Identification of Market Power

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Empirical IO

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Outline

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- 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.

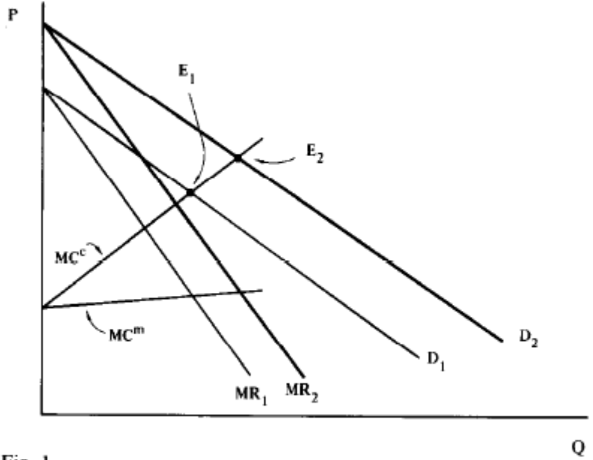


Fig. 1.

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

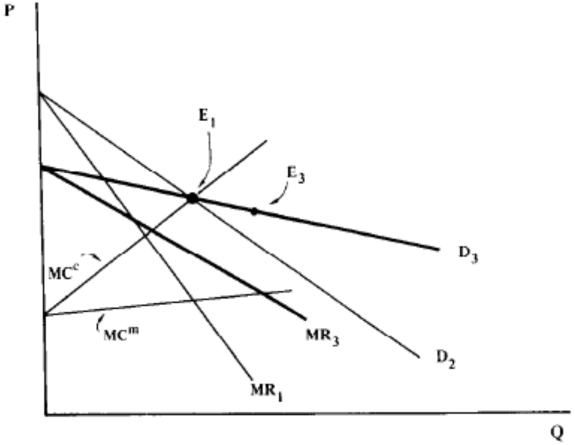


Fig. 2.

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.

"Markups and Firm-Level Export Status"
De Loecker and Warzynski (2012)

Overview

- Demonstrates how production function can be used to make inferences about markups
- Applied question: how do markups of exporters differ from non-exporters, and how does a firm's productivity change when it becomes an exporter.
- Findings:
  - Exporters have higher markups than importers
  - Markups increase when a firm becomes an exporter
  - Note similarity to De Loecker (2011), but focus is now on exporter status rather than trade liberalization

Sketch of main idea I

- Definition of markup: $\mu = P/MC$
- Let P_{it}^{v} represent the price of input v and let P_{it} represent the price of output.
- Production function:

$$Q_{it} = Q_{it}\left(X_{it}^{1}, \ldots, X_{it}^{V}, K_{it}, \omega_{it}\right)$$

  where $v = 1, 2, \ldots, V$ indexes variable inputs.
- Assumption: variable inputs are set each period to minimize costs.

Sketch of main idea II

- Lagrangian for cost minimization problem:

$$L\left(X_{it}^{1},\ldots,X_{it}^{V},K_{it},\lambda_{it}\right)=\sum_{v=1}^{V}P_{it}^{v}X_{it}^{v}+r_{it}K_{it}+\lambda_{it}\left(Q_{it}-Q_{it}\left(\cdot\right)\right)$$

- First-order condition:

$$P_{it}^{v}-\lambda_{it}\frac{\partial Q_{it}\left(\cdot\right)}{\partial X_{it}^{v}}=0,$$

where λ_{it} is the marginal cost of production at production level Q_{it}.

Sketch of main idea III

- First-order condition:

$$P_{it}^{v} - \lambda_{it} \frac{\partial Q_{it}(\cdot)}{\partial X_{it}^{v}} = 0.$$

- Multiplying by X_{it}^{v}/Q_{it}:

$$\frac{\partial Q_{it}(\cdot)}{\partial X_{it}^{v}} \frac{X_{it}^{v}}{Q_{it}} = \frac{1}{\lambda} \frac{P_{it}^{v} X_{it}^{v}}{Q_{it}}.$$

- With $\mu_{it} \equiv P_{it}/\lambda_{it}$,

$$\frac{\partial Q_{it}(\cdot)}{\partial X_{it}^{v}} \frac{X_{it}^{v}}{Q_{it}} = \mu_{it} \frac{P_{it}^{v} X_{it}^{v}}{P_{it} Q_{it}}$$

where we have multiplied and divided by P_{it} on the RHS.

The markup formula

This leads to a simple expression:

$$\mu_{it} = \theta_{it}^{v} \left(\alpha_{it}^{v}\right)^{-1}$$

where θ_{it}^{v} is the output elasticity with respect to input v, and α_{it}^{v} is expenditures on input v as a share of revenues.

- On its own, this formula is nothing new
- What's new about DLW is how flexible they are about estimating θ_{it}^{v} and how they base their inferences about markups on careful production function estimation.

The demand-based approach

- Recall the formula for monopoly pricing:

$$\frac{p}{mc} = \frac{1}{1 + \mathcal{E}_D^{-1}}$$

  where $\mathcal{E}_D^{-1}$ is the inverse elasticity of demand.

- In more complicated settings (e.g., differentiated products), we can still solve for markups as a function of demand elasticities.

- Demand-based approach has been the standard, but notice the many assumptions involved:
  - Typically static Nash-Bertrand competition (or at least some imperfect competition game where we can easily solve for the equilibrium)
  - Instruments to identify demand
  - Functional form assumptions on demand system, model of consumer heterogeneity

CD: example

- Assume labor is a flexible input.
- With Cobb-Douglas production function,

$$Q_{it} = \exp\left(\omega_{it}\right) L^{\beta_L} K^{\beta_K},$$

output elasticity of labor is just a constant:

$$\theta_{it}^{L} = \frac{\partial Q_{it}}{\partial L_{it}} \frac{L_{it}}{Q_{it}} = \beta_L.$$

- Markup:

$$\mu_{it} = \frac{\beta_L}{\alpha_{it}^{L}}$$

CD: concerns

Cobb-Douglas markup:

$$\mu_{it} = \frac{\beta_L}{\alpha_{it}^L}$$

Some things we might worry about:

- Bias in estimating β_L without appropriate econometric strategy (always a concern in production function estimation)
- Cobb-Douglas is very restrictive, imposing output elasticity which does not depend on Q nor the relative levels of inputs. Variation in expenditure shares will be only source of variation in markups.
- If we assume variation of input share is independent of output elasticity, then any variation in productivity which affects the input share is being treated as variation in markups.

Translog production function

- DLW's main results are based on a translog production function:

$$y_{it} = \beta_l l_{it} + \beta_k k_{it} + \beta_{ll} l_{it}^2 + \beta_{kk} k_{it}^2 + \beta_{lk} l_{it} k_{it} + \omega_{it} + \varepsilon_{it}.$$

- Translog output elasticities:

$$\hat{\theta}_{it}^L = \hat{\beta}_l + 2\hat{\beta}_{ll} l_{it} + \hat{\beta}_{lk} k_{it},$$

so translog production is flexible enough to allow for a first-order approximation to how output elasticities vary with input use.

Empirical framework

- Consistent with production function estimation literature, they assume Hicks-neutral productivity shocks:

$$Q_{it} = F\left(X_{it}^{1}, \ldots, X_{it}^{V}, K_{it}; \beta\right) \exp\left(\omega_{it}\right).$$

- Also allow for some measurement error in production:

$$y_{it} = \ln Q_{it} + \varepsilon_{it}$$

$$y_{it} = f\left(x_{it}, k_{it}; \beta\right) + \omega_{it} + \varepsilon_{it}$$

The control function

- Following Levinsohn and Petrin, use materials to proxy for productivity

$$m_{it} = m_t\left(k_{it}, \omega_{it}, \mathbf{z}_{it}\right)$$

where $\mathbf{z}_{it}$ are controls.

- Note: a big claim of the paper is estimating "markups without specifying how firms compete in the product market"
- But here, $\mathbf{z}_{it}$ must control for everything which shifts input demand choices or else there will be variation in productivity they're not controlling for (and hence some of the variation in their inferred markups may actually come from variation in productivity)
- In the appendix, they explain that $\mathbf{z}_{it}$ includes input prices, lagged inputs (meant to capture variation in input prices), and exporter status.

Physical output vs. sales

- Note that the theory is developed in terms of outputs, but DLW only have sales (as usual).
- For a price-taking firm, there's no problem rewriting the formula in terms of sales:

$$\frac{\partial R_{it}(\cdot)}{\partial X_{it}^v} \frac{X_{it}^v}{R_{it}} = \frac{P_t \partial Q_{it}(\cdot)}{\partial X_{it}^v} \frac{X_{it}^v}{P_t Q_{it}} = \mu_{it} \frac{P_{it}^v X_{it}^v}{P_{it} Q_{it}}$$

  because $\frac{\partial R_{it}(\cdot)}{\partial X_{it}^v} = \frac{P_t \partial Q_{it}(\cdot)}{\partial X_{it}^v}$.
- However, if the firm has market power,

$$\frac{\partial R_{it}(\cdot)}{\partial X_{it}^v} = \frac{\partial Q_{it}(\cdot)}{\partial X_{it}^v} \left(P_{it} + \frac{\partial P_{it}}{\partial Q_{it}} \right).$$

TABLE 2—ESTIMATED MARKUPS

	Methodology	Markup
	Hall[a]	1.03 (0.004)
	Klette[a]	1.12 (0.020)
Specification		
	I (Cobb-Douglas)	1.17
	II (I w/ endog. productivity)	1.10
	III (I w/ additional moments)	1.23
	IV (Translog)	1.28
	V (II w/ export input)	1.23
	VI (Gross Output: labor)	1.26
	VI (Gross Output: materials)	1.22
	VII[a] (**I** w/ single markup)	1.16 (0.006)
	VIII[a] (First difference)	1.11 (0.007)

[a]Markups are estimated jointly with the production function (as discussed in Section III), and we report the standard errors in parentheses. The standard deviation around the markups in specifications **I–VI** is about 0.5.

TABLE 3—MARKUPS AND EXPORT STATUS I: CROSS-SECTION

Methodology	Export Premium
Hall	0.0155 (0.010)
Klette	0.0500 (0.090)
Specification	
I (Cobb-Douglas)	0.1633 (0.017)
II (I w/ endog. productivity)	0.1608 (0.017)
IV (Translog)	0.1304 (0.014)
V (II w/ export input)	0.1829 (0.017)
VIII (First difference)	0.1263 (0.013)

Notes: Estimates are obtained after running equation (21) where the different specifications refer to the different markup estimates, and we convert the percentage markup difference into levels as discussed above. The standard errors under specifications **I–V** are obtained from a nonlinear combination of the relevant parameter estimates. All regressions include labor, capital, and full year and industry dummies as controls. Standard errors are in parentheses.

"Testing static oligopoly models: conduct and cost in the sugar industry, 1890-1914"
Genesove and Mullin (1998)

Overview

- Bresnahan (1982) and BLP pioneered demand-based estimation of marginal cost and markups, but there are some concerns with these strategies:
  - Functional form assumptions are crucial.
  - θ might not be stable, in which case Bresnahan's regressions can give a biased estimate of the mean level of market power.

- Genesove and Mullin aim to identify the level of market power within sugar industry, where we have at least a rough idea of what marginal cost should be.

- Looking at the US sugar industry 1890-1914 is interesting because the industry became more competitive; it was the time in between the Sherman Act's passage and when antitrust policy actually started being enforced.
  - Also, price wars

Industry background

- Sugar Trust controlled 80-95% of US sugar refining capacity in late 19th century
- There were documented periods of price wars in 1889-1892 and 1898-1900 following entries
- Dissolution of the trust in 1911 after federal government filed suit.

Marginal costs: direct measures

- The main input in sugar refining is raw sugar, with approximately 1.075 units of raw sugar needed per unit of refined sugar.
- A measure of refined sugar's marginal cost:

$$c = c_0 + 1.075 * P_{RAW}$$

  where c_0 represents the cost of inputs other than raw sugar.
- Genesove and Mullin argue that we can derive a lower bound on c_0 by assuming labor costs are fully fixed, and an upper bound by assuming labor is fully proportional to output.
  - This places c_0 between \$ 0.18 and \$ 0.26 per 100 pounds of sugar. This is a small range of uncertainty as the non-raw-sugar inputs are only about 5% of costs.

Identification of market power

- Recall Bresnahan's generalized pricing condition:

$$P + \theta Q P'(Q) = c$$

- We can show that θ is equal to the elasticity-adjusted Lerner index:

$$\theta = \eta(P) \frac{P - c}{P}$$

- Thus, given demand estimates and a measure of cost, we can *construct* θ directly. However, we're also interested in *estimating* c and comparing to the direct measures.

Demand

- GS consider a general demand function:

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

- They estimate several versions of this demand system. For example, the estimating equation for the linear case ($\gamma = 1$) is:

$$Q = \beta(\alpha - P) + \epsilon.$$

- They use imports from Cuba to instrument for price (arguing that the only variable shifting Cuban imports are supply shocks in Cuba).

TABLE 5 **Lerner Indices by Year**

	Lerner Index				
	Unadjusted		Elasticity Adjusted (linear)		
Year	Mean	Standard Deviation	Mean	Standard Deviation	American Sugar Refining Co.'s Market Share
1890	.00	.01	.00	.08	67.7
1891	.05	.04	.06	.08	65.2
1892	.11	.07	.20	.15	91.0
1893	.12	.03	.29	.10	85.7
1894	.10	.05	.17	.09	77.0
1895	.09	.03	.19	.07	76.6
1896	.09	.05	.26	.13	77.0
1897	.10	.01	.26	.12	71.4
1898	.03	.04	.16	.19	69.7
1899	−.02	.02	−.09	.08	70.3
1900	.02	.04	.05	.10	70.1
1901	.08	.01	.20	.06	62.0
1902	.08	.03	.11	.05	60.9
1903	.07	.04	.11	.07	61.5
1904	.04	.04	.06	.06	62.3
1905	.06	.03	.16	.13	58.1
1906	.05	.03	.07	.05	57.3
1907	.06	.03	.08	.06	56.8
1908	.05	.01	.07	.03	54.3
1909	.02	.02	.03	.04	50.4
1910	.02	.01	.03	.02	49.2
1911	.04	.03	.06	.04	50.1
1912	.04	.02	.06	.04	45.5
1913	.03	.02	.03	.01	44.0
1914	.02	.02	.02	.02	43.0
Average	.05	.05	.11	.12	63.1

Notes: The market share figures are from the *Weekly Statistical Sugar Trade Journal.*

Price wars

Estimating θ

- After estimating demand, they can jointly estimate the cost parameters and θ.
- For the linear case, they estimate using the following moments:

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

- Is the identification idea here the same as in Bresnahan (1982)?

TABLE 7 **NLIV Estimates of Pricing Rule Parameters**

	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

- Note that the estimated θ is lower than the constructed θ. (maybe due to dynamics described to Rotemberg and Saloner)

TABLE 9 Cost and Price Estimates for Different Behavioral Models

	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)		
Predicted price changes, Cuban Revolution									
$\widehat{\Delta P}$	.689	.729	.620	.608	.300	.365	.179	.365	.702
	(.059)		(.040)		(.086)		(.086)		

Notes: Demand parameters are taken from the linear form in Table 4, estimated separately by season. Cost parameters are constrained to be nonnegative. Predicted increase in refined prices is based upon the increase in the price of raw sugar by 68 cents per hundred pounds from the third quarter of 1896 to the third quarter of 1897.

Estimates and implied responses to a $ 0.68 increase in the raw sugar price.

External validation

- One thing that can go wrong in the external validation is that misestimating k implies the wrong passthrough of inputs to costs:

$$\Delta P = k \Delta P_{RAW}$$

- The other thing that goes wrong is that if we have the wrong θ, we have the wrong passthrough of costs to price:

$$P = \frac{\theta \alpha + \gamma c}{\gamma + \theta}$$

- For instance, the monopoly model predicts a price increase which is way too small because it predicts a very low cost-to-price passthrough.

Comments

- Perhaps surprisingly, the sugar industry around 1900 appears to have been much closer to perfect competition than monopoly.
- The potential for bias from seasonality points to a broader issue: there's little reason to expect θ (or markups) to be stable in a changing environment.
- Therefore, one might say it makes more sense to use Bresnahan's strategy to validate a model of competition than as a reduced-form model on its own.

"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,

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

- 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

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

  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 $V_i'(y_i) = 0$. 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:

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

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 $\beta_3 = -\ln\left(1+\theta_t/\alpha_t\right)$.

Equations for estimation

- Demand:

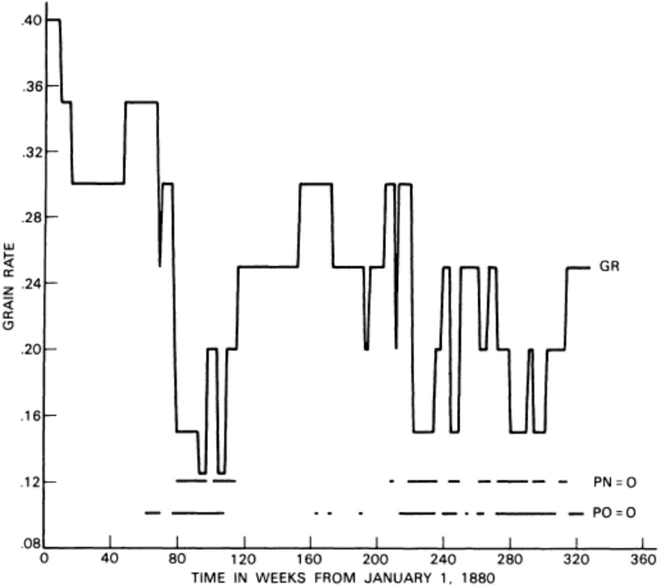
$$\ln Q_t = \alpha_0 + \alpha_1 \ln p_t + \alpha_2 L_t + U_{1t} \tag{1}$$

- 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 $P(Q_t, \varepsilon_t)$, 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,

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

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:

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

- 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: $\Pi^s = Q_t (P_t - c)$.
- 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
$D\text{-}W$	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.

"Rules, Communication, and Collusion: Narrative Evidence from the Sugar Institute Case"

Genesove and Mullin (2001)

Background

- In contrast to Sugar Trust (c. 1891-1911), the Sugar Institute (c. 1927-1936) was ostensibly a trade organization which was not *explicitly* aimed at limiting competition.
- Extensive internal memos reveal that it was undoubtedly *unofficially* aimed at limiting competition. The Institute served to help firms coordinate on rules which facilitated tacit collusion.
- In 1936, Supreme Court rules its practices illegal. "The stated aim of [the Institute's] rules was to eliminate discriminatory pricing... why it would have been in their interest to do so was never explained. The defendants... were silent on why compliance required collective action."

Important features

- Some broad features are consistent with theoretical literature:
  - Secret price cutting (understood broadly) was the main threat to cooperation.
  - Collusion was sustained by threat of retaliation.
- Other features contrast with theories of collusion:
  - Collusive agreements were incomplete (the games actual firms play are much more complicated than Bertrand or Cournot games).
  - Extensive communication was involved; it's definitely not the case that firms only acquired information through some exogenous information structure.
  - Cheating was typically not met with strong punishments (e.g., reversion to competitive conditions). Punishment strategies resembled tit-for-tat more than grim triggers.

TABLE 1—EFFECT OF THE SUGAR INSTITUTE ON PERFORMANCE MEASURES

(1) Year	(2) Proper margin	(3) Proper margin −0.60	(4) Lerner index	(5) Output	(6) Profits	(7) Beet share	(8) Foreign refined share
1914	0.99	0.39	0.047	106	3.7		
1915	0.95	0.35	0.036	114	3.9		
1916	1.04	0.44	0.041	118	4.3		
1917	1.31	0.70	0.068	103	7.4		
1918	1.04	0.44	0.048	93	3.9		
1919	0.88	0.27	0.029	121	4.2		
1920	1.94	1.34	0.129	113	12.2		
1921	1.06	0.46	0.073	128	6.0		
1922	0.97	0.36	0.060	157	5.9		
1923	0.88	0.28	0.033	123	3.3		
1924	1.06	0.45	0.061	128	5.4	15.3	0.5
1925	0.80	0.19	0.035	143	2.6	16.1	0.5
1926	*0.79*	*0.18*	*0.034*	*142*	*2.7*	*15.4*	*0.5*
1927	0.74	0.14	0.023	130	2.0	14.7	2.5
1928	1.00	0.40	0.071	122	4.9	18.7	6.2
1929	1.00	0.39	0.077	128	5.1	14.7	8.3
1930	1.04	0.44	0.091	126	5.6	17.0	8.0
1931	0.96	0.36	0.071	107	3.8	20.5	9.6
1932	1.07	0.47	0.093	103	4.7	21.0	12.8
1933	1.14	0.54	0.093	99	5.3	21.6	14.7
1934	1.17	0.56	0.104	94	5.3	25.1	11.0
1935	1.07	0.47	0.083	96	4.4	22.1	11.1
1936	1.03	0.42	0.072	98	4.2		
1937	1.03	0.43	0.077	108	4.9		
1938	0.98	0.37	0.077	100	3.7		
1939	1.01	0.41	0.079	99	3.9		
1940	1.01	0.41	0.086	100	3.9		
1941	0.85	0.25	0.048	116	3.0		

- list prices; Sugar Institute probably had larger effect in actual prices

Secret price cuts

- "The Sugar Institute was primarily a mechanism to increase the probability of detection of sectret price cuts." But "secret price cuts" must be understood broadly.
- The Institute had many rules to avoid various forms of secret price cuts.
  - The "full details" of sales of damaged sugar had to be documented.
  - Favorable credit terms were banned as they are a substitute for price cuts.
  - Refiners were prohibited from operating storage warehouses for customers through which discounts could be laundered.
  - Refiners were required to enforce their contracts (especially specified delivery times)
  - Freight rates could be cut rather than f.o.b. prices, and eventually refiners switched to c.i.f. (delivered) pricing.

Quality suppression

- Some of the forms of secret price cuts could be understood as quality of auxiliary services, and the Institute's avoidance of them could be understood as collusion in quality suppression.
- "We view the supppression of non-price competition as complementary to contractual harmonization... If one is already choosing, and enforcing, one single contractual standard among many, one might as well limit nonprice competition along the way."

Communication

- The first reason for extensive communication was in updating the terms of collusion: closing loopholes, updating to changing circumstances. This happened mostly at weekly meetings
- Firms also were expected to notify each other before many actions. This meant the firms knew what each other were up to, and if a firm was found to be engaging in an unapproved practice without notification, it would raise a red flag.
- Prior notification also facilitated mutually beneficial changes (e.g., if the monopoly price falls, all firms will want to lower their prices together) without triggering retaliation.
- The meetings were important to clarify when retaliation was warranted, and to ensure that retaliations were not seen as instances of cheating on their own.

Punishments

- "When one firm openly lowered its rate for rail shipments... other firms would respond by lowering their rail rates to the same level. When the Pacific refiners gave a freight allowance on certain contracts, American announced that it would match it... the response to a deviation was generally restricted to the instrument of violation."
- These observations contrast with theories of optimal collusive equilibria in repeated games, where the best collusive equilibria involve the most extreme punishments available.

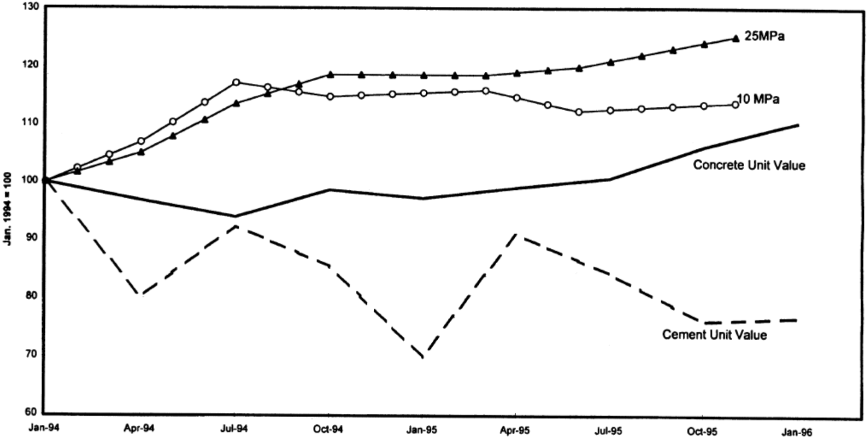
"Government-Assisted Oligopoly Coordination? A Concrete Case"
Albæk, Møllgaard, and Overgaard (1997)

Abstract

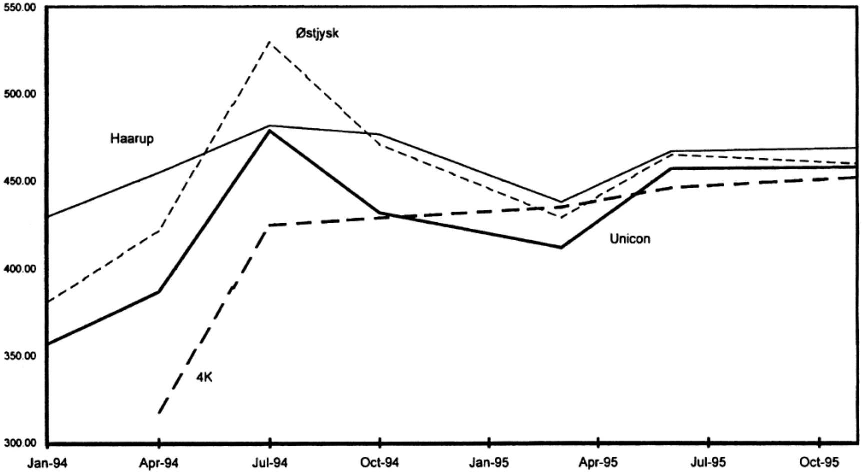
"In 1993 the Danish antitrust authority decided to gather and publish firm-specific transactions prices for two grades of ready-mixed concrete in three regions of Denmark. Following initial publication, average prices of reported grades increased by 15-20 percent within one year. We investigate whether this was due to a business upturn and/or capacity constraints, but argue that these seem to have little explanatory power. We conclude that a better explanation is that publication of prices allowed firms to reduce the intensity of oligopoly price competition and, hence, led to increased prices contrary to the aim of the authority."

The antitrust authority stopped publishing the transaction prices in December 1996.

Average concrete prices



Prices at concrete plants around Aarhus



"Ohio School Milk Markets: An Analysis of Bidding"
Porter and Zona (1999)

Overview

- Milk processors and distributors bid for school milk contracts on an annual basis.
- Unfortunately, the market is well suited to collusion.
- Price fixing convictions in ≥ 12 states with 90 convictions!
- Looking at auctions in the 1980's in Ohio, Porter and Zona find that bidding behavior for most firms is consistent with competitive bidding, but behavior for accused firms is measurably different.

The setting

- Demand is seen as very inelastic – schools will pay a high price for milk if they have to.
- Milk is arguably a commodity, and firms bid only in price, so there is no incentive for product differentiation.
- Firms basically have the same production cost structure (milk processing is a mature industry), but delivery costs vary depending on plant and school locations.
  - Firms typically face the same input (raw milk) costs due to regulation.

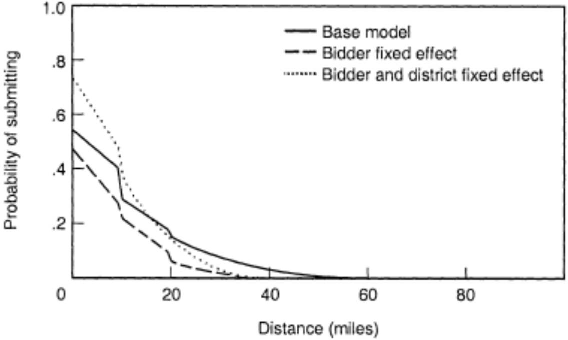
Aspects facilitating collusion

- Bids and identities of bidders are publicly announced after auctions.
- Auctions are held at different times of the year for different schools.
  - Multi-market contact (see Bernheim and Whinston (1990))
- Milk processors are frequent customers of one another and have trade associtations.
- Typically a small number of plants are close enough to be viable suppliers for a given school. 45% of auctions receive one bid, 34% of auctions receive two, ...

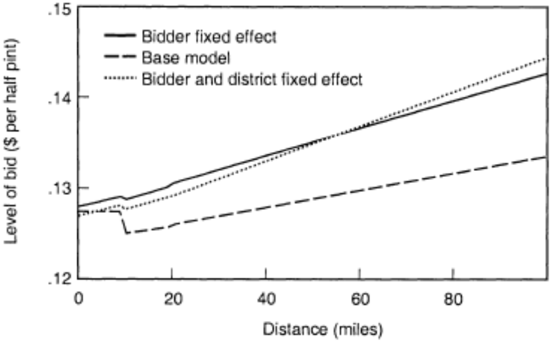
Empirical model

- They estimate a model of bidder behavior with two pieces:
  - A model of the probability firm j will submit a bid for the auction in school s
  - A model of bid prices for submitted bids.
- Both models involve a bunch of characteristics of the firm, school, and (most importantly) the distance between the two.
- For non-accused firms, bid submissions and bid prices have the expected relationship with distance.

PREDICTED PROBABILITY OF SUBMITTING A BID BY DISTANCE



PREDICTED LEVEL OF SUBMITTED BIDS BY DISTANCE: CONTROL GROUP



- On the other hand, firms in Cincinatti (which admitted to coordinating their bids for nearby schools) had relatively high bids for nearby auctions.

Porter and Zona (1999)

TABLE 6 Percent Deviations in Predicted and Actual Bid Submissions by Distance: Cincinnati Dairies

Distance in Miles	Coors Brothers	Meyer	Louis Trauth
	(a)	(b)	(c)
0–10	24.2% >	5.6% >	7.0% >
10–20	42.9% >	8.2%	15.2% >
20–30	22.9% >	18.5% >	20.6% >
30–40	−17.1% <	18.6% >	.1%
40–50	−9.5% <	−2.2%	−4.3%
50–60	−6.0%	−5.5%	6.9%
60–70	−6.0%	−18.6% <	47.1% >
70–80	−4.9% <	−25.0% <	10.0% >
80–90	−2.4% <	−17.5% <	−2.5% <
90–100	−1.7%	−7.7% <	−11.8% <
100–110	−1.3%	30.7% >	8.7% >
110–120	−.6%	.5%	−4.2% <
120–130	−.5%	−.9%	−3.6% <
130–140	−.2%	−.3%	−2.0%
140–150	−.2%	−.1%	−1.2%

Damages

- They do a reduced-form regression to assess damages. Basically, this involves regressing prices on the number of collusive firms involved in an auction.
- What are the limitations of this? What else could they do?