

## Porter (1983): Motivation

- Price series: two “regimes” of pricing. Can periods of low pricing be explained as “price wars”?
- Repeated games theory: view observed price series as realization of equilibrium price process.
- Standard repeated games (e.g. repeated Cournot game) with unchanging economic environment: equilibrium price path is *constant!*

Note: Need to specify punishment strategies which support collusive equilibrium, but punishment is never “observed” on the equilibrium path.

Need for model with nonconstant equilibrium price process.

## Two famous models

1. Rotemberg and Saloner (1986): with *i.i.d.* demand fluctuations, fixed discount rate, and constant marginal production costs, collusive prices will be lower in periods of above-average demand (“Price wars during booms”).

Intuitively: cheat when (current) gains exceed (future) losses. Current gains highest during “boom” periods; reduce incentives to cheat by lowering collusive price. Demand shocks are observed by firms.

2. Green and Porter (1983): same framework as R-S, but introduce *imperfect information* — firms cannot observe the output choices of their competitors, only observed realized market price. Prices can be lower during periods of low demand (“Price wars during recessions”).

Note: market price can be low due to either (i) cheating; or (ii) adverse demand shocks. Firms cannot distinguish.

Intuitively: equilibrium “trigger” strategies involve “low price” regime when prices are low.

General theory: Abreu-Pearce-Stachetti papers

Note: these two models generate periods of low and high pricing on the equilibrium path. But low prices *not caused by cheating*; rather they are manifestation of collusive behavior!

## Porter (1983) 1

- Test the Green–Porter model: two regimes of behavior (“cooperative” vs. “noncooperative/price war”).  
Subtle: noncooperative regime arises due to low demand, *not* due to cheating.
- Empirical problem: don’t (or only imperfectly) observe when a “price war” is occurring. How can you estimate this model then?
- *Prices* should be lower in price war periods, holding the demand function constant. Price war triggered by change in firm behavior
- Estimate *simultaneous-equation switching regression model* with *unobserved regimes*.

## Porter (1983) 2

- Observed data are market-level output ( $Q_t$ ) and price ( $p_t$ ) for weekly grain shipments between 1880 and 1886.
- $N$  firms (railroads), each producing a homogeneous product (grain shipments). Firm  $i$  chooses  $q_{it}$  in period  $t$ .
- Market demand:  $\log Q_t = \alpha_0 + \alpha_1 \log p_t + \alpha_2 L_t + U_{1t}$ , where  $Q_t = \sum_i q_{it}$ .  
 $L_t$  is demand shifter: =1 if Great Lakes open to navigation (availability of substitute to rail transport)
- Firm  $i$ 's cost fxn:  $C_i(q_{it}) = a_i q_{it}^\delta + F_i$
- Firm  $i$ 's pricing equation:  $p_t(1 + \frac{\theta_{it}}{\alpha_1}) = MC_i(q_{it})$ , where:
  - $\theta_{it} = 0$ : Bertrand pricing
  - $\theta_{it} = 1$ : Monopoly pricing
  - $\theta_{it} = s_{it}$ : Cournot outcome

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- After some manipulation, aggregate supply relation is:

$$\log p_t = \log D - (\delta - 1) \log Q_t - \log(1 + \theta_t/\alpha_1)$$

with empirical version

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

$S_t$  are supply-shifters (dummies DM1, DM2, DM3, DM4 for entry by additional rail companies)

- $(U_{1t}, U_{2t})' \sim N(0, \Sigma)$ , estimate using FIML as in previous example:

Structural model is  $Y\Gamma = XB + \Delta I + U$ , with  $Y = (\log Q_t, \log p_t)'$ .

$$L(Y_t) = |\Sigma|^{-1/2} |B| \exp \left\{ \frac{1}{2} (Y\Gamma - XB + \Delta I)' \Sigma^{-1} (Y\Gamma - XB + \Delta I) \right\}$$

## Porter (1983) 4

- Problem: don't observe  $I_t$ . Treat it as a “nuisance parameter” and integrate out over its distribution:

$$L(Y_t) = \int L(Y_t | I_t)g(I_t)dI_t$$

- $I_t$  follows a discrete, two-point distribution (from structure of GP equilibrium):

$$I_t = \begin{cases} 1 & \text{with prob } \lambda \\ 0 & \text{with prob } 1 - \lambda \end{cases}$$

Treatment is “exogenous”. Endogeneity in this model arises from simultaneity of  $Q_t$  and  $p_t$ .

- So likelihood function is:

$$L(Y_t) = \lambda L(Y_t | I_t = 1) + (1 - \lambda)L(Y_t | I_t = 0)$$

## Porter (1983) 4

Results:

- Estimate of  $\beta_3$  is 0.545: prices higher when firms are in “cooperative” regime.
- If we assume that  $\theta = 0$  in non-cooperative periods, then this implies  $\theta=0.336$  in cooperative periods. Low? (Recall  $\theta = 1$  under cartel maximization)
- What if we assume  $\theta_1$  and  $\theta_2$  in the two different regimes?
- Cartel earns \$11,000 more in weeks when they are cooperating

## Porter (1983) 5

What if  $I_t$  is endogenous (arising from, eg., price wars more likely when demand is low, etc.)?

- If regime observed,  $\beta_2$  is the “treatment effect” of  $I_t$ . Possible to use other methods to estimate treatment effect?
  - Data structure is not DID: there are no “control units” for which  $I_t = 0$  throughout the sample period. So cannot distinguish effect of  $I_t$  apart from week dummies.
  - IV approach, with  $L_t$  as (discrete) instrument? But need another demand shifter, because only one IV ( $L_t$ ) for two endogenous variables ( $I_t$  and  $Q_t$ ).



## Ellison (1994)

Ellison (1994, RAND) extends the analysis on several fronts:

- Allows for variables to enter  $\lambda$ : theory gives guidance that price wars precipitated by “triggers”: low demand (in GP model), large shifts in market share. Allows  $I_t$  to be an endogenous in this fashion.
- Allows unobserved  $I_t$ 's to be serially correlated
- Also tests Rotemberg and Saloner (1986) model: alternative explanation for price wars (where serial correlation in demand, not unobserved firm actions, drives price fluctuations). In equilibrium, prices lower in periods of relatively high demand, when demand is expected to fall in the future. Finds little evidence in favor of this hypothesis.
- Test for explicit cheating on the part of firms, which doesn't happen in the equilibrium of *any* of these models. Introduces additional regimes to the model.

## Other work on collusion

- Bresnahan's (1987, *Journal of Industrial Economics*) work on price wars in the automobile industry. Focuses on static pricing models, among *differentiated* products. Evidence that manufacturers colluding in 1955, but not in surrounding years.
- Borenstein and Shepard (1996, *RAND*) find support for Rotemberg and Saloner theory in retail gasoline markets.
- Pakes and Ferschtmann (2000, *RAND*) examine the feasibility of collusion in rich model of oligopolistic industry in which firms can choose quality investment as well as price, and entry and exit can occur.
- Chevalier, Kashyap, Rossi (2000, working paper): tests R-S models versus other explanations of "price wars during booms".