revise their plans a week later (Read and van Leeuwen 1998).

Introduction

This paper

Problem

We allow for changes in preferences in storable good markets.
How is consumer stockpiling behavior affected?
How does this affect dynamic pricing?
What are the implications?

1. A fraction of consumers is **naïve** – Underestimate utility (actual MU is increasing) or overestimate (actual MU is decreasing).
2. Consumers are fully **rational** but face **uncertainty** about future preferences.
3. **Extensions** – Non-linear pricing, commitment.
4. Empirical implications (under construction).

Introduction

Preliminaries

- **Ex ante** and **ex post** storage are critical. So far the literature consider those two identical.
- Increasing demand can lead to discounts and lower prices.
- Decreasing demand can lead to higher prices.
- Uncertain demand when it is slightly increasing can lead to lower prices.
- With non-linear pricing the firm design incentive compatible menus $\longrightarrow$ information rents $+$ additional rents in some cases.
- Under commitment a firm can induce or deter storage (ex ante or ex post) more easily and distort prices at its convenience.

The Model

Consumers

- Two-period market
- Continuum of consumers; a proportion λ sophisticated and $1-\lambda$ are naïve.

Definition

Underestimating consumers $u^{n\prime}(\cdot) > u^{s\prime}(\cdot)$ *and* $|u^{n\prime\prime}(\cdot)| \geq |u^{s\prime\prime}(\cdot)|$
Overestimating consumers $u^{n\prime}(\cdot) < u^{s\prime}(\cdot)$ *and* $|u^{n\prime\prime}(\cdot)| \leq |u^{s\prime\prime}(\cdot)|$

- Buyers can store at a unit cost $c \geq 0$.
- Static demand is $D^i(p_\tau)$, $i = s, n$ and $\tau = 1, 2$.
- Aggregate demand is $\sigma(p_\tau) \triangleq \lambda D^s(p_\tau) + (1-\lambda) D^n(p_\tau)$
- $S(p_1, p_2^e)$ the *ex ante* storage demand, and $\overline{S}(p_1, p_2^e)$ the *ex post* or *residual* storage.

The Model

Firm & timing

- The firm's aggregate profit is $\Pi \triangleq \Pi_1 + \Pi_2$

$$\Pi_1 = p_1 \left[D^s \left(p_1 \right) + S \left(p_1, p_2^e \right) \right] \quad \text{and} \quad \Pi_2 = p_2 \left[\sigma \left(p_2 \right) - \overline{S} \left(p_1, p_2^e \right) \right].$$

Timing:

1. $\tau = 1$
   1. the firm sets the price for the good
   2. consumers purchase a quantity of the good
   3. consumers learn their actual preferences and consumption takes place
2. $\tau = 2$ same as $\tau = 1$ but now consumers know their actual preferences.

Relevant benchmark

1. Consumers are perfectly aware of their actual preferences.
   The firm's static profit max problem $\max_{p_\tau} p_\tau \sigma(p_\tau) \longrightarrow p_\tau^m$ remains constant over time.
2. $1-\lambda$ of the consumer population consists of naïfs but there is no storage.
   In $\tau = 1$ $\max_{p_1} p_1 D^s(p_1) \longrightarrow p_1^{sm}$
   In $\tau = 2$ $\max_{p_2} p_2 \sigma(p_2) \longrightarrow p_2^m$

Underestimating consumers

- Ex ante storage is

$$S\left(p_1, p_2^e\right) = \begin{cases} \sigma\left(p_1 + c\right) & \text{if} \quad p_1 + c < p_2^e \\ \left[0, \sigma\left(p_1 + c\right)\right] & \text{if} \quad p_1 + c = p_2^e \\ 0 & \text{if} \quad p_1 + c > p_2^e. \end{cases}$$

- **Storability constraint.** $p_1 + c \geq p_2$.
- $p_1 + c > p_2$. This removes consumers' storage incentives and leads to the static monopoly prices.
- $p_1 + c = p_2$. Consumers are indifferent between storing the good in the first period and purchasing it in the second period.
- **Sequential optimality constraint.**

$$p_2\left(\overline{S}\left(p_1, p_2^e\right)\right) \triangleq \arg\max_{\widetilde{p}_2} \widetilde{p}_2 \left[\sigma\left(\widetilde{p}_2\right) - \overline{S}\left(p_1, p_2^e\right)\right].$$

Underestimating consumers

Feasibility

- Firm's optimization problem

$$\max_{\{p_1,p_2\}} \Pi(p_1,p_2) \quad s.t. \quad p_2\left(\overline{S}(p_1,p_2^e)\right) \triangleq \arg\max_{\widetilde{p}_2} \widetilde{p}_2\left[\sigma(\widetilde{p}_2) - \overline{S}(p_1,p_2^e)\right]$$

Lemma

For $c < \overline{c}^u$ the dynamic storage solution is feasible. Prices are $p_2^{*u} = p_1^{*u} + c$, ex ante storage is $S^{*u} > 0$ and ex post storage $\overline{S}^{*u} = \lambda S^{*u} > 0$.

- Naifs do not store as their marginal utility ex post $+ c >$marginal utility in $\tau = 2$, i.e., p_2^{*u}.

Underestimating consumers

Equilibrium

Proposition

For relatively low values of the storage cost in equilibrium the dynamic storage solution arises.

- If $\lambda \leq \widetilde{\lambda}$ the firm may prefer the dynamic storage solution to the static one.
- If $\lambda > \widetilde{\lambda}$ the two solutions are mutually exclusive and the dynamic storage solution can be harmful.
  - A dynamic solution without storage can emerge as an equilibrium.

Underestimating consumers

Equilibrium pricing

Proposition

In the **first** *period, the equilibrium price can be* **lower** *than the static monopoly price if λ is low enough. In the* **second** *period, the equilibrium price is* **lower** *than the static monopoly price in the presence of storage.*

- If λ sufficiently large and c low enough prices are higher.
  - Storability constraint is binding
  - ex post storage is sufficiently harmful and the firm must deter it.
- If λ sufficiently small it can be that dynamic storage $\succeq$ static monopoly when both feasible and prices are lower.

Proposition

The price with storage increases with λ in each period if it is sufficiently lower than the static monopoly price in the first period.

Overestimating consumers

- $p_2^e < p_1$, removes consumers' incentives for ex ante storage, i.e., $S(p_1, p_2^e) = 0$
- Ex post storage can emerge, i.e., $\overline{S}(p_1, p_2^e) > 0$.
- $\overline{S}(p_1, p_2^e)$ is obtained from equalizing marginal utilities of the naifs

$$u^{n\prime}\left(D^s(p_1) - \overline{S}(p_1, p_2^e)\right) + c = u^{n\prime}\left(D^n(p_2^e)\right),$$

where $u^{n\prime}\left(D^n(p_2^e)\right) = p_2^e$.

Proposition

The **first** *period price is* **higher** *than the static monopoly price if the storage cost is low enough. The* **second** *period price is* **lower** *than the static monopoly price in the presence of storage.*

Overestimating consumers

Proposition

The price with storage decreases with λ in the first period and increases with λ in the second period.

- **Counterintuitive**: Higher $\lambda \longrightarrow$ higher second period demand$\longrightarrow$ higher ex post storage incentives.
- This could push the firm to increase the first period price.
- But a higher λ reduces the impact of naïfs' aggregate storage on the second period demand, which allows the firm to alleviate the price distortion from the static monopoly level.

Rational consumers

- Consumers are uncertain about their preferences at $\tau = 1a, b$ and hold unbiased beliefs.
- At $\tau = 1a, b$ assign a prob. $\theta \in (0, 1)$ of having u^h and $1 - \theta$ of having u^l.
- $\widetilde{D}(p_\tau) \triangleq \arg\max_q \left\{\theta u^h(q) + (1-\theta) u^l(q) - q p_\tau\right\}$ the static demand function arising from the consumer expected utility maximization problem.
- Two main cases.
  1. consumers buy in $\tau = 1$ to store ex ante. When prices are expected to increase in the second period, $S(p_1, p_2^e) > 0$. Prices are linked $p_1 + c = p_2$.
  2. they don't store ex ante.

Rational consumers

- When prices are expected to increase in the second period, $S\left(p_1, p_2^e\right) > 0$. Prices are linked $p_1 + c = p_2$.
- After learning their preferences, buyers choose consumption$\rightarrow$ $\overline{S}\left(p_1, p_2^e\right)$ carried in the second period.
- If $p_1 + c > p_2 \rightarrow S\left(p_1, p_2^e\right) = 0$ and $\overline{S}\left(p_1, p_2^e\right) > 0$.
- Define $\widetilde{D}_2\left(\cdot\right)$ second period demand and $\partial \widetilde{D}_2 / \partial \zeta > 0$.
- Ex ante and ex post storage are determined by sequential optimality and equalization of marginal utilities (when both are positive).

Rational consumers

Results

Proposition

A. When ζ is sufficiently high, $S^* > 0$ and $\overline{S}^* > 0$ emerge in equilibrium for $c < \overline{c}^*$. Prices are p_1^* and $p_2^* = p_1^* + c$.
B. When ζ is sufficiently low, $\overline{S}^{**} > 0$ for $c < \overline{c}^{**}$. Prices are p_1^{**} and p_2^{**}, with $p_1^{**} + c > p_2^{**}$.

- Trade-off between promoting ex ante storage $S(\cdot)$ or only ex post storage $\overline{S}(\cdot)$.
- $(+)$ $S(\cdot) > 0$ increases consumption and sales to consumers with high valuation.
- $(-)$ $\overline{S}(\cdot) > 0$ low valuation consumers carry the amount of ex ante storage that is profit detrimental.

Rational consumers

Results

- When $(+) > (<) \left|(-)\right|$ then a growing $\widetilde{D}_2(\cdot)$ is beneficial for the firm and wants to promote (deter) ex ante storage.
- If $p_1^{**} + c > p_2^{**}$ only ex post storage emerges and the firm wants to deter storage.

Proposition

A. In $\tau = 1$, the price with ex ante and ex post storage is lower (higher) than the static monopoly price if ζ is low (high) enough and θ is high (low) enough. In $\tau = 2$, it is lower than the static monopoly price.
B. In $\tau = 1$, the price with only ex post storage is higher than the static monopoly price. In $\tau = 2$, it is lower than the static monopoly price.

- Results are consistent to the ones under consumer naïvete.

Robustness and extensions

Nonlinear pricing

- The firm can discriminate across consumers in order to extract their surplus.
- Given that consumers are ex ante identical, discriminating contracts can be provided only in $\tau = 2$.
- By revelation principle the menu constitutes an incentive compatible mechanism.
- High valuation consumers receive some informational rents from mimicking low valuation consumers.
- The opportunity to consume stored quantity provides consumers with some surplus in the second period.
- This leads the firm to offer some discount in the second period payment.

Robustness and extensions

Nonlinear pricing

- The firm intends to recoup such discount by charging a higher upfront payment in the first period.
- Then consumers have incentives to skip purchases in $\tau = 1$ and enjoy the discount in $\tau = 2$.
- With underestimating consumers, naïfs' retain some surplus.
- With overestimating consumers, naïfs can end up with losses as they are willing to accept an excessively high upfront payment.
- The firm can almost fully extract the surplus of sophisticates unless they benefit from skipping purchases (from an arbitrary deviating consumer).

Robustness and extensions

Commitment

- When the firm prefers to promote ex ante storage the equilibrium prices are still linked through the binding storability constraint.
- The firm is able to induce consumers to store the entire second period demand.
- Ex ante and ex post storage can coexist.
- When the firm prefers to promote ex ante storage first period and second period price increases are more effective compared to limited commitment.
- When the firm prefers to remove ex post storage a first period price increase and a second period price decrease are more effective compared to limited commitment.

Related literature and contribution

- Storable goods: Anton and Das Varma (2004), Hendel, Dudine and Lizzeri (2006), Hendel and Nevo (2013), Hendel, Lizzeri and Roketskiy (2015), Antoniou and Fiocco (2019, 2023).
  - No discrimination between ex ante and ex post storage.
  - Storage can be good or bad.

- Ericson and Laibson (2019), Strack and Taubinsky (2022), Eliaz and Spiegler 2006, DellaVigna and Malmendier 2004, Heidhues and Kőszegi (2009, 2017, 2021)
  - Time inconsistency, multiselves model.
  - The presence of naifs can benefit sophisticates.

Implications

- We separate storage decisions to ex ante and ex post. This affects pricing decisions in a critical manner.
- The presence of naïfs acts in a procyclical manner for the economy (if their share is large enough).
- Higher volatility in storable good markets can imply lower markups (slightly growing demand).
- Higher volatility in storable good markets can imply higher markups (significantly growing demand, constant or decreasing demand).
- Correlation between the VIX index or any similar constructed index and markups.

Thank You!!

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