Market Power, Collusion, and Cartels I

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Empirical IO

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Outline

- First, we consider the identification of market power in broad terms: can we tell whether an industry is collusive or competitive?
- Second, we will discuss theory and empirical work aiming to understand price wars:
  - Green and Porter (1984) - a theory of price wars based on imperfect information
  - Porter (1983) - empirical study based on Green and Porter (1984)
  - Rotemberg and Saloner (1986) - alternative theory of price wars based on demand shocks

Policy background: US

- In the US, cartels have been illegal since the Sherman act (1890).
- Certain groups/industries are exempt (Major League Baseball, farmers).
- Price fixing is always illegal – even before damages are assessed, conspiring to fix prices is a crime. (But the US government sponsors a program to fix milk prices.)
- Enforcement by Department of Justice and Federal Trade Commission.
- Fined various airlines $1.8bil in cargo price fixing case in 2010.

Policy background: EU

- Antitrust policy is generally a more recent development in Europe, arriving in the 1950's in much of Europe. In the EU, Article 101 of the Treaty on the Functioning of the European Union forbids cartels.
- Enforcement by European Commission.
- Fined various airlines €800mil in cargo price fixing case in 2010.

Identification of market power

- Can we tell a collusive market apart from a competitive one?
- We typically lack reliable data on firms' costs, so a related question is what we need to infer markups.
- Let's look at two examples:
  - A repeated duopoly game
  - Bresnahan's (1982) identification argument

Repeated Bertrand Duopoly: equilibria

- Suppose two firms engage in Bertrand price competition each period witih market demand $Q = 1 - P$. Each firm has discount factor δ.
- One subgame perfect equilibrium is to play the static Nash equilibrium each period, meaning firms always price at marginal cost: $P_1, P_2 = mc$.
- As long as $\delta \geq \frac{1}{2}$, another subgame perfect equilibrium is for both firms to play the monopoly price on the equilibrium path with the threat of a "grim trigger" punishment if either firm ever deviates.

Repeated Bertrand Duopoly: observational equivalence

- If we only observe prices and quantities, we can never tell apart the collusive and competitive equilibria.
- Say we observe that firms always play price P_0 and the aggregate quantity is Q_0. It could be the case that:
  - Firms price at marginal cost, and $mc = P_0$
  - Firms split the monopoly profits and $mc = 2P_0 - 1$
  - A continuum of possibilities in between.

Multiplicity and inference

- "Folk Theorems" basically state that any feasible combination of payoffs can be rationalized in equilibrium with sufficiently patient agents.
  - Fudenberg and Maskin (1986) - perfect information
  - Fudenberg, Levine, and Maskin (1994) - public signals
  - Recent work by Takuo Sugaya and others on private information
- Such rich multiplicity presents a problem for inference
- In a repeated game, Markov Perfect Equilibrium is very powerful for equilibrium selection because it implies repeated static Nash equilibrium. However, see Ulrich Doraszelski's work for examples of (relatively simple) dynamic games with several MPE.

"The Oligopoly Solution Concept is Identified"
Tim Bresnahan (1982)

Main idea

- Bresnahan argues that we can actually estimate how much market power firms have, as long as we can estimate demand.

Model

- Demand: $Q = D(P, Y, \alpha) + \epsilon$, where Y are some exogenous demand shifters and α are parameters.

- A supply relationship nesting monopoly $(MR = MC)$ and perfect competition $(P = MC)$:

$$P = c(Q, W, \beta) - \lambda h(Q, Y, \alpha) + \eta$$

  where W are some exogenous supply shifters, β are parameters, and $P + h(Q, Y, \alpha)$ is market-level marginal revenue.
- $\lambda = 1$ monopoly
- $\lambda = 0$ perfect competition
- $\lambda = 1/n$ Cournot

Estimation I

- Consider a linear case:

$$
\begin{aligned}
Q &= \alpha_0 + \alpha_1 P + \alpha_2 Y + \epsilon && (1)\\
MC &= \beta_0 + \beta_1 Q + \beta_2 W && (2)\\
\Rightarrow & && \\
P &= \lambda(-Q/\alpha_1) + \beta_0 + \beta_1 Q + \beta_2 W + \eta && (3)
\end{aligned}
$$

  where $h(Q, W, \alpha) = -Q/\alpha_1$.

- While we can estimate the (1) and (3) using instrumental variable regressions, the supply relation gives us an estimate of $\lambda/\alpha_1 + \beta_1$. We cannot separate λ and β_1.

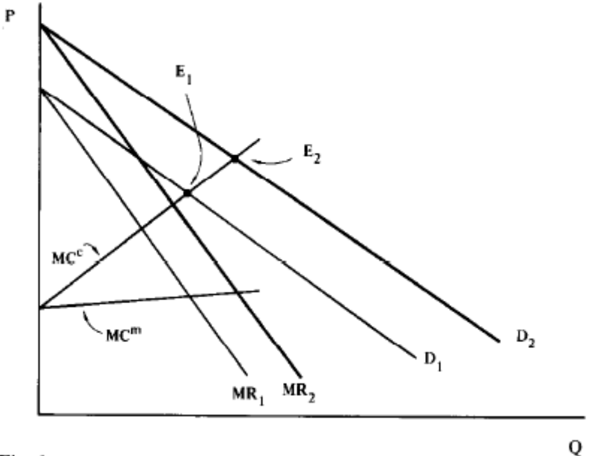


Fig. 1.

With a change in the demand intercept, we can rationalize observed change in prices and quantities with a monopolistic or a perfectly competitive model.

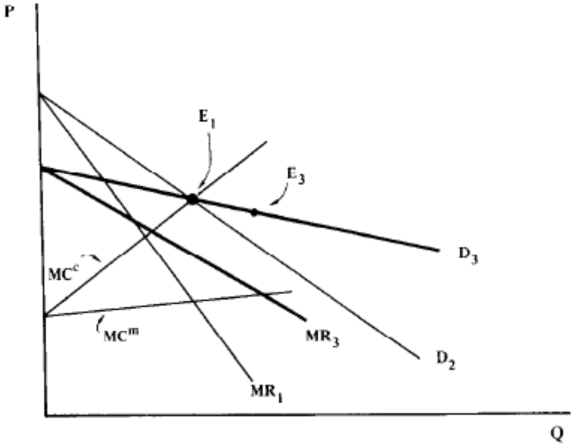


Fig. 2.

However, with a rotation of the demand curve, the two models yield distinct predictions.

Estimation II

- Consider a linear case:

$$
\begin{aligned}
Q &= \alpha_0 + \alpha_1 P + \alpha_2 Y + \alpha_3 PZ + \alpha_4 Z + \epsilon && (1)\\
MC &= \beta_0 + \beta_1 Q + \beta_2 W && (2)\\
&\Rightarrow \\
P &= \lambda \tfrac{-Q}{\alpha_1 + \alpha_3 Z} + \beta_0 + \beta_1 Q + \beta_2 W + \eta && (3)
\end{aligned}
$$

  where $h(Q, W, \alpha) = \frac{-Q}{\alpha_1 + \alpha_3 Z}$.

- Now marginal revenue depends on Z which is excluded from the marginal cost equation. This can be used to identify λ.
  Note: $\frac{-Q}{\alpha_1 + \alpha_3 Z}$ is not collinear with Q.

Summary

- **Conclusion**: we can learn about market power by estimating demand.
  - "Translation of the demand curve will always trace out the supply relation. Rotations of the demand curve around the equilibrium point will reveal the degree of market power."
- Next: Green and Porter (1984) study another case in which collusive behavior can be identified because of periodic breakdowns in cooperation.

"Noncooperative Collusion under Imperfect Price Information"
Green and Porter (1984)

Overview

- A model of tacit collusion with imperfect public information in the tradition of Stigler's theory of dynamic oligopoly: collusion is supported by the threat of punishment.
- Perfect collusion is impossible because of the imperfect information. The price wars (Cournot episodes) are essential in sustaining collusion.
- The theoretical foundation for Porter's (1983) study of a 19th Century railroad cartel.

Model I

- n firms engage in repeated Cournot competition. No entry or exit.
- Each period, each firm chooses a quantity x_{it}.
- There is uncertainty about the price. The observed price is

$$p_t = \theta_t p \left(\sum_i x_{it} \right)$$

  where θ_t is an i.i.d. demand shock with $E(\theta_t) = 0$.
- Firms cannot observe θ_t or other firm's quantity choices. The price is public information.

Model II

- $\pi_i(x_i, p)$ represent's i's net return from producing x_i units sold at price p.
- Firms are risk neutral and maximize

$$E\left[\sum_{t=0}^{\infty} \beta^t \pi_i(x_{it}, p_t)\right]$$

  where β is a common discount factor.
- Green and Porter consider trigger-price strategies:
  - The cartel starts out in a "normal" regime with restricted output. If the price follows below $\bar{p}$, the regime switches to a reversionary episode.
  - In a reversionary episode, firms play the static Cournot quantities for $T - 1$ periods before the regime switches back to normal.

Verifying the equilibrium

- Let $z = (z_1, \ldots, z_n)$ denot the Cournot output profile and let $y = (y_1, \ldots, y_n)$ denote restricted (collusive) outputs.
- We need to check that a firm has no incentive to deviate in any period. Recalling the one-shot deviation principle, we can verify that the equilibrium is subgame perfect as long as there are no profitable deviations in any particular state.
- For reversionary periods, verifying optimality is trivial. Firms play static best responses, and their actions have no dynamic consquences.

Verifying the equilibrium II

- In normal periods, a firm must consider how its choice impacts the probability of triggering a reversionary episode.
- The static profits from $x_{it} = r$ are

$$\gamma_i(r) = E\left[\pi_i\left(r, \theta p\left(r + w_i\right)\right)\right].$$

- The expected profits in reversionary periods are:

$$\delta_i = E\left[\pi_i\left(z_i, \theta p\left(\sum_{j=1}^{n} z_j\right)\right)\right]$$

- Let $V_i(r)$ be the expected profits in a normal period if a firm sets $x_{it} = r$. Let $w_i = \sum_{j \neq i} y_j$ be the aggregate quantity of firms other than i in normal periods.

Verifying the equilibrium III

- If a firm plays r in normal periods,

$$\begin{aligned} V_i(r) &= \gamma_i(r) + \beta Pr(\bar{p} \leq \theta p(r + w_i)) V_i(r) \\ &\quad + Pr(\theta p(r + w_i) \leq \bar{p}) \left[\textstyle\sum_{t=1}^{T-1} \beta \delta_i + \beta^T V_i(r) \right] \end{aligned}$$

- This can be solved for $V_i(r)$:

$$V_i(r) = \frac{\gamma_i(r) - \delta_i}{1 - \beta + (\beta - \beta^T) F(\bar{p}/p(r + w_i))} + \frac{\delta_i}{1 - \beta}.$$

  where F is the distribution function for θ.

- For y_i to be optimal in normal periods, we require $V_i'(y_i) = 0$ for all i.

How would we construct an explicit equilibrium?

- For example, we could check whether there is a symmetric equilibrium in which firms split the monopoly quantity each period: $y_i = x^m/n$. Given the distribution function F, we can compute

$$V_i\left(r\right) = \frac{\gamma_i\left(r\right) - \delta_i}{1 - \beta + \left(\beta - \beta^T\right) F\left(\bar{p}/p\left(r + w_i\right)\right)} + \frac{\delta_i}{1 - \beta}.$$

  for a given cutoff $\bar{p}$ and reversionary duration T.

- For a given T, we could search for a value of $\bar{p}$ such that $V_i'\left(y_i\right) = 0$. That would be an equilibrium which involves joint monopoly profits in normal periods and periodic episodes of reversion to Cournot play.

Comments

- Sometimes it is impossible to support the joint monopoly profits in normal periods.
- To see how to solve for optimal equilibria, see Abreu, Pearce, and Stacchetti (1986) and Porter (1983) "Optimal Cartel Trigger Price Strategies."

Summary

- Green and Porter's model rationalizes a particular industry pattern: there can be sustained periods of relatively high prices, followed by periods of low prices before the price rises again.
- "Every competitor is able to figure out what i will do to maximize profits. The market price reveals information about demand only, and never leads i's competitors to revise their beliefs about how much i has produced... despite the fact that firms know that low prices reflect demand conditions rather than overproduction by competitors, it is rational for them to participate in reversionary episodes."

"A Study of Cartel Stability: The Joint Executive Committee, 1880-1886"
Rob Porter (1983)

Overview

- Porter estimates a model of the Joint Executive Committee, a 19th Century railroadh cartel.
- One of few *empirical* studies of dynamic collusion.
- Early application of the EM algorithm.
- Similar to Green and Porter (1984), but with price competition.

Background

- There were several railroad routes from Chicago to the Atlantic seaboard in the late 19th Century. Their primary business was in grain shipments, and the different railroads colluded to raise the "grain rate," the price of shipping grain.
- The JEC predates the Sherman act, so it was legal. A trade magazine even reported on whether or not a price war was occurring.
- The main competitor were lake and canal-based shipping operations. However, the lakes were closed every winter, and Porter uses lake closure status as a (residual) demand shifter.

Demand

- Demand for grain shipments:

$$\ln Q_t = \alpha_0 + \alpha_1 \ln p_t + \alpha_2 L_t + U_{1t}$$

where L_t is a dummy indicating whether the lakes were open.

Supply I

- A "general" model of price setting:

$$p_t\left(1+\theta_{it}/\alpha_1\right)=MC_i\left(q_{it}\right)$$

where $\theta_{it}=0$ for all firms is competitive pricing, $\theta_{it}=1$ for all firms is monopoly pricing, and θ_{it} equal to the market share would be Cournot.

- Adding up the individual supply relations weighted by shares,

$$p_t\left(1+\theta_t/\alpha_1\right)=\sum_i s_{it}MC_i\left(q_{it}\right)$$

with $\theta_t=\sum_i s_{it}\theta_{it}$.

Supply II

- Assuming the cost function

$$C_i\left(q_{it}\right) = a_i q_{it}^{\delta} + F_i,$$

Porter claims that the competitive, monopoly, and Cournot pricing cases all imply constant market shares for each firm over time:

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

Supply III

- We can then write the aggregate supply relation:

$$p_t\,(1+\theta_t/\alpha_t) = DQ^{\delta-1}$$

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

- Taking logs,

$$\ln p_t = \beta_0 + \beta_1 \ln Q_t + \beta_2 S_t + \beta_3 I_t + U_{2t}$$

where S_t is a vector of dummies indicating periods over which the set of active firms are constant, and I_t indicates when the industry is in a cooperative regime. Note that $\beta_0 = \ln D$, $\beta_1 = \delta - 1$, and $\beta_3 = -\ln\,(1+\theta_t/\alpha_t)$.

Equations for estimation

- Demand:

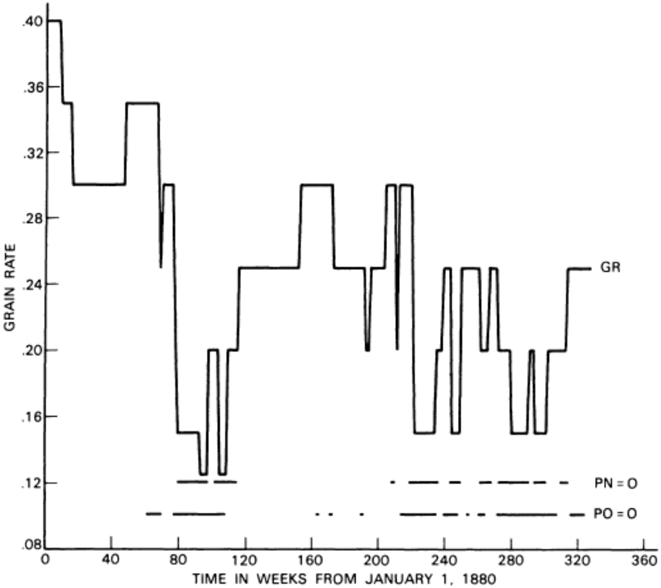
$$\ln Q_t = \alpha_0 + \alpha_1 \ln p_t + \alpha_2 L_t + U_{1t} \tag{1}$$

- Supply:

$$\ln p_t = \beta_0 + \beta_1 \ln Q_t + \beta_2 S_t + \beta_3 I_t + U_{2t} \tag{2}$$

- Equations (1) and (2) form a simultaneous system. If I_t were observed, we could use FIML (or GMM). Porter estimates a mixture model using the EM algorithm, using FIML for each M-step.

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


.40
.36
.32
.28
.24
.20
.16
.12
.08
GRAIN RATE
GR
PN = O
PO = O
0
40
80
120
160
200
240
280
320
360
TIME IN WEEKS FROM JANUARY 1, 1880

Summary

- Given assumption that reversion periods are competitive pricing, the collusive periods appear to have markups corresponding roughly to the Cournot equilibrium.
- The distortions are large: 66% higher prices and 33% lower prices in cooperative periods. Revenues were roughly 11
- Note that this was not a repeated game like Green and Porter. Porter assumes that the structural changes may change the punishment phase (competitive) prices, but the difference between these prices and the collusive prices are held constant.
- A potential issue: Porter does not observe negative demand residuals before punishment phases. This may be due to omitted variables (e.g., lake shipping prices).

"A Supergame-Theoretic Model of Price Wars during Booms"
Rotemberg and Saloner (1986)

Overview

- Departs from the repeated game setting and considers collusion in an industry with demand fluctuations.
- When demand is high, temptation to deviate is larger, collusion is harder, and cartel may have to coordinate on an outcome that is further from maximum joint profits.
- This is at odds in Green and Porter (1984) where price wars occur when demand is low. To support the theory, they observe:
  - price/cost ratios tend to be "countercyclical in more concentrated industries"
  - They find cement prices are strongly countercyclical.

Comment on Green and Porter

- In Green and Porter (1984), "price wars occur when demand is unexpectedly low. Then, firms switch to competition because they confuse the low price that prevails in equilibrium with cheating on the part of other firms."

Comment on Green and Porter

- In Green and Porter (1984), "price wars occur when demand is unexpectedly low. Then, firms switch to competition because they confuse the low price that prevails in equilibrium with cheating on the part of other firms."
- That's not right – the firms know what's going on in Green and Porter, and it is always optimal for them to go along with the equilibrium.

Model I

- The inverse demand function is $P\left(Q_t, \varepsilon_t\right)$, where ε_t is the demand shock, which is i.i.d. across periods.
- The demand shock is observed before firms move each period. Firms compete in prices (they also look at quantities) for a homogeneous product with unit cost c.
- Firms can steal the monopoly profits by slightly undercutting other firms. For cooperation to be optimal,

$$N\Pi^m\left(\varepsilon_t\right) - K \leq \Pi^m\left(\varepsilon_t\right)$$

  where $N\Pi^m$ is the monopoly profits, N the number of firms, and K is the punishment inflicted on a cheater in the future. K is endogenous and will be derived later.

Model II

- There is some maximal level of the demand shock $\varepsilon^*(K)$ for which the monopoly profits are sustainable:

$$(N-1)\,\Pi^m(\varepsilon^*(K)) = K$$

- In any period in which $\varepsilon_t \leq \varepsilon^*(K)$, the joint profit maximizing outcome can be sustained.
- When $\varepsilon_t > \varepsilon^*(K)$, the highest sustainable profits (per firm) are $K/(N-1)$. In other words, the maximum sustainable profits are given by

$$\Pi^s(\varepsilon_t) = \begin{cases} \Pi^m(\varepsilon_t) & \text{if } \varepsilon_t \leq \varepsilon_t^*(K) \\ \frac{K}{N-1} & \text{if } \varepsilon_t > \varepsilon_t^*(K) \end{cases}$$

Model III

- To maximize the equilibrium profits, we must maximize the punishment. This is done by using the grim-trigger punishment (permanent reversion to marginal cost pricing), in which case

$$K = \frac{\delta}{1-\delta} E\left[\Pi^s\left(\varepsilon_t\right)\right]$$

- Note: because ε_t is i.i.d., the punishment is independent of the state.

Equilibrium behavior

- For $\varepsilon_t > \varepsilon^*$, higher demand shocks lead to higher ouptut and lower prices but the same level of profits: $\Pi^s = Q_t \left(P_t - c\right)$.
- Thus, as demand rises above some cutoff, the cartel lowers its price to deter deviations.
- Unlike Green and Porter, we punishments are not observed in equilibrium here.

TABLE 1—THE CYCLICAL PROPERTIES OF CEMENT PRICES
(Yearly Data from 1947 to 1981)[a]

Coefficient	Dependent Variable			
	P^c/PPI	P^c/PPI	P^c/P^{con}	P^c/P^{con}
Constant	.025	.025	.038	.037
	(.010)	(.012)	(.007)	(.008)
GNP	−.438	−.456	−.875	−.876
	(.236)	(.197)	(.161)	(.149)
ρ		.464		.315
		(.173)		(.183)
R^2	.10	.15	.48	.52
D-W	1.03	1.73	1.28	1.92

[a] P^c is the price of cement, PPI is the Producer Price Index, and P^{con} is the price index of construction materials. Standard errors are shown in parentheses.

TABLE 4—RAILROADS IN THE 1880'S

	Estimated Nonadherence	Rail Shipments (Million bushels)	Fraction Shipped by Rail	Total Grain Production (Billion Tons)[a,b]	Days Lakes Closed 4/1–12/31[a]
1880	0.00	4.73	22.1	2.70	35
1881	0.44	7.68	50.0	2.05	69
1882	0.21	2.39	13.8	2.69	35
1883	0.00	2.59	26.8	2.62	58
1884	0.40	5.90	34.0	2.98	58
1885	0.67	5.12	48.5	3.00	61
1886	0.06	2.21	17.4	2.83	50

[a] Obtained from the Chicago Board of Trade (1880–86).

[b] This total is constructed by adding the productions of wheat, corn, rye, oats, and barley in tons.

Summary

- Green and Porter's price wars are realizations of punishment phases in a dynamic game with unobservable demand shocks.
- Rotemberg and Saloner's are prices wars are periods in which cooperation must be reigned in because demand is high in a dynamic game with observable demand shocks.
- Rotemberg and Saloner's prediction that price wars will occur during periods of high demand seems to have some support in the data.
- An unfortunate macroeconomic implication: distortions from imperfect competition will be worse during recessions.