Identification of Market Power

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Empirical IO

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Plan

- In this lecture, we consider the identification of market power in broad terms: can we tell whether an industry is collusive or competitive? How do we estimate what markups are?
- In the next lecture, we will discuss theory and empirical work aiming to understand collusion and cartels.

Outline

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. Lysine cartel breakup in 1992 was beginning of new era in agressive anti-cartel intervenion.
- Big money: US fined various airlines $1.8bil in cargo price fixing case in 2010.
- Many cartels have been exposed by whistelblowers. It is thought that whistleblower protection may deter many more cartels.

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. i.e., $h = \frac{dP}{dQ}Q$

- $\lambda = 1$ 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.

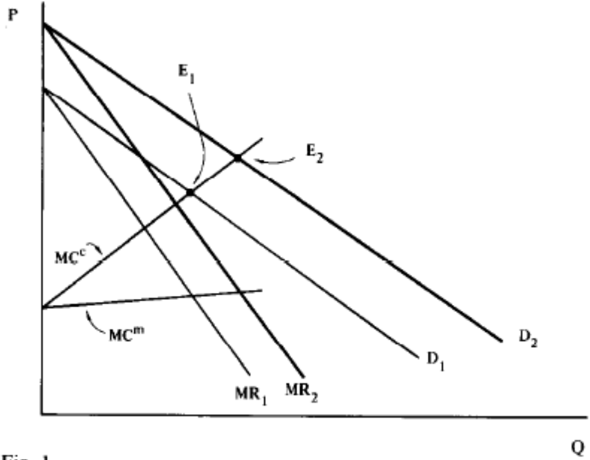

Fig. 1.

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

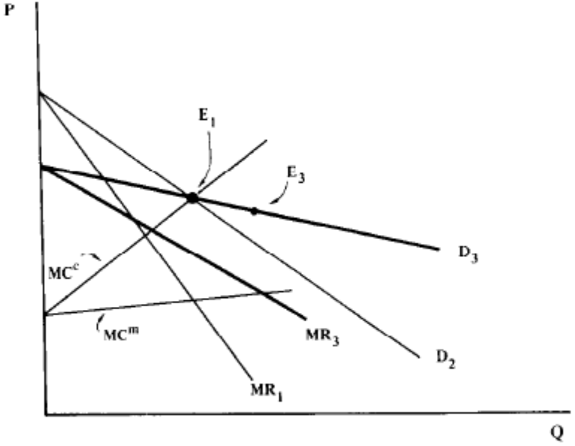

Fig. 2.

However, with a rotation of the demand curve, the two models yield distinct predictions – a rotation of demand around the equilibrium price should not change the price in a competitive market.

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."

"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 test a Bresnahan-based estimation of costs for the 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. Entrants were subsequently absorbed into the trust.
- 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).

Genesove and Mullin (1998)

TABLE 5 **Lerner Indices by Year**

	Lerner Index				
	Unadjusted		Elasticity Adjusted (linear)		American Sugar Refining Co.'s Market Share
Year	Mean	Standard Deviation	Mean	Standard Deviation	
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

Price wars

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

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

Concerns

- Note that the estimated θ is lower than the constructed θ.
- This might reflect bias resulting from dynamics (Rotemberg and Saloner).
- What about buyer power? Genesove and Mullin address the concern that P_{RAW} can be affected by demand shocks, but what if it is also endogenous to the Sugar Trust's decision?

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.

"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,

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

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,

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

- We should also consider endogeneity of input prices. The bias from the two price responses may largely cancel.

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.