Lecture 7
Conduct and P/Q Competition

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Economics 220C, UC Berkeley
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Outline

• Overview of identification in supply-demand oligopoly models
• Testing models of collusion
  – Porter/(Green and Porter)
  – (Rotemberg and Saloner)
  – Ellison
  – Borenstein and Shepard
Identification

• Oligopoly model for competing firms that set price or quantity

• Interest centers on conduct parameter (monopoly, competition, something in between the two)

• Bresnahan (1982):
  – under what conditions can we identify conduct (responsiveness of marginal revenue to output)?
Oligopoly model

demand and profits for \( i \)th firm
\[
Q^D = f(p,Y,\alpha) + \varepsilon
\]
\[
\pi_i = p(Q)q_i - c_i(q_i) \quad i = 1,\ldots,N \text{ firms}
\]
profit maximization yields
\[
p(Q) + p'(Q)\frac{\partial Q}{\partial q_i}q_i = p(Q) + p'(Q)\theta_i q_i = c_i'(q_i)
\]
Bertrand, perf comp: \( \theta_i = 0 \) Cournot: \( \theta_i = 1 \)
Monopoly, collusion: \( \theta_i = \frac{1}{s_i} = N \) (for symmetric firms)

\( \theta_i \) is firm’s conjecture about effect of changing its own output on industry output (\( \theta \) varies from 0 to \( \infty \)). We can’t go much further without functional form assumptions
Linear demand and supply

Demand: \( Q = \alpha_0 + \alpha_1 p + \alpha_2 Y + \epsilon \)

MR=MC: \( p(Q) + p'(Q)\theta_i q_i = c_i'(q_i) \)

Substitute in linear marginal cost function:

\[
p(Q) + \theta_i \frac{q_i}{\alpha_1} = \beta_0 + \beta_1 q_i + \beta_2 W_i + \eta_i
\]

\[
\Rightarrow p = \beta_0 + \left( \beta_1 - \frac{\theta_i}{\alpha_1} \right) q_i + \beta_2 W_i + \eta_i
\]

with symmetric firms:

\[
p = \beta_0 + \left( \beta_1 - \frac{\theta}{\alpha_1} \right) \frac{Q}{N} + \beta_2 W + \eta
\]

Conclusion: demand and supply identified, but market power or conduct (\( \theta \)) is not.
How to achieve identification

1. fixed MC (does not vary with $q$) – not very attractive for merger analysis, because the trade-off is between efficiency (cost-reducing scale) and market power

2. supply shocks (*Porter 83*) – instruments that shift MC (and identify $\beta_1$) but do not change MR condition.

3. direct measures of MC.

4. more complex functional forms so that terms multiplying $Q$ in supply relation are not both constant (*Bresnahan 82*)
Bresnahan 1982

$Z$ both shifts demand curve and changes its slope (e.g, the price of a substitute):

$$Q = \alpha_0 + \alpha_1 p + \alpha_2 Y + (\alpha_3 p + \alpha_4)Z + \epsilon$$

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

$$\Rightarrow p = \beta_0 + \beta_1 Q - \frac{\theta_i}{(\alpha_1 + \alpha_3 Z)} Q + \beta_2 W + \eta$$

$\alpha_1$ and $\alpha_3$ are identified by the demand curve, so both $\beta_1$ and $\theta$ are identified here since there are two sources of variation with which to identify them.

more complex functional forms would work too, but how to choose them?
Empirical studies of collusion

- **Porter (1983)** - we observe price and quantity movements over time. Are they due to shifts in demand and cost functions? or are they due to price wars?
- **Ellison (1994)** – Are theories of cartel stability (Green & Porter 1984; Rotemberg and Saloner 1986) consistent with experience of JEC?
- **Borenstein-Shepard (1996)** – Is pricing of retail gasoline consistent with predictions of Rotemberg-Saloner type model?
Railway cartel background

JEC (Joint Economic Committee)

- cartel that controlled eastbound freight from Chicago (predated Sherman Anti-trust Act)
- most shipments were grain (homogenous good) – other prices tied to it
- enforcement a “trigger quantity” mechanism, because quantity rather than price observed by all firms
- monopoly on shipping when Great Lakes frozen, otherwise some competition (provides an instrument)
Green and Porter (1984)

• Is a cartel sustainable?
  – model where firms set quantity and demand uncertain
  – firms observe market price each period, if price falls, either
    • low demand
    • someone is cheating (producing more output)
  – trigger price equilibrium
    • if price falls below a certain level, firms play Cournot for $T$ periods

• Predictions of model:
  – price wars should sometimes occur, when demand low
  – firms should not cheat (in equilibrium, price wars only happen because of demand shocks)
  – output during cooperative periods exceeds monopoly, but higher than Cournot
Porter (1983) Railway Cartel Data

Graph showing the grain price in dollars per 100 pounds and the collusion dummy over the weeks from 1 to 313.
Porter model (1983)

Constant elasticity demand and supply; asymmetric firms

$$\log Q_t = \alpha_0 + \alpha_1 \log p_t + \alpha_2 L_t + \varepsilon_t$$

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

Let market share $s_{it} = q_{it}/Q$ and $\theta_{it} = (\partial Q/\partial q_{it})s_{it}$ (note that this is not the same $\theta$ as in Bresnahan, varies from 0 to 1)

Then we can derive the marginal revenue condition for each firm:

$$p(Q_t) + p'(Q_t) \frac{\partial Q}{\partial q_{it}} q_{it} = c_i'(q_{it})$$

$$=> p(1 - \theta_{it} / \alpha_1) = \delta a_i q_{it}^{\delta-1}$$

Add up MR and solve for quantities, obtain industry MR:

$$p(1 - \theta_t / \alpha_1) = DQ^{\delta-1} \text{ where } D = \delta \sum_{i=1}^{N} (a_i^{1/(1-\delta)})^{1-\delta}$$
Porter (1983) continued

Implied supply equation:
\[ \log p_t = -\log(1 + \theta_t / \alpha_1) + \log D + (\delta - 1)\log Q_t \]

Actual estimating equation:
\[ \log p_t = \beta_0 + \beta_1 \log Q_t + \beta_2 S_t + \beta_3 I_t + u_{2t} \]

where \( S \) are a set of market structure dummies for entry
and \( I \) is a dummy equal to one when collusive at \( t \)

Assume two regimes, one collusive and one not – \( \beta_3 \) higher
if collusive

Estimation:
\( I_t \) known: estimation same as in Bresnahan.
not known: use ML or Kiefer’s E-M algorithm, \( I_t \) a Bernouilli R.V.
ML for regime switching model

Porter (83) uses Kiefer’s algorithm; better treatment in Lee and Porter (84) and Coslett and Lee (85)

We have some info on regime classification, but observed regime a noisy indicator of true regime = > OLS biased.

Outline of model:
- Two regimes, \( I = 0 \) and \( I = 1 \), with \( \Pr(I=1) = \lambda \)
- Each regime described by joint distn of endog vars (p,q) with respect to exog vars (lakes, etc). Denote conditional distn as
  \[
  h_0 = f(y \mid X, I = 0)
  \]
  \[
  h_1 = f(y \mid X, I = 1)
  \]
- We do not observe \( I \), but we do observe a noisy indicator, \( w \):
  \[
  \Pr[w_t = 1 \mid I_t = 1] = 1 - \Pr[w_t = 0 \mid I_t = 1] = 1 - p_{10} = p_{11}
  \]
  \[
  \Pr[w_t = 1 \mid I_t = 0] = 1 - \Pr[w_t = 0 \mid I_t = 0] = 1 - p_{00} = p_{01}
  \]
ML for regime switching model

$l, w$ assumed independent of structural error

observed data: $y, X$, and measured regime $w$

⇒ each piece of likelihood is a weighted sum of the two distributions $h_0$ and $h_1$ with weights that depend on the probability of the regime given $w$.

$L(\alpha, \beta, \theta | y, X, w = 1) = h_1 \lambda p_{11} + h_0 (1 - \lambda)(1 - p_{00})$

$L(\alpha, \beta, \theta | y, X, w = 0) = h_1 \lambda (1 - p_{11}) + h_0 (1 - \lambda)p_{00}$

⇒ total log likelihood is

$\log L(\alpha, \beta, \theta | y, X, w) = \sum_{w=1} \log \left[ h_1 \lambda p_{11} + h_0 (1 - \lambda)(1 - p_{00}) \right]$

$+ \sum_{w=0} \log \left[ h_1 \lambda (1 - p_{11}) + h_0 (1 - \lambda)p_{00} \right]$

Note that for full identification, $h_0$ and $h_1$ will have to differ quite a bit.
Two special cases

1. Sample separation known \((p_{11} = p_{00} = 1)\):

   (Columns 1 and 2). Likelihood is

   \[
   \log L(\alpha, \beta, \theta \mid y, X, w) = \sum_{w=1} \log h_1 + \sum_{w=0} \log h_0 + N_1 \log \lambda + N_0 \log(1 - \lambda)
   \]

   easy to show that ML estimate of \(\lambda\) is \(N_1/N\), the share of regime 1 obs in the sample, and this does not affect estimation of the other params.

2. Sample separation completely unknown

   \((p_{11} = p_{10} = p_{01} = p_{00} = 0.5)\); likelihood is

   \[
   \log L(\alpha, \beta, \theta \mid y, X, w) = \sum_{all} \log \left[ h_1 \lambda + h_0 (1 - \lambda) \right] + N \log(0.5)
   \]

   This is what Porter uses in cols. 3 and 4.
# Porter (1983) results

<table>
<thead>
<tr>
<th>RHS variable</th>
<th>Demand</th>
<th>Supply</th>
<th>Demand</th>
<th>Supply</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price ($/100 lb. shipped)</td>
<td>-.742 (.121)</td>
<td>-.800 (.091)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lakes</td>
<td>-.437 (.120)</td>
<td>-.430 (.120)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cheating dummy</td>
<td>.382 (.059)</td>
<td>.545 (.032)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Q of grain</td>
<td>.251 (.171)</td>
<td>.090 (.068)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Market structure dummies</td>
<td>included</td>
<td>included</td>
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</tbody>
</table>
Discussion of results

• Price elasticity less than one = > MR of industry demand is negative, inconsistent with single period profit max.
• Estimated $\beta_3$ and $\alpha_1$ imply $\theta = 0.34$ (*Cournot with 3 firms?*)
• Paper documents existence of price wars but not how long or why they last
• Is the assumption that $u_{2t}$ is i.i.d. reasonable?
• What kind of specification tests would it make sense to do?
• Are there alternative explanations for the paper’s findings?
Ellison 1994

- Are theories of cartel stability (Green & Porter 1984; Rotemberg and Saloner 1986) consistent with experience of JEC?
- different from Porter’s analysis:
  - looking for good fit to data
  - considers alternative theory and tests between them
- implication of Green and Porter:
  - price wars should occur sometimes (tested in Porter 83)
  - should happen when demand low – Porter 85 regresses price war D on demand, finds nothing; low power
  - firms should not cheat in equilibrium (Ellison looks at this in the last part of paper)
Ellison model

like Porter but with Markov price war variable (more plausible):

\[
\Pr(I_{t+1} | I_t, Z_t) = \frac{e^{\gamma W_t}}{1 + e^{\gamma W_t}} \quad \text{where} \quad W_t = (I_t, Z_t)
\]

\(W_t = 1\) gives Porter's Bernoulli model
\(W_t = I_t\) gives simple Markov model

Assume disturbance unrelated to the structural disturbances. Likelihood function is the joint probability of all 3 components (structural model for each regime and the transition equation):

\[
L(\alpha, \beta, \gamma, \theta | \gamma, X, I) = \Pr[I_t = 1 | I_{t-1}]h_1 + \Pr[I_t = 0 | I_{t-1}]h_0
\]

Also assumes demand is serially correlated \((\rho = .84)\). gets much higher conduct parameter \((0.85)\)
### Ellison (1994) Table 2

<table>
<thead>
<tr>
<th>RHS variable</th>
<th>ML; no serial correl.</th>
<th>ML</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Demand</td>
<td>Supply</td>
</tr>
<tr>
<td>Price ($/100 lb. shipped)</td>
<td>-.843 (.193)</td>
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<tr>
<td>Lakes</td>
<td>-.460 (.348)</td>
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<td>Seasonal dummies</td>
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<td>included</td>
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<tr>
<td>Cheating dummy</td>
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<td>.660 (.406)</td>
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<td>Total Q of grain</td>
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<td>.398 (.928)</td>
</tr>
<tr>
<td>Market structure dummies</td>
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<td>included</td>
</tr>
</tbody>
</table>

Notes: ML; no serial correl. refers to a Maximum Likelihood estimation without considering serial correlation. The values in parentheses represent standard errors.