Lecture 6: Collusion and Cartels, Part 2

EC 105. Industrial Organization

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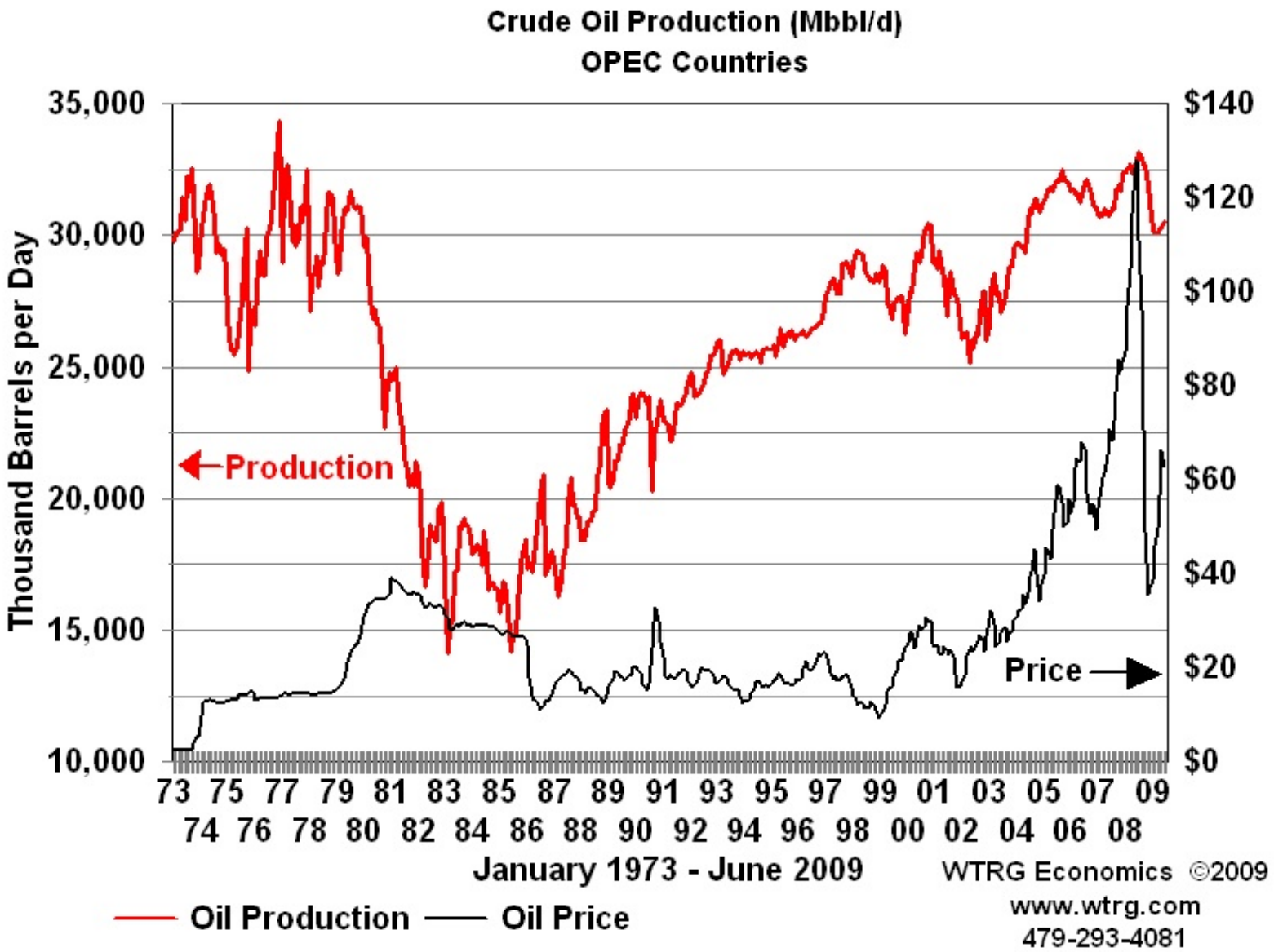
Outline

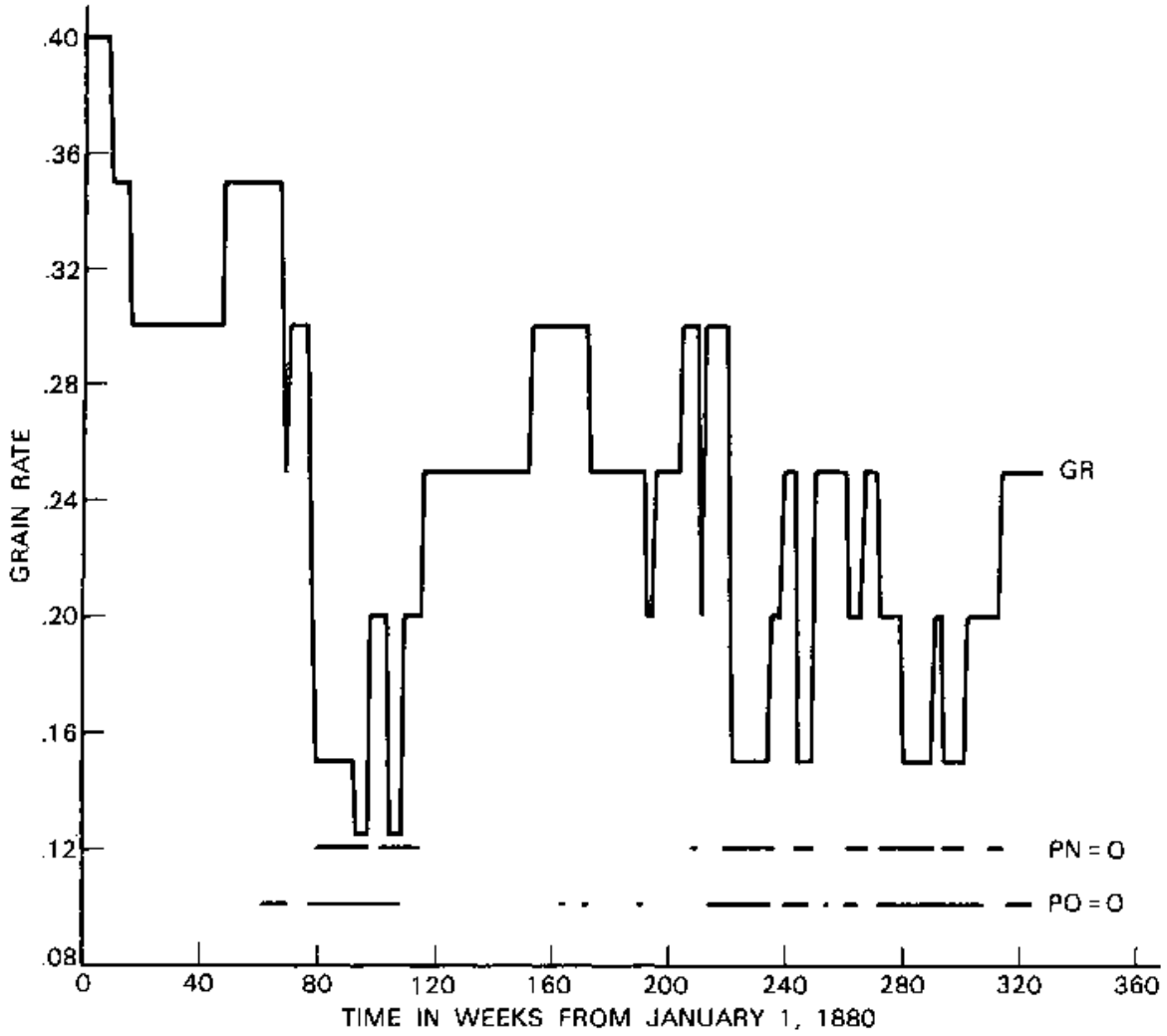
Does theory match reality? OPEC



Does theory match reality? JEC

FIGURE 1

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



Empirical predictions of tacit collusion

- *Constant* production, price
- Does not match empirical and anecdotal evidence from real-world cartels: defection, price-wars, etc.
- Consider two approaches which generates time-varying pricing and production
  1. Rotemberg-Saloner model: "price war during booms"
  2. Green-Porter model: secret price cuts
- Important: both models predict time-varying pricing *on the equilibrium path*
  - Changing prices/profitability in any period not due to cheating or punishment.
- Evidence: supermarket pricing
- Case study: Joint Executive Committee (railroad cartel in nineteenth-century US) **[skip]**

Fluctuating Demand: Rotemberg Saloner's (1986) theory of price wars during booms.

- Demand is stochastic.
  1. At each period t, it can be low ($q = D_1(p)$) or high ($q = D_2(p)$) with probability 1/2 ($D_2(p) > D_1(p)$ for all p). Independent across periods.
  2. At each period firms learn current state before choosing their prices simultaneously: *Bertrand*.
- Look for an optimal stationary symmetric SPNE. A pair of prices $\{p_1, p_2\}$ such that
  1. Firms charge p_s when the state is s,
  2. Prices $\{p_1, p_2\}$ are sustainable in equilibrium
  3. Expected present discounted profit of each firm along the equilibrium path is Pareto optimal
- Consider infinite stream of payoffs $\pi_0 + \delta\pi_1 + \delta^2\pi_2 + \cdots + \delta^n\pi_n + \cdots \equiv \Pi(< \infty)$. Then $(1-\delta)\Pi$ is implied "per-period" payoff. Convenient shorthand in what follows.

Price wars during booms II

- First see whether "fully collusive outcome", where both firms charge monopoly price p_s^m in each state, is sustainable in eqm.
- Note that payoffs of firm i are, in general:

$$\hat{\Pi}^i = \sum_{t=0}^{\infty} \delta^t \left(\frac{1}{2} \frac{D_1(p_1)}{2} (p_1 - c) + \frac{1}{2} \frac{D_2(p_1)}{2} (p_2 - c) \right)$$
$$= \left(\frac{1}{2} \frac{D_1(p_1)}{2} (p_1 - c) + \frac{1}{2} \frac{D_2(p_2)}{2} (p_2 - c) \right) / (1 - \delta)$$

(Capital Π denotes discounted present value of profit stream.)

- When firms are setting the monopoly prices each period, then the discounted profits (when the the current state is $s \in \{1, 2\}$) is

$$(1 - \delta) \frac{1}{2} \Pi_s^m + \delta \frac{1}{4} (\Pi_1^m + \Pi_2^m)$$

The superscript m denotes monopoly profits.

Price wars during booms III

- It suffices to consider the harshest punishment of switching to competitive price c forever after a deviation ("Bertrand reversion"). If firm i deviates in state s obtains $(1-\delta)\Pi_s^m + \delta 0$.

- Since $\Pi_1^m < \Pi_2^m$, cheating firms will do so only in state 2; i.e., *incentive constraint* is:

$$(1-\delta)\Pi_2^m < (1-\delta)\frac{1}{2}\Pi_2^m + \delta\frac{1}{4}(\Pi_1^m + \Pi_2^m) \qquad (*)$$

$$\text{or} \qquad \delta > \underline{\delta} \equiv \frac{2\Pi_2^m}{3\Pi_2^m + \Pi_1^m} \in \left[\frac{1}{2}, \frac{2}{3}\right]$$

  - Temptation to undercut @ high demand. Compared to stable high demand, face same cheating reward (*-LHS) but lower collusion reward (*-RHS).
  - When $\delta \in [1/2, \underline{\delta}]$, full collusion not sustained in high-demand state.
  - (Recall: in stationary case, collusion sustainable down to $\delta > \frac{1}{2}$)

Price wars during booms IV

- What is best that firms can do when $\delta \in [1/2, \underline{\delta}]$??
- They can play a **constrained collusion** outcome.
- Choose p_1 and p_2 to: $\max \left(\frac{1}{2} \frac{\Pi_1(p_1)}{2} + \frac{1}{2} \frac{\Pi_2(p_2)}{2} \right)$
  - subject to the constraints that for $s = 1, 2$

$$(1-\delta)\frac{1}{2}\Pi_s(p_s) \leq \delta \frac{1}{4}(\Pi_1(p_1) + \Pi_2(p_2))$$

  - Which can be written as:

$$\Pi_1(p_1) \leq \frac{\delta}{2-3\delta}\Pi_2(p_2) \quad \text{and} \quad \Pi_2(p_2) \leq \frac{\delta}{2-3\delta}\Pi_1(p_1)$$

- As before, the binding constraint is that of state 2. Choosing $p_1 = p_1^m$ increases the objective function and relaxes the constraint for p_2. Price p_2 is then chosen as high as possible:

$$\Pi_2(p_2) = \frac{\delta}{2-3\delta}\Pi_1^m$$

Price wars during booms: Conclusions

- For $\delta \in [1/2, \underline{\delta}]$ some collusion is sustainable.
  1. In the low state of demand, firms charge the monopoly price in that state.
  2. In the high state of demand, firms charge a price below the monopoly price in that state.

- Rotemberg and Saloner interpret this as showing the existence of price war during booms.

  - But note price in high state can be lower or higher than the monopoly price in the low demand state depending on the demand function.

  - This is not a price war in the usual sense, because the price may actually be higher during booms than during busts: we do not obtain from here the implication that oligopoly prices move contercyclically.
  - But *less market power* (lower profitability) during boom periods.

Empirical evidence: Supermarket pricing

- RS predicts that *profitability lower during booms*
- But testing this is challenging: how to separately measure firm profitability and whether economy is in a "boom"?
- Chevalier, Kashyap, Rossi: "Why Don't Prices Rise During Peak Demand?"
  - Consider a number of grocery items.
  - Items have idiosyncratic peak demand periods (tuna/Lent, beer/July4): *not related* to state of economy.
  - Store also has general peak demand periods (Thanksgiving, Christmas)
  - Compare *retail margins* during peak and non-peak demand periods
  - Regression results: look for *negative signs* during peak demand periods.

Products with seasonal demand

TABLE 4—SEASONAL CHANGES IN RETAIL MARGINS

Panel A: Seasonal Categories

Variable	Beer	Eating soup	Oatmeal	Cheese	Cooking soup	Snack crackers	Tuna
Linear trend	−0.21	0.04	0.04	−0.009	0.04	0.01	−0.01
	(0.03)	(0.01)	(0.01)	(0.010)	(0.01)	(0.01)	(0.01)
Quadratic trend	0.0004	−0.00009	−0.00008	0.00006	−0.00003	0.00002	0.00006
	(0.00007)	(0.00002)	(0.00002)	(0.00002)	(0.00001)	(0.00002)	(0.00002)
Cold	−0.01	**−0.07**	**−0.04**	0.004	0.02	0.00	−0.02
	(0.04)	**(0.03)**	**(0.02)**	(0.03)	(0.02)	(0.03)	(0.04)
Hot	**−0.03**	−0.10	−0.02	−0.08	−0.05	−0.03	−0.07
	(0.04)	(0.03)	(0.02)	(0.03)	(0.02)	(0.03)	(0.04)
Lent							**−5.03**
							(1.06)
Easter	0.88	0.34	0.66	−2.57	−1.49	−0.39	−1.82
	(1.48)	(1.07)	(0.65)	(1.17)	(0.84)	(1.20)	(1.47)
Memorial Day	**−4.36**	1.35	1.17	−0.54	0.42	1.59	−1.16
	(1.44)	(1.11)	(0.69)	(1.22)	(0.87)	(1.24)	(1.49)
July 4th	**−4.08**	2.18	0.27	−0.33	0.81	−1.01	1.82
	(1.36)	(1.18)	(0.67)	(1.29)	(0.92)	(1.31)	(1.57)
Labor Day	**−2.61**	1.42	0.19	0.27	0.05	−4.61	−1.50
	(1.33)	(1.15)	(0.65)	(1.25)	(0.90)	(1.28)	(1.53)
Thanksgiving	−1.31	1.54	0.01	**−5.18**	**−0.68**	**−5.04**	2.27
	(1.54)	(1.08)	(0.66)	**(1.18)**	**(0.84)**	**(1.29)**	(1.36)
Post-Thanksgiving	−3.12	0.87	−1.25	−4.15	0.13	−4.54	0.63
	(2.00)	(1.44)	(0.88)	(1.59)	(1.13)	(1.72)	(1.81)
Christmas	**−2.66**	2.34	−0.42	**−3.23**	**0.51**	**−8.47**	1.00
	(1.25)	(0.90)	(0.55)	**(0.98)**	**(0.70)**	**(1.06)**	(1.15)
Constant	28.57	18.42	17.99	34.38	14.21	22.84	25.64
	(2.88)	(0.74)	(1.00)	(0.81)	(0.58)	(0.83)	(0.96)
Number of weeks	219	387	304	391	387	385	339

Non-seasonal items

Panel B: Nonseasonal Categories

Variable	Analgesics	Cookies	Crackers	Dish detergent
Linear trend	0.01	0.01	0.02	−0.11
	(0.00)	(0.01)	(0.01)	(0.01)
Quadratic trend	0.00002	0.00001	0.00000	0.00028
	(0.00001)	(0.00002)	(0.00002)	(0.00002)
Cold	−0.02	0.1	−0.01	0.02
	(0.02)	(0.03)	(0.03)	(0.04)
Hot	−0.01	−0.08	−0.03	−0.07
	(0.02)	(0.03)	(0.03)	(0.04)
Easter	0.92	−2.71	0.93	1.46
	(0.73)	(1.11)	(1.10)	(1.39)
Memorial Day	0.08	1.84	0.16	1.10
	(0.75)	(1.15)	(1.14)	(1.44)
July 4th	0.88	1.61	−0.31	0.60
	(0.80)	(1.21)	(1.21)	(1.52)
Labor Day	−0.87	1.29	0.58	2.13
	(0.78)	(1.18)	(1.18)	(1.49)
Thanksgiving	−0.51	−1.11	0.73	0.53
	(0.73)	(1.19)	(1.19)	(1.40)
Post-Thanksgiving	−1.57	−0.53	−0.55	1.99
	(0.98)	(1.60)	(1.59)	(1.88)
Christmas	0.50	1.04	0.40	1.16
	(0.61)	(0.95)	(0.98)	(1.17)
Constant	25.25	24.14	27.05	27.09
	(0.50)	(0.77)	(0.77)	(0.96)
Number of weeks	391	387	385	391

Notes: The dependent variable in each column is the log of the variable-weight retail margin for each category. Units in the table are percentage points. Bold type indicates periods of expected demand peaks. Standard errors are in parentheses.

Secret Price Cuts

- Up to now, we assume that firm's pricing choices are observed by its rival, who can respond by punishing when they observe price cuts. However, (effective) prices may not be observable.
- Must rely on observation of its own realized market share or demand to detect any price undercutting by the rival. But a low market share may be due to the aggressive behavior of one's rival or to a slack in demand.
- Remark: Under uncertainty, mistakes are unavoidable and maximal punishments (eternal reversion to Bertrand behavior) need not be optimal.

Secret Price Cuts

- Framework of our basic repeated game with:
- In each period, there are two possible realizations of demand (states of nature), i.i.d..
  - With probability α, there is no demand for the product sold by the duopolists (the "low-demand" state).
  - With probability $1 - \alpha$, there is a positive demand $D(p)$ (the "high-demand" state).
- A firm that does not sell at some date is unable to observe whether the absence of demand is due to the realization of the low-demand state or to its rival's lower price.

Secret Price Cuts

- Look for an equilibrium with the following strategies:
  - There is a collusive phase and a punishment phase. The game begins in the collusive phase. Both firms charge p^m until one firm makes a zero profit. (note this is common knowledge).
  - The occurrence of a zero profit triggers a punishment phase. Here both firms charge c for exactly T periods, where T can a priori be finite or infinite.
  - At the end (if any) of the punishment phase, the firms revert to the collusive phase.

- We want to look for a length of the punishment phase such that the expected present value of profits for each firm is maximal subject to the constraint that the associated strategies form a SPNE.

Secret Price Cuts

- Let V^+ denote the present discounted value of a firm's profit from date t on, assuming that at date t the game is in the collusive phase.
- Similarly, let V^- denote the present discounted value of a firm's profit from date t on, assuming that at date t the game is in the punishment phase.
  - By the stationarity of the prescribed strategies, V^+ and V^- do not depend on time, and by definition, we have:

$$V^+ = (1-\alpha)\left((1-\delta)\Pi^m/2 + \delta V^+\right) + \alpha\delta V^- \tag{1}$$

and

$$V^- = \delta^T V^+ \tag{2}$$

Secret Price Cuts

- Since strategies need to be a SPNE, we need to include *incentive constraints* which rule out profitable deviations in both phases.
- Easy to see there are no profitable 1-shot deviations in punishment phase. Thus, we only consider incentives in the collusive phase:

$$V^+ \geq (1-\alpha)((1-\delta)\Pi^m + \delta V^-) + \alpha(\delta V^-) \tag{3}$$

  - (3) expresses the trade-off for each firm. If a firm undercuts, it gets $(1-\delta)\Pi^m > (1-\delta)\Pi^m/2$. However, undercutting triggers the punishment phase, which yields valuation V^- instead of V^+.
  - To deter undercutting, V^- must be sufficiently lower than V^+. This means that the punishment must last long enough.
- But because punishments are costly and **occur with positive probability**, T should be chosen as small as possible subj to. Eq. (3)

Secret Price Cuts

- Using (1), we can write (3) as

$$\frac{\delta}{(1-\delta)}(V^+ - V^-) \geq \Pi^m/2 \tag{4}$$

- Also, from (1) and (2) we can get

$$V^+ = \frac{(1-\alpha)(1-\delta)}{(1-(1-\alpha)\delta - \alpha\delta^{T+1})}\frac{\Pi^m}{2} \tag{5}$$

- From (2) we can get $V^+ - V^- = V^+(1-\delta^T)$, and thus, substituting this and (5) into (4), we can express the incentive constraint as:

$$2(1-\alpha)\delta - \delta^{T+1}(1-2\alpha) \geq 1 \tag{6}$$

Secret Price Cuts

- Note that now we can express the problem as that of maximizing V^+ subject to (6). And furthermore, since V^+ is decreasing in T, we want to find the lowest T such that (6) holds.

- Note that the constraint is not satisfied with $T = 0$, and that therefore, since the LHS of (6) decreases with T if $\alpha \geq 1/2$, that in this case there is no solution (no strategy profile of this sort is a SPNE). Thus we need $\alpha < 1/2$.

- Assuming in fact that $(1-\alpha)\delta \geq 1/2$, so that the constraint is satisfied for $T \to \infty$, there exists a (finite) optimal length of punishment T^* In fact,

$$T^* = int^+ \left(\frac{Ln\left(\frac{2(1-\alpha)\delta - 1}{1-2\alpha}\right)}{Ln(\delta)} - 1 \right)$$

Secret Price Cuts

- This model predicts periodic price wars, contrary to the perfect observation models.
- Price wars are involuntary, in that they are triggered not by a price cut but by an unobservable slump in demand.
  - Price wars purely to provide incentives
  - ... even though firms know that there is no cheating in equilibrium! (that is, no firm is engaging in secret price-cutting)
- Note also that price wars are triggered by a recession, contrary to the Rotemberg-Saloner model.
  - "price wars during recessions" vs. "price wars during booms"

Secret Price Cuts

- Under imperfect information, the fully collusive outcome cannot be sustained.
  - It could be sustained only if the firms kept on colluding (charging the monopoly price) even when making small profits, because even under collusion small profits can occur as a result of low demand.
  - However, a firm that is confident that its rival will continue cooperating even if its profit is low has every incentive to (secretly) undercut - price undercutting yields a short-term gain and creates no long-run loss.
  - Thus, full collusion is inconsistent with the deterrence of price cuts.

Secret Price Cuts

- Oligopolists are likely to recognize the threat to collusion posed by secrecy, and take steps to eliminate it.
  - Industry trade associations
    1. collect detailed information on the transactions executed by the members.
    2. allows it members to cross-check price quotations.
    3. imposes standarization agreements to discourage price-cutting when products have multiple attributes.
    4. Case study: Joint Executive Committee. Railroad cartel in the late 19th century US.
  - Resale-price maintenance on their retailers, or "most favored nation " clause.
    1. Simplify observation and detection

Porter (1983): Case study of JEC

- Fit data to game theoretic model where behavioral regime – "cooperative" vs. "non-cooperative" – varies over time.
- Reminder: "non-cooperative" phase in repeated games models not due to cheating!
- Measure market power (markup) in both regimes.
- JEC: railroad cartel in 1800s-US.
  - Set price for grain shipments from Midwest to East Coast.
- Data: Table 1
  - Price (GR) and quantity (grain shipments TGR)
  - PO: collusion indicator (could be mismeasured)
  - PN: collusion variable, estimated from model.
  - S_t are *supply-shifters* (dummies DM1, DM2, DM3, DM4 for entry by additional rail companies)
  - $LAKES_t$: dummy when Great Lakes was open to traffic. *Demand shifter* (reduces demand for rail services)

TABLE 1 List of Variables*

GR	grain rate, in dollars per 100 lbs.
TQG	total quantity of grain shipped, in tons.
LAKES	dummy variable; =1 if Great Lakes were open to navigation; =0 otherwise.
PO	cheating dummy variable; =1 if colluding reported by *Railway Review*; =0 otherwise.
PN	estimated cheating dummy variable.
DM1	=1 from week 28 in 1880 to week 10 in 1883; =0 otherwise; reflecting entry by the Grand Trunk Railway.
DM2	=1 from week 11 to week 25 in 1883; =0 otherwise; reflecting an addition to New York Central.
DM3	=1 from week 26 in 1883 to week 11 in 1886; =0 otherwise; reflecting entry by the Chicago and Atlantic.
DM4	=1 from week 12 to week 16 in 1886; =0 otherwise; reflecting departure of the Chicago and Atlantic from the JEC.

* The sample is from week 1 in 1880 to week 16 in 1886.

Porter (1983): Model

- N firms (railroads), each producing a homogeneous product (grain shipments). Firm i chooses q_{it} in period t.
- Market demand:

$$logQ_t = \alpha_0 + \alpha_1 \log p_t + \alpha_2 LAKES_t + U_{1t}, \quad Q_t = \sum_i q_{it}.$$

- 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:
  - $\theta_{it} =$: 1: (Monopoly/Perfect Collution); s_{it} (Cournot); 0 (Bertrand)
- After some manipulation, aggregate supply relation is:

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

$(D = \delta \left(\sum_i a^{1/(1-\delta)}\right)^{1-\delta})$ with empirical version

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

Porter (1983): Results, Table 3

- Estimate two specifications (differ in whether collusion indicator *PO* is used)
- *GR*: price elasticity < 1 in abs. value. Not consistent with optimal monopoly pricing.
- $LAKES_t$ reduces demand;
- *DM* variables lowered market price
- Coef on PO/PN is > 0: prices higher when firms are in "cooperative" regime.
  - If we assume that $\theta = 0$ in non-cooperative periods, then this implies θ=0.336 in cooperative periods.
  - Is this too small? (Note $\theta = 1$ w/ perfect cartel)
- Table 4:
  - prices higher and quantity lower in "noncooperative" ($PN = 1$) periods.
  - Cartel earns \$11,000 more in weeks when they are cooperating

TABLE 3 Estimation Results*

	Two Stage Least Squares (Employing *PO*)		Maximum Likelihood (Yielding *PN*)**	
Variable	Demand	Supply	Demand	Supply
C	9.169	−3.944	9.090	−2.416
	(.184)	(1.760)	(.149)	(.710)
LAKES	−.437		−.430	
	(.120)		(.120)	
GR	−.742		−.800	
	(.121)		(.091)	
DM1		−.201		−.165
		(.055)		(.024)
DM2		−.172		−.209
		(.080)		(.036)
DM3		−.322		−.284
		(.064)		(.027)
DM4		−.208		−.298
		(.170)		(.073)
PO/PN		.382		.545
		(.059)		(.032)
TQG		.251		.090
		(.171)		(.068)
R^2	.312	.320	.307	.863
s	.398	.243	.399	.109

* Monthly dummy variables are employed. To economize on space, their estimated coefficients are not reported. Estimated standard errors are in parentheses.

** *PN* is the regime classification series $(\hat{I}, \ldots, \hat{I}_T)$. The coefficient attributed to *PN* is the estimate of β_1.

TABLE 4 Price, Quantity, and Total Revenue for Different Values of *LAKES* and *PN**

Price	*LAKES*	
	0	1
PN 0	.1673	.1612
1	.2780	.2679

Quantity	*LAKES*	
	0	1
PN 0	38680	25904
1	25775	17261

Total Revenue**	*LAKES*	
	0	1
PN 0	129423	83514
1	143309	92484

* Computed from the reduced form of the maximum likelihood estimates of Table 3, with all other explanatory variables set at their sample means.

** Total Revenue = 20 (Price × Quantity), to yield dollars per week.

Summary

- Difficulties with taking pure tacit collusion to data: stationary model predicts that prices are unchanging over time
- Rotemberg-Saloner model
  - Perfect information
  - Predictions about varying firm profitability across the business cycle
  - "Price war during booms"
- Green-Porter model
  - Imperfect information; secret price cuts
  - "Price wars during recessions"
- In both cases, price wars arise *not from cheating*, but in order to provide intertemporal incentives to coorperating firms in nonstationary economic environment.