Stores versus Storage

V. Bhaskar [1] Nikita Roketskiy [2]

[1]UT Austin

[2]University College London

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Theme

- Nonlinear pricing
- Storable goods

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  - instrument to extract rents
  - stark implications for consumer surplus and welfare
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  - storable
  - homogeneous
  - divisible

NB: Storable goods not to be confused with durable goods, although there are similarities

Menu of pack sizes

Question

How does ability to store affect

- extraction of rent,
- consumer surplus,
- prices and bundle sizes?

Summary

- Sellers' ability to extract surplus is reduced by consumers' ability to store
- Induced heterogeneity in inventories
- Sellers respond with a menu pricing to screen consumers.
- Rent cannot be extracted in bulk.
- Always a variety of pack sizes:
  - Small items for immediate consumption priced linearly
  - Large items for stockpiling priced using 2-part tariff
  - No intermediate items
  - Infrequent shopping
- Both sellers and consumers receive rents even when storage is almost costless (no Coasian dynamics)
- Long-lived monopolist limits arbitrage by being more conservative in the amount sold.

Roadmap

- Related literature
- Two-period setup
- Endogenous heterogeneity of inventories
- Characterization of equilibria
- Stationary environment
- Conclusion

Related literature

- *Storable goods:* Benabou (1989), Hong, McAffee and Nayyar (2002), Hendel and Nevo (2004, 2006a,b, 2013), Anton and Das Varma (2005), Su (2007, 2010), Ariga, Matsui and Watanabe (2010), Nava and Schiraldi (2012), Hendel, Lizzeri and Roketskiy (2014), Antoniou and Fiocco (2019, 2022)
- *Hidden savings:* Chiappori, Macho, Rey and Salanié (1994), Cole and Kocherlakota (2001), Park (2004)
- *Moral hazard contracts with renegotiation:* Fudenberg and Tirole (1990), Ma (1991), González (2004), Netzer and Scheuer (2010), Bhaskar and Roketskiy (2021, 2023)
- *Inf. design:* Condorelli and Szentes (2017), Roesler and Szentes (2017)
- *Common agency:* Bernheim and Whinston (1986), Martimort and Stole (2003), Calzolari and Pavan (2006)
- *Non-linear prices with heterogeneous consumers:* Mirrlees (1971), Mussa and Rosen (1978) onwards

Setup

- Two sellers, 1 and 2
  - marginal cost k
  - seller 1 offers a take-it-or-leave-it menu $p(x)$
  - seller 2 offers a take-it-or-leave-it menu $q(y)$
  - maximize profit, e.g.

$$\mathbb{E}[p(x) - kx]$$

- Continuum of **identical** consumers
  - **visit seller 1 in period 1 and seller 2 in period 2 or stay at home**

$$\begin{aligned} \max\{u(c_1) + \delta u(c_2) - p(x) - \delta q(y)\} \\ c_1 + \beta(s) = x \\ c_2 = y + s \\ c_1, c_2, s \geq 0 \end{aligned}$$

  - choice of s is **private**
  - past menus are not obserserved by sellers

Storage costs

- $\beta(s)$ is increasing, convex, twice cont. differentiable
- costly $\beta'(0) > 1$, ...
- but relevant $\beta'(0) < \delta u'(0)/k$
- e.g., iceberg: $\beta(s) = bs$, where $b \in (1, u'(0)/k)$.

Social planner's problem

- Welfare

$$W(x, y) = u(c_1) + \delta u(c_2) - kx - \delta ky$$

- Social optimum $x = y = c^*$ and $s = 0$:

$$u'(c^*) = k$$

Perfect information

Standard (static) reasoning does not apply
Inefficiency due to use of storage

- Period 2 at history s

  $q(y) = u(s+y) - u(s)$ $\qquad$ $\boxed{V(s) = u(s)}$

  $u'(s+y) = k$ $\qquad$ $c_2(s) = c^*$

- Period 1:

  $\beta'(s)u'(x - \beta(s)) = \delta u'(s)$ $\qquad$ $\boxed{u'(s) = \delta^{-1}\beta'(s)k}$

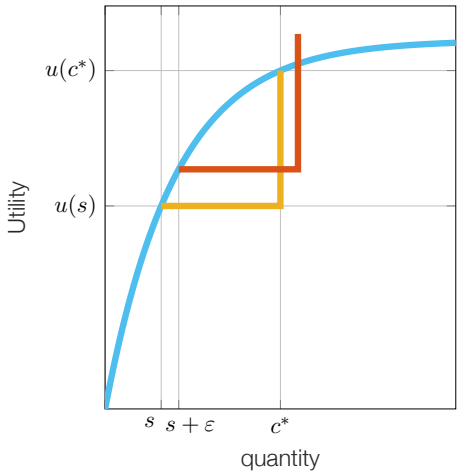
  $p(x) = u(x - \beta(s)) + u(s)$ $\qquad$ $c_1 = c^*$

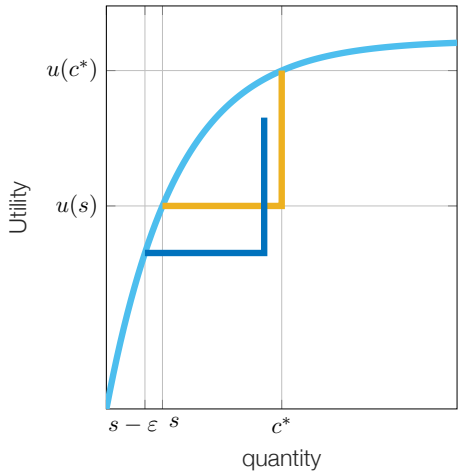
Symmetric strategies with unobserved inventories

Heterogeneity w.r.t. inventories
No extraction of rent in bulk

- suppose consumer stores $s < c^*$
- $c_2 = c^*$
- $y = c^* - s$ and $q = u(c^*) - u(s)$
- $V(s) = u(s)$

Symmetric strategies: Deviations





Symmetric strategies: Contradiction

- ε more units stored

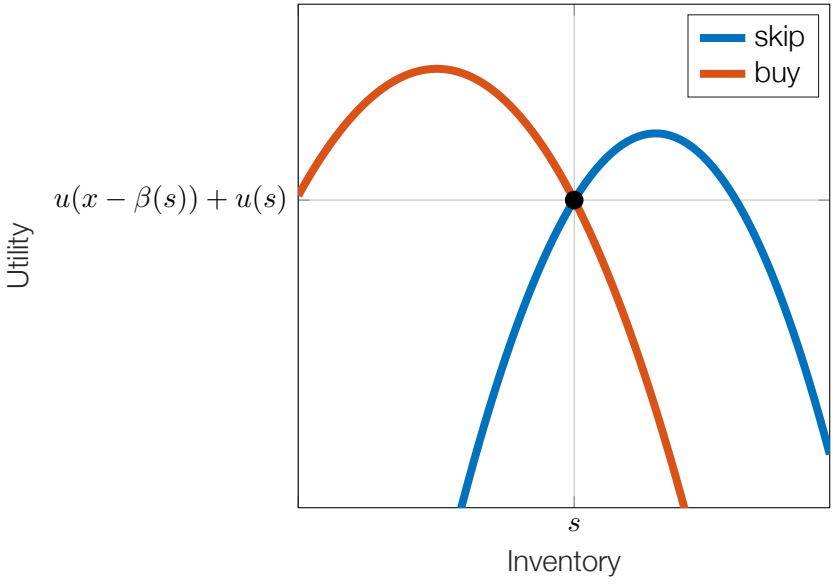
loss, $t = 1$	gain, $t = 2$
$-\varepsilon\beta'(s)u'(x-s)$	$\varepsilon\delta u'(s)$

- ε less units stored

gain, $t = 1$	loss, $t = 2$
$\varepsilon\beta'(s)u'(x-s)$	$-\varepsilon\delta u'(c^*)$

- at least one is profitable because $u'(s) > u'(c^*)$

Symmetric strategies: Contradiction, pt.2



“Big hammer” proposition

Recall that the consumer chooses the amount stored s privately.

Proposition

Fix menus offered by the sellers and consider a consumer who stores $\hat{s} > 0$ in the first period and purchases y_1 in the second period.
If the consumer is offered $y_2 < y_1$ such that the consumer is indifferent between buying y_1 and y_2, there exists a profitable deviation by the consumer.

Note: $y_2 \sim_{\hat{s}} y_1$ means that $y_1 - y_2$ is priced as if there’s symmetric info and seller has all bargaining power.

Scope and “nails”

Applies to all time horizons and short/long-lived sellers.

The proposition rules out consumer’s indifferences:
after every on-path history, the consumer has a unique optimal choice.

Binding IR and IC constraints (inequalities) imply indifferences.

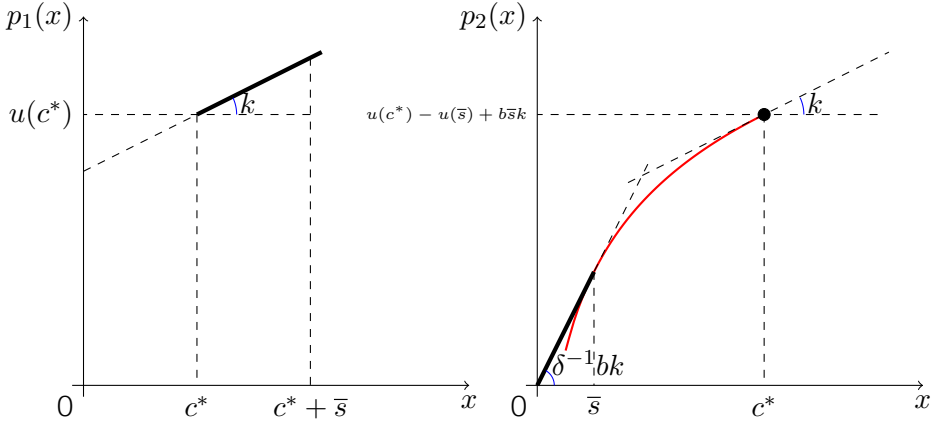
The consumer is excluded if she has the largest on-path (“worst”) inventory,no atoms or gaps in the distribution of inventories (except at zero).

Heterogeneous inventories

Proposition

In any period except the first, consumers are heterogeneous in inventories and sellers offer a variety of pack sizes on their menus.

Equilibrium (past menus not observed)



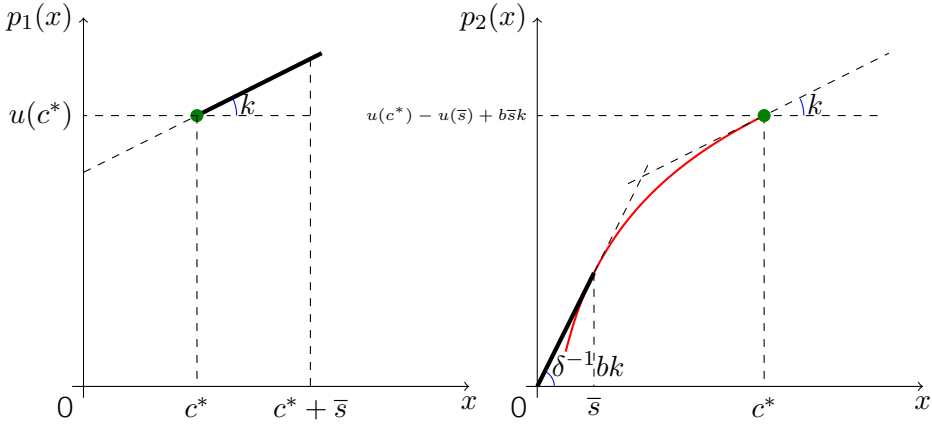
Equilibrium consumer behaviour

First-period consumption is efficient: $c_1 = c^*$.
Two broad **endogenous** categories of consumers:

- stockpilers (heterogeneous)
- **shop-to-mouth** consumers (homogeneous)

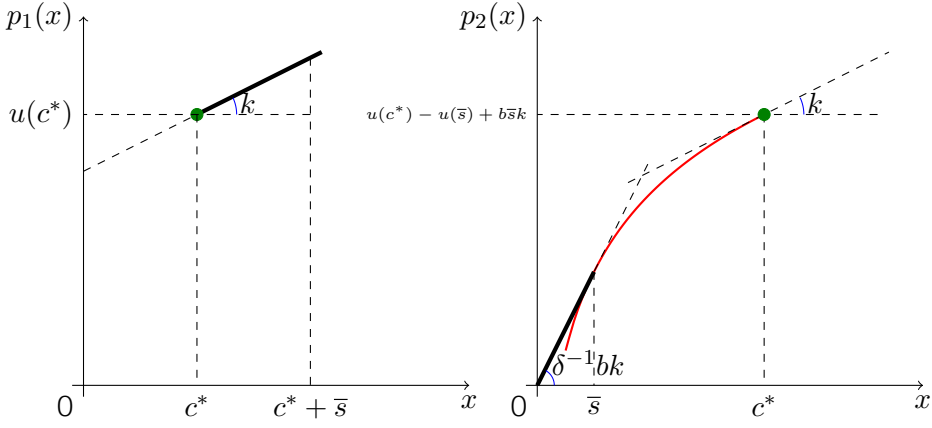
Shop-to-mouth consumers

keep no inventory; second-period consumption is efficient $\hat{c}_2(0) = c^*$



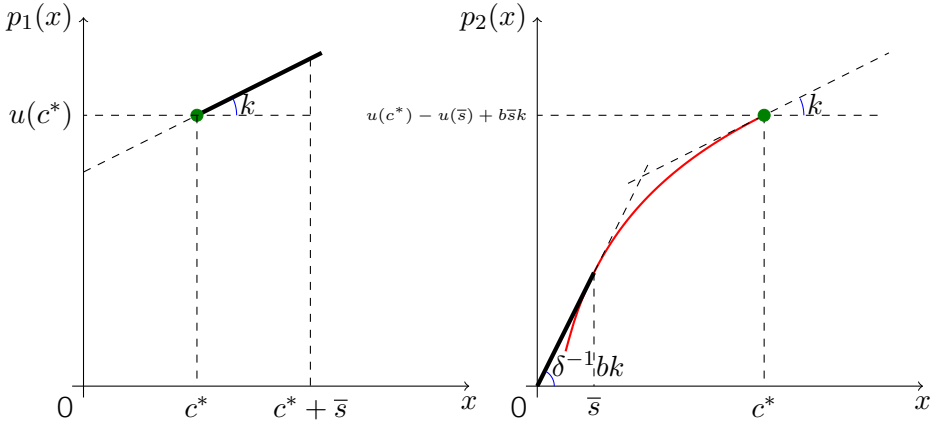
Shop-to-mouth consumers

added value of $c^* - \overline{s}$ is fully extracted by seller 2 because seller 1 cannot compete in a segment in which marginal utility is below $\delta^{-1}bk$



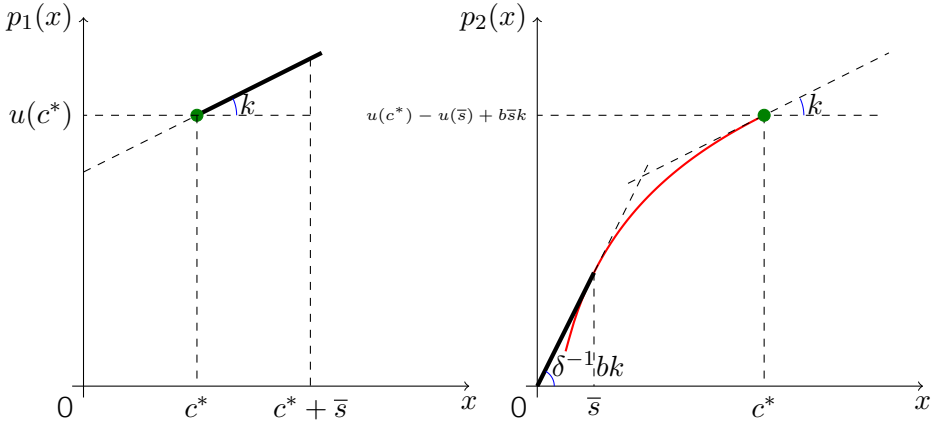
Stockpilers

purchase $c^* + bs$ in period 1; $s \sim F$, with the support $[0, \overline{s}]$;
consumption is distorted: $\hat{c}_2(s) = \overline{s}$

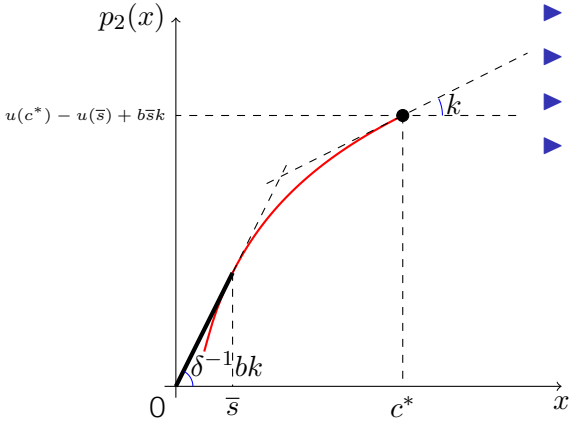


Stockpilers

their presence inhibits the ability to extract too much rent and reduces the prices in period 2 to a linear schedule $p_2(x) = \delta^{-1} bkx$.



Key equations



- seller 1: $u'(\hat{c}_1(s)) = k$
- stockpilers: $\beta'(s)u'(\hat{c}_1(s)) = \delta u'(\hat{c}_2(s))$.
- shop-to-mouth: $\beta'(0)u'(\hat{c}_1(0)) > \delta u'(c^*)$.
- screening:

$$-u''(\hat{c}_2(s))F(s) = \left[u'(\hat{c}_2(s)) - k\right] f(s)$$

Is two-period model special? Stationary environment

- **Two endogenous types of items: for consumption and for stockpiling**
- **Infrequent shopping**
- **Consumer surplus independent of storage cost**
- **“Violation” of Coase conjecture**

Setup

- Infinite time horizon
- Consumers:

$$\sum_{t=0}^{\infty} \delta^t [u(c_t) - p_t]$$

- Stationary equilibrium: $F_t(s) = F(s)$ for all t.
- **Important!** a consumer needs to come to the store to see the prices: $a_t \in \{0, 1\}$, no costs involved

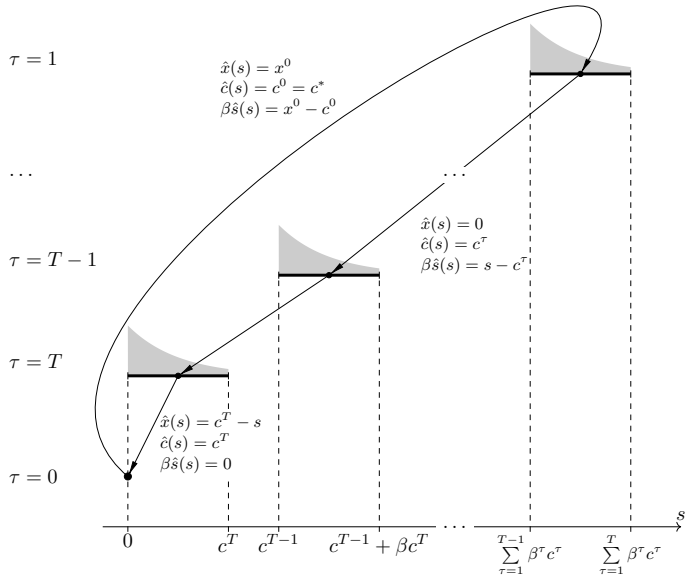
Consumption

Consumption cycle of length $T+1$ (better storage technology→longer cycle).

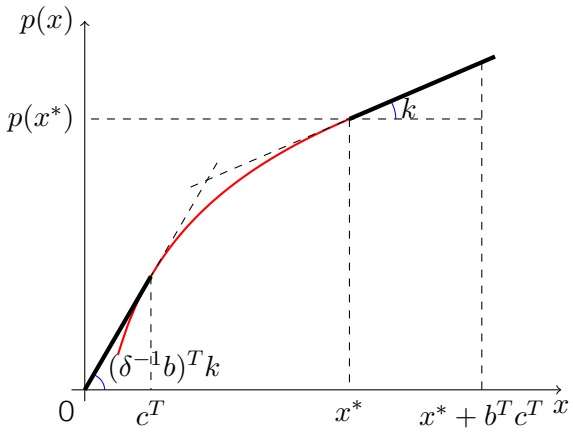
$$\boxed{u'(c^\tau) = (\delta^{-1}b)^\tau k}, \quad \tau = 0, 1, ..., T$$

Cross-sectional distribution = time-series distribution to achieve stationarity.

Consumption, pt. 2



Prices

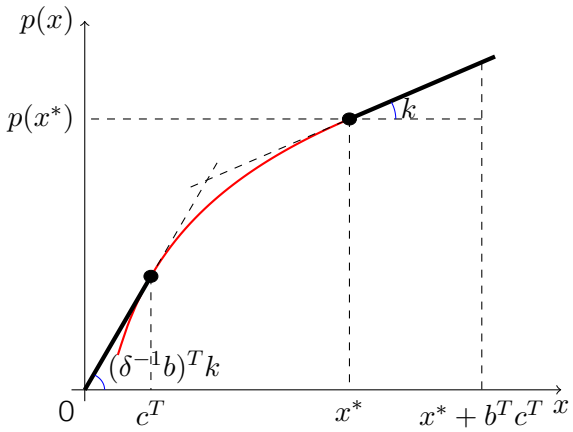


Two broad endogenous market segments:

- large packs for stockpiling
  - fixed fee and low per-unit price
  - x^* sufficient for the first $T-1$ periods of the cycle
- small packs for immediate consumption
  - no fee and large per-unit price

$$x_1 = x^* + b^T s, \qquad x_T = c^T - s, \qquad s \sim F$$

Consumer's payoff



Each consumer shops twice per cycle

- on one occasion the consumer is a stockpiler
- on the other—shop-to-mouth consumer

Per-unit price for small packs limits the fixed fee for the large packs

$$x_1 = x^* + b^T s, \qquad x_T = c^T - s, \qquad s \sim F$$

How long is the consumption cycle?

- Per-unit price $\rho := [\delta^{-1}b]^T k$ must be large enough.
- The mass of active consumers with large inventory must be small.
- This puts lower bound on ρ and, hence, T

$$\log 2 \geq g(\rho, k) := \frac{-u''(u'^{-1}(\rho))}{(\rho - k)} u'^{-1}(\rho)$$

- in the PE equilibrium, ρ is essentially independent of b: $\log 2 \approx g(\rho, k)$.

Consumer surplus

Proposition

Per-period consumer surplus of a consumer without inventory is

$$\max_c \{u(c) - \rho c\}.$$

The surplus is

- *independent of storage cost* b *and discounting* δ*, and*
- *decreasing in marginal cost* k*.*

Comments on payoffs

- Information rent cannot be extracted ex ante because ouside option of not buying leads to high future willingness to pay.
- This is a common feature for imperfect substitutes: off-path deviations protect the consumers from being exploited by the seller.
- On Coase: always strictly positive markup.

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- *Long-lived monopolist:
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