# A Study of Cartel Stability: The Joint Executive Committee

Porter

1983

- Time series data on the Joint Executive Committee of the railroad cartel from 1880 to 1886.
- Did the observed prices and quantities reflect switches from collusive to noncooperative behavior? Use switching regression.

# Green Porter (1984) Trigger Strategy Equilibrium

Incomplete information. Firms do not know the quantity of other firm's output. Only own demand is known.

- Trigger Strategy: Subgame perfect credible punishment against a deviating firm. Revert from a collusive output to a one shot noncooperative (Cournot or Bertrand) Nash equilibrium output-price wars.
- Incomplete information: If own demand drops, firms cannot tell whether that is due to other firms' deviation from the cooperative output or due to unexpected demand drop. If the own demand drops below the "trigger level", firms revert to one-shot Nash.

- In the equilibrium of this dynamic game, price wars should occur after unexpected drop in demand, regardless of whether there actually was a defection or not.
- Length of one-short Nash period is adjusted to support an equilibrium. The longer the Nash period, the more severe the punishment for deviation.

Use simultaneous switching equation switching regression to estimate the periods of collusion and price war.

# The Empirical Model

- Aggregate demand:

$$logQ_t = \alpha_0 + \alpha_1 logp_t + \alpha_2 L_t + u_{1t}$$

  $L_t$: Great Lakes open or closed for ships.
  $u_{1t}$: i.i.d. normal
- Cost:

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

  Fixed cost $F_i$ is small enough that firms find advantageous to produce.

Recall from lecture 2, we have

$$\frac{P - MC_i}{P} = \frac{s_i}{\eta}\theta_i$$

Define $\theta_{it} \equiv s_{it}\theta_i = s_{it}\theta$. Then,

$$p_t[1 + \frac{\theta_{it}}{\alpha_1}] = MC_i(q_{it}) \qquad (*)$$

Market share is constant over time and

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

- One shot Bertrand, Perfect Competition: $\theta_{it} = 0$
- One shot Cournot: $\theta_{it} = s_{it}$
- Joint prfit maximization (monopoly): $\theta_{it} = 1$

# Industry Supply equation

Now, take a weighted sum of equation (*) over firms where $s_i$ are the weights.

$$p_t[1 + \frac{\theta_t}{\alpha_1}] = MC$$

- $MC = \sum^i s_{it} MC_i(Q_{it}) = DQ_t^{\delta - 1}$
- $D = \delta(\sum_i a_i^{1/1-\delta})^{1-\delta}$
- $\theta_t = \sum^i s_i \theta_{it}$

- One shot Bertrand, Perfect Competition: $\theta_t = 0$
- One shot Cournot: $\theta_t = H = \sum_i s_i^2$
- Joint prfit maximization (monopoly): $\theta_t = 1$

## Repeated Game Equilibrium

- Cooperative regime ($I = 1$): Joint profit maximization
- Noncooperative regime ($I = 0$): One shot Bertrand (or Cournot)

Firms switch in between cooperative and noncooperative regime.

- Bertrand one-shot equilibrium: $logP_t = logD + (\delta - 1)logQ_t$
- Joint profit maimization:
  $logP_t = logD + (\delta - 1)logQ_t - log[1 + \frac{1}{\alpha_1}]$
- Cournot one shot equilibrium:
  $logP_t = logD + (\delta - 1)logQ_t - log[1 + \frac{H}{\alpha_1}]$

Supply equation:

$$logP_t = \beta_0 + \beta_1 logQ_t + \beta_2 S_t + \beta_3 I_t + u_{2t}$$

$S_t$: supply shifters.

$I_t$ unknown.

- $I_t = 1$ with probability $\lambda$
- $I_t = 0$ with probability $1 - \lambda$

## Estimating Equations

- demand: $logQ_t = \alpha_0 + \alpha_1 logP_t + \alpha_2 I_t + u_{1t}$
- supply: $logP_t = \beta_0 + \beta_1 logQ_t + \beta_2 S_t + \beta_3 I_t + u_{2t}$

$(u_{1t}, u_{2t})$ are jointly normally distributed.

$$\begin{bmatrix} u_{1t} \\ u_{2t} \end{bmatrix} \sim N(0, \Sigma)$$

# Matrix Notation

$$By_t = \Gamma X_t + \Delta I_t + U_t$$

$$y_t = \begin{pmatrix} logQ_t \\ logP_t \end{pmatrix}, X_t = \begin{pmatrix} 1 \\ L_t \\ S_t \end{pmatrix}, U_t = \begin{pmatrix} u_{1t} \\ u_{2t} \end{pmatrix},$$

$$B = \begin{pmatrix} 1 & -\alpha_1 \\ -\beta_1 & 1 \end{pmatrix}, \Delta = \begin{pmatrix} 0 \\ \beta_3 \end{pmatrix}, \Gamma = \begin{pmatrix} \alpha_0 & \alpha_2 & 0 \\ \beta_0 & 0 & \beta_2 \end{pmatrix}$$

$$U_t \sim N(0, \Sigma), \Sigma = \begin{pmatrix} \sigma_1^2 & \sigma_1\sigma_2 \\ \sigma_2\sigma_1 & \sigma_2^2 \end{pmatrix}$$

# Likelihood Increment

Suppose in each period you know whether firms are in the collusive or non-collusive regime. Then, the likelihood increment in each period is:

$$h(y_t \mid I_t, X_t, \phi) = \frac{1}{2\pi} |\Sigma|^{-\frac{1}{2}} |B| \; exp\left\{-\frac{1}{2}(By_t - \Gamma X_t - \Delta I_t)' \Sigma^{-1} (By_t - \Gamma X_t - \Delta I_t)\right.$$

But we do not know the regime. We then specify that firms can be in cooperative regime ($I_t = 1$) with probability $\lambda$ or in noncooperative regime ($I_t = 0$) with probability $1 - \lambda$

# Likelihood increment at period $t$

$$increment = \lambda \times cooperation + (1 - \lambda) \times noncooperation$$

$$f\left(y_t \mid X_t, \phi\right) = \lambda h(y_t \mid I_t = 1, X_t, \phi) + (1 - \lambda) h(y_t \mid I_t = 0, X_t, \phi)$$

## Likelihood function

$$L\left(Y, X, \phi\right) = \prod_{t=1}^{T} f\left(y_t \mid X_t, \phi\right)$$

Maximum Likelihood: Choose parameter vector $\theta$ to maximize the likelihood function.

# Data

- GR: Grain price: in dollars per 100 lb.
- TQG: total quantity of grain shipped, in tons.
- LAKES: 1 if Great Lakes are open. 0 if closed.
- PO 1 if collusion, 0 otherwise (not used in the ML estimation)
- DM1, DM2, DM3, DM4: dummies for structural breaks (entry)
- Seasonal dummy.

# Estimation Results

## 2SLS

- Use PO for regime classification. PO is from the newspaper reports about collusion. Collusion was legal.
- Endogenous price and quantities: use LAKES, DM, seasonal dummies for IV.

| variable | demand | supply |
| --- | --- | --- |
| Constant | 9.169 (0.184) | -3.944 (1.760) |
| LAKES | -0.438 (0.120) | |
| GR (P) | -0.742 (0.121) | |
| DM1 | | -0.201 (0.055) |
| DM2 | | -0.172 (0.080) |
| DM3 | | -0.322 (0.064) |
| DM4 | | -0.208 (0.170) |
| PO | | 0.382 (0.059) |
| TQG (Q) | | 0.251 (0.171) |
| Rsq | 0.312 | 0.320 |

- Price elasticity (GR), negative but absolute value less than 1. Not consistent with single period profit maximization.
- Price significantly higher in cooperative periods.
- Quantity coefficient positive (insignificant): weak diseconomies of scale.

# ML without using regime data

| variable | demand | supply |
|---|---|---|
| Constant | 9.090 (0.149) | -2.416 (0.710) |
| LAKES | -0.430 (0.120) | |
| GR (P) | -0.800 (0.091) | |
| DM1 | | -0.165 (0.024) |
| DM2 | | -0.209 (0.036) |
| DM3 | | -0.284 (0.027) |
| DM4 | | -0.298 (0.073) |
| PO | | 0.545 (0.032) |
| TQG (Q) | | 0.090 (0.068) |
| Rsq | 0.307 | 0.863 |

- regime coefficient more negative than before.
- $\theta = 0.336$: Closest to cournot behavior in cooperative periods.
- Price 66% higher, quantity 33% lower in cooperative regime.
- Price wars were not preceded by large negative demand residuals.

# Discussion

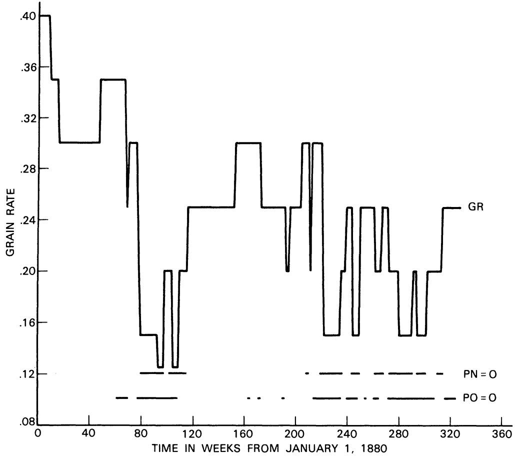
Functional form assumptions are crucial in estimating the regime change. supply: $logP_t = \beta_0 + \beta_1 logQ_t + \beta_2 S_t + \beta_3 I_t + u_{2t}$

- For ML $I_t$ is assumed to be unobservable. Hence, $\beta_3 I_t + u_{2t}$ is the error term. $I_t$ only shows up in the error term. Hence, functional form assumption that the error term is a mixture of two normals with different means (0 and $\beta_3$) estimates the regime parameters.
- But the mixture normal distribution could be because the marginal cost shocks could have the mixture distribution.

- Model Validation: The authors compare the observed regime dummy and the regime dummy computed from the model ($I_t = 1$ *if* $Pr(I_t \mid y_t, X_t, \phi) > 0.5$). Two regime series are very similar.

FIGURE 1

PLOT OF GR, PO, PN AS A FUNCTION OF TIME




As predicted by Stigler (1964), unpredictable fluctuations in market shares were probably more decisive. In this sample, price wars (as measured by either *PO* or *PN*) were not preceded by large negative demand residuals.

The 1881 and 1884 incidents both began about 40 weeks after the entry of the Grand Trunk and the Chicago and Atlantic, respectively. While entry may not have immediately caused reversion to noncooperative behavior, it is quite plausible that it increased the