The Anatomy of a Cartel Price Path: Theory Meets Practice

Joe Harrington

Johns Hopkins University

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Recent developments in anti-cartel policy
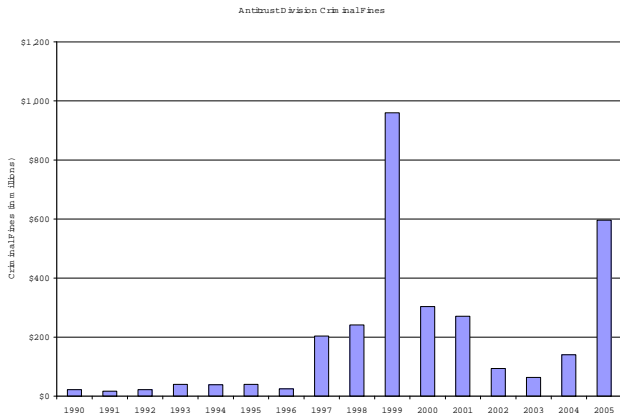
- Leniency programs
  - United States
    - First firm to come forward is relieved of all government penalties.
    - Customer damages are reduced from treble to single damages.
  - European Union
    - First firm to come forward is relieved of some or all government penalties.
    - Later firms can receive partial leniency.
  - At least 28 countries and unions have leniency programs.

- More severe penalties

Antitrust Division Criminal Fines

- ▶ Sources of higher penalties
    - ★ Stronger case due to leniency programs.
    - ★ In the U.S., legislation has increased maximal penalties.

- More intense enforcement

European Commission Decisions (Brenner, 2005)

	1990-1995	1996-2003
Number of cases	15	38
Fines per case (millions €)	71,94	143,12
Reductions of fines per case	-	51,40
Net fines per case	71,94	91,72
Average duration (years)	7,20	6,08

- Are we on the verge of exterminating cartels?

  - Is the cartel rate falling?

    - Challenge: Cartel rate is not measurable.

  - Is cartel formation unprofitable?

    - Challenge: Frequency with which cartels are caught is not measurable.

- Cartels are probably not on the verge of extinction.
    - Cartels continue to form.
    - EC officials report that many applicants to the leniency program are from "near-to-die" cartels.
    - Financial penalties are too low to deter.
        - On the order of the amount of incremental profit from collusion.
    - Example: Vitamins (Connor, 2006)
        - U.S.: fines and damages were about twice the gain.
        - EU: fines were about 30% of the gain.
        - Global: penalties were less than the gain.

- What will it take to make collusion unprofitable?
    - Higher penalties
        - Financial penalties alone would risk bankruptcy.
        - Criminalization: use prison sentences.
    - Higher probability of being caught and paying penalties.

- Screening
  - Screening is the monitoring of markets for illegal activity.
  - Screening is currently being used to find
    - ★ tax evasion
    - ★ insider trading
    - ★ credit card fraud.

- Economic research can play a vital role in the performance of screening for collusion.

    ▶ Theory

        ★ What should we look for?
        ★ What kind of price and quantity patterns are consistent with collusion?

    ▶ Empirical methods

        ★ How should we look?
        ★ What is the best way to monitor a market and test for possible collusion?

- Objectives of today's talk

  - ▸ Coalesce some of what we know about cartels.
  - ▸ Lay out a research agenda for collusion relevant to screening.

- Parameters to talk

  - ▸ Focus is on explicit collusion.
  - ▸ Focus is on cartel behavior rather than cartel formation.
  - ▸ Caveat: Facts are limited to *discovered* cartels.

- Overview

  - ▸ Pricing behavior.
  - ▸ Strategies with regards to monitoring and enforcement.
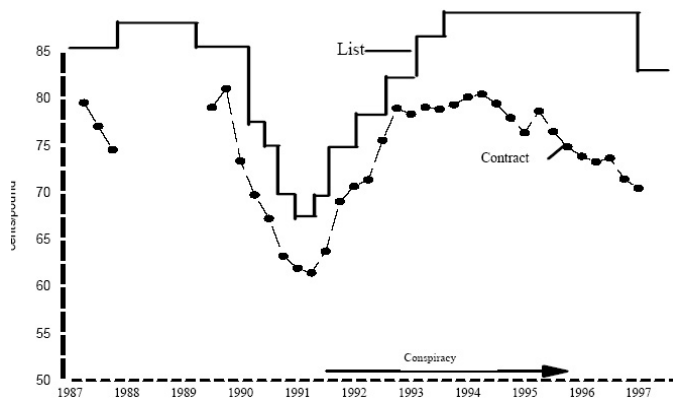 - ▸ Organizational and procedural aspects of a cartel.

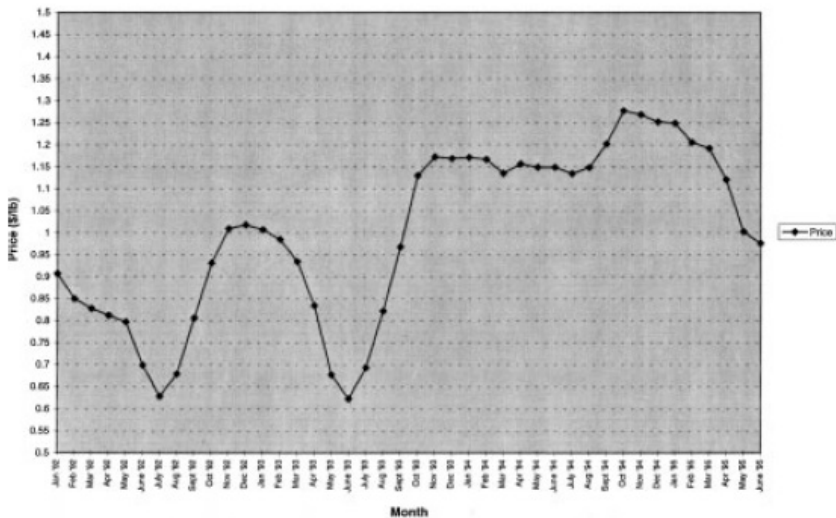# Describing and Understanding a Cartel Price Path
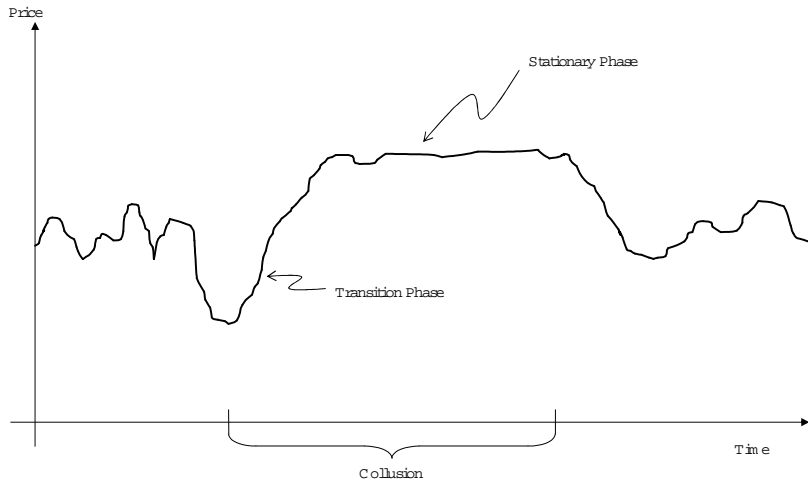
Canonical Cartel Price Path

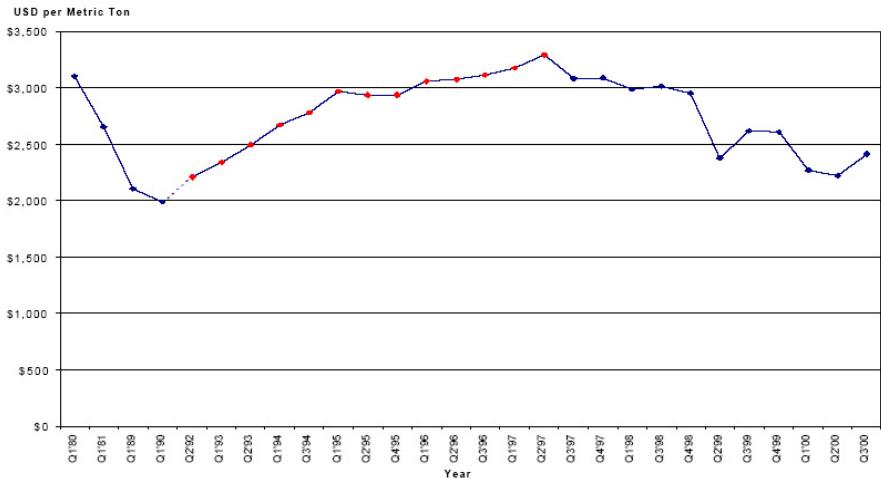# Transition Phase of a Cartel Price Path: Evidence

- Property: cartel gradually raises price.

Citric Acid Price Path (Connor, 2001)

Lysine Price Path (Connor, 2001)

Graphite Electrodes Price Path (Levenstein and Suslow, 2001)

- Documentary evidence
  - Cartel members would agree to a series of future price increases.

Choline Chloride (Nov. 16, 1992 meeting)

Date of Planned Price Increase	50% Dry	60% Dry	75% Liquid
January 1993	1000	1200	1000
July 1993	1100	1320	1100
January 1994	1100	1320	1200

  - District heating pipes cartel: "A common price list was devised; agreed discounts were to be progressively reduced with the declared aim of raising prices 30% in two years.

- Standard collusive pricing models do not generate such a path.
  - Models fail to recognize that a cartel inherits a non-collusive price.
  - Focus is on stationary properties of the cartel price path.
- Possible factors driving the transition.
  - Intertemporal demand substitution: avoiding (industrial) buyer resistance.
  - Learning and experimentation: cartel members are uncertain as to how high a price is stable.
  - Avoiding detection: gradual price increases may avoid discovery that a cartel has formed.

Transition Phase of a Cartel Price Path: Theory

- Harrington and Chen (2005)
- Model
  - Infinite horizon oligopoly game with perfect monitoring.
  - Linear demand function:

  $$D(P) = a - bP.$$

  - Common and stochastic linear cost function,

  $$C^t(q) = c^t q,$$

  where c^t is a random walk,

  $$c^t = c^{t-1} + \varepsilon^t,$$

  $\varepsilon^t \sim N\left(\mu_\varepsilon, \sigma_\varepsilon^2\right)$ and *iid*.

- If firms decide to form a cartel and the cartel is currently active then

  - ▸ Firms agree to a common price and realize profit.
  - ▸ With some probability, the cartel is detected.

    - ★ Each firm pays a penalty and receives non-collusive profit thereafter.
    - ★ $V^{nc}(c^t)$ denotes the expected non-collusive payoff (before netting out penalties).

  - ▸ If the cartel is not detected then collusion continues to the next period.

- Endogenizing the probability of detection

  - ▸ Buyers are pure empiricists.

    - ★ Null hypothesis is that firms compete.
    - ★ An "unlikely" price series may trigger buyers to reject the null.

  - ▸ Prior information of buyers

    - ★ Price is a random walk:

$$P^t = P^{t-1} + \eta^t.$$

    - ★ $\eta^t \sim N(?, ?)$ is normally distributed.
    - ★ Buyers do not know the moments of the distribution on η^t.

- Moments of buyers' beliefs in period t
  - Finite memory of k periods:

  $$\left\{\eta^{t-k}, \ldots, \eta^{t-1}\right\}$$

  where $\eta^\tau \equiv P^\tau - P^{\tau-1}$.
  - Use the sampling moments so buyers' distribution on η^t is

  $$N\left(m_1^{t-1}, m_2^{t-1} - \left(m_1^{t-1}\right)^2\right)$$

  where

  $$m_i^{t-1} \equiv \left(\frac{1}{k}\right) \sum_{\tau=t-k}^{t-1} \left(\eta^\tau\right)^i.$$

  - Approximate the equation of motion on buyer's moments with:

  $$m_i^t = \lambda_i m_i^{t-1} + (1 - \lambda_i)\left(\eta^t\right)^i.$$

- Buyers assess the "reasonableness" of recent price changes.
  - Buyers "test" a sequence of the $z\,(< k)$ most recent price changes.
  - Likelihood of these z price changes is a "moving" likelihood:

  $$l^t \equiv \Pi_{\tau=t+1-z}^t f\left(\eta^\tau; m_1^{\tau-1}, m_2^{\tau-1} - \left(m_1^{\tau-1}\right)^2\right).$$

  - ml^t is the maximum likelihood

  $$ml^t \equiv \Pi_{\tau=t+1-z}^t \max_{y^\tau} f\left(y^\tau; m_1^{\tau-1}, m_2^{\tau-1} - \left(m_1^{\tau-1}\right)^2\right).$$

- Detection depends on relative likelihood:

$$L^t \equiv \frac{l^t}{ml^t} = \frac{\Pi_{\tau=t+1-z}^t f\left(\eta^\tau; m_1^{\tau-1}, m_2^{\tau-1} - \left(m_1^{\tau-1}\right)^2\right)}{\Pi_{\tau=t+1-z}^t \max_{y^\tau} f\left(y^\tau; m_1^{\tau-1}, m_2^{\tau-1} - \left(m_1^{\tau-1}\right)^2\right)}$$

- Approximate the equation of motion on the relative likelihood with:

$$
\begin{aligned}
L^t &= \left(L^{t-1}\right)^{\zeta} \left[\frac{f\left(\eta^t; m_1^{t-1}, m_2^{t-1} - \left(m_1^{t-1}\right)^2\right)}{\max_y f\left(y; m_1^{t-1}, m_2^{t-1} - \left(m_1^{t-1}\right)^2\right)} \right] \\
&= \left(L^{t-1}\right)^{\zeta} \varphi\left(\eta^t, m_1^{t-1}, m_2^{t-1}\right)
\end{aligned}
$$

- Probability of detection, $\phi\left(L^t\right)$, is decreasing in L^t.

- Evolution of penalties
  - X^t is penalty to be paid if caught in period t.

    $$X^t = \beta X^{t-1} + \gamma x \left(P^t, c^t \right) \text{ where } \gamma \geq 0 \text{ and } \beta \in (0, 1).$$

  - $x \left(P^t, c^t \right)$ is the additional penalty due to collusion in period t where

    $$\frac{\partial x \left(P^t, c^t \right)}{\partial P^t} \geq 0.$$

- Cartel's problem
    - Fix the variance of buyers' beliefs at the non-collusive price variance.
    - State variables:
    $$\left(P^{t-1}, X^{t-1}, c^t, m_1^{t-1}, L^{t-1} \right)$$
    - Equations of motion:
    $$P^t = P^{t-1} + \eta^t$$
    $$c^{t+1} = c^t + \varepsilon^{t+1}$$
    $$X^t = \beta X^{t-1} + \gamma x \left(P^{t-1} + \eta^t, c^t \right)$$
    $$m_1^t = \lambda m_1^{t-1} + (1 - \lambda) \eta^t$$
    $$L^t = \left(L^{t-1} \right)^{\zeta} \varphi \left(\eta^t, m_1^{t-1} \right)$$

- Cartel's value function:

$$
\begin{aligned}
& V^c \left(P^{t-1}, X^{t-1}, c^t, m_1^{t-1}, L^{t-1} \right) \\
= \; & \max_{\eta^t} \pi \left(P^{t-1} + \eta^t, c^t \right) + \delta \phi \left(\left(L^{t-1} \right)^{\zeta} \varphi \left(\eta^t, m_1^{t-1} \right) \right) \times \\
& \left[\int V^{nc} \left(c^t + \varepsilon \right) f \left(\varepsilon; \mu_{\varepsilon}, \sigma_{\varepsilon}^2 \right) d\varepsilon - \beta X^{t-1} - \gamma x \left(P^{t-1} + \eta^t, c^t \right) \right] \\
& + \delta \left[1 - \phi \left(\left(L^{t-1} \right)^{\zeta} \varphi \left(\eta^t, m_1^{t-1} \right) \right) \right] \times \\
& \int V^c \left(P^{t-1} + \eta^t, \beta X^{t-1} + \gamma x \left(P^{t-1} + \eta^t, c^t \right), \right. \\
& \left. c^t + \varepsilon, \lambda m_1^{t-1} + (1 - \lambda) \eta^t, \left(L^{t-1} \right)^{\zeta} \varphi \left(\eta^t, m_1^{t-1} \right) \right) f \left(\varepsilon; \mu_{\varepsilon}, \sigma_{\varepsilon}^2 \right) d\varepsilon.
\end{aligned}
$$

- Simulated cartel price paths
  - Numerically solve for the value function.
  - Use value function to produce the policy (price) function.
  - Generate price path.
    - Specify initial values for the state variables.
    - Run model for 40 periods when firms are competing.
   - "Turn on" collusion in period 41.

- Properties of collusive price path
  - Two phases
    - ⋆ Transitory phase - price rises largely independent of cost.
    - ⋆ Stationary phase - price is responsive to cost.
  - If cost variance is higher, transition path is shorter.

Stationary Phase of Cartel Price Path: Evidence

- (Tentative) property: low price variance.

Frozen Perch Prices and Costs: 1/6/87 - 9/26/89
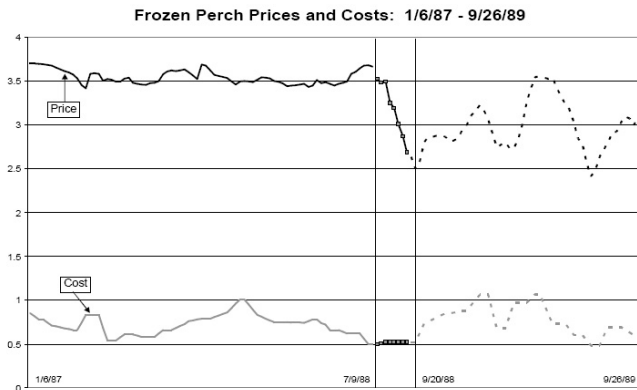
Frozen Perch Price Path (Abrantes-Metz, Froeb, Geweke, and Taylor, 2005)

Stationary Phase of Cartel Price Path: Theory

- What does theory have to say about the variance of price under collusion?
  - ▸ Imperfect monitoring
  - ▸ Avoiding detection
  - ▸ Trading off cartel efficiency and cartel stability

Imperfect Monitoring and the Price Variance

- Green and Porter (1984), Abreu, Pearce and Stachetti (1986)
- Model
  - Infinite horizon quantity game with homogeneous goods.
  - Market demand is stochastic

  $$P^t = P(Q^t, \theta^t)$$

  where θ^t is an *iid* random variable.
  - Informational structure
    - ★ A firm knows all past prices and its own past quantities.
    - ★ Only past prices are common knowledge.
  - In equilibrium, a firm's price can be conditional only on past prices.

- Equilibrium strategy
  - If in the *cooperative phase* in period $t-1$ and
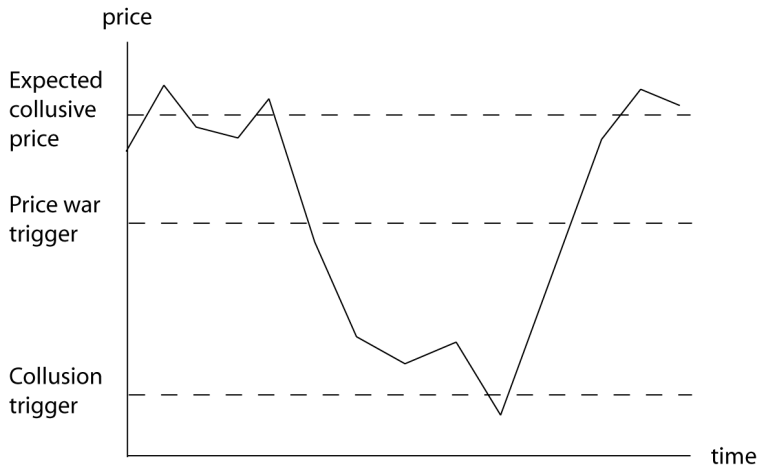   - $P^{t-1} \geq \bar{P}$ then $q_i^t = q^c$ (collusive quantity) and remain in the cooperative phase.
    - $P^{t-1} < \bar{P}$ then $q_i^t = q^p$ (punishment quantity) and go to the punishment phase.
  - If in the *punishment phase* in period $t-1$ and
    - $P^{t-1} \leq \underline{P}$ then $q_i^t = q^c$ and go to the cooperative phase.
    - $P^{t-1} > \underline{P}$ then $q_i^t = q^p$ and remain in the punishment phase.

- Intuition: Price wars in response to a low price induces firms to supply the collusive quantity.
- Implications regarding price variance
  - Compared to competition, price variance is higher because of regime changes.
  - Within a regime, price variance could be higher or lower.

Avoiding Detection and the Price Variance

- Harrington and Chen (2005)
- During the stationary phase, collusive price variance is much lower than the non-collusive price variance.

Average Variance of Price Changes

Cost Variance	Non-collusion, σ_{nc}^2	Collusion, σ_c^2	σ_{nc}^2/σ_c^2
$\sigma_\varepsilon^2 = 1$	0.485	.029	16.72
$\sigma_\varepsilon^2 = 2$	0.967	.078	12.40
$\sigma_\varepsilon^2 = 3$	1.576	.144	10.94
$\sigma_\varepsilon^2 = 4$	1.980	.255	7.76

- Intuition: Avoids large price changes to make price changes seem "reasonable" to buyers.

Cartel Efficiency and the Price Variance

- Athey and Bagwell (2001, 2004), Athey, Bagwell, and Sanchirico (2004).
- Model
  - Infinite horizon homogeneous goods price-setting game with two firms.
  - Demand is perfectly inelastic:

  $$D\left(p\right) = \left\{ \begin{array}{ll} 1 & \text{if } p \leq r \\ 0 & \text{if } r < p \end{array} \right.$$

  - Firms have constant marginal cost that may take two possible values.
    - ★ Each firm's cost is private information.
    - ★ Cost is independent across firms but may be persistent over time.
  - Stage game
    - ★ Nature chooses each firm's cost.
    - ★ Each firm makes an announcement from {Low, High, Silence}.
    - ★ Each firm chooses price.
  - In equilibrium, a firm's price can be conditional on
    - ★ its current and past cost realizations.
    - ★ both firms' announcements and prices.

- Joint profit maximum
    - If one firm has low cost and the other has high cost then the low-cost firm prices at r and has market share of 1.
    - If both firms have the same cost then both price at r and the allocation is irrelevant.
    - Implementation requires that firms truthfully reveal their cost types in the announcement stage.
- Tension between cartel efficiency and stability.
    - A high cost firm may want to signal it has low cost to have a positive allocation.
    - To induce a high cost firm to be truthful, the collusive price may need to be set relatively low when a firm announces low cost.

- Equilibrium when cost persistence is high relative to the discount factor.
  - ▶ Messages are uninformative.
  - ▶ Firms equally share market demand in every period.
  - ▶ Collusive price is independent of cost.
  - ▶ Price variance is lower under collusion since the collusive price does not vary with cost.
- Intuition: Firms prefer to forego efficiency in order to support higher collusive prices.

- Summary of theoretical findings.
  - ▶ Collusion can result in a higher price variance due to periodic price wars.
  - ▶ Collusion can result in a lower price variance as price becomes less sensitive to cost because
    - ★ it helps avoid detection by buyers.
    - ★ it allows firms to sustain a higher price.

Pre-cartel Price Path: Evidence

- Property: cartel formation is often preceded with a significant price decline.
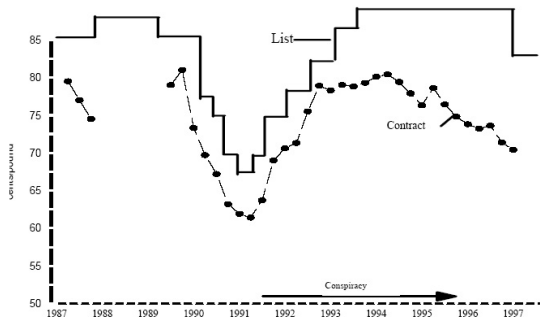

Citric Acid Price Path
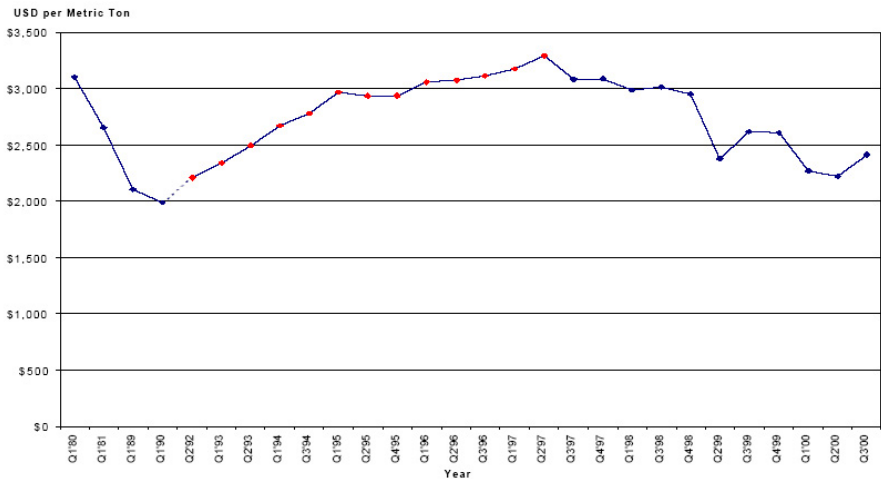
Graphite Electrodes Price Path

Modelling the Pre-Cartel Price Path

- Possible factors
  - ▶ Weakening demand conditions
  - ▶ Entry and/or capacity expansion (endogenous)
  - ▶ Breakdown of tacit collusion

- Weakening demand conditions.
  - ▶ Preceded the formation of cartels in carbonless paper, fine arts auction houses, graphite electrodes, and seamless steel tubes.
  - ▶ Graphite electrodes
    - ★ Suffered a substantial decline in demand in the 1980s as reflected in a capacity utilization rate under 60%.
    - ★ Led to a restructuring process whereby several plants were closed.
    - ★ Formation of cartel in 1992.

- Fine arts auction houses (April 1993 to February 2000) - Sotheby's
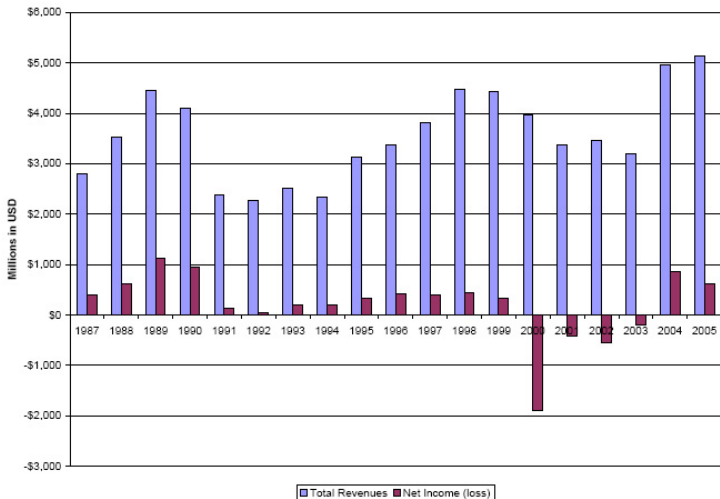
- Entry and/or capacity expansion

  - Plasterboard

    - From 1988 to 1992, the price of plasterboard fell by 50-75%.
    - European Commission attributed this to European integration.

  - Citric acid: Substantial capacity expansion by a firm which then sought to increase its market share.
  - Entry and capacity expansion are endogenous events presumably triggered by cost and demand changes.

- Grout and Sonderegger (2005) provide additional evidence.

- Breakdown of tacit collusion
  - ▶ Small changes in demand or cost may cause tacit collusion to break down.
  - ▶ Entry and capacity expansion could cause the breakdown of collusion due to the desire of a firm to increase its market share or sales.
  - ▶ Commercial explosives (U.S.)
    - ★ Prices were heavily depressed because of a price war between two brothers owning competing companies.
    - ★ After they sold their companies, some of the remaining explosive manufacturers formed a cartel.

- Need for research
  - Currently no theory that pertains to the pre-cartel price path.
  - Requirements of a theory
    - ★ Endogenize cartel formation.
    - ★ Generate a significant price decline preceding cartel formation.
  - Candidate model
    - ★ Endogenous capacity
    - ★ Capacity-constrained price competition
    - ★ Persistent demand shocks

Other Properties of the Cartel Price Path
Parallel price movements

- Issues
    - Is there evidence of parallel price movements?
    - Are firms' prices more positively correlated under collusion?
    - Is it more than under competition?
- Evidence that cartels are avoiding parallel movements by staggering their prices.
    - Clear orchestration of which firm would move first and when other firms would follow.
    - Cases: carbonless paper, electrical and mechanical carbon and graphite products, copper plumbing tubes, fine arts auction houses, sorbates.

- Vitamins A and E: "The parties normally agreed that one producer should first 'announce' the increase, either in a trade journal or in direct communication with major customers. Once the price increase was announced by one cartel member, the others would generally follow suit. In this way the concerted price increases could be passed off, if challenged, as the result of price leadership in an oligopolistic market."

- Auctions
  - Porter and Zona (1993), Bajari and Ye (2003)
  - Data: highway construction and maintenance procurement auctions
  - Competitive hypothesis: After controlling for (all) publicly available information, firms' bids should be independent.
  - Empirical model: Estimate a reduced form model of a firm's bid. The residuals should be independent.
  - Rejection of competitive model: Some firms' bids are positively correlated.
  - Explanation for why colluders' bids should be correlated.
    - ★ One cartel member is designated to submit the "cartel bid".
    - ★ Other colluding firms submit complementary uncompetitive bids.
    - ★ Lack of independence if complementary bids are proportional to the "cartel bid".
  - Colluding firms could satisfy independence by scaling their competitive bids.

- Are parallel price movements a useful screening device?
  - ▶ Not clear that prices are more highly correlated under collusion.
  - ▶ Firms can easily manipulate their prices or bids to avoid having parallel behavior.
  - ▶ Need for more theory.

Other Properties of the Cartel Price Path

Periodicity of price changes

- Is there greater periodicity of price movements under collusion?
- Marshall, Marx, and Raiff (2005)
  - ▶ Data - price increases reported in trade journals over 1970-2001 for six vitamins.
  - ▶ Time period included both non-cartel and cartel regimes.
  - ▶ Empirical model
    - ★ Logit model was estimated for the probability that a new price is announced in a given month.
    - ★ Conditional on *delay* - the time since the last price announcement.
    - ★ Conditional on several cost and demand triggers for a price change.
  - ▶ Findings
    - ★ During the non-cartel regime: no statistically significant relationship between *delay* and the probability of making a new price announcement.
    - ★ During the cartel regime: statistically significant positive relationship between *delay* and the probability of making a new price announcement.
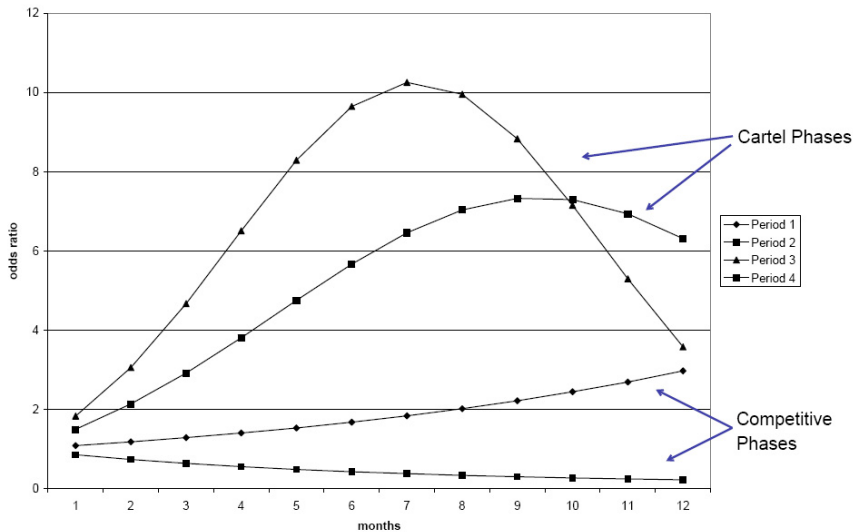
Log Odds Ratio for Price Change

- Summary of some facts
  - Cartel price path has two phases
    - Transition with steady price increases.
    - Stationary phase with low price variance.
  - Cartel price path is preceded with significant price decline.
  - Cartel price changes have greater periodicity.

Describing and Understanding the Cartel Strategy

- What are the strategies that lie behind this behavior?
  - ▸ How is an agreement (price and quantity) monitored?
  - ▸ How is an agreement enforced?

- Evidence comes from a study of about 20 European Commission decisions over 2000-2004.

Monitoring: Evidence

- Agreement to be monitored.

  - Price
  - Market allocation, often with sales quotas.

Sales Quotas (1992, tons) - Lysine

Company	Global Sales (Mkt Share)	European Sales (Mkt Share)
Ajinomoto	73,500 (39.7%)	34,000 (51.9%)
ADM	48,000 (25.9%)	5,000 (7.6%)
Kyowa	37,000 (20.0%)	8,000 (12.2%)
Sewon	20,500 (11.1%)	13,500 (20.6%)
Cheil	6,000 (3.2%)	5,000 (7.6%)

- Monitoring of price was secondary.

  - Collusion is usually in a market with industrial buyers.
  - Price is private information between a seller and a buyer.
  - Monitoring of the agreement in terms of price can be difficult.

- Monitoring of sales was primary.

  ▸ Routinely, firms collected information on firms' sales and matched it with the agreed-upon allocation.
  ▸ Dealing with the incentives of a firm to underreport its sales.

    ★ Some cartels - including citric acid, lysine, plasterboard, and vitamins - sought independent verification (such as Swiss accountants).
    ★ Sorbates: Japanese export data provided a check on the sales being reported by the Japanese producers.

Frequency of Communication for Monitoring

Market	Frequency
Choline chloride	semi-monthly
Citric acid	monthly
Copper plumbing tubes	monthly
Electrical mechanical carbon graphite	weekly/monthly
Graphite electrodes	semi-annual
Isostatic graphite	semi-annual
Lysine	monthly
Organic peroxides	quarterly
Plasterboard	quarterly
Sorbates	semi-annual
Vitamins (A, E)	weekly/quarterly
Zinc phosphate	monthly

- Lysine: "Each month, the five companies telephoned or mailed their lysine volumes of sales to [an employee of cartel member Ajinomoto], who prepared a running spreadsheet that was handed out and discussed at the quarterly maintenance meetings. The participants compared the allocated production quotas for 1994 with the actual sales figures realized during the same year."

Monitoring: Theory

- Comparison between theory and practice
  - ▸ The standard collusive model has price monitoring.
  - ▸ Does it make a difference whether it is modelled as firms monitoring price or sales?
    - ★ With price monitoring, collusion can be easily sustained with periodic price wars.
    - ★ With sales monitoring, collusion *cannot* be easily sustained through price wars.

- Harrington and Skrzypacz (2005)
- Model
    - Infinitely repeated price game.
    - Fixed market demand at m discrete units.
    - Stochastic firm demand: $\psi\left(\underline{q};\underline{p}\right)$ is the probability of realizing quantity vector $\underline{q}$ given price vector $\underline{p}$.
        - ★ Smoothness: ψ is continuously differentiable with respect to firms' prices.
        - ★ Symmetry: ψ depends only on firms' prices and not their identities.
        - ★ Local invariance: At a common price, ψ remains unchanged if firms make small identical price changes.
    - Demand assumptions hold for the discrete choice model without an outside option.
    - Cost functions are common and linear.
    - Imperfect monitoring
        - ★ Firms' prices are private information.
        - ★ Quantities (or market shares) are common knowledge.

- Strongly symmetric public equilibrium
  - A firm's price conditions only on publicly observed sales.
  - Punishments are symmetric price wars.
- Impossibility Result: Symmetric punishments cannot sustain any symmetric collusive outcome, *for any discount factor*.

- Intuition - duopoly case
    - Suppose punishment occurs when market shares are too skewed.
    - A firm that marginally undercuts the collusive price
        - ★ raises the probability that its market share triggers a price war
        - ★ *lowers* the probability that the other firm's market share triggers a price war.
    - For small price cuts, these two effects exactly offset each other.
    - A firm's future payoff is then unaffected by its price.
    - An equilibrium price for the infinite horizon game must then be a price that maximizes current expected profit.

- Robustness: When demand is highly, but not perfectly, inelastic then price wars can only sustain a small amount of collusion.
- Implication: Price wars are not the preferred punishment mechanism when firms monitor sales rather than price.

Enforcement: Evidence

- How is an agreement enforced?
- If sales monitoring is used then theory predicts that price wars are unlikely to be the method of punishment.
- Common enforcement mechanism
  - ▶ Main Principle: Those members who overproduced compensate those who underproduced.
  - ▶ Cartels using this mechanism include choline chloride, citric acid, lysine, organic peroxides, sodium gluconate, sorbates, most vitamins, zinc phosphate.

- Citric acid: "A compensation scheme was agreed to as a corollary to the quota agreement and in order to penalise those companies selling above their assigned sales quota and at the same time compensate those that did not reach it. If a company went over its assigned quota in any one year, it would be obliged to purchase product from the company or companies with sales below their quota during the following year."

- Properties
  - Emphasis on compensation
    - Organic peroxides cartel: explicit that the buy-back was done for purposes of compensation as it was to reflect the firms' foregone profit.
    - If a deviating firm is only required to "return excessive sales" than it is not much of a punishment.
    - Is there an implicit punishment of aggressive pricing?
  - Emphasis on avoiding buy-backs.
    - Some cartels - citric acid, lysine, vitamins (A, E) - engaged in high-frequency monitoring.
    - Allowed sales to be adjusted to meet quotas at year's end (when buy-backs would be performed).

- Vitamins A and E - "The managers who attended the European regional meetings had weekly telephone contact in order to monitor the agreements on pricing and sales volumes. The information for the whole year was maintained on a cumulative monthly basis to ensure that each party kept to its agreed market share; if one was seen to be selling more than its allocated quota, it would have to 'slow down' sales to enable the others to catch up. If at the end of the year a producer was substantially ahead of its quota, it had to purchase vitamins from the others in order to compensate them for the corresponding shortfall in their allocation."

- Use of aggressive pricing (price wars) as a punishment.
    - Though there is some reference to aggressive pricing, there is nothing as explicit as with buy-backs.
    - There could still be implicit ("unwritten") punishments in that firms recognize that poor behavior may lead to aggressive pricing.

Enforcement: Theory
Harrington and Skrzypacz (2005)

- Collusive market-sharing scheme
  - ▶ Each of n symmetric firms is assigned a (market share) quota of $1/n$.
    - ★ a firm pays $z \geq 0$ for each unit it sells
    - ★ the proceeds are shared equally among cartel members.
  - ▶ A firm's net transfer:
    - ★ is zero if its market share equals its quota.
    - ★ is positive (negative) when its market share is more (less) than $1/n$.
- 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.
- If firms are sufficiently patient then this scheme is sustainable.
  - ▶ Though symmetric price wars cannot sustain collusion, asymmetric punishments can.
  - ▶ Transfers can be consummated through inter-firm purchases.

Enforcement: Theory
Athey and Bagwell (2001, 2004)

- A cartel is designing an optimal mechanism when firms have private information about cost.
- Trading off efficiency with stability.
  - ▶ Joint profit maximum has only the low cost firm(s) selling.
  - ▶ When firms' patience is low relative to cost persistence, rigid prices was the optimal mechanism.
  - ▶ When firms' patience is high relative to cost persistence, the joint profit maximum can be supported through intertemporal market share favors.
    - ★ Messages are informative.
    - ★ Only the low cost firm(s) sell.

- Mechanism uses intertemporal market share favors
  - If a firm announces high cost and the other firm announces low cost then only the latter sells.
  - The firm with zero sales is "compensated" by having a future market share above $1/2$ when both firms announce they have the same cost.
- Form of bid rotation scheme (Blume and Heidhues, 2003; Skrzypacz and Hopenhayn, 2004).

Some Research Directions Related to Monitoring and Enforcement

- Modelling real-time avoidance of buy-backs.
  - ▶ Cartels actively sought to avoid the necessity of buy-backs.
  - ▶ The period length for receiving sales information (and monitoring) was shorter than the period length for determining buy-backs.

- More realistic modelling of monitoring.
  - ▶ Perfect monitoring of sales was assumed.
    - ★ Need to model the reporting of sales by firms and understand the incentives to truthfully report.
  - ▶ No monitoring of price was assumed.
    - ★ In practice, there is some information on competitors' prices.
  - ▶ The truth lies between pure price monitoring and pure sales monitoring.

Research Direction: Market Allocation & Firm Asymmetries

Form of allocation scheme

- A cartel might allocate the market by allocating
  - sales or market share
  - customers
  - territories
- Questions
  - What determines which allocation scheme is used? How does it depend on industry traits?
  - How does price and quantity behavior depend on the allocation scheme?
- Relevant forces
  - Efficiency - argues for sales quotas (maximal discretion in matching buyers and sellers)
  - Monitoring - argues for customer allocation or exclusive territories.
  - Avoiding detection - argues against customer allocation and perhaps also exclusive territories.

Allocation Scheme

Market	Sales quotas	Customer	Territories
Choline chloride	✓	✓	✓
Citric acid	✓		
Copper plumbing tubes	✓		
District heating pipes	✓	✓	
Elec. mech. carb. graphite	✓	✓	
Graphite electrodes	✓		
Lysine	✓		
Nucleotides		✓	✓
Organic peroxides	✓	✓	
Plasterboard	✓		
Sorbates	✓		
Vitamins (A, E)	✓		
Zinc phosphate	✓		

Research Direction: Market Allocation & Firm Asymmetries

How is the allocation determined?

- Existing collusive models
  - ▸ If firms are symmetric then the best symmetric outcome.
  - ▸ If asymmetric then the Nash Bargaining Solution.

- Actual behavior in setting sales quotas
  - ▸ Vast firm asymmetries.
  - ▸ Historical precedence.
    - ★ Previous year's sales: copper plumbing tubes, organic peroxides, several of the vitamins.
    - ★ Average of previous 3 or 4 years: citric acid, sorbates, zinc phosphate.
  - ▸ Relate to a firm's share of industry capacity
    - ★ Norwegian cement industry (Röller and Steen, 2006)
    - ★ In some cases, such as lysine, there was sharing of information about capacity.

Research Direction: Organizational and Agency Issues

- Questions
  - How does the internal organization of a cartel affect cartel behavior?
  - How does modelling managerial incentives affect cartel behavior?

- Who makes decisions and what motivates them?
  - Are they senior management, middle-level managers, sales managers, sales representatives?
  - What difference does it make who is involved?
    - ★ How sensitive is their compensation to higher profit? to corporate penalties?
    - ★ How are they benefitted by leniency? If caught, are they imprisoned? fired? retained?
    - ★ Are some agents relied upon to implement an agreement when they are unaware of collusion?

Organizational Structure of Cartels

Market	Level	Employees
Carbonless paper	Top	CEOs, directors
	Regional, national	Sales managers
Citric acid	Top ("Masters")	Senior managers
	Technical ("Sherpa")	Sales managers
Copper plumbing tubes	Top ("Elephants")	
	Operational ("Dung-movers")	Senior managers
Graphite electrodes	Top ("Top guy")	CEOs
	Working level	Sales managers
Isostatic graphite	Top ("Top level")	Senior managers
	International working level	Experts
	Regional/European	Local managers
	Local/national	Local managers
Vitamins (A, E)	Summit ("Shareholders")	Senior managers
	Budget	Marketing heads
	Global product marketing	Operations managers
	Regional product marketing	Regional marketing heads

- Compliance and sales representatives.
  - ▶ Though senior managers may decide on the allocation, uninformed sales representatives implement it.
- Fine arts auction house cartel
  - ▶ Implementation of the non-negotiability of the commission schedule relied on lower-level employees not deviating from it, nor finding ways around it.
  - ▶ "[An officer of Christie's] identified an unintended risk that could arise; their department chiefs would vie with each other to get quality business by making excessive estimates of what items would fetch. (If the estimates were excessive, it would increase the risks attached to guarantees and loans). To avoid this problem, [an officer of Christie's] suggested a formal procedure for estimates with three signatures required over a certain amount."

- Lysine
  - [ADM executive Michael Andreas said:] "The salesman could go off to another company and turn in the top people at ADM and report that there's price-fixing. So, the salesmen couldn't be trusted."
  - When a salesman gave a customer a price below the mandated (collusive) price, he was fired.
  - ADM centralized pricing authority "at the highest level".

- Collusion may require constraining sales reps in suspicious ways.
  - Industrial and medical gases: Moratorium on approaching another company's customers during price change.

- Uninformed sales reps and imperfect monitoring.
  - In the imperfect monitoring literature, unobservable shocks are exogenous.
  - If prices and realized sales are due to the behavior of sales reps, they may be an *endogenous* source of shocks.
  - Senior management can influence the distribution on shocks through the compensation and monitoring of sales reps.

Status Report

- Cartel price path
  - Cartel formation induces a transition path from the non-collusive price to stationary pricing.
    - ★ Status: almost no theory
  - Collusion reduces price variance.
    - ★ Status: some but not much theory
  - Cartel formation is preceded by a significant price decline.
    - ★ Status: no theory

- Cartel strategy
  - Cartels focus on the monitoring of sales.
    - ★ Status: almost no theory
  - Cartel enforcement emphasizes compensation.
    - ★ Status: some but not much theory

- Internal organization of cartel
  - Status: no theory

Challenges and Future Directions

- Opportune time for research into cartels
  - ▸ It can have a substantive and immediate policy impact by increasing the efficacy of screening.

- To be most effective, modelling should
  - ▸ use the rich details we have about hard core cartels.
    - ★ European Commission decisions are especially valuable.
    - ★ A positive benefit of leniency programs is that they result in cartel members providing details as to how the cartel operated.
  - ▸ try to model explicit (as opposed to tacit) collusion.
    - ★ Model avoidance of detection.
    - ★ Model communication.

- Close the theory-practice gap regarding explicit and tacit collusion.