Imperfect Competition with Costly Disposal

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Motivation

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- Average unsold items in the fashion industry around 20%
- New products worth $900 million are yearly discarded all over France
- Since 2016, grocery stores are prohibited to dispose of edible food
- *Loi anti-gaspillage* broadens the regulation to non-food products, e.g., textiles, electronics, daily hygiene products
- Unsold products have to be recycled or donated
- The regulation is expected to come into effect in 2023

How do firms react to such a regulation? How are consumers affected?

Preview

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- Firms produce either early at low costs and with little information about demand, or later with more information yet at higher costs

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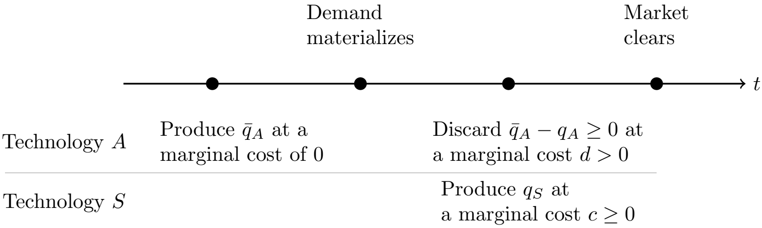
- Ex-ante demand is uncertain
- Firms produce either early at low costs and with little information about demand, or later with more information yet at higher costs
- Results:
  1. Firms delay production and forgo an early production cost advantage if and only if demand uncertainty and disposal costs are **both** simultaneously high
  2. Expected disposal decreases if the disposal cost goes up. However, production decreases, resulting in lower expected trade volume
  3. Ex-ante symmetric firms may choose asymmetric production strategies. Disposal cost substitutes information about demand, i.e., the better-informed firm's profit increases if disposal is costly

Literature

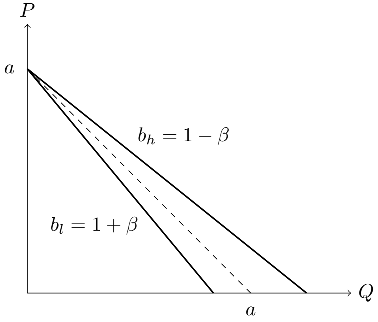
- **Commitment of production** Saloner (1986), Dada and van Mieghem (1999), Anupindi and Jiang (2008)
- **Observable inventory** Arvan (1985), Pal (1991), Thille (2006), Mitraille and Moreaux (2013)
- **Unobserved inventory** Allaz and Vila (1993), Hughes and Kao (1997), Ferreira (2006), Montez and Schutz (2021)
- **Information acquisition** Li et al. (1987), Vives (1988), Hwang (1993), Sasaki (2001)
- **First-mover advantage** Gal-Or (1985, 1987), Bagwell (1995), van Damme and Hurkens (1997, 1999), Liu (2005), Wang and Xu (2007)

Model's Timeline



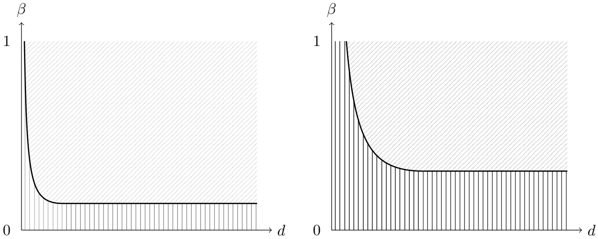
- **Production in advance A:**
  Produce inventory $\bar{q}_A$ when demand is uncertain at a marginal cost normalized to zero. After the demand realization, choose a sales volume $q_A \leq \bar{q}_A$ and dispose the rest of at a marginal cost $d > 0$
- **Production on the spot S:**
  Wait until demand is realized and produce sales volume q_S at a marginal cost $c \geq 0$

Stochastic Inverse Demand



- Linear demand with uncertain slope, $P(Q) = a - b_s Q$ with $s \in \{l, h\}$
- Both states are equally likely with $b_l = 1 + \beta$ and $b_h = 1 - \beta$, for $\beta \in [0, 1)$
- β measures the difference between the demand states, i.e., demand uncertainty
- Uncertain number of consumers with identical preferences

Monopoly Results I



(a) Low cost advantage (b) High cost advantage

Proposition: *The monopolist forgoes an early production cost advantage if and only if demand uncertainty and disposal costs are both simultaneously high.*

- If the monopolist knows the demand in advance, it produces $a/2b_s$
- Instead, suppose products are perfectly reversible, i.e., $d = 0$
- The monopolist produces $a/2b_h$ and sells $a/2b_l$ in the low demand state Sales volume

Monopoly Results II

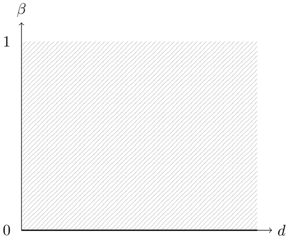
Proposition: *The monopolist's expected profit*

$$\mathbb{E}[\pi] = \begin{cases} \frac{(a+d)^2}{8(1+\beta)} + \frac{(a-d)^2}{8(1-\beta)}, & \text{if } d < \beta a \leq \frac{2ac-c^2+d^2}{2d}; \\ \frac{a^2}{4}, & \text{if } \beta a \leq \min\{d, \sqrt{c(2a-c)}\}; \\ \frac{(a-c)^2}{8(1+\beta)} + \frac{(a-c)^2}{8(1-\beta)}, & \text{else,} \end{cases}$$

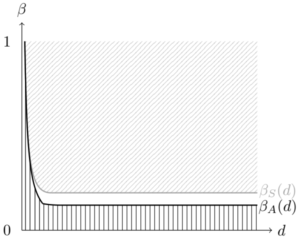
expected consumer surplus $\mathbb{E}[CS] = \mathbb{E}[\pi]/2$ *and expected disposal*

$$\mathbb{E}[\bar{q}_1 - q_1] = \begin{cases} \frac{\beta a - d}{2(1-\beta)^2}, & \text{if } d < \beta a \leq \frac{2ac-c^2+d^2}{2d}; \\ 0, & \text{else,} \end{cases}$$

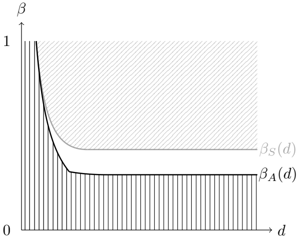
decrease in the disposal cost d. The expected price is not affected by the disposal cost.



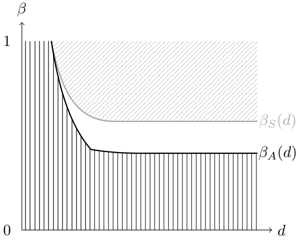
(a) No cost advantage



(b) Low cost advantage



(c) Med. cost advantage



(d) High cost advantage

Two Firms, Unobserved Inventory: Results

Proposition: *The firms forgo an early production cost advantage if and only if demand uncertainty and disposal costs are both simultaneously high.*

Proposition: *An increase in the cost to dispose of decreases*

(i) *the expected disposal;*

(ii) *the expected consumer surplus except*

   a. *the first mover postpones and produces on spot, at* $d = \min\{d|\beta_S(d) = \beta\}$ *expected consumer surplus increases discontinuously;*

(iii) *firms' expected profits except*

   a. *one firm postpones its production and becomes a second mover, at* $d = \min\{d|\beta_A(d) = \beta\}$ *the first mover's expected profits increase discontinuously;*
   b. *in the asymmetric equilibrium, the second mover's expected profit increases continuously.*

Extensions

1. **Combined Technology** Firms can use both simultaneously
   - There exists a unique perfect Bayesian equilibrium
   - Firms use technology S if and only if demand uncertainty and disposal costs are both simultaneously high
   - Expected profits, expected consumer surplus, and expected disposal decrease with the disposal cost
2. **Observable Inventories** Firms observe their competitor's inventory
   - There exists an additional (strategic) effect; if the disposal cost is high, the first mover can credibly commit to disposing of little
   - The first mover's profit may also increase continuously with the disposal cost
   - An asymmetric equilibrium also exists with the combined technology
3. **Perfectly Elastic Demand** Price may be below marginal cost
   - Modified demand function $P_\vartheta(Q) = \max\{a - b_\vartheta Q, 0\}$
   - Instead of disposing of their product, firms may give it away for free
   - This forms an equilibrium for high demand uncertainty

Conclusion

- Firms delay their production and forgo an early production cost advantage if and only if demand uncertainty and disposal costs are **both** simultaneously high
- An increase in the disposal cost lowers the disposed of amount
- Firms lower their inventory, resulting in an overall negative effect on the expected trade volume
- An increase in the cost of disposal decreases expected consumer surplus (with **few** exception)
- An increase in the cost of disposal decreases firms' expected profits (with **several** exceptions)

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Thank you

Monopolist's Strategy

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- Using strategy A the monopolist produces in advance
- Given its inventory $\bar{q}_1$ the optimal sales volume is

$$\underset{q_1 \in [0, \bar{q}_1]}{\operatorname{argmax}} P(q_1) q_1 - d(\bar{q}_1 - q_1)$$

- Taking the disposal costs into account, the optimal inventory and sales volumes are

q_1	high demand	low demand
$d < \beta a$	$\frac{a-d}{2(1-\beta)}$	$\frac{a+d}{2(1+\beta)}$
$d \geq \beta a$	$\frac{a}{2}$	$\frac{a}{2}$

- If the disposal cost is low, discard if demand is below expectations. Else sell the total inventory

Competition with Unobserved Inventories I

- Two firms (firm 1, and firm 2) produce a homogeneous product
- Demand is linear with an uncertain slope as before
- Firms choose either technology A or S
- In stage 1, firms with production technology A manufacture $\bar{q}_i \geq 0$ at marginal costs normalized to 0
- Then, demand materializes
- In stage 2, firms with technology S produce $q_{i,S} \geq 0$ at marginal costs $c \geq 0$ and simultaneously firms with technology A dispose $\bar{q}_i - q_{i,A} \geq 0$ at marginal costs $d \geq 0$
- Firms observe their competitor's production technology A or S yet not the competitor's inventory $\bar{q}_i$
- We assume $a \geq 2c + d$

Competition with Unobserved Inventories II

- Four different subgames exist
- A symmetric subgame (A, A)
  - A unique Nash-equilibirum in pure strategies exists
  - The firms' expected profits, consumer surplus and expected disposal decreases in d
- A symmetric subgame (S, S)
  - A unique Nash-equilibirum in pure strategies exists
  - The firms' expected profits, consumer surplus and expected disposal are independent of d
- Two asymmetric subgames (A, S) and (S, A)
  - A unique Nash-equilibirum in pure strategies exists
  - The leader's expected profit, consumer surplus and expected disposal decreases in d
  - The follower's expected profit increases

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Multiple Production Technologies

Extension

- We assumed firms have only one of the two production technologies
- We extend the model and allow firms to either dispose of or produce additional quantities after the demand realization
- There exists a unique symmetric Nash-equilibrium in pure strategies
- Firms forgo an early productioncost advantage if and only if demand uncertainty and disposal costs are both simultaneously high.
- Firms' expected profits, consumer surplus and expected disposal decrease in d

Observable Inventories I

- If firms observe their competitor's inventory an additional effect comes into play
- The inventory indicates intended sales: with large disposal costs, a firm can credibly sell almost its entire inventory even if demand is below expectations
- With a single production technology there exist a unique subgame perfect equilibrium
  - The same type of subgames exist as with unobserved inventories
  - Symmetric subgames (A, A) and (S, S) are equivalent
  - In the asymmetric subgame (A, S) the leader benefits from the additional effect
  - Both firms' expected profits or consumer surplus may increase in disposal costs

Observable Inventories II

- The additional effect of the inventory's credibility may also exist if firms have multiple production technologies
  - The same symmetric equilibrium exists as whit unobserved inventories
  - Additionally, there may exist an asymmetric equilibrium in which one firm has a larger inventory than the other
  - The large firm disposes of if demand is lower than expected and sells its inventory in the high demand state
  - The small firm sells its inventory if demand is low and produces additional quantities in the high demand state
  - Both firms' expected profits may increase in disposal costs; expected consumer surplus decreases

Observable Inventories II

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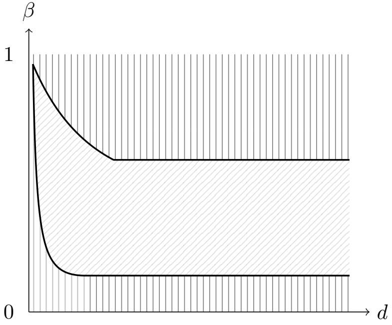
  - Both firms' expected profits may increase in disposal costs; expected consumer surplus decreases
- The European fast fashion market displays a similar pattern
  - H&M and Inditex (Zara, etc.) are the two biggest player in the market
  - H&M mainly produces in Asia; Zara mainly produces in Europe
  - Zara claims clothes are in retail within two weeks of the original design, while the shipment from Asia to Europe takes already more time alone
  - Zara discards 10%, half of the industry average

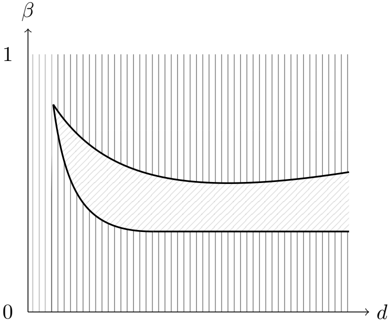
Demand Function I

- Results hinge to some extend on the assumption made on the demand function
- Since production costs in the first stage are normalized to zero, we allow for negative prices
- Demand may become perfect elastic for low prices
- If consumers and firms face the same disposal cost the demand is $P(Q) = \max\{a - b_s Q, -d\}$ and the results do not change
- As extension, we also present the case $P(Q) = \max\{a - b_s Q, 0\}$. Firms can insure against losses by selling large inventories
- For large levels of β, firms do not forgo an early production cost advantage. If demand is lower than expected, firms sell the total inventory at a price of 0

Demand Function II



(a) Low cost advantage



(b) High cost advantage

Leader Follower Subgame (A, S)

Suppose one chooses Strategy A, the other Strategy S

1. Leader (firm 1) chooses quantity $\bar{q}_1 \geq 0$
2. Demand materializes
3. Inventory $\bar{q}_1$ is *not* observed by the follower
4. Leader disposes of $\bar{q}_1 - q_1 \geq 0$ at a marginal cost d, simultaneously the follower (firm 2) chooses quantity $q_2 \geq 0$ at a marginal cost c
5. The market clears

Leader Follower Subgame Equilibrium I

- There exists a unique Nash-equilibrium in pure strategies

q_1	high demand	low demand
$d < \beta\frac{a+c}{2}$	$\frac{a-2d+c}{3(1-\beta)}$	$\frac{a+2d+c}{3(1+\beta)}$
$d \geq \beta\frac{a+c}{2}$	$\frac{a+c}{3}$	$\frac{a+c}{3}$

q_2	high demand	low demand
$d < \beta\frac{a+c}{2}$	$\frac{a+d-2c}{3(1-\beta)}$	$\frac{a-d-2c}{3(1+\beta)}$
$d \geq \beta\frac{a+c}{2}$	$\frac{2a-4c+\beta(a+c)}{6(1-\beta)}$	$\frac{2a-4c-\beta(a+c)}{6(1+\beta)}$

Leader Follower Subgame Equilibrium II

Lemma: *The leader's expected profit*

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$$\mathbb{E}[\pi_1] = \begin{cases} \frac{(a+2d+c)^2}{18(1+\beta)} + \frac{(a-2d+c)^2}{18(1-\beta)}, & \text{if } d < \beta\frac{a+c}{2}; \\ \frac{(a+c)^2}{9}, & \text{if } d \geq \beta\frac{a+c}{2} \end{cases}$$

expected consumer surplus $\mathbb{E}[CS] = \mathbb{E}[b_s(q_1 + q_2)^2/2]$ *and expected disposal*

$$\mathbb{E}[\bar{q}_1 - q_1] = \max\left\{\frac{\beta(a+c) - 2d}{3(1-\beta)^2}, 0\right\}$$

decrease in the disposal cost d*. The follower's expected profit*

$$\mathbb{E}[\pi_2] = \begin{cases} \frac{(a-d-2c)^2}{18(1+\beta)} + \frac{(a+d-2c)^2}{18(1-\beta)}, & \text{if } d < \beta\frac{a+c}{2}; \\ \frac{4(a-2c)^2+\beta^2(a+c)(5a-7c)}{36(1-\beta^2)}, & \text{if } d \geq \beta\frac{a+c}{2} \end{cases}$$

increases; the expected price is unaffected by the disposal cost.

Symmetric Subgame (A, A)

- If both firms produce with strategy A, there exists a unique Nash-equilibrium in pure strategies

back

q_A	high demand	low demand
$d < \beta a$	$\frac{a-d}{3(1-\beta)}$	$\frac{a+d}{3(1+\beta)}$
$d \geq \beta a$	$\frac{a+c}{3}$	$\frac{a+c}{3}$

Lemma: *The firms' expected profits*

$$\mathbb{E}[\pi_A] = \begin{cases} \frac{(a+d)^2}{18(1+\beta)} + \frac{(a-d)^2}{18(1-\beta)}, & \text{if } d < \beta a; \\ \frac{a^2}{9}, & \text{if } d \geq \beta a, \end{cases}$$

expected consumer surplus $\mathbb{E}[CS] = 2\mathbb{E}[\pi_A]$ *and expected disposal* $\mathbb{E}[\bar{q}_A - q_A] = \max\{2(\beta a - d)/3(1-\beta^2), 0\}$ *decrease in* d*; the expected price is unaffected.*

Equilibrium I

- If both firms produce with timing strategy S, the standard Cournot outcome arises resulting in expected profits $\mathbb{E}[\pi_S] = (a-c)^2/9(1-\beta^2)$.

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Lemma: *Nothing is disposed of. The firms' expected profits, expected consumer surplus and the expected price is unaffected by the disposal cost.*

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back

Lemma: *Nothing is disposed of. The firms' expected profits, expected consumer surplus and the expected price is unaffected by the disposal cost.*

- Combining the results from the three subgames, we can derive the equilibrium production strategy
- If $\mathbb{E}[\pi_A] \leq \mathbb{E}[\pi_2] \Leftrightarrow \beta \leq \beta_A(d)$, both firms produce in advance
- If $\mathbb{E}[\pi_S] \geq \mathbb{E}[\pi_1] \Leftrightarrow \beta \geq \beta_S(d)$, both firms produce in the second stage
- Else, one firm produces in advance and the other firm follows

Multiple Production Technologies I

- We assumed firms have only one of the two production technologies
- Now, we assume firms have both technologies/ multiple production facilities
- In stage 1, firms produce $\bar{q}_i$ at zero costs
- Then demand materializes
- In stage 2, firms may dispose of $\bar{q}_i - q_i \geq 0$ at a marginal cost d or produce additional quantities $q_i - \bar{q}_i \geq 0$ at a marginal cost c
- Firms do not observe their competitor's inventory $\bar{q}_i$
- We assume $a \geq \max\{c/2, d/2\}$

Multiple Production Technologies II

- There exists a unique Nash-equilibirum in pure strategies

q_i	high demand	low demand
$d \leq \min\{\beta a, c\}$	$\frac{a-d}{3(1-\beta)}$	$\frac{a+d}{3(1+\beta)}$
$\beta a \leq \min\{c, d\}$	$\frac{a}{3}$	$\frac{a}{3}$
$c \leq \min\{\beta a, d\}$	$\frac{a+c}{3(1-\beta)}$	$\frac{a+c}{3(1+\beta)}$

Proposition: *The firms produce in the second stage if and only if demand uncertainty and disposal costs are both simultaneously high.*

Multiple Production Technologies III

Proposition: *Firms' expected profits*

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$$\mathbb{E}[\pi_i] = \begin{cases} \mathbb{E}[\pi_A], & \text{if } c > \min\{\beta a, d\}; \\ \mathbb{E}[\pi_S], & \text{if } c \leq \min\{\beta a, d\}, \end{cases}$$

expected consumer surplus $\mathbb{E}[CS] = 2\mathbb{E}[\pi_i]$ *and expected disposal*

$$\mathbb{E}[\bar{q}_1 - q_1] = \begin{cases} \frac{2(\beta a - d)}{3(1-\beta^2)}, & \text{if } d \leq \min\{\beta a, c\}; \\ 0, & \text{else}, \end{cases}$$

decrease in the disposal cost d*. The expected prices is unaffected.*

- Results also hold for $N \geq 2$ firms
- Competition increases with the number of firms yet so does the disposed of amount
- An increase in disposal cost may decrease the number of competitors, thereby increasing firms' profits discontinuously