Outline

1. Introduction
2. Price Wars During Booms
3. Supermarket pricing
4. Secret Price Cuts
Does theory match reality? OPEC
Does theory match reality? JEC
Empirical predictions of tacit collusion

- *Constant* production, price
- Does not match empirical and anecdotal evidence from real-world cartels: defection, price-wars, etc.
- Consider one such model which generates time-varying activity: Rotemberg-Saloner model
- Evidence: supermarket pricing
- Case study: Joint Executive Committee (railroad cartel in nineteenth-century US)
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 the current state of demand before choosing their prices simultaneously.

- 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.
We first examine whether the “fully collusive outcome”, in which the two firms charge the monopoly price $p_s^m$ in each state, is sustainable in equilibrium.

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 $\Pi$ 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:

$$
(1 - \delta)\Pi^2_m < (1 - \delta)\frac{1}{2} \Pi^m_2 + \delta \frac{1}{4} (\Pi^m_1 + \Pi^m_2) \quad \text{or} \quad \delta > \delta \equiv \frac{2\Pi^m_2}{3\Pi^m_2 + \Pi^m_1} \in \left[\frac{1}{2}, \frac{2}{3}\right]
$$

- Temptation to undercut when demand is high. Compared to stable high demand, face same reward and lower punishment.

- When $\delta \in [1/2, \delta]$, full collusion cannot be sustained in the high-demand state, contrary to the case of deterministic demand.
We now tackle the problem we set up to solve for \( \delta \in [1/2, \bar{\delta}] \) (otherwise we have either no collusion or full collusion).

Choose \( p_1 \) and \( p_2 \) to: 
\[
\max \left( \frac{1}{2} \Pi_1(p_1) + \frac{1}{2} \Pi_2(p_2) \right)
\]
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 $\delta \in [1/2, \delta]$ 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 counter cyclically.
Empirical evidence: Supermarket pricing

- 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)
- Store also has general peak demand periods (Thanksgiving, Christmas)
- Compare *retail margins* during peak and non-peak demand periods
- Regression results
Table 4—Seasonal Changes in Retail Margins

<table>
<thead>
<tr>
<th>Variable</th>
<th>Beer</th>
<th>Eating soup</th>
<th>Oatmeal</th>
<th>Cheese</th>
<th>Cooking soup</th>
<th>Snack crackers</th>
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<td>(0.02)</td>
<td>(0.03)</td>
<td>(0.04)</td>
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<td>Easter</td>
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<td>0.34</td>
<td>0.66</td>
<td>$-2.57$</td>
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<td>$-0.39$</td>
<td>$-1.82$</td>
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<td>(1.07)</td>
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<td>(1.17)</td>
<td>(0.84)</td>
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<td>1.59</td>
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<td>July 4th</td>
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<td>1.54</td>
<td>0.01</td>
<td>$-5.18$</td>
<td>$-0.68$</td>
<td>$-5.04$</td>
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<td>(1.08)</td>
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<td>(1.18)</td>
<td>(0.84)</td>
<td>(1.29)</td>
<td>(1.36)</td>
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<tr>
<td>Post-Thanksgiving</td>
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<td>$-4.15$</td>
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<td>$-4.54$</td>
<td>0.63</td>
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<td>(2.00)</td>
<td>(1.44)</td>
<td>(0.88)</td>
<td>(1.59)</td>
<td>(1.13)</td>
<td>(1.72)</td>
<td>(1.81)</td>
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<tr>
<td>Christmas</td>
<td>$-2.66$</td>
<td>2.34</td>
<td>$-0.42$</td>
<td>$-3.23$</td>
<td>0.51</td>
<td>$-8.47$</td>
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<td>(1.25)</td>
<td>(0.90)</td>
<td>(0.55)</td>
<td>(0.98)</td>
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<td>(1.06)</td>
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<td>17.99</td>
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<td>14.21</td>
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<td>(0.74)</td>
<td>(1.00)</td>
<td>(0.81)</td>
<td>(0.58)</td>
<td>(0.83)</td>
<td>(0.96)</td>
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Number of weeks: 219  387  304  391  387  385  339

Notes:
- Number of weeks
- Constant
- Linear trend
- Quadratic trend
- Cold
- Hot
- Lent
- Easter
- Memorial Day
- July 4th
- Labor Day
- Thanksgiving
- Post-Thanksgiving
- Christmas
- Table 4 shows the seasonal changes in retail margins for various products.
- The table includes linear and quadratic trends for each category.
- Standard errors are in parentheses.
## Non-seasonal items

### Table 4: Seasonal Changes in Retail Margins

<table>
<thead>
<tr>
<th>Category</th>
<th>Analgesics</th>
<th>Cookies</th>
<th>Crackers</th>
<th>Dish detergent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linear trend</td>
<td>0.01</td>
<td>0.01</td>
<td>0.02</td>
<td>-0.11</td>
</tr>
<tr>
<td>Quadratic trend</td>
<td>0.00002</td>
<td>0.00001</td>
<td>0.00000</td>
<td>0.00028</td>
</tr>
<tr>
<td>Cold</td>
<td>-0.02</td>
<td>0.1</td>
<td>-0.01</td>
<td>0.02</td>
</tr>
<tr>
<td>Hot</td>
<td>-0.01</td>
<td>-0.08</td>
<td>-0.03</td>
<td>-0.07</td>
</tr>
<tr>
<td>Easter</td>
<td>0.92</td>
<td>-2.71</td>
<td>0.93</td>
<td>1.46</td>
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<td>Memorial Day</td>
<td>0.08</td>
<td>1.84</td>
<td>0.16</td>
<td>1.10</td>
</tr>
<tr>
<td>July 4th</td>
<td>0.88</td>
<td>1.61</td>
<td>-0.31</td>
<td>0.60</td>
</tr>
<tr>
<td>Labor Day</td>
<td>-0.87</td>
<td>1.29</td>
<td>0.58</td>
<td>2.13</td>
</tr>
<tr>
<td>Thanksgiving</td>
<td>-0.51</td>
<td>-1.11</td>
<td>0.73</td>
<td>0.53</td>
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<tr>
<td>Post-Thanksgiving</td>
<td>-1.57</td>
<td>-0.53</td>
<td>-0.55</td>
<td>1.99</td>
</tr>
<tr>
<td>Christmas</td>
<td>0.50</td>
<td>1.04</td>
<td>0.40</td>
<td>1.16</td>
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<tr>
<td>Constant</td>
<td>25.25</td>
<td>24.14</td>
<td>27.05</td>
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</table>

**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, firm’s past choice is perfectly observed by its rival. However, (effective) prices may not be observable (discounts, quality, etc).

- 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 $\alpha$, 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.
  - Remark: all or nothing demand function is an extreme simplification, but it allows us to study the problem with a nontrivial inference problem in the basic setup; a more general approach would require us to introduce differentiated products.
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.
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:

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

and

$$V^- = \delta^T V^+$$  \hspace{1cm} (2)$$
Since strategies need to be a SPNE, we need to include incentive compatibility constraints ruling out profitable deviations in both phases.

Easy to see that there are no profitable one shot deviations in the punishment phase. Thus, it suffices to consider incentives in the collusive phase. This is:

\[ V^+ \geq (1 - \alpha)((1 - \delta)\Pi^m + \delta V^-) + \alpha(\delta V^-) \]  \hspace{1cm} (3)

(3) expresses the trade-off for each firm. If a firm undercuts, it gets \( \Pi^m > \Pi^m/2 \). However, undercutting automatically 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 given that 3 is satisfied.
Using (1), we can write (3) as

\[ \frac{\delta}{(1 - \delta)}(V^+ - V^-) \geq \Pi^m/2 \]  

(4)

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

\[ V^+ = \frac{(1 - \alpha)(1 - \delta)}{(1 - (1 - \alpha)\delta - \alpha\delta^{T+1})} \frac{\Pi^m}{2} \]  

(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:

\[ 2(1 - \alpha)\delta - \delta^{T+1}(1 - 2\alpha) \geq 1 \]

(6)
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,

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

Note also that price wars are triggered by a recession, contrary to the Rotemberg-Saloner model.
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 (secretely) 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 in both regimes.
- Data: Table 1
  - Price \((GR)\) and quantity \((\text{grain shipments } TGR)\)
  - \(S_t\) 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.
Porter (1983): Model

- $N$ firms (railroads), each producing a homogeneous product (grain shipments). Firm $i$ chooses $q_{it}$ in period $t$.
- Market demand: $\log Q_t = \alpha_0 + \alpha_1 \log p_t + \alpha_2 \text{LAKES}_t + U_{1t}$, where $Q_t = \sum_i q_{it}$.
- 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:
  - $\theta_{it} = 0$: Bertrand pricing
  - $\theta_{it} = 1$: Monopoly pricing
  - $\theta_{it} = s_{it}$: Cournot outcome
- 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
  $$\log p_t = \beta_0 + \beta_1 \log Q_t + \beta_2 S_t + \beta_3 I_t + U_{2t}$$
Porter (1983): Results, Table 3

- Estimate in two ways (results quite similar):
  1. Two-stage least squares
  2. Maximum likelihood

- \( GR \): price elasticity < 1 in abs. value. Not consistent with optimal monopoly pricing.

- \( LAKES_t \) reduces demand;

- \( DM \) variables lowered market price

- Estimate of \( \beta_3 \) is 0.382/0.545: 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)

- Table 4:
  - prices higher and quantity lower in “noncooperative” \((PN = 1)\) periods.
  - Cartel earns $11,000 more in weeks when they are cooperating