MASTER OF COMMERCE IN COMPETITION AND ECONOMIC REGULATION

Quantitative Methods and Econometrics for application in Competition and Economic Regulation (QEC9X01)

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Lecture 3: Identification of Conduct

“Quantitative Techniques for Competition and Antitrust Analysis”
by Peter Davies and Eliana Garces

Chapter: 6

New Empirical Industrial Organization (NEIO)

- The SCP relationship is jointly determined by underlying primitives and equilibrium assumption.

- Every individual industry has potentially important idiosyncrasies → should not expect much to be revealed looking across industries.

- Postulates industry-level analysis and application of game theory → firm and industry conduct should be viewed as unknown parameters to be estimated, i.e., competition, strategic interaction, collusion.

- **Bresnahan (1982):** Can we detect/distinguish collusive and competitive pricing behaviour from (P,Q) data ?

Frameworks for Analysis in IO

Structure- Conduct-Performance

Market Structure

(market shares, HHI)

Firm Conduct

(compete or collude)

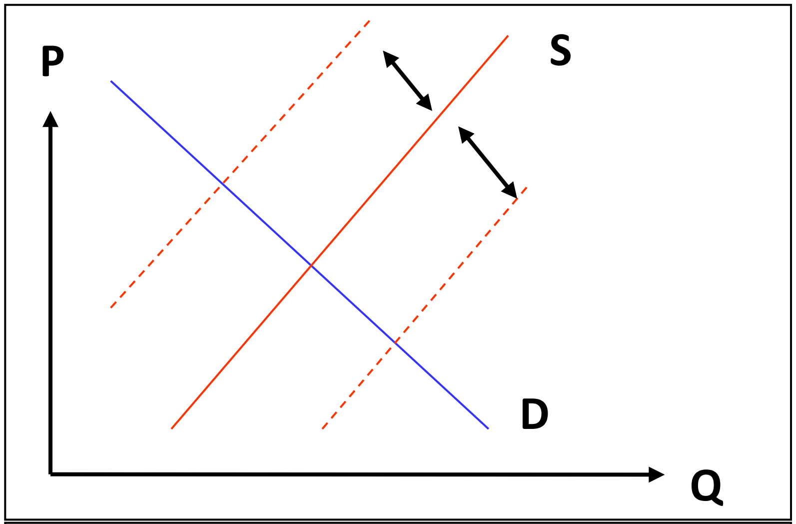
Performance

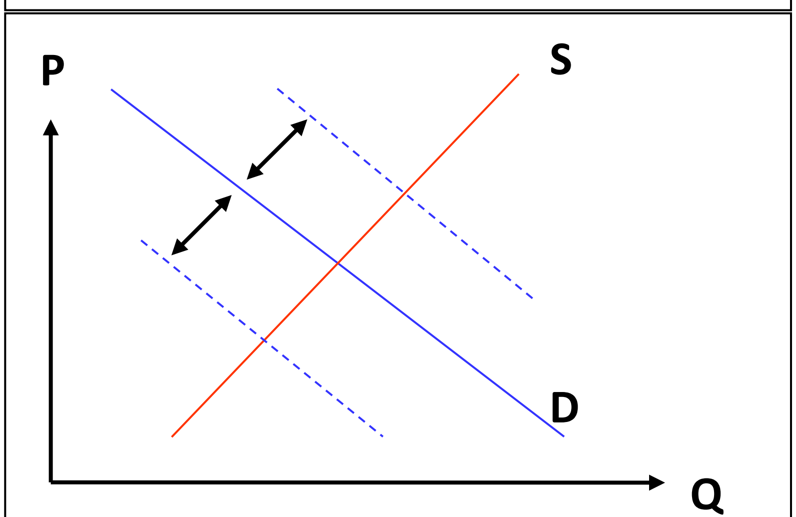
(profits, welfare)

Game Theory informed IO *adds* feedbacks

Demand and supply identification

Suppose there is given a supply function and a demand function, can we pin them down using data on (P,Q), perhaps over time? → you need a demand shifter to identify supply and a supply shifter to identify demand.





Supply shifters identify the Demand curve

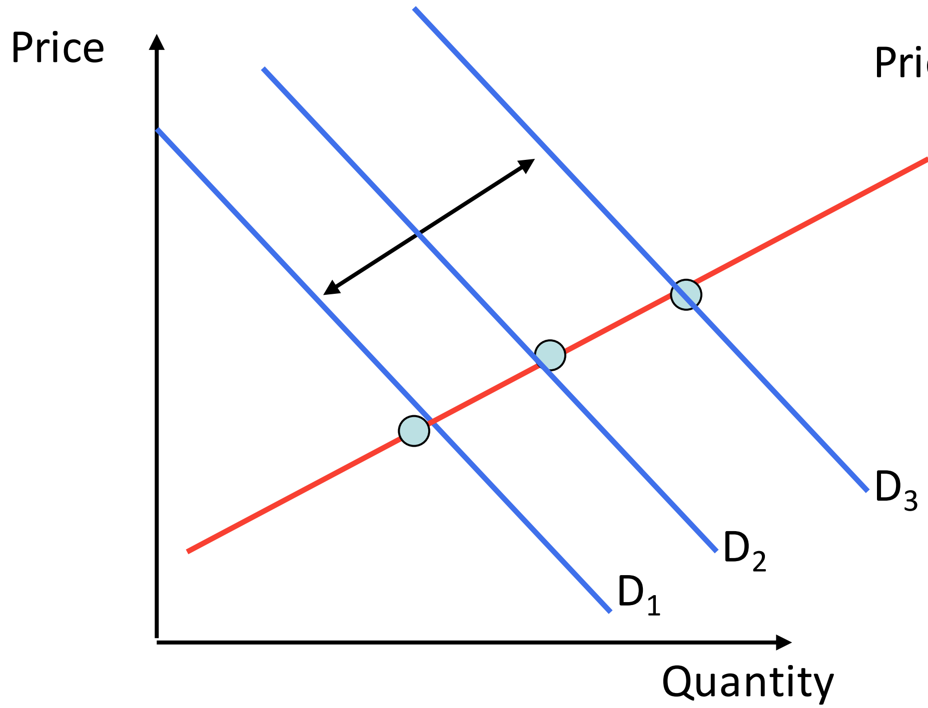
E.g., day-to-day weather variation will help identify how sensitive the demand for fish is to price increases if catch depends on weather conditions. Alternatively, use input factor prices.

Demand shifters identify the Supply curve

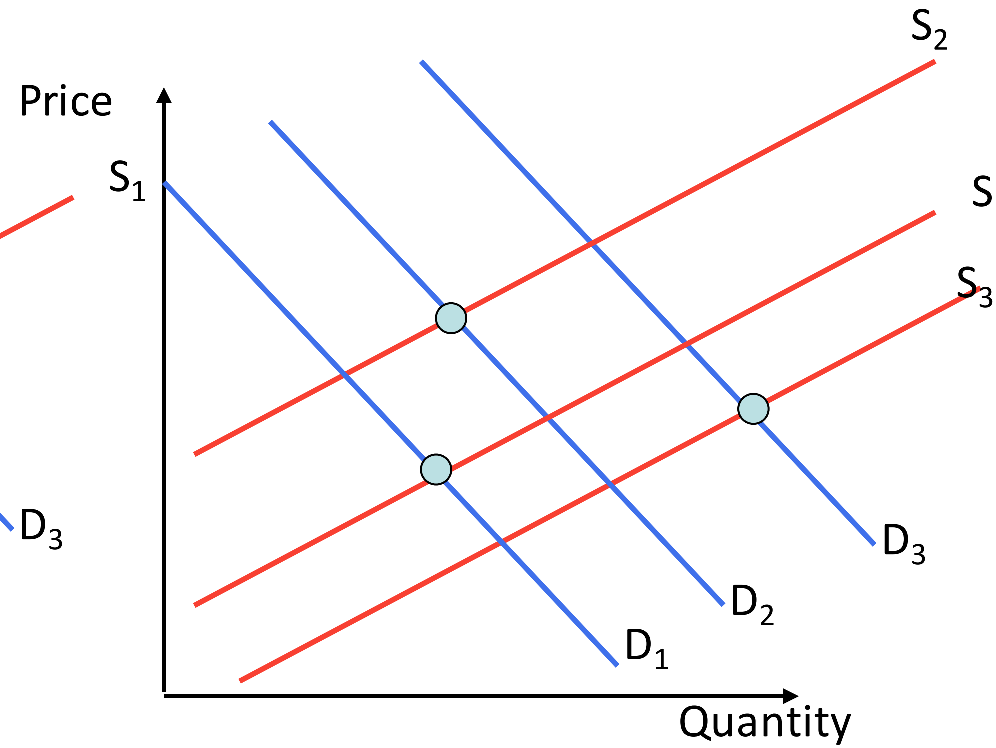
E.g., day-to-day weather variation will help identify how sensitive the supply of ice-cream is to price increases if demand for ice-cream depends on weather conditions. Alternatively use demand driver such as income.

Failure of identification of demand

If observed (P,Q) are not due to supply shifting then what we get is:



(i) trace out the supply curve if demand shifts are generating all the observed variation in (P,Q)



(ii) will get junk (neither supply or demand equation) if both supply and demand shifts generate observed variation in (P,Q)

Supply and demand in structural form

- Consider the following supply and demand equations:

$$Q_t = a_t^D - a_{12} P_t$$

$$Q_t = a_t^S + a_{22} P_t$$

- Suppose there is exactly one demand and one supply shifter

$$a_t^D = c_{11} X_t + u_t^D$$

$$a_t^S = c_{22} W_t + u_t^S$$

- Then we can write our system of equations in a 'structural form'

$$\begin{bmatrix} 1 & a_{12} \\ 1 & -a_{22} \end{bmatrix} \begin{bmatrix} Q_t \\ P_t \end{bmatrix} = \begin{bmatrix} c_{11} & 0 \\ 0 & c_{22} \end{bmatrix} \begin{bmatrix} X_t \\ W_t \end{bmatrix} + \begin{bmatrix} u_t^D \\ u_t^S \end{bmatrix} \begin{matrix} \longleftarrow \text{Demand equation} \\ \longleftarrow \text{Supply equation} \end{matrix}$$

Identification of supply and demand

$$\begin{bmatrix} 1 & a_{12} \\ 1 & -a_{22} \end{bmatrix} \begin{bmatrix} Q_t \\ P_t \end{bmatrix} = \begin{bmatrix} c_{11} & 0 \\ 0 & c_{22} \end{bmatrix} \begin{bmatrix} X_t \\ W_t \end{bmatrix} + \begin{bmatrix} u_t^D \\ u_t^S \end{bmatrix}$$

- Let $y_t = [Q_t, P_t]'$ and $\mathrm{Z}_\mathrm{t} = [X_t, W_t]'$
- We can write the 'structural' supply and demand equations as:

$$Ay_t = CZ_t + u_t$$

- Inverting A, we get the 'reduced form' equations:

$$y_t = A^{-1}CZ_t + A^{-1}u_t$$

Identification of supply and demand

$$y_t = A^{-1}CZ_t + A^{-1}u_t$$

$$y_t = \Pi Z_t + v_t \,,$$

- where

$$\Pi \equiv A^{-1}C \quad \text{and} \quad \mathrm{v}_{\mathrm{t}} \equiv A^{-1}u_t$$

- Given enough data, we can learn about the reduced form parameters in Π.
- However, can we also learn about the structural parameters in (A,C) from knowledge of Π ?

Supply and demand identification

- The set of sufficient conditions are
  - The ‘normalization’ conditions $a_{11} = a_{21} = 1$
  - The ‘exclusion’ restrictions $c_{12} = c_{21} = 0$

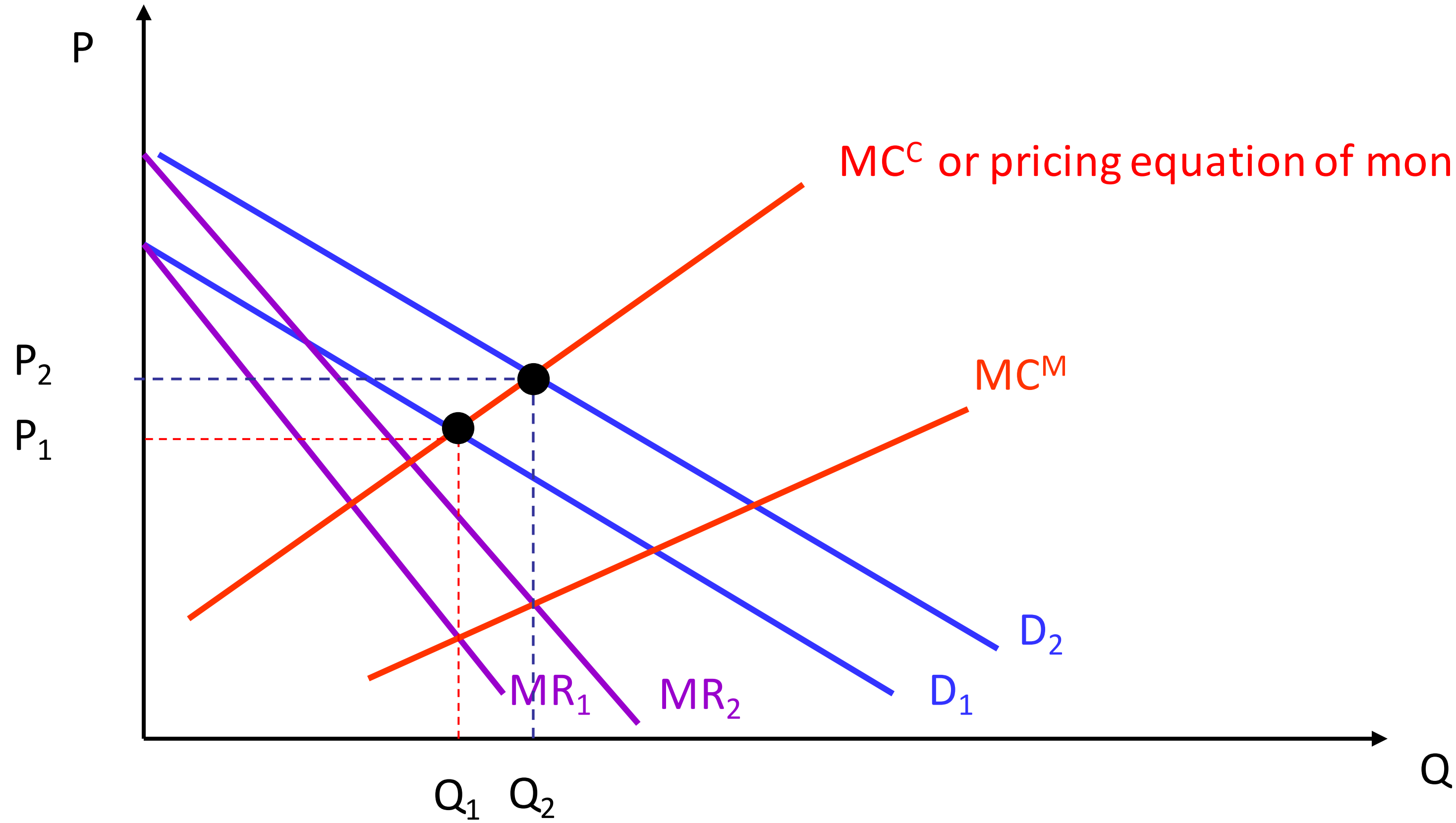
$$\begin{bmatrix} 1 & a_{12} \\ 1 & -a_{22} \end{bmatrix} \begin{bmatrix} Q_t \\ P_t \end{bmatrix} = \begin{bmatrix} c_{11} & 0 \\ 0 & c_{22} \end{bmatrix} \begin{bmatrix} X_t \\ W_t \end{bmatrix} + \begin{bmatrix} u_t^D \\ u_t^S \end{bmatrix}$$

$$\Pi = A^{-1}C = \begin{bmatrix} 1 & a_{12} \\ 1 & -a_{22} \end{bmatrix}^{-1} \begin{bmatrix} c_{11} & 0 \\ 0 & c_{22} \end{bmatrix} = \frac{1}{-a_{22} - a_{12}} \begin{bmatrix} -a_{22}c_{11} & -a_{12}c_{22} \\ -c_{11} & c_{22} \end{bmatrix}$$

- So for example

$$\frac{\pi_{11}}{\pi_{21}} = \frac{\dfrac{-a_{22}c_{11}}{-a_{22} - a_{12}}}{\dfrac{-c_{11}}{-a_{22} - a_{12}}} = a_{22}$$

Demand shifts and identification of conduct



- Demand shifts would trace out a pricing curve in monopoly/oligopoly case and marginal costs in perfect competition case.
- Both (P_1,Q_1) and (P_2, Q_2) can be rationalized under both types of conduct → demand shifts do not help distinguish conduct.
- Observing marginal costs would help to identify conduct which is usually not the case.

Conjectural variations

$$\frac{\partial \pi_i(q_j, q_{-j})}{\partial q_j} = P(\sum_{k=1}^{N} q_k) + q_j P'(\sum_{k=1}^{N} q_k) - C_j^{'}(q_j) = 0$$

- We can generalize FOC under Cournot to allow for different conduct values θ_j:

$$P(Q) + P'(Q)\theta_j q_j - C'_j = 0$$

- The conduct parameter is interpreted as a conjectural behavior parameter → firms maximize profits by choosing output and making a conjecture about their rivals' response to an increase in own output (elasticity of rivals' output):

$$\theta_j = \frac{dQ}{dq_j} = 1 + \sum_{k \neq j} \frac{\partial q_k}{\partial q_j}$$

Conjectural variations

$$P(Q) + P'(Q)\theta_j q_j - C'_j = 0$$

- This models nests various special cases:
  - perfect competition: $\theta_j = 1 + \sum_{k \neq j} \frac{\partial q_k}{\partial q_j} = 1 - 1$
  - under Cournot: $\theta_j = 1 + \sum_{k \neq j} \frac{\partial q_k}{\partial q_j} = 1 + 0$
  - under full collusion: $\theta_j = 1 + \sum_{k \neq j} \frac{\partial q_k}{\partial q_j} = 1 + \sum_{k \neq j} \frac{q_k}{q_j} = \frac{Q}{q_j}$

Conjectural variations

- Adding up the first-order conditions and dividing by the number of firms, N, results in the following aggregate supply relation:

$$P(Q) + P'(Q)\sum_j \frac{\theta_j q_j}{N} = \sum_j \frac{C'_j(q_j)}{N}$$

$$P(Q) + \theta P'(Q)\frac{Q}{N} = \overline{C}'$$

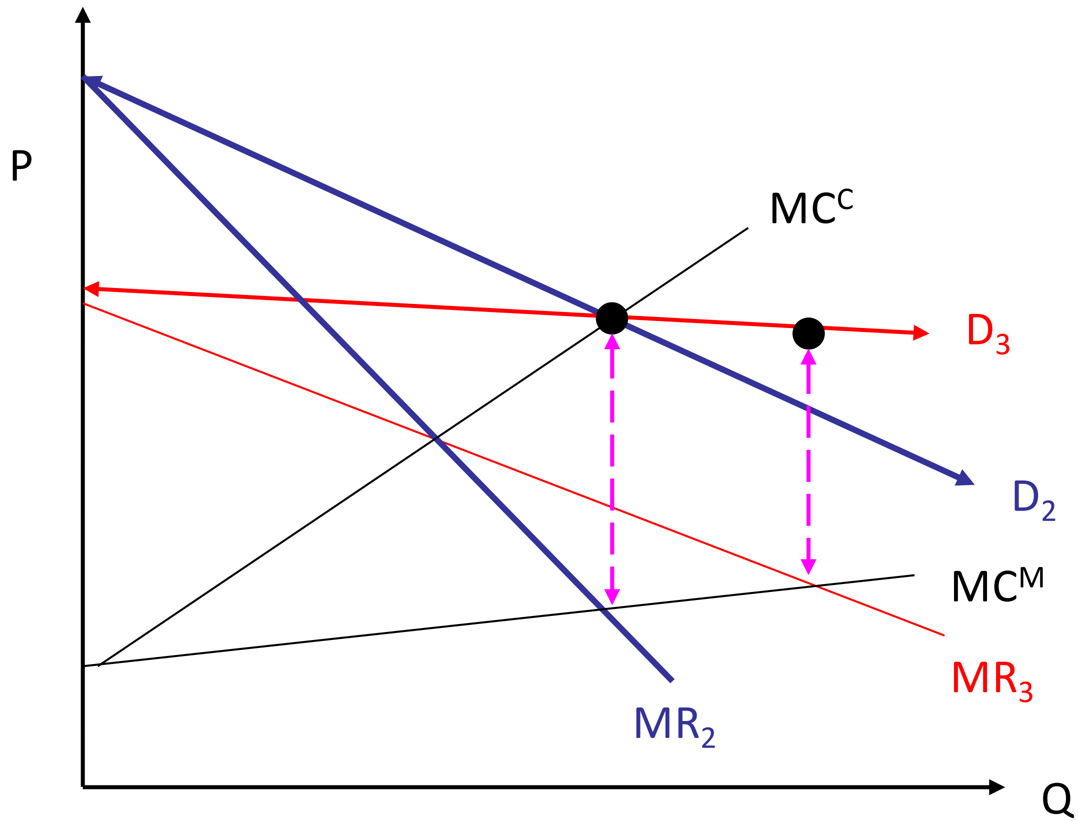
- Assuming that we estimated demand function we still have two unknowns in the supply equation:
  - We do not know marginal costs.
  - We do not necessarily know the conduct.

Conjectural variations

$$P(Q) + \theta P'(Q)\frac{Q}{N} = \overline{C}'$$

- We can proceed in the following way to identify supply equation (assuming we know demand elasticity):
  1. Having estimates of **marginal costs** → estimate **conduct** and compare it to our three theoretical conduct values.
  2. Knowing/assuming **conduct** → estimate **marginal costs** and possibly compare them to any known industry cost proxies.
  3. We can try to estimate simultaneously **both conduct and marginal costs**, which is possible under certain conditions.

Demand rotations and identification of conduct



Under competition, outcome doesn't change

Under monopoly outcome *does* change – higher elasticity means lower optimal markup.

(P_1,Q_1) stays at (P_1,Q_1) under competition, but moves to (P_2, Q_2) under collusion pricing → demand rotations do help to distinguish conduct.

Demand rotators

- We need some factor which affects the price sensitivity of consumers.
- Example: Demand for electricity are certainly different in summer and winter in SA:
    1. Seasonality demand shifter

$$Q_t = \alpha_0 - \alpha_1 P_t + \underline{\alpha_2 D_t} + \varepsilon_t$$

    2. Possibly demand becomes also less price-sensitive in summer due to intense use of air-conditioning → seasonal dummy is also a demand rotator.

$$Q_t = \alpha_0 - \alpha_1 P_t + \alpha_2 D_t + \alpha_3 \underline{(P_t * D_t)} + \varepsilon_t$$

Revenue by market structure

- Market demand: $$Q = \alpha_0 - \alpha_1 P + \alpha_2 Y + \varepsilon$$
- Inverse demand: $$P = \frac{\alpha_0}{\alpha_1} - \frac{1}{\alpha_1} Q + \frac{\alpha_2}{\alpha_1} Y + \frac{1}{\alpha_1} \varepsilon$$
- Marginal cost: $$MC(Q) = \beta_0 + \beta_1 Q + \beta_2 W + \eta$$
- First order conditions:

$$P(Q) + \lambda P'(Q) Q = \overline{C}' \qquad \lambda = \frac{\theta}{N} = \begin{cases} 0 & \text{Bertrand competition} \\ 1/N & \text{Symmetric Cournot} \\ 1 & \text{Perfect collusion} \end{cases}$$

$$\boxed{P(Q) + \frac{\lambda}{-\alpha_1} Q = \beta_0 + \beta_1 Q + \beta_2 W + \eta}$$

The pricing equation

$$
\begin{aligned}
P &= \lambda\left(\frac{Q}{\alpha_1}\right) + \beta_0 + \beta_1 Q + \beta_2 W + \eta \\
&= \beta_0 + \left(\beta_1 + \frac{\lambda}{\alpha_1}\right) Q + \beta_2 W + \eta \\
&= \beta_0 + \gamma Q + \beta_2 W + \eta
\end{aligned}
$$

- Demand parameters (α_0,α_1,α_2) are identified whatever form supply is, so long as we have a pricing equation shifter, e.g., anything that shifts MC like input factor prices.
- Pricing equation parameters are identified given demand shifters, but cannot separate out the cost/margin parameters.
- You can identify $\gamma = \left(\beta_1 + \frac{\lambda}{\alpha_1}\right)$ but not individual components (β_1, λ)

Identification with MC not dependent on Q

- Pricing equation: $$P = \beta_0 + \left(\beta_1 + \frac{\lambda}{\alpha_1}\right)Q + \beta_2 W + \eta$$

- Recall $$MC = \beta_0 + \beta_1 Q + \beta_2 W + \eta$$

- If MC is constant in Q, i.e., $\beta_1=0$

- Then $$\gamma = \left(\beta_1 + \frac{\lambda}{\alpha_1}\right) = -\frac{\lambda}{\alpha_1}$$

- And so we can learn about the conduct parameter λ (provided we can learn the demand parameter α_1, e.g., from a cost shifter W).

Identification of conduct with demand rotators

- Demand with rotator, Z:

$$Q = \alpha_0 - \alpha_1 P + \alpha_2 Y + \alpha_3 P * Z + \varepsilon$$

- Supply relation (pricing equation) becomes:

$$P = \lambda\left(\frac{Q}{\alpha_1 - \alpha_3 Z}\right) + \beta_0 + \beta_1 Q + \beta_2 W + \eta$$

- Now you can identify the conduct parameter λ.

- Same point holds more generally:
  - Shifting demand will identify the pricing equation but not conduct.
  - Identifying firm conduct requires demand rotators unless we know more about costs, e.g., mc is constant so b_1=0.

Conjectural variations: interpretation issues

$$P(Q) + \theta P'(Q)\frac{Q}{N} = \overline{C}' \qquad \theta_j = \frac{dQ}{dq_j} = 1 + \sum_{k \neq j} \frac{\partial q_k}{\partial q_j}$$

- The conjectural variation → firm’s expectation of changes in total output in response to an increase in its own output.
- Conjectural variations in this sense capture dynamic interactions but dynamics cannot be sensibly captured within a static model → should be treated explicitly in games of repeated interaction.

Conjectural variations: interpretation issues

- Researchers have often continued to interpret θ as an "as-if conjectural variation", i.e., a measure of the degree of competition or "average collusiveness".

- Rearrange the first-order condition of a symmetric version of the model to write:

$$P(Q)+\theta P'(Q)\frac{Q}{N}=\overline{C}' \Rightarrow \frac{\theta}{N}=\frac{(P-\overline{C}')/P}{1/\eta}$$

- So, θ divided by N, measures the actual markup relative to what a monopoly (or cartel) could obtain, which is given by an inverse of price elasticity. This motivates the interpretation of θ as a measure of the degree of competition.

Conjectural variations: interpretation issues

- Corts (1999) argued that the estimated conduct parameter in general, cannot be interpreted as an “as if” conjectural variations parameter indexing intermediate levels of collusive behavior if the underlying behavior is not the result of a conjectural variations equilibrium.

Genesove & Mullin (1998):

“Testing Static Oligopoly Models: Conduct and Cost in the Sugar Industry, 1890-1914”, RAND

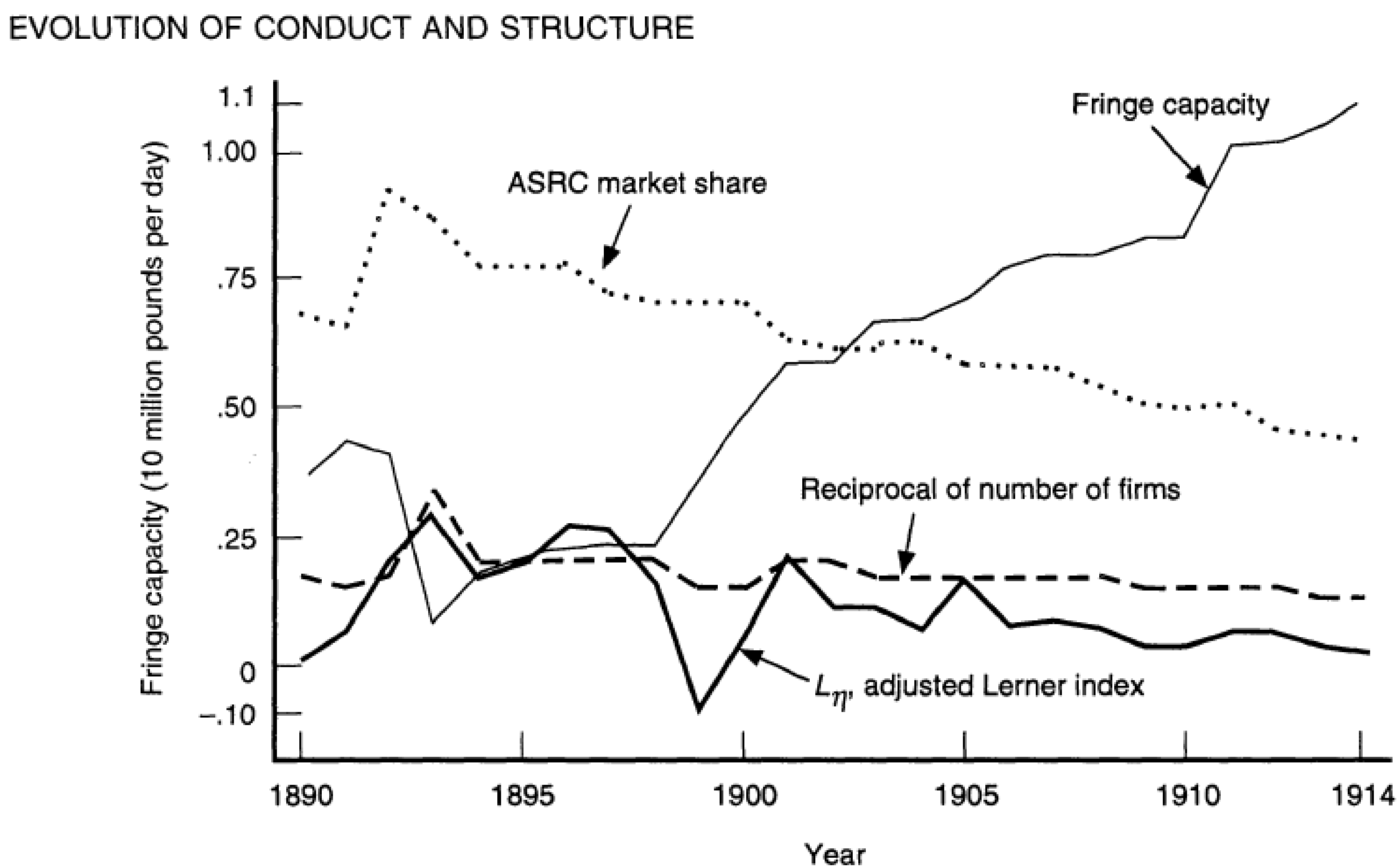
- Purpose of this paper is to assess the NEIO approach by comparing estimated market conduct with observed (derived using information on marginal costs), as well as estimated marginal costs with observed.

- Use data from the US East Coast cane sugar refining industry at the turn of the 19th century:
  - the industry underwent dramatic changes in the degree of competition: entry, price wars, collusion.
  - the production technology is simple.

- Therefore, the evaluation of the NEIO methodology under different structural conditions is possible.

Genesove & Mullin: sugar industry

- The industry during period of study is characterized by high levels of concentration, episodes of entry, price wars, acquisition by or accommodation with American Sugar Refining Company (ASRC).



Genesove & Mullin: production technology

- Raw sugar is transformed at a fixed, and known, coefficient into a final product, which is refined sugar
  - prices of both raw and refined sugar are observed
  - estimates of labor and other cost are available

- Marginal cost and the price cost margins can be calculated

$$c = c_0 + k \times P_{RAW} = .26 + 1.075 \times P_{RAW}$$

  - c marginal cost of producing 100 pounds of refined sugar.
  - c_0 represents all variable cost other than the cost of raw sugar: c_0 = 26 cents per 100 pounds.
  - k represents fixed coefficient of production between raw and refined sugar: k = 1.075 = 1 / 0.93.

Genesove & Mullin: demand

- They postulate a general demand formula:

$$Q(P) = \beta(\alpha - P)^{\gamma}$$

  - the quadratic demand curve: $\gamma = 2$
  - the linear demand curve: $\gamma = 1$
  - the log-linear demand curve: $\alpha = 0$, $\gamma < 0$
  - the exponential demand curve in the limit: α, γ →∞ and α/γ is constant.

$$\begin{array}{cc}
\text{quadratic} & \ln Q = \ln(\beta) + 2\ln(\alpha - P) + \varepsilon \\
\text{linear} & Q = \beta(\alpha - P) + \varepsilon \\
\text{log} - \text{linear} & \ln Q = \ln(-\beta) + \gamma \ln(P) + \varepsilon \\
\text{exponential} & \ln Q = \ln(\beta) + \dfrac{\gamma}{\alpha} P + \varepsilon
\end{array}$$

Genesove & Mullin: FOC

- Demand elasticity:

$$Q(P) = \beta(\alpha - P)^{\gamma} \Rightarrow \eta = \frac{\partial Q}{\partial P}\frac{P}{Q} = -\beta\gamma(\alpha - P)^{\gamma-1}\frac{P}{Q} = -\gamma P(\alpha - P)^{-1}$$

- Generalized first-order condition: $P + \theta Q \dfrac{\partial P}{\partial Q} = c$

- Elasticity adjusted Lerner index: $\theta = -\eta \dfrac{P(Q) - c}{P(Q)}$

- Optimality condition for a constant marginal cost, c, and conduct parameter, θ, is given by:
  - General price: $P(c) = \dfrac{\theta\alpha + \gamma c}{\gamma + \theta}$
  - Monopoly price (θ=1): $P(c) = \dfrac{\alpha + \gamma c}{\gamma + 1}$

$$Q = \beta(\alpha - p)^{\gamma}$$

$$\frac{\partial Q}{\partial p} = \gamma\beta(\alpha - p)^{\gamma-1} \cdot (-1)$$

$$p + \theta Q \frac{\partial p}{\partial Q} = c$$

$$p + \theta Q \cdot \frac{1}{-\gamma\beta(\alpha - p)^{\gamma-1}} = c$$

$$\beta(\alpha - p)$$

$$p + \theta \cdot \cancel{\beta(\alpha - p)^{\gamma}} \cdot \frac{1}{-\gamma\cancel{\beta(\alpha - p)^{\gamma-1}}} = c$$

$$p + \theta(\alpha - p) \cdot \frac{1}{-\gamma} = c$$

$$p - \frac{\theta\alpha}{\gamma} + \frac{p}{\gamma}\theta = c$$

$$p\left(1 + \frac{\theta}{\gamma}\right) = c + \frac{\theta\alpha}{\gamma} \quad / \cdot \gamma$$

$$p(\gamma + \theta) = \gamma c + \theta\alpha$$

$$\boxed{p = \frac{\theta\alpha + \gamma c}{\gamma + \theta}}$$

Genesove & Mullin: instruments

- Price of raw sugar is not used as an instrument because US consumption ≈ 25% of world total consumption (too large to be exogenous) → P_{RAW} is correlated with US demand shocks.
- Instead: imports of Cuban raw sugar to US (vast majority went to US). It should be exogenous to US consumption → no alternative destination, no storage possibility in Cuba, no planting of sugar canes in anticipation of demand.
- High season dummy (intense fruit canning activity in third quarter).

Genesove & Mullin: estimation of demand

- Estimates for all four specifications are comparable.
- No specification can be rejected in favor for another.
- During high season demand is less elastic.

	(1) Quadratic	(2) Linear	(3) Log-linear	(4) Exponential
Low season	2.18	2.24	2.03	2.13
High season	1.03	1.04	1.10	1.05

Genesove & Mullin: Lerner index

- Elasticity adjusted Lerner index: $\theta = \eta \dfrac{P(Q) - c}{P(Q)}$

	(1) Quadratic	(2) Linear	(3) Log-linear	(4) Exponential
Mean	0.099	0.107	0.095	0.097
Standard error	0.024	0.028	0.021	0.022

- For all demand specifications the adjusted Lerner index is about 0.10, which corresponds to the conduct of a static, ten-firm symmetric Cournot oligopoly.

- On average there were six firms in the industry with the largest firm having an average market share of 63%.

Genesove & Mullin: Lerner index

- "As if" interpretation: the six firms are behaving as if there were ten.
- Likely explanation: industry pricing was constrained by threat of (domestic) entry and foreign imports.
- Variation over time in the Lerner index is correlated with the trade union's (ASRC) market share declining over time.
- Seasonal pattern: higher market power in the second quarter and greatest competition in the third (high season).

	Quarter I		Quarter II		Quarter III		Quarter IV	
	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
Unadjusted	.048	.042	.065	.042	.064	.047	.038	.047
Linear	.102	.106	.162	.138	.075	.063	.086	.134

Genesove & Mullin: implied prices

- Implied monopoly prices: $P(c) = \frac{\theta\alpha + \gamma c}{\gamma + \theta} = \frac{\theta\alpha}{\gamma + \theta} + \frac{\gamma}{\gamma + \theta} c$
- With $c = 0.26 + 1.075\, P_{RAW}$ the mean monopoly prices for the low and high season would be USD 4.80 and USD 5.90.
- Observed refined prices are: USD 3.99 and USD 4.14 (well below monopoly prices).

	(1) Quadratic	(2) Linear	(3) Log-linear	(4) Exponential
$P(c;\theta)$ in low season	$\frac{7.72\theta}{2+\theta} + \frac{2}{2+\theta} c$	$\frac{5.82\theta}{1+\theta} + \frac{1}{1+\theta} c$	$\frac{2.03}{2.03-\theta} c$	$1.89\,\theta + c$
$P(c;\theta)$ in high season	$\frac{11.88\theta}{2+\theta} + \frac{2}{2+\theta} c$	$\frac{7.91\theta}{1+\theta} + \frac{1}{1+\theta} c$	$\frac{1.10}{1.10-\theta} c$	$3.85\,\theta + c$

Genesove & Mullin: using NEIO to estimate θ

- Substituting marginal cost function into pricing rule gives us:

$$P = \frac{\theta\alpha + \gamma c_0}{\gamma + \theta} + \frac{\gamma}{\gamma + \theta} kP_{RAW}$$

- This equation is estimated for all demand specifications with similar results.
- If γ = 1 (linear demand) and by multiplying by 1 + θ:

$$E[\{(1+\theta)P - \alpha\theta - c_0 - kP_{RAW}\}Z] = 0$$

- Z is the vector of instruments: a constant, high season, log of Cuban imports.
- Recall: α, β are known from the demand estimation, where α takes different values in the different seasons.

Genesove & Mullin: using NEIO to estimate θ

- To identify θ without complete cost information, the authors rely on non-proportional shifts, seasonal shifts in inverse demand generated by the use of sugar in fruit canning in the summer month.

$$P = \frac{\theta}{1+\theta}\alpha + \frac{c_0}{1+\theta} + \frac{k}{1+\theta}P_{RAW}$$

	Linear		Direct Measure
	(1)	(2)	(3)
$\hat{\theta}$	.038 (.024)	.037 (.024)	.10
$\hat{c}_o$	.466 (.285)	.39 (.061)	.26
$\hat{k}$	1.052 (.085)		1.075

Genesove & Mullin: assume θ to estimate MC

- The authors evaluate: perfect competition (θ =0), monopoly (θ=1) and symmetric Cournot I (θ=1/N) and asymmetric in capacities Cournot II.

	Perfect Competition		Cournot I		Cournot II		Monopoly		Direct Measure
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$\hat{c}_o$	.674	.476	.00	.069	.00	.00	.00	.00	.26
	(.281)	(.034)	(.239)	(.071)	(.922)	(.400)	(1.65)	(.563)	
$\hat{k}$	1.015		1.096		.883		.529		1.075
	(.087)		(.071)		(.253)		(.471)		

Genesove & Mullin: results

- NEIO methodology overall does pretty well tracking calculated price-cost margins independent of the assumed demand function → estimated conduct is close to direct measure derived from full cost information.

- θ is underestimated due to the correlation between L_η and high season: refined prices rise in high season but proportionately less than the elasticity falls. Monopoly (θ=1) can be rejected.

- Cost estimates are sensitive to the model assumed. The predictive power improved when direct cost measures replaced one or both estimated cost parameters.

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