# Graduate Industrial Organization

## Introduction & Measuring Market Power

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# Introduction

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  - Background:
    - Undergraduate in Economics at Kyoto
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    - Ph.D. in Economics at Northwestern
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# Course Description and Requirement

- Go to syllabus.

# Theme 1 (/2): Introduction to Graduate IO

- What is IO?: Cabral (2017) "the working of markets and industries, in particular the way firms compete with each other"

- Economics of **imperfect competition**
  1. Is there market power?
  2. How do firms acquire and maintain market power?
  3. Implications of market power?
  4. Role for public policy?

# Theme 2 (/2): Introduction to Structural Estimation IO

- 3 Steps in **structural econometric modeling**
  - Step 1: Construct an explicit economic model,
  - Step 2: Estimate model primitives (preference, technology, etc)
  - Step 3: Simulation of counterfactual cases
- Complementary to **causal inference / program evaluation**

## Course Plan

1. Measuring market power
   - Issue: How to measure markup and test market conduct when cost information is not observable?

2. Estimation of Production function
   - Technology (cost function) / Evolution & distribution of TFP
   - Issue: How to deal with endogeneity issue due to *"unobserved productivity"*?

3. Estimation of demand function (differentiated products)
   - So many things we can answer!
   - Issue: How to model and estimate consumer demand in a tractable way?

4. Estimation of Single-Agent Dynamic Discrete Choice Model
   - Durable goods, inventory, investment, entry/exit, etc
   - Issue: How to estimate a forward-looking model by avoiding *computational burden*?

# Caveat: Topics I do NOT cover

- Econometrics of models with **strategic interactions** (except for oligopoly pricing)
  1. Auction models
  2. Static discrete games (e.g., entry/exit)
  3. Dynamic games (e.g., investment, R&D, merger, etc)
  4. Models with information asymmetry
- Why?
  1. Time constraint.
  2. **Multiplicity of equilibria** makes econometrics tough.
- Might have lectures in "Economic Studies" in Spring 2019?

# Topic 1: Measuring Market Power

- Goal: Infer the "competitiveness" of market from data without cost information
  - Quantify markup (= price - MC).
  - Test the mode of competition (Cournot? Collusion?)
- We focus on the case with homogeneous goods
  - Later on differentiated products
- Plan:
  - Review of basic oligopoly theory (Reference: Tirole 1988)
  - Empirical analysis in History: Structure-Conduct-Performance paradigm
  - "New" Empirical IO (NEIO) or "De facto" Empirical IO (DEIO) (by Steven Berry)

## Monopoly Problem

- Consider monopolist's problem with inverse demand $P(Q)$ and cost $C(Q)$

$$\max_Q P(Q) \cdot Q - C(Q)$$

- FOC

$$P(Q) + \frac{\partial P}{\partial Q} Q - MC(Q) = 0$$

- Then,

$$\underbrace{P(Q) + \frac{\partial P}{\partial Q} Q}_{MR} = MC(Q)$$

- Or,

$$\underbrace{\frac{P(Q) - MC(Q)}{P(Q)}}_{markup} = -\frac{\partial P}{\partial Q}\frac{Q}{P} = \frac{1}{|\epsilon_d|}$$

  - Lerner's index or inverse-elasticity rule

- Lerner's formula:

$$P\left(1+\frac{1}{\epsilon_d}\right)=MC$$

- Implication 1: Higher $|\epsilon_d|$ implies lower markup
- Implication 2: The monopolist never produces in the inelastic portion ($|\epsilon_d|<1$) of the demand curve.
- Implication 3: If you knew $\epsilon_d$, you can back out $MC$.

# Oligopoly: Cournot Model (Nash in quantity)

- Consider $N$ firms index by $i$
- Profit

$$\pi_i = P(Q)q_i - C_i(q_i)$$

  where $Q = \sum_i q_i$ (total quantity in the market).
- FOC (given $Q_{-i} = \sum_{j \neq i} q_j$)

$$(P(Q) - MC_i(q_i)) + q_i \frac{\partial P}{\partial Q} = 0$$

- Again,

$$P(Q) + q_i \frac{\partial P}{\partial Q} = MC_i(q_i)$$

$$P\left(1 + s_i \cdot \frac{Q}{P}\frac{\partial P}{\partial Q}\right) = MC_i(q_i)$$

- Or,

$$\frac{P - MC_i}{P} = \frac{s_i}{|\epsilon_D|}$$

- It nests several cases:
  - Perfect competition: $n \to \infty$(or $s_i \to 0$)
  - Monopoly: $n = 1$ ($s_i = 1$)
- Market-share-weighted

$$LI \equiv \sum_i \frac{P - MC_i}{P} s_i$$

$$= \sum_i \frac{s_i^2}{|\epsilon_D|} = \frac{HHI}{|\epsilon_D|}$$

where Hirschman-Herfindal Index $HHI \equiv \sum_i s_i^2$.

## HHI and Antitrust Policy

- Let weighted MC $\bar{MC} = \sum_i s_i MC_i$

$$\frac{P - \bar{MC}}{P} = \frac{HHI}{|\epsilon_D|}$$

  - *HHI* as an "incomplete" measure of market power!!
  - Markup depends on both *HHI* and $\epsilon_D$.

- HHI is used as a screening devise in merger review by antitrust authorities.
- Ex: Japanese-FTC does not review a proposed merger in detail if it satisfies
  1. $HHI \leq 1500$ before merger
  2. $HHI > 1500$ & $HHI \leq 2500$ before merger and $\Delta HHI \leq 250$
  3. $HHI > 2500$ before merger and $\Delta HHI < 150$.

## Summary of Theory

- Consider quantity competition of homogeneous goods.
- Firm-level FOC (or firm-level markup) is

$$\frac{P - MC_i}{P} = \frac{\theta_i}{|\epsilon_D|},$$

where

$$\theta_i = \begin{cases} 1 & monopoly(collusion) \\ s_i & Cournot \\ 0 & perfect\ competition \end{cases}$$

- Note: Bertrand (price competition)?
  - Bertrand competition in homogeneous goods leads to competitive outcome (Bertrand paradox).
  - Kreps and Scheinkman (1983): Production choice in 1st stage & price competition in 2nd stage" leads to Cournot outcome.
  - Bertrand competition is used for differentiated products case.

# Empirical Approach 1: SCP Paradigm

- Classical (but obsoleted) approach: Structure-Conduct-Peformance Paradigm
  - Idea: Market Structure $\to$ Conduct $\to$ Performance
  - Regress "performance" on "structure".

- In Cournot equilibrium, $\frac{P-MC}{P} = \frac{HHI}{|\epsilon_D|}$, motivating the regression

$$\log(\frac{P - MC_j}{P}) = \beta_0 + \beta_1 \log(HHI_j) + \beta_2 \log(|\epsilon_{D,j}|) + u_j$$

  for $j = 1, \cdots, J$ cross-section of markets (industries).
  - Effects of HHI (structure) on margin (performance)

- Cournot competition: $\beta_1 = 1$, Perfect competition: $\beta_1 = 0$. Test these.
- Or, you might want to discuss "effects of competition on profit".

## Many Problems!!

1. Data:
   - Dep var: accounting profits/returns on assets, price-cost-margin from Census of manufacturing
     - None of these are true economic margins (Fisher and McGowan 1983)
   - Additional variables: elasticity of demand, product differentiation
     - Rarely observed $\rightarrow$ cannot control for differences across markets/industries.

2. Simultaneity issues:
   - Do we think *HHI* is exogenous? No!
     - *HHI* depends on market shares, which depends on $P$ and $MC$
   - S-C-P affect each other!!

3. Interpretation
   - Positive correlation between *HHI* and profits can be due to cost advantage (good performance) or high markups (bad performance).

# A bit of digression: SCP approach in more general

- SCP paradigm has been used to answer questions other than testing market power.
- In particular, effects of **competition** on **something**
  - Ex: R&D (investment), advertisement, product variety, etc.
- Biggest issue: Endogeneity of competition.

# Example : Effects of competition on R&D

- Two counteracting forces of competition on R&D
  - Positive: Replacement effect (Arrow, 1962), Preemptive motivation
  - Negative: Schumpeterian effect. Bigger firms are likely to have a higher ability to innovate, thus concentration would be good.
- Inverted U-shape relationship

# Aghion et al (2006, QJE): a kind of SCP approach

- The relationship between patents on learner index at year-industry level.

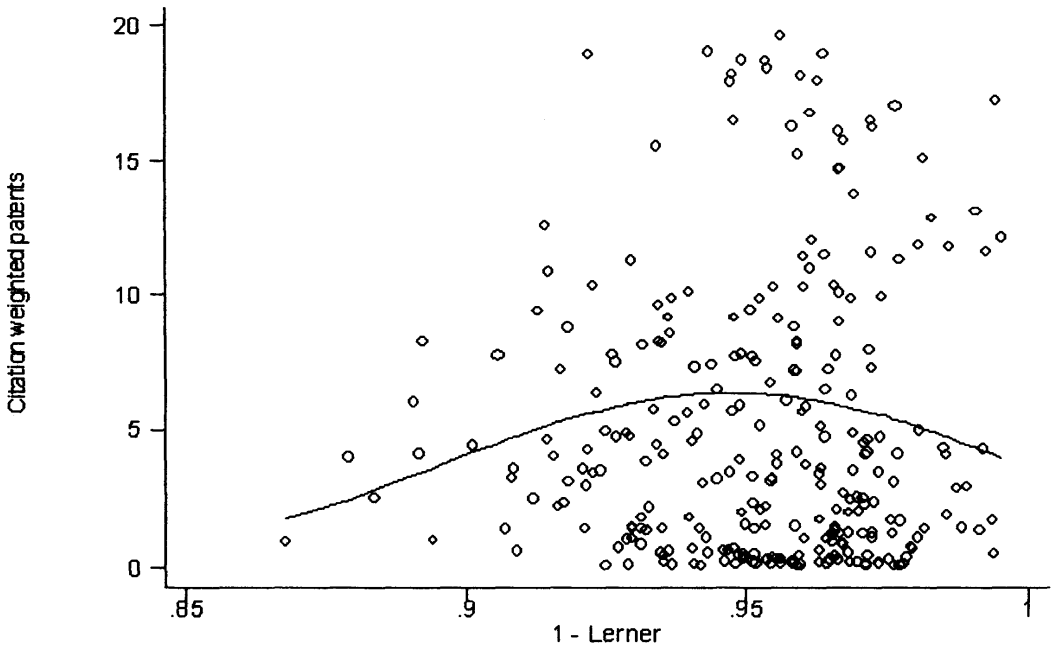



FIGURE I

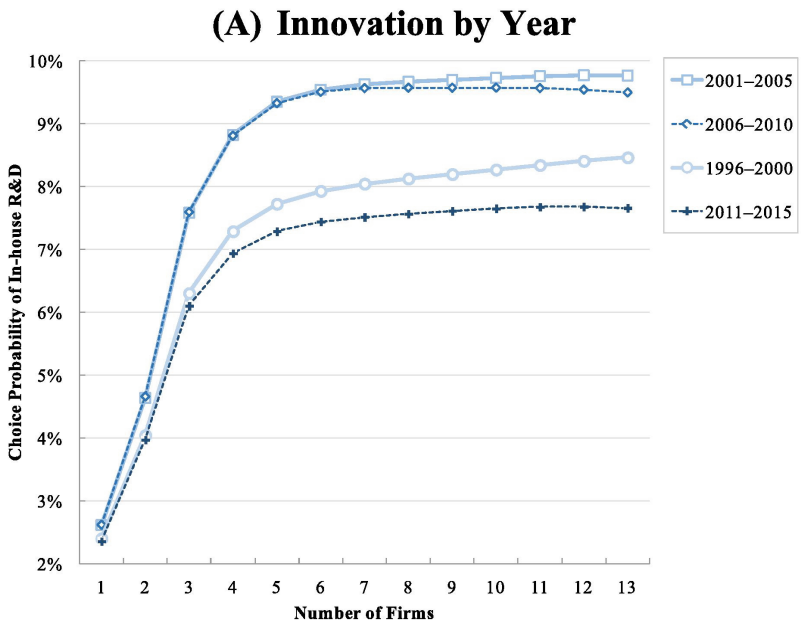
Scatter Plot of Innovation on Competition

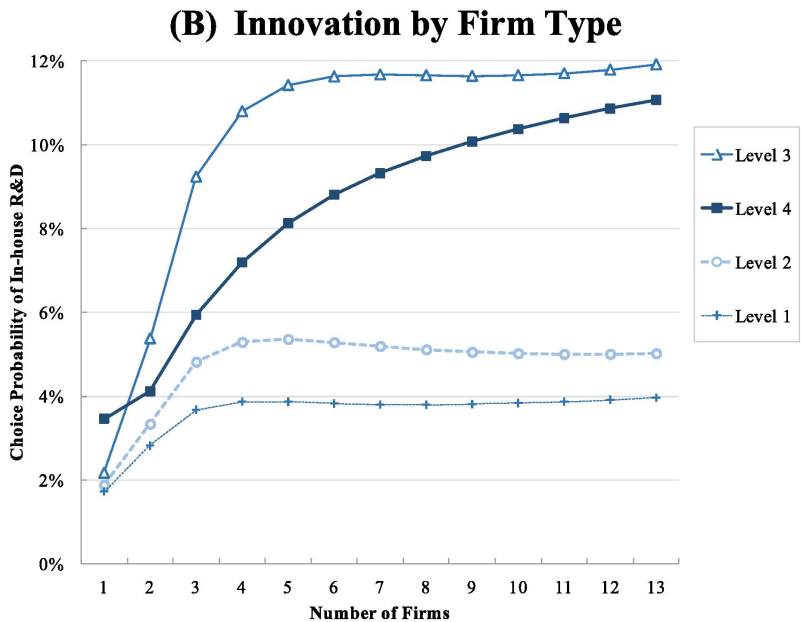
The figure plots a measure of competition on the $x$-axis against citation-weighted patents on the $y$-axis. Each point represents an industry-year. The scatter shows all data points that lie in between the tenth and ninetieth deciles in the citation-weighted patents distribution. The exponential quadratic curve that is overlaid is reported in column (2) of Table I.

- They use change in antitrust policy & privatization as IV for Lerner index in regression, and still find inverted-U.

# Igami and Uetake (2018): Fully structural approach

- Estimate and solve dynamic game of mergers, innovation, and exit
- Prob of R&D as a function of # of competitors in the market




- Plateau shape.

## Some Recent Paper with good instruments

- Illanes and Moshary (2018): "Market Structure and Product Variety: Evidence from a Natural Experiment in Liquor Licensure"
- Question: Effects of market structure (# of firms) on prices, quantities, and product assortment.
- Context:
  - Since the end of Prohibition, a monopoly on spirit sales in Washington.
  - Washington privatize sales of alcohol goods in 2011.
  - Private retailers were allowed to enter the market so long as their store size exceeded 10,000 feet squared.
- Use **regression discontinuity design** to estimate the effect of the number of firms.

- Chandra and Weinberg (2018, Management Science) "How Does Advertising Depend on Competition? Evidence from U.S. Brewing"
  - Exploit the merger at the national-level to obtain the (exogenous) variation of local-lvel concentration

# Approach in New Empirical IO

1. Price-cost-margin are not assumed to be observed, rather we estimate marginal costs.

2. Study a specific industry, using time series or a cross section of geographical markets.
   2.1 Deal with the simultaneity problem.

3. Conduct is viewed as a parameter to be estimated
   3.1 Ties more directly to theory (not always) and deals with interpretation.

## Bresnahan (1982, Economic Letters)

- Question: Can we distinguish between competitive & non-competitive behavior in the absence of marginal cost data?
- Demand (homogenous goods) for market (period) $t$

$$Q_t = \alpha_0 + \alpha_1 P_t + \alpha_2 Y_t + \epsilon_t$$

  - $Q_t$: quantity, $P_t$: price, $Y_t$: exogenous demand shifter
- Marginal cost (symmetric for all firms):

$$MC_t = \beta_0 + \beta_1 Q_t + \beta_2 W_t + \eta_t$$

  - $W_t$: exogenous cost shifter (fuel cost, wage, etc)

- Consider the supply relationship from FOC $MR_t = MC_t$:
- Write $MR_t$ with **conduct parameter** $\theta$

$$MR = P_t + \theta \left( \frac{\partial P}{\partial Q} \right) Q$$

- The supply relationship:

$$P_t = \theta \left( -\frac{Q_t}{\alpha_1} \right) + \beta_0 + \beta_1 Q_t + \beta_2 W_t + \eta_t$$

- $\theta$ indexes different models of pricing
  - $\theta = 1$ if monopoly,
  - $\theta = 0$ if perfect competition
  - $\theta = 1/N_t$ if Cournot competition

# Review: Identification of Demand-Supply Equations

- Suppose $\theta = 0$ for now, so that

$$\begin{aligned} \textit{Demand}: & Q_t = \alpha_0 + \alpha_1 P_t + \alpha_2 Y_t + \epsilon_t \\ \textit{Supply}: & P_t = \beta_0 + \beta_1 Q_t + \beta_2 W_t + \eta_t \end{aligned}$$

- Equilibrium is determined by the intersection of these two curves.
- We observe $\{Q_t, P_t, Y_t, W_t\}_{t=1}^{T}$
- Under what conditions can we identify (estimate) demand and supply curves?
- (See blackboard)
  - Demand: Need cost shifter for instrumenting $P_t$
  - Supply: Need demand shifter for instrumenting $P_t$.

# Going back to Bresnahan (1982)

- We have

$$Demand: Q_t = \alpha_0 + \alpha_1 P_t + \alpha_2 Y_t + \epsilon_t$$

$$Supply: P_t = \beta_0 + \left(-\frac{\theta}{\alpha_1} + \beta_1\right) Q_t + \beta_2 W_t + \eta_t$$

- Question: Can we identify (estimate) $\theta$?

- We can estimate $(\alpha_0, \alpha_1, \alpha_2)$ by using $W_t$ as an IV for $P_t$ in demand model.
- Using $Y_t$ as an IV for $Q_t$, we estimate $\beta_0, -\frac{\theta}{\alpha_1} + \beta_1$, and $\beta_2$.
- However, we cannot distinguish $\theta$ and $\beta_1$!!

# Figure: Two $MC$ ($MC^c$ and $MC^m$) can be rationalized by data

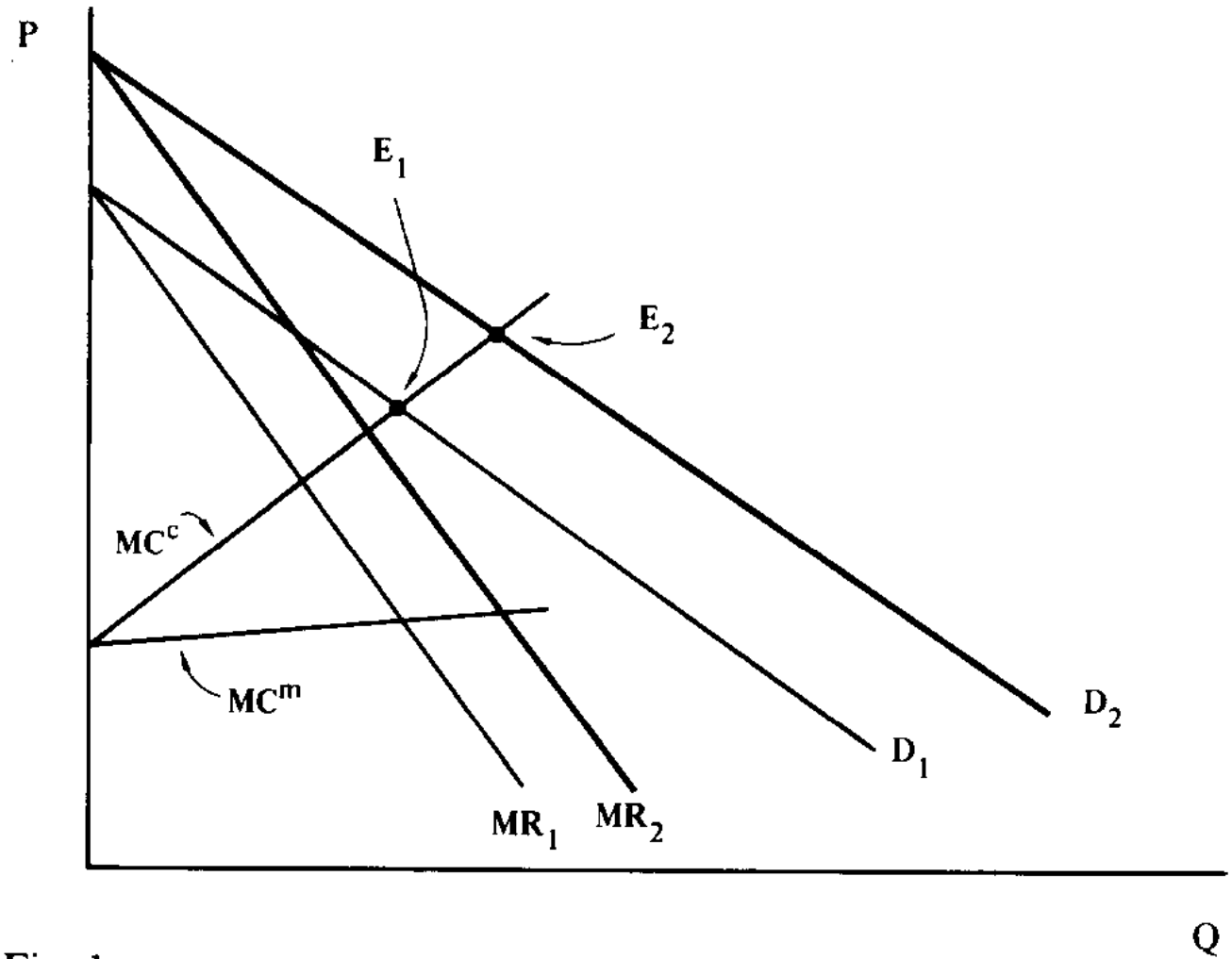



Fig. 1.

## When can we identify $\theta$?

- Idea 1: Assume constant MC (i.e., $\beta_1 = 0$). Can get $\theta$.
- Idea 2: Demand rotation

$$Q_t = \alpha_0 + \alpha_1 P_t + \alpha_2 Y_t + \alpha_3 P_t Z_t + \epsilon_t$$

  - Demand slope changes with $Z_t$
- Supply relationship is

$$P_t = \beta_0 + \left( -\frac{\theta}{\alpha_1 + \alpha_3 Z_t} + \beta_1 \right) Q_t + \beta_2 W_t + \eta_t$$

- Define $Q_t^* = -Q_t/(\alpha_1 + \alpha_3 Z_t)$. Then,

$$P_t = \beta_0 + \beta_1 Q_t + \beta_2 W_t + \theta Q_t^* + \eta_t$$

- Using instruments, we can identify all the parameters!!

# Figure with Rotation

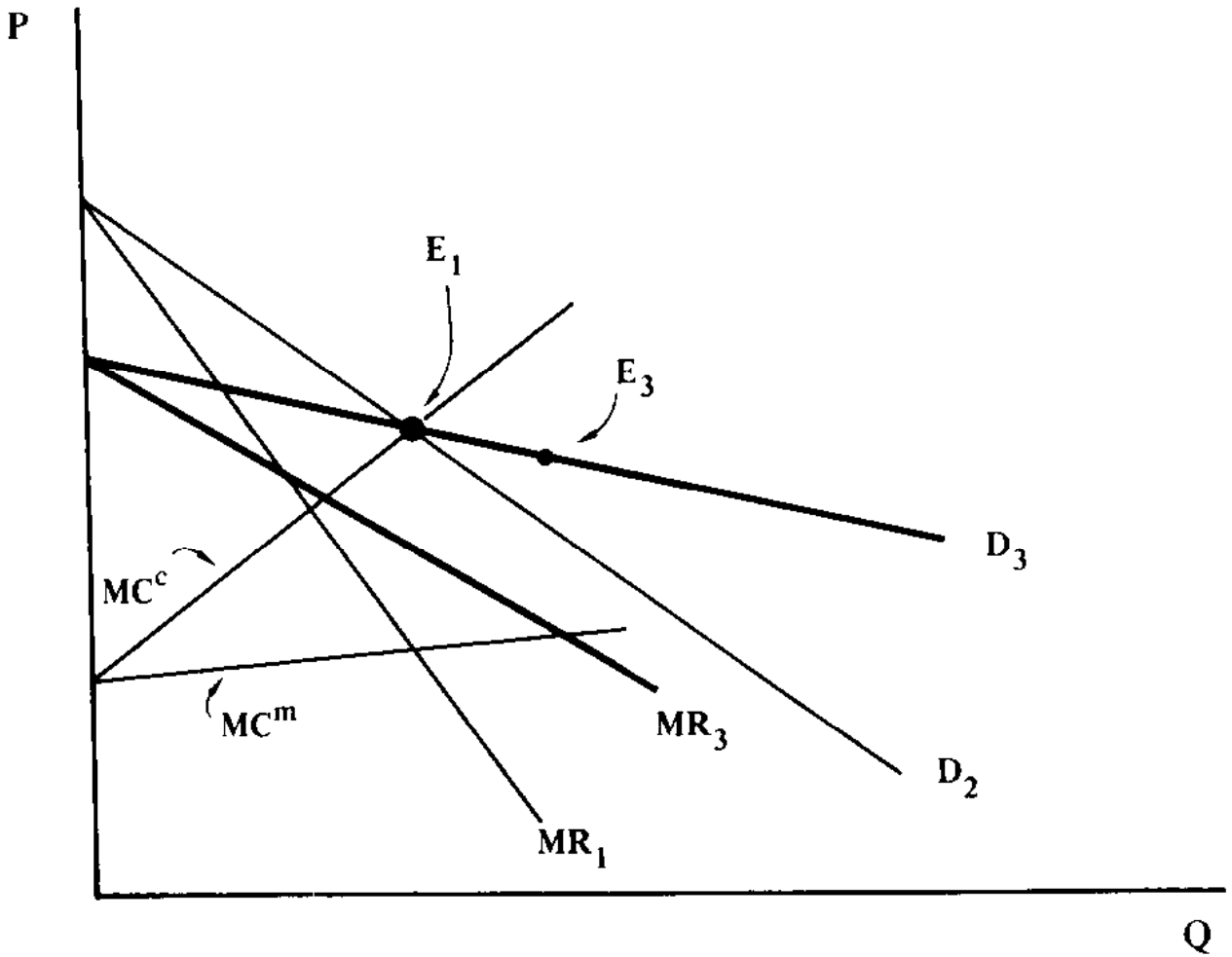



Fig. 2.

## Some Comments

- Though the model is parametric and linear, same argument can be applied to more general setting.
  - Lau (1982, Economics letters) for nonlinear setting
  - Berry and Haile (2014, EMA) for nonparametric setting.

# Porter (1983, Bell): "Joint Executive Committee"

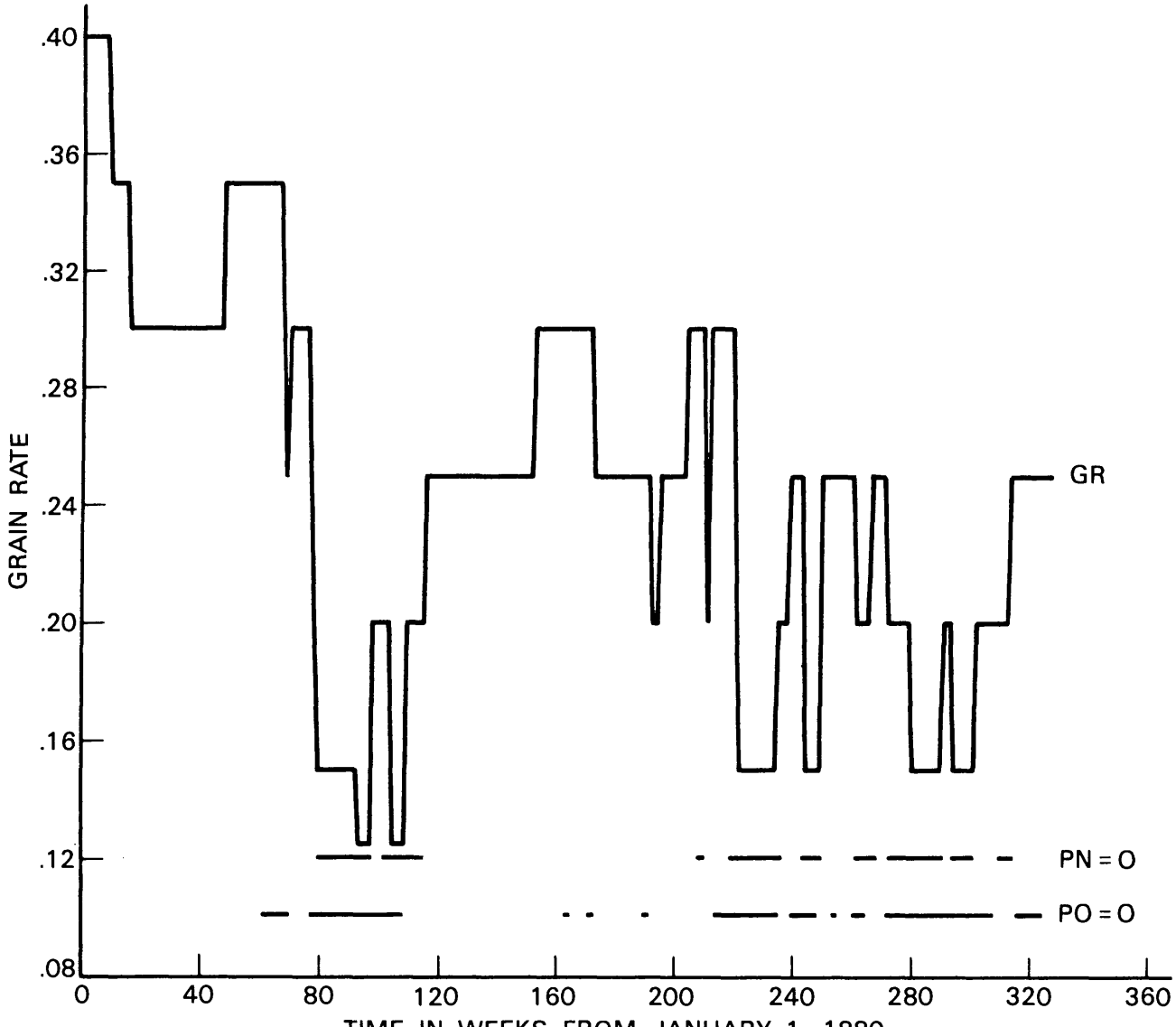
- Question: We observe price (and quantity) shifts over time. Are they due to
  - (exogenous) shifts in the demand and cost functions, or
  - due to price wars (collusive to noncooperative behavior)?

- Background:
  - The Joint Executive Committee (JEC) was a cartel that controlled the eastbound railway grain shipment.
  - It was before the Sherman Act and therefore was explicit.
  - The cartel used an internal enforcement mechanism similar to the trigger strategy.

# Price changes over time

FIGURE 1

PLOT OF GR, PO, PN AS A FUNCTION OF TIME



# Theory from Green and Porter (1984, Econometrica)

- Dynamic model of collusion under demand unvertainty
  - Firms compete in prices;
  - Demand uncertainty;
  - Firms collude: set price between Bertrand and monopoly;
  - Firms observe demand, which is a noisy signal of competitors behavior.
    - low demand could be due to a deviation in collusion or aggregate low demand;
  - If the demand falls below a threshold (trigger) then firms switch to Bertrand pricing for $T$ periods, i.e., there is a price war;

- Prediction:
  - along the equilibrium path price wars occur.
  - Other predictions: timing of price wars (triggers) and no cheating in equilibrium.

- Empirical analysis: Is this theory consistent with the data?
  - Is price fluctuation consistent with the change in behavior?

## Model

- Demand:

$$\log Q_t = \alpha_0 + \alpha_1 \log P_t + \alpha_2 L_t + (\textit{month dummies}) + U_{Dt}$$

  - $L_t = 1$ if lake opens. (Lake steamers as substitutes)
- Note: No rotation of demand shock. How to ID conduct?
- N firms with cost function

$$C_i(q_{it}) = a_i q_{it}^{\delta} + F_i,$$
$$MC_i(q_{it}) = \delta a_i q_{it}^{\delta-1}$$

where $\delta > 1$ and $F_i$ is fixed cost (assume to be small).

- Supply relationship

$$P_t \cdot \left(1 + \frac{\theta_{it}}{\alpha_1}\right) = mc_i(q_{it})$$

1. $\theta_{it} = 1$ if joint-profit-maximization,
2. $\theta_{it} = 0$ if competitive pricing.
3. $\theta_{it} = s_{it} (= q_{it}/Q_t)$ if Cournot

- Aggregate to market-level

$$P_t \cdot \left(1 + \frac{\theta_t}{\alpha_1}\right) = \sum_{i=1}^{N} s_{it} mc_i(q_{it})$$

where $\theta_t \equiv \sum_i s_{it}\theta_{it}$.

- Given functional form assumption, the market share is

$$s_{it} = \frac{a_i^{1/(1-\delta)}}{\sum_j q_j^{1/(1-\delta)}} \equiv s_i$$

in each of the three cases.

- The supply relationship is now

$$P_t \cdot \left(1 + \frac{\theta_t}{\alpha_1}\right) = DQ_t^{\delta-1}$$

where $D = \delta(\sum_i a_i^{1/1-\delta})^{1-\delta}$ and

$$\log(P_t) = \log(D) - \log\left(1 + \frac{\theta_t}{\alpha_1}\right) + (\delta - 1) \cdot \log Q_t$$

- You cannot distinguish $D$ and $\theta_t$ from this equation!!
- Idea: use systematic change in conduct $\theta_t$

## Estimating Equation

- Supply equation for estimation

$$\log(P_t) = \beta_0 + \beta_1 \log(Q_t) + \beta_2 S_t + \beta_3 I_t + U_{2t}$$

  - $S_t$: structural dummies (reflecting entry of new firms).
  - $\beta_0 = \log(D)$, $\beta_1 = (\delta - 1)$
  - $U_{2t}$: error term
- $I_t$ represents regime of competition

$$I_t = \begin{cases} 1 & \textit{if cooperative} \\ 0 & \textit{if price wars} \end{cases}$$

  - if firms max joint profits during cooperative period, $\beta_3 = -\log(1 + 1/\alpha_1)$
- $\beta_3$ measures difference in conduct between $I_t = 0$ and $I_t = 1$.

# Estimation

- Case 1: If you observe $I_t$,
  - 2SLS regressions
  - Trade press reports the regime (colluding or not).
- Case 2: Unobserved $I_t$
  - mis-measurement of $I_t$ might be a concern.
  - Assume that

$$I_t = \begin{cases} 1 & \textit{with prob } \lambda \\ 0 & \textit{with prob } 1-\lambda \end{cases}$$

    where $\lambda$ is parameter to be estimated.
  - The model becomes a switching regression and can be estimated by MLE.

# Results

**TABLE 3 Estimation Results***

| | Two Stage Least Squares (Employing *PO*) | | Maximum Likelihood (Yielding *PN*)** | |
|---|---|---|---|---|
| Variable | Demand | Supply | Demand | Supply |
| *C* | 9.169 | −3.944 | 9.090 | −2.416 |
| | (.184) | (1.760) | (.149) | (.710) |
| *LAKES* | −.437 | | −.430 | |
| | (.120) | | (.120) | |
| *GR* | −.742 | | −.800 | |
| | (.121) | | (.091) | |
| *DM1* | | −.201 | | −.165 |
| | | (.055) | | (.024) |
| *DM2* | | −.172 | | −.209 |
| | | (.080) | | (.036) |
| *DM3* | | −.322 | | −.284 |
| | | (.064) | | (.027) |
| *DM4* | | −.208 | | −.298 |
| | | (.170) | | (.073) |
| *PO/PN* | | .382 | | .545 |
| | | (.059) | | (.032) |
| *TQG* | | .251 | | .090 |
| | | (.171) | | (.068) |
| $R^2$ | .312 | .320 | .307 | .863 |
| *s* | .398 | .243 | .399 | .109 |

* Monthly dummy variables are employed. To economize on space, their estimated coefficients are not reported. Estimated standard errors are in parentheses.

- Cooperative period prices exceed those implied by competitive setting.
- But, are lower than those under static joint profit maximization.

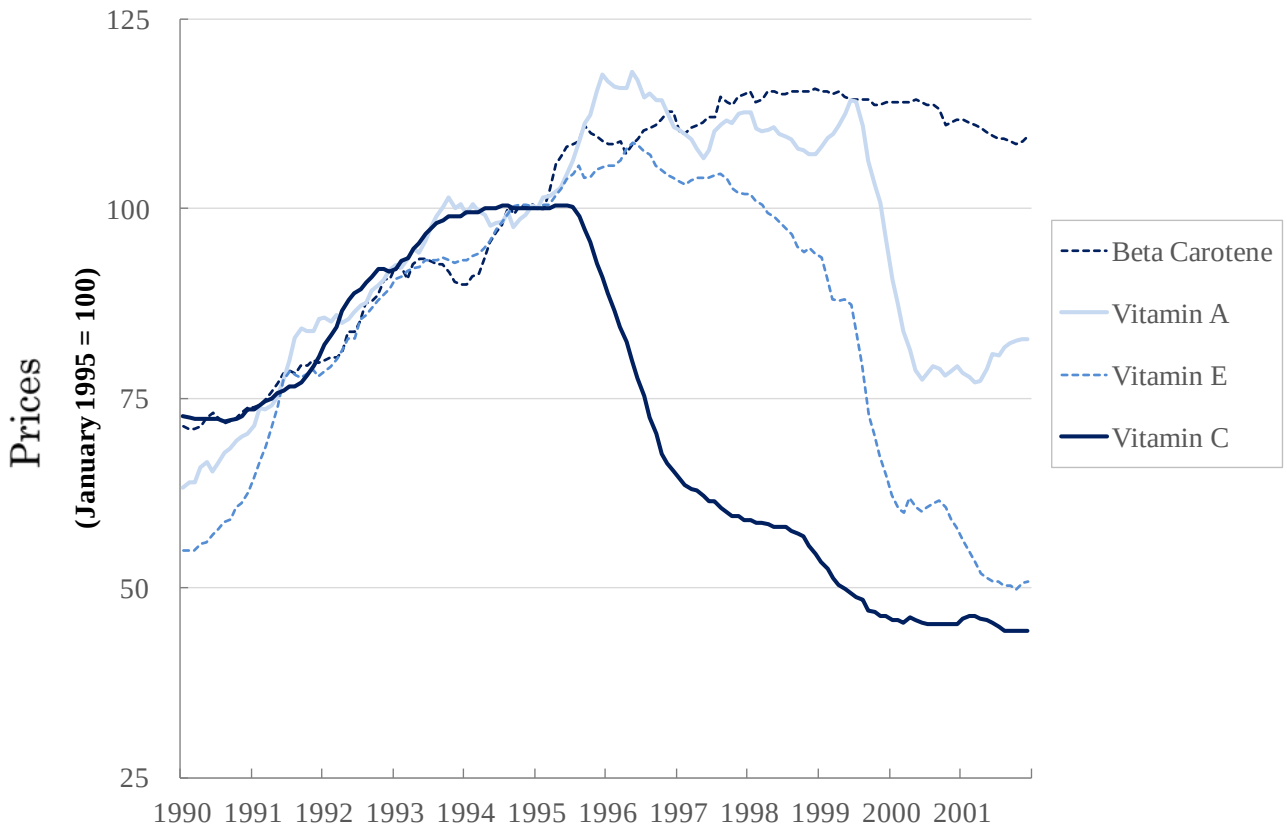
- He formally tests the model without switching against the one with switching, and reject the former.

# Other Approach– With direct measure of costs

- It needs to be a good measure, of course!
- Sugar industry (Genosove and Mullin, 1998)
- Vitamin Cartel (Igami and Sugaya 2018)
- Electricity industry:
  - Bushnell, Borenstein, and Wolak (2002), Wolfram (1999)
  - Fabra and Reguant (2014)
  - Hortacsu and Puller (2006), Hortacsu et al (2018)

# Igami and Sugaya (2018) "Vitamin Cartels"

- Question: Why did some cartels survive for a decade while others collapsed after only a few years?



# Background and Approach

- Brief history:
  - 1989: Start collusion between Roche and BASF. Later invite others (RP, Japanese makers, etc)
  - 1999: RP applied for Corporate Leniency Program (end of cartels).
- Great deal of data is available !!
  - Investigation by EC: details on strategy and belief
  - Bernheim report in litigation: detailed cost information
- Empirical analysis : Test incentive compatibility constraints (ICC)
  - Theory: "cooperation is stable if-and-only-if incentive compatible".
  - Use cost data and demand to measure the ICC!

## Model

- Expected profit in $\tau$ given info at $t$: $\pi_{i,\tau|t} = (P_{\tau|t} - c_{i,t})q_{i,\tau|t}$ .
  - Note: we know costs!
- Three cases:
  - $\pi^C_{i,\tau|t}$: joint-profit maximization
  - $\pi^D_{i,\tau|t}$: Deviation (non-compliance)
  - $\pi^N_{i,\tau|t}$: Static Nash (noncooperation). Punishment (trigger strategy).
- Payoff if comply with the cartel agreement

$$V^C_{i,\tau|t} = \sum_{s \geq \tau} \beta^{\tau-1} \pi^C_{i,s|t}$$

- Payoff if not comply

$$V^D_{i,\tau|t} = \underbrace{\sum_{s=\tau}^{\tau+2} \beta^{s-1} \pi^D_{i,s|t}}_{\textit{deviation return}} + \underbrace{\sum_{s \geq \tau+3} \beta^{s-1} \pi^N_{i,s|t}}_{\textit{punishment}}$$

## Incentive compatibility constraint (ICC)

- The trigger strategy is equilibrium if and only if

$$\min_{i \in I, \tau \geq t} \underbrace{V^C_{i,\tau|t} - V^D_{i,\tau|t}}_{\equiv \Delta V_{i,\tau|t}} \geq 0$$

  - Given information at period $t$, the predicted payoff from deviation should be positive for all future periods and all firms.

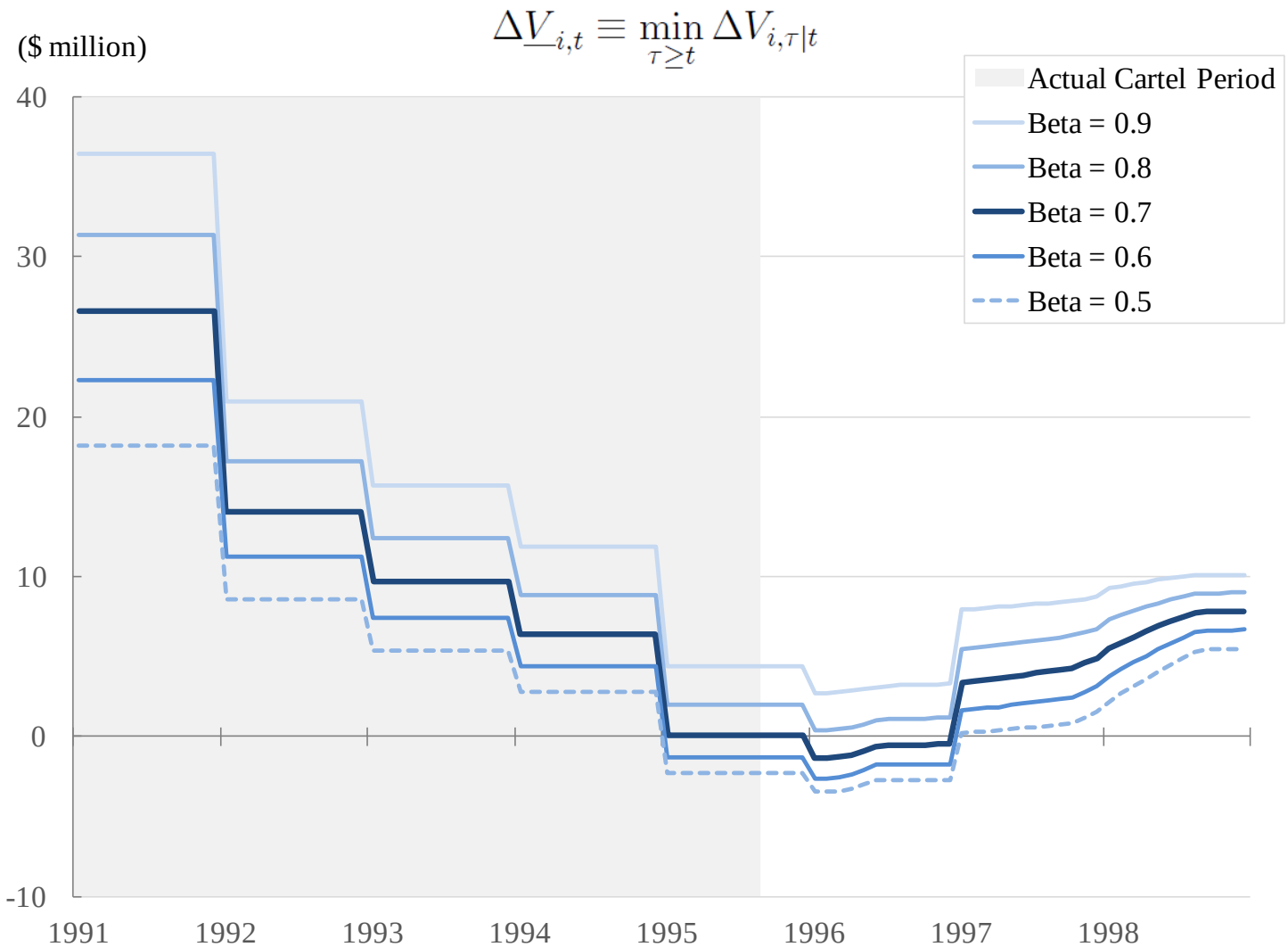
- Use cost and demand information to construct

$$\Delta \underline{V_{i,t}} \equiv \min_{\tau \geq t} \Delta V_{i,\tau|t}$$

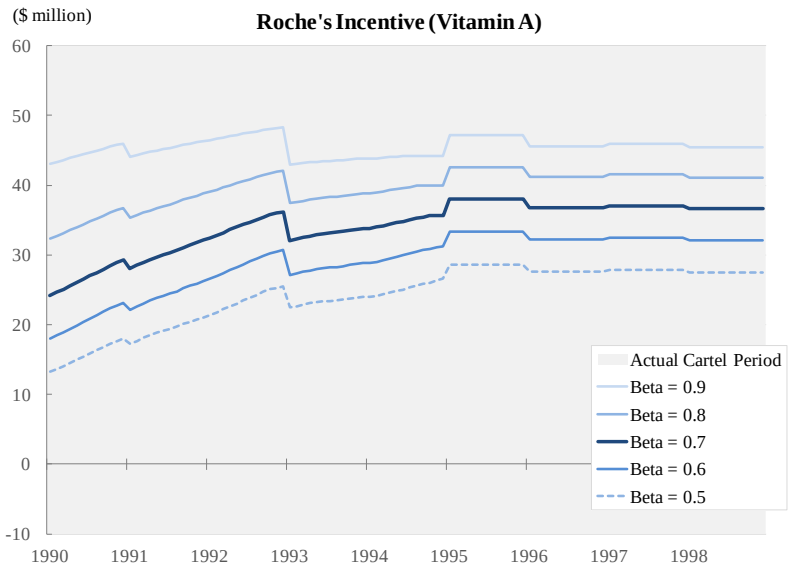
  and to see whether (and when) $\Delta \underline{V_{i,t}}$ becomes negative.

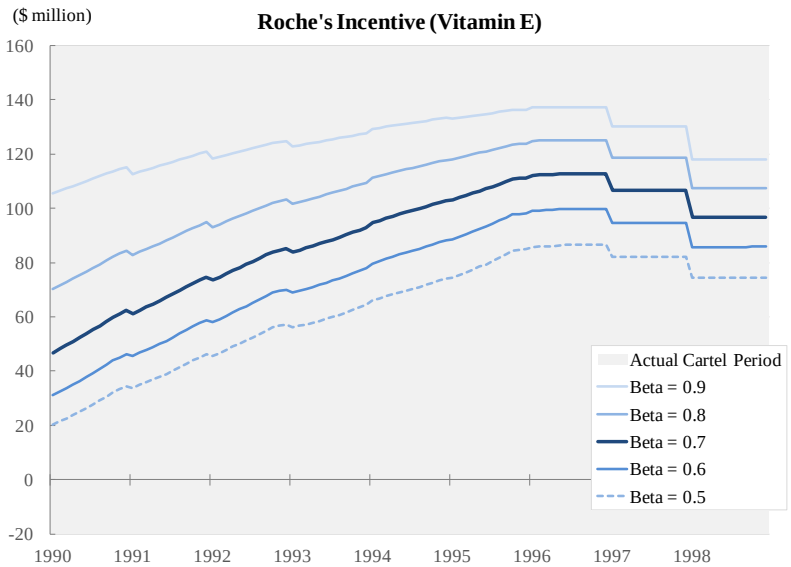
- Note: several discount factor $\beta$ should be examined.

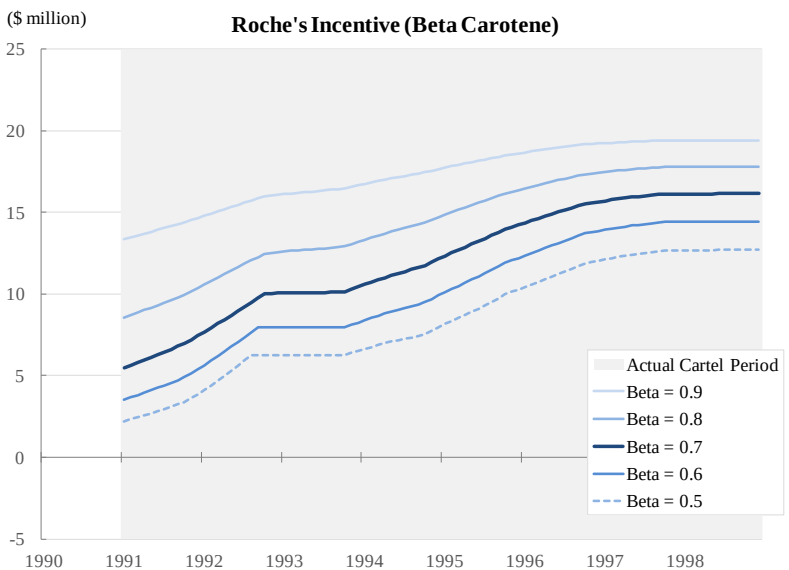
# Roche's ICC for Vitamin C (Cartel collapsed)



# Roche's ICC for Other Vitamin (Cartel continued till investigation)



## Applications from Electricity Markets (generation in wholesale market)

- Fuel cost is a good cost measure of electricity generation.
  - especially for fossil-fuel plants (coal, gas, and oil)
- Bushnell, Borenstein, and Wolak (2002), Wolfram (1999)
  - Q: How far the market outcome is from competitive benchmark?
  - Use cost data and demand curve to simulate competitive outcome.
- Fabra and Reguant (2014)
  - Q: Do power plants consider opportunity costs of emissions permits for CO2 in their pricing (bidding) strategy in wholesale electricity market?
  - A: Yes! Almost full consideration.
- Hortacsu and Puller (2008), Hortacsu et al (2018)
  - Q: Do firms follow Bayes-Nash equilibrium in their bidding strategy?
  - Simulate BNE with cost data and (exp-post) residual demand.
  - A: Bigger firms do, but smaller firms not. Difference due to level of strategic thinking (level-$k$ theory).