Communication and Monitoring in Cartels: Explaining the Stability of the Citric Acid, Lysine, and Vitamins Cartels

Joe Harrington (Johns Hopkins)

3rd Conference of the Research Network on Innovation and Competition Policy: "Competition Policy and Innovation: Where Do We Stand?"

30-31 October 2009

Introduction

- How does the theory of collusion match up with what we know about cartels?
- Leniency programs have produced vast information about the operation of cartels.
  - J. Harrington, *How Do Cartels Operate?* (*Foundations and Trends in Microeconomics*, 2006) is based on European Commission decisions, 2000-04.
- Given this new information, can theory be improved so that we better understand:
  - market conditions suitable to collusion (structural markers)
  - implications of collusion for behavior (behavioral markers)

Cartel Case Studies

Lysine (1992-95): Collusive Outcome

- Ajinomoto and Sewon wanted to have exclusive geographic markets.
- Terry Wilson (ADM) argued against customer allocation because a "don't touch [each other's] customers policy" could create suspicions.
- Firms settled on a market sharing agreement with sales quotas.

Market Allocation (tons)

Company	Global	Europe
Ajinomoto	73,500	34,000
ADM	48,000	5,000
Kyowa	37,000	8,000
Sewon	20,500	13,500
Cheil	6,000	5,000

Cartel Case Studies
Lysine (1992-95): Monitoring


Kanji Mimoto


Terry Wilson

- Each company telephoned or mailed their sales to Kanji Mimoto of Ajinomoto.
- Mimoto prepared a spreadsheet that was distributed at the quarterly maintenance meetings.
- Terry Wilson (ADM): "... if I'm assured that I'm gonna get 67,000 tons by the year's end, we're gonna sell it at the prices we agreed to and I frankly don't care what you sell it for." (March 10, 1994 meeting of the lysine cartel)

- Enforcement
  - "Guaranteed buy-ins" - A company that sold more then its quota would have to buy product from producers who were below quota.
- Collusion was effective.
  - By the end of 1994, reported sales volume were only 1.4% higher than the targeted amount.
  - Sewon was farthest from its allotted share - selling 14.3% instead of 14.7%.
  - Mark Whitacre (ADM): "And that total for us for the year, calendar year is 68,000; 68,334. 68,334 and our target was 67,000 plus alpha. Almost on target." (January 18, 1995 meeting of the lysine cartel)

Cartel Case Studies

Citric acid (1991-95): Cartel Organization

- Hierarchical structure
  - "Masters" meetings: Presidents, CEOs, and General Managers would meet about twice a year to decide on price and a market allocation.
  - "Sherpa" meetings: Sales managers would meet to implement the agreement.
- Standard format
  - Discuss the latest cartel sales reports.
  - Discuss price levels and decide whether to raise prices.
  - Share information about non-cartel competitors.
  - Discuss "problems affecting the group" (cheating).

- Prices
  - Agreed to "floor" and "target" prices to be implemented.
  - Discount of up to 3% off the list price for major customers.
- Quantities
  - Sales quotas were allocated to each firm and fixed on a worldwide basis.
  - Quotas were based on the average of the previous three years' sales (1988-90).

Allocation of Market Shares

Company	Market Share
Haarman & Reimer	32.0%
ADM	26.3%
Jungbunzlauer	23.0%
Hoffman LaRoche	13.7%
Cerestar Bioproducts	5.0%

Cartel Case Studies

Citric acid (1991-95): Monitoring and Enforcement

- Monitoring of volume agreement
  - Monthly, each company's sales was reported to an executive of Hoffmann-La Roche.
  - Data was assembled and then reported back to the members by telephone.
  - Annual checking by independent Swiss auditors.
- Enforcement
  - Buy-back system: If a company exceeded its assigned quota in any one year, it would be obliged to purchase output from the companies with sales below their quota during the following year.
  - Example: At the meeting in Nov 1991 in Brussels, it was determined that Haarmann & Reimer had to buy 7,000 tons from ADM.

Cartel Case Studies

Zinc phosphate (1994-98)

- Coordination
  - Prices: Set "minimum" and/or "recommended" prices.
  - Market share allocations were based on market shares over 1991-93.
  - Some customer allocation: Large customer Teknos was sequentially allocated to the cartel members.
- Monitoring
  - Monthly, each producer sent its sales data to the trade association.
  - The trade association aggregated them and sent the market size to all five producers.
  - On an annual basis, market shares closely followed allocated shares.
- Enforcement
  - Allocation of Teknos was used as a form of compensation: "SNCZ seemed to have undersold and was 'allocated' Teknos for 6 months."

Cartel Case Studies
Common Features

- Product is homogeneous.
- Demand is largely from industrial buyers.
- Price is set bilaterally between seller and buyer and is generally not public information.
- Collusive agreement is monitored in terms of sales compared to quotas.
- Punishment involved transfers.

Cartel Case Studies

International Steel Agreement (1926)

- Articles 3 and 4: Fixed sales quotas.

Country	Allocated Market Share
Germany	40.45%
France	31.89%
Belgium	12.57%
Luxemburg	8.55%
Saar Territory	6.54%

- Article 5: "Every month each country's actual net production of crude steel during that month shall be ascertained ..."
- Articles 6 and 7: "If the quarterly production of a country exceeds [its] quota, that country shall pay in respect of each ton in excess a fine of 4 dollars ... If the production of any country has been below [its] quota, [it] shall receive in compensation ... the sum of two dollars per ton short."

Objective of Research Project

- Develop a better theory of hard-core cartels.
- Collusion when prices are private information and sales are public information (joint with Andy Skrzypacz, *RAND Journal of Economics*, 2007)
  - Impossibility result: Price wars cannot sustain collusion.
  - Possibility result: Asymmetric punishments (buy-backs) can sustain collusion.
- Collusion when prices and sales are private information (joint with Andy Skrzypacz, 2009)
  - If demand is not too volatile, there is an equilibrium in which firms truthfully report sales and condition punishments on those reports.

Model

- Infinitely repeated game in which $n \geq 2$ firms make simultaneous price decisions.
- Market demand
  - m^t is total sales and is *iid* over time.
  - $\rho(m) : \{\underline{m}, \underline{m}+1, \ldots, \overline{m}\} \rightarrow [0,1]$

$$\mu \equiv \sum_{m=\underline{m}}^{\overline{m}} \rho(m)\, m$$

  - Market demand does not depend on firms' prices.

- $\psi_i\left(q; m, \underline{p}\right)$ is the probability function on firm i's sales given total demand is m and the price vector.
- ψ_i is continuously differentiable with respect to p_i, $\forall i$. [smoothness]
- ψ_i is symmetric.
- $\sum_{j=1}^{n}\left(\frac{\partial\psi_i(q|p,\ldots,p)}{\partial p_j}\right) = 0$, $\forall\left(q, m, p\right)$. [local invariance]
    - Satisfied when ψ_i depends only on the price differences
    - Example: Discrete choice model (without an outside option).
    - Only needed for impossibility result.

Model

- Common constant marginal cost, c.
- Information structure
  - Imperfect monitoring as firms' prices are private information.
  - Firms' quantities are common knowledge.
- Perfect public equilibria - a firm conditions its price on the publicly observed history of quantities (and not on the privately observed history of prices).

- A Nash equilibrium is *strongly symmetric* when, for any history, continuation payoffs are the same.
- Additional properties: *exchangeability* and *history-relevance*.

Theorem

The set of "reasonable" strongly symmetric Nash equilibrium prices for the infinite horizon game coincides with the set of symmetric Nash equilibrium prices for the stage game.

Collusion with Public Sales Information

Symmetric Punishments

- Example: duopoly
- Consider a strategy profile in which there is a low continuation payoff ("price war") if either firm has a market share exceeding some threshold, $\widehat{s}$.
- If firm 1 marginally reduces its price,
  - it *increases* the probability that $s_1 > \widehat{s}$ and makes a price war *more* likely.
  - it *decreases* the probability that $s_2 > \widehat{s}$ and makes a price war *less* likely.
- Locally, those two effects are of the same size.
- A firm's price then has no effect on its expected continuation payoff.
- Equilibrium price maximizes expected current profit.

Collusion with Public Sales Information
Asymmetric Punishments

- If firms are in the collusive state then
  - a firm pays $z \geq 0$ for each unit it sells
  - the proceeds are shared equally among the remaining members of the cartel.
- State of the industry
  - Firms start in the collusive state.
  - Firms remain in the collusive state as long as transfers are paid.
  - Failure to make a transfer causes firms to switch to static Nash equilibrium forever.

Collusion with Public Sales Information
Asymmetric Punishments

Firm 1's payoff in the collusive phase -

$$\sum_{m=\underline{m}}^{\overline{m}} \rho(m) \sum_{q=0}^{m} \psi_1(q; m, \underline{p}) \left[(p_1 - c)\, q + z\left(\frac{m-q}{n-1}\right) - zq \right] + \delta V$$

Equilibrium condition -

$$\widehat{p} \in \arg\max \sum_{m=\underline{m}}^{\overline{m}} \rho(m) \sum_{q=0}^{m} \psi_1(q; m, p_1, \widehat{p}, \ldots, \widehat{p}) \times \left(p_1 - c - \left(\frac{n}{n-1}\right) z\right) q$$

Equilibrium price: $\widehat{p} = p^N\left(c + \left(\frac{n}{n-1}\right) z\right).$

Collusion with Public Sales Information

Asymmetric Punishments

- Assumption: The one-shot game with cost c has, $\forall c \geq 0$, a symmetric Nash equilibrium price $p^N(c)$ that is increasing, continuous, and unbounded in c.

Theorem

For any price $p > p^N(c)$, there exists $\delta^* < 1$ such that for all $\delta \geq \delta^*$ there exists a public perfect equilibrium in which the cartel sets a price of p in every period.

- Equilibrium condition (price): For any $p > p^N$ choose the per-unit transfer z so that

$$p = p^N \left(c + \frac{n}{n-1} z \right)$$

- Equilibrium condition (transfer):
  - It is sufficient to verify the incentives of a firm that sells to all customers given maximal market demand:

$$-\overline{m}z + \delta V(p) \geq \delta V^N \Leftrightarrow \delta \left[V(p) - V^N \right] \geq \overline{m}z$$

    - $V(p)$ is the collusive value.
    - V^N is the non-collusive (Nash) value.
  - As $\delta \rightarrow 1$, $\delta \left[V(p) - V^N \right] \rightarrow \infty$.

Collusion with Public Sales Information

Asymmetric Punishments

- Symmetric price wars are not effective at sustaining collusion.
  - Robust to market demand being highly price-inelastic.
- Asymmetric punishments in the form of transfers can sustain collusion.
  - Transfers can be consummated through inter-firm sales.
  - Robust to when firms set customer-specific prices.

Collusion with Self-Reported Sales

- Firms self-reported their sales in cartel meetings, but were these reports truthful?
- Lysine cartel - some episodes of misleading reports
  - Cheil claims that it misreported sales on occasion.
  - Ajinomoto hid 3,500 tons of lysine out of the cartel's auditors; for example, an internal memo read: "Hide 1,000 tons in Thailand internal business."
- Carbonless paper cartel:
  - "Comparison of these figures with information on real sales figures confirms that the sales volume information exchanged at the meeting was accurate."

Collusion with Self-Reported Sales

- $\sigma_i \left(m; q, \underline{p} \right)$ is the probability that market demand is m given firm i's sales is q and firms' prices.

$$\sigma_i \left(m; q, \underline{p} \right) = \frac{\rho\left(m \right) \psi_i \left(q; m, \underline{p} \right)}{\sum_{m'=\underline{m}}^{\overline{m}} \rho\left(m' \right) \psi_i \left(q; m', \underline{p} \right)}.$$

- Assumption: $\sigma_i \left(\overline{m}; q, \underline{p} \right) > 0, \forall q, \forall \underline{p}$.
- Assumption: If $q' > q''$ then $\sigma \left(\cdot \left| q', \underline{p} \right. \right)$ first-order stochastically dominates $\sigma \left(\cdot \left| q'', \underline{p} \right. \right)$.

Collusion with Self-Reported Sales

Extensive Form

- Stage 1 (price): Each firm chooses price.
- Stage 2 (demand): With prices being private information, market demand is realized and each firm learns its sales.
- Stage 3 (report): With prices and quantities being private information, each firm submits a publicly observed costless message (which can be interpreted as a sales report).
- Stage 4 (transfer): With prices and quantities being private information but reports being public information, each firm makes a payment to the other $n-1$ firms.

- Price stage
  - If in the collusive phase, price at $\widehat{p}$.
  - If in the non-collusive phase, price at p^N.
- Report stage: report q_i^t.
- Transfer stage
  - If in the collusive phase, pay zr_i^t (where r_i^t is firm i's report)
  - If in the non-collusive phase, pay zero.

- If there exists firm i such that its transfer is different from zr_i^t then go to the non-collusive phase
- If all appropriate transfers have been made then
  - remain in the collusive phase with probability. $1 - \phi\left(\sum_{j=1}^{n} r_j^t\right)$
  - shift to the non-collusive phase with probability $\phi\left(\sum_{j=1}^{n} r_j^t\right)$

Collusion with Self-Reported Sales

Equilibrium

Theorem

For any $\varepsilon > 0$ and $\widehat{p} > p^N$, if δ is sufficiently close to one and $\frac{\mu}{\overline{m}-\mu}$ is sufficiently high then the **lysine strategy profile** *with collusive price $\widehat{p}$ is a semi-public perfect equilibrium and the probability of a price war is less than ε.*

- A *semi-public perfect equilibrium* has actions (prices and payments) depend only on the public history, and messages depend only on the public history and the most recent private history.
- μ is average market sales.
- $\overline{m}$ is maximal market sales.

- Given report r_i, firm i makes a transfer of zr_i iff

$$
\begin{aligned}
& \sum_{m=\underline{m}}^{\overline{m}} \sigma_i \left(m \,\middle|\, q_i, \underline{p}\right) \Bigg[z \left(\frac{m-q_i}{n-1} \right) - zr_i + \\
& \phi\left(m + r_i - q_i\right) \delta V^N + \left(1 - \phi\left(m + r_i - q_i\right)\right) \delta V \Bigg] \\
\geq \quad & \sum_{m=\underline{m}}^{\overline{m}} \sigma_i \left(m \,\middle|\, q_i, \underline{p}\right) \left[z \left(\frac{m-q_i}{n-1} \right) + \delta V^N \right]
\end{aligned}
$$

$$
\begin{aligned}
& \sum_{m=\underline{m}}^{\overline{m}} \sigma_i \left(m \,\middle|\, q_i, \underline{p}\right) \left(1 - \phi\left(m + r_i - q_i\right)\right) \delta \left(V - V^N \right) \\
\geq \quad & zr_i
\end{aligned}
$$

Collusion with Self-Reported Sales

Equilibrium Condition: Report

- Given sales q_i, firm 1's expected payoff from reporting r_i is

$$\sum_{m=\underline{m}}^{\overline{m}} \sigma_i\left(m \,\middle|\, q_i, \underline{p}\right)\left\{\left[\left(p_i - c\right)q_i + z\left(\frac{m-q_i}{n-1}\right) - zr_i\right]\right.$$
$$\left. + \phi\left(m - q_i + r_i\right)\delta V^N + \left(1 - \phi\left(m - q_i + r_i\right)\right)\delta V\right\}.$$

- Reporting q_i is preferred to reporting $r_i\ (\neq q_i)$ iff

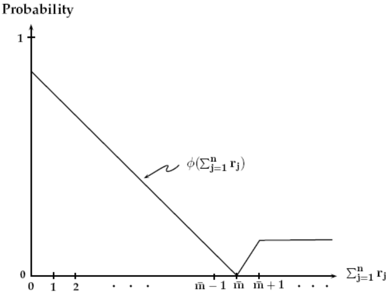
$$\sum_{m=\underline{m}}^{\overline{m}} \sigma_i\left(m \,\middle|\, q_i, \underline{p}\right)\left[\phi\left(m - q_i + r_i\right) - \phi\left(m\right)\right]\delta\left(V - V^N\right)$$
$$\geq z\left(q_i - r_i\right)$$

- Discourage under-reporting
  - Assumption: $\phi(R^t)$ is decreasing in aggregate reported sales, $R^t \equiv \sum_{j=1}^{n} r_j^t$.
- Discourage over-reporting
  - Assumption: For $R^t > \overline{m}$, $\phi(R^t)$ is large relative to $\max\{\phi(m) : m \leq \overline{m}\}$.
- Avoid inefficiencies from price wars.
  - Assumption: $\lim_{\delta \to 1} \max\{\phi(m) : \underline{m} \leq m \leq \overline{m}\} = 0$.
- Assumption: $\phi(R^t)$ is weakly convex in R^t.

- Probability of punishment function

$$\phi(m) = \begin{cases} \beta(\overline{m} - m)(1-\delta) & \text{if } m \le \overline{m} \\ (1-\delta)^{\omega} & \text{if } \overline{m} < m \end{cases}$$

where $\beta > 0$ and $0 < \omega < 1$.



Research Directions

1. Combining noisy signals of price and sales with self-reporting.
   - Citric acid cartel used Swiss auditors to check on reported sales.
   - A firm's sales representatives collect some price information of other firms.
   - How does this alter the structure of the collusive agreement?

Research Directions

1. Combining noisy signals of price and sales with self-reporting.
2. What explains variation in the frequency of meetings across cartels?

Research Directions

Cartel	Frequency of Meetings
Choline chloride	every 2-3 weeks
Citric acid	monthly
Copper plumbing tubes	every 1-2 months
Elec. mech. carb. graphite	weekly/monthly
Graphite electrodes	2-3/year
Isostatic graphite	2/year
Lysine	monthly
Organic peroxides	quarterly
Plasterboard	quarterly
Sorbates	2/year
Vitamins (A, E)	weekly/quarterly
Zinc phosphate	monthly

Research Directions

1. Combining noisy signals of price and sales with self-reporting.
2. What explains variation in the frequency of meetings across cartels?
3. What explains variation in the allocation mechanism?
    - sales quotas
    - customer allocation
    - exclusive territories?

Research Directions

Cartel	Sales Quotas	Customer Allocation	Exclusive Territories
Choline chloride	✓	✓	✓
Copper plumbing tubes	✓		
District heating pipes	✓	✓	
Elec. mech. carb. graphite	✓	✓	
Graphite electrodes	✓		
Isostatic graphite			✓
Nucleotides		✓	✓
Organic peroxides	✓	✓	
Plasterboard	✓		
Sorbates	✓		
Vitamins (A, E)	✓		