

How Does Illegality and Enforcement Constrain Collusion?

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Legal and Illegal Cartels
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Introduction

What is the impact of illegality and enforcement on collusion?

- ① Cartel formation: How does it affect when collusion occurs?
- ② **Cartel participation: How does it affect who engages in collusion?**
- ③ **Collusive practices: How does it affect how collusion operates?**
- ④ **Collusive outcomes: How does it affect collusive prices?**

Introduction

- Focus on the theory of collusion and how it is modified when there are competition laws that are enforced.
- Such an analysis is useful because
 - ▶ it provides the theoretical underpinnings for empirically assessing the impact of competition policy
 - ▶ it allows inferences to be drawn about unlawful cartels using data on lawful cartels.

How does enforcement affect who engages in collusion?

Participation in collusion operates at two levels:

- Inter-firm: Which firms participate in the cartel?
 - ▶ Why are some cartels not all-inclusive?
 - ▶ What is the impact of less than full inclusivity?
 - ▶ Does enforcement contribute to less than full inclusivity?
- Intra-firm: For a cartel member, which employees are involved?
 - ▶ How many employees participate?
 - ▶ From what managerial levels do participants come?
 - ▶ Does enforcement constrain who is involved?

How does enforcement affect who engages in collusion?

Participation by firms

Many unlawful cartels are not all-inclusive

EC Decisions (2000-09)

Case name	Number of cartel members	Cartel market share
Amino Acids (Lysine)	5	almost 100%
Carbonless Paper	11	85-90%
Choline Chloride	6	82%
Citric Acid	5	1991 - 70%, 1993 - 60%, 1994 - 52%
Copper Plumbing Tubes	8	79%
Electrical and Mechanical Carbon and Graphite Products	6	90%+
Flat Glass	4	about 80%
Food Flavour Enhancers	4	almost 100%
Graphite Electrodes	8	almost 100%
Industrial and Medical Gases	7	about 90%
Industrial Tubes	6	60-90%
Methionine	4	60-70%
Methylglucamine	2	100%
Organic Peroxides	5	70-80%
Plasterboard	4	90%+
Rubber Chemicals	4	58%
Sorbates	5	70-80%
Specialty Graphite (Isostatic)	8	75-90%
Vitamins	13	70%+
Zinc Phosphate	6	90%+

Marshall, Marx, and Samkharadze (2011)

How does enforcement affect who engages in collusion?

Participation by firms

Bos and Harrington (RJE 2010)

- n firms offering homogeneous products with market demand $D(p)$
- Infinitely repeated capacity-constrained price game with perfect monitoring
- Identical constant marginal cost, c
- Capacity stocks are fixed and allowed to be heterogenous,

$$k_1 \geq k_2 \geq \dots \geq k_n.$$

- $K \equiv \sum_{j=1}^n k_j$ is industry capacity
- $K_\Gamma \equiv \sum_{j \in \Gamma} k_j$ is total capacity of cartel $\Gamma \subseteq \{1, 2, \dots, n\}$.
- $D(p) - (K - K_\Gamma)$ is cartel's residual demand.

How does enforcement affect who engages in collusion?

Participation by firms

- Focus on equilibrium strategy profiles for which
 - ▶ past behavior by non-cartel members has no effect on cartel members' current behavior (no exclusion)
 - ▶ any deviation from the collusive price by a cartel member results in infinite reversion to a static Nash equilibrium.
- Non-cartel members' pricing behavior
 - ▶ Static equilibrium response of the non-cartel members is to undercut the collusive price and produce up to capacity.

How does enforcement affect who engages in collusion?

Participation by firms

- Cartel Γ faces the problem:

$$p^*(\Gamma) = \max_p \left(\frac{1}{1-\delta} \right) (p - c) [D(p) - (K - K_\Gamma)] \left(\frac{k_i}{K_\Gamma} \right)$$

subject to

$$\left(\frac{1}{1-\delta} \right) (p - c) [D(p) - (K - K_\Gamma)] \left(\frac{k_i}{K_\Gamma} \right) \geq (p - c) k_i$$

- Equilibrium collusive value for firm i :

$$k_i V(\Gamma) \equiv k_i \left(\frac{1}{1-\delta} \right) (p^*(\Gamma) - c) [D(p^*(\Gamma)) - (K - K_\Gamma)] \left(\frac{k_i}{K_\Gamma} \right)$$

How does enforcement affect who engages in collusion?

Participation by firms

- If $K_{\Gamma''} > K_{\Gamma'}$ then $p^*(\Gamma'') \geq p^*(\Gamma')$.
 - ▶ If more capacity is controlled by the cartel then the collusive price is higher.
- If $\Gamma' \subset \Gamma''$ then $V(\Gamma'') > V(\Gamma') \Rightarrow k_i V(\Gamma'') > k_i V(\Gamma') \forall i \in \Gamma'$.
 - ▶ If the cartel is made more inclusive than all original cartel members are better off.
- A cartel is stable if
 - ▶ all cartel members prefer to be in the cartel (internal stability)
 - ▶ all non-cartel members prefer to be outside of the cartel (external stability)

How does enforcement affect who engages in collusion?

Participation by firms

- Cartel members always want non-cartel members to join.
- A non-cartel member may or may not want to join
 - ▶ Higher collusive price as the cartel controls more capacity.
 - ▶ Lower firm quantity as it has to constrain output below capacity.
- A firm with more capacity is more inclined to join the cartel.
 - ▶ Rise in price is large relative to the proportional fall in firm's quantity.
- If a firm is sufficiently small, it prefers not to join the cartel.
 - ▶ Rise in price is small relative to the proportional fall in firm's quantity.
- Partial cartels can be stable.

How does enforcement affect who engages in collusion?

Participation by firms

Bos and Harrington (IER 2014)

- Introduces anti-cartel enforcement
- Per period probability that cartel Γ pays penalties = $\rho(\Gamma)$
 - ▶ If $\Gamma' \subset \Gamma''$ then $\rho(\Gamma') < \rho(\Gamma'')$.
 - ▶ Cartels with more members are more likely to be caught.
- Penalty in the event of conviction is proportional to collusive value = $\gamma k_i V(\Gamma)$
- Expected penalty of firm $i \in \Gamma$ is $\rho(\Gamma) \gamma k_i V(\Gamma)$.

How does enforcement affect who engages in collusion?

Participation by firms

- Enforcement undermines internal stability and can decrease the size of the largest stable cartel.
 - ▶ By joining the cartel, a firm adds to cartel value by having the cartel control more capacity \Rightarrow higher collusive price.
 - ▶ Detracts from cartel value by making detection more likely.
 - ▶ Cartel value can then rise when a firm leaves the cartel.
- Enforcement undermines internal stability and can increase the size of the smallest stable cartel.
 - ▶ Enforcement reduces the collusive value which tightens the ICC.
 - ▶ This could cause a partial cartel to lose the ability to sustain a collusive price in which case it needs to be more inclusive.
- Enforcement compresses cartel size.
- Enforcement can result in the maximal stable cartel being less than all-inclusive.

How does enforcement affect who engages in collusion?

Participation by employees

- When a cartel is lawful, one would expect all relevant employees to be involved so as to enhance efficacy.
- When unlawful, greater inclusion increases the chances of detection.
 - ▶ More employees means more chances for information to leak out.
 - ▶ Employees at different levels could have different incentives regarding cartel participation and whistleblowing.
 - ★ Lysine: ADM executive Michael Andreas: "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."

How does enforcement affect who engages in collusion?

Participation by employees

What are some implications of not involving sales people?

- They may unknowingly disrupt collusion by competing too aggressively.
 - ▶ Lysine: "The sales reps had a tendency to become buyer advocates and to cut price. They told the cartel that, in the previous week, ADM's best salesman had given a customer a price of only \$1.13. The salesman was fired." [Lieber 2000]
 - ▶ Industrial and medical gases: "There are a number of instances in which a firm had offered gases at prices below what had been agreed. Some of these instances may have been acts of retaliation, others may have been carried out by over-zealous salesmen." [European Commission, 2002]

How does enforcement affect who engages in collusion?

Participation by employees

What are some implications of not involving sales people?

- To control such behavior, they may have their incentive contracts changed or their authority transferred to higher levels.
 - ▶ Industrial and medical gases cartel: "Departures from the collusive price was particularly a concern during the several month period in which firms were, in a staggered manner, implementing new price increases. To deal with this problem, a moratorium was put in place whereby each company's customers were not to be approached; this was expressly conveyed to their sales people." [European Commission, 2002]
- Isostatic graphite: The risk of sales people deviating from the collusive prices was considered serious enough that senior management decided to bring them in on the scheme.
 - ▶ "Cartel members agreed to enlarge the meetings to include the salesmen, in an attempt to impress on the sales force the importance of following the pricing directives that they received from their supervisors." [European Commission, 2002]

How does enforcement affect who engages in collusion?

- Need for more research into which firms joins a cartel and how it depends on whether the cartel is illegal.
- Need for research that takes into account organizational structure and incentives with regards to collusion.
 - ▶ What market and organizational factors determine who within the firm is involved in collusion?
 - ▶ How does illegality affect the allocation of authority between those involved and not involved in the cartel?
 - ▶ How does illegality affect incentive contracts of those not involved in the cartel?
 - ▶ Modelling imperfect monitoring with uninvolved sales representatives - stochastic nature of firms' market shares now depends on the behavior of sales reps which is endogenous

How does enforcement affect how collusion operates?

- Elements of collusive practices
 - ▶ Collusive outcome - outcome upon which firms coordinate
 - ▶ Monitoring - manner in which compliance is monitored.
 - ▶ Punishment - manner in which evidence of noncompliance is determined and punished
- When unlawful, firms want to avoid creating
 - ▶ *suspicion*s that there is collusion - appear competitive
 - ▶ *evidence* of collusion - do not leave a "paper trail".

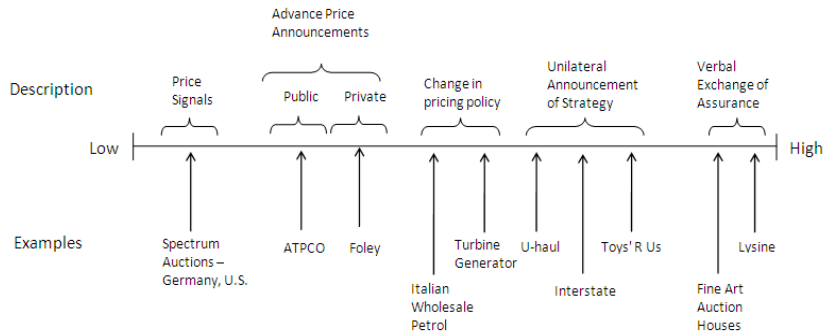
How does enforcement affect how collusion operates?

These concerns can impact practices because they influence

- who within the firm is involved in the cartel
 - ▶ Lack of involvement of some personnel may limit information and constrain practices
- form and frequency of communication
 - ▶ Communications are clandestine and could be infrequent
 - ▶ Communications may be indirect
 - ▶ Less likely to use third party auditors to assist in monitoring

How does enforcement affect how collusion operates?

Coordinating Practices Ranked according to Efficacy



How does enforcement affect how collusion operates?

Colluding firms may limit the frequency of meetings.

Frequency of Meetings

(Source: European Commission Decisions)

Market	Monitoring	Allocation
Choline chloride	2-3 weeks	6 months
Zinc phosphate	monthly	3 months
Citric acid	monthly	6 months
Organic peroxides	3 months	3-6 months
Sorbates	6 months	6 months

Would they have met more frequently if lawful?

How does enforcement affect how collusion operates?

- Customer allocation may be best for monitoring but perhaps not for avoiding detection
 - ▶ Lysine: "Wilson [of ADM] told the cartel that volume limitations did not mean dividing up the market by captive consumers and refuse to sell to others. A 'don't touch [each other's] customers policy' could create suspicions. The cartel had agreed, upon the urging of Wilson, not to permanently assign customers because it would have been too obvious." [Lieber 2000]
- Outcome may be less sensitive to market conditions
 - ▶ With unlawful cartels, market shares are often set at historical levels.
 - ★ Their inflexibility can be a source of cartel collapse.
 - ★ Would they be more flexible if the cartel was lawful?
 - ▶ If lawful, would price adjust more quickly to market conditions?

How does enforcement affect how collusion operates?

Lawful cartel may not want industrial buyers to know there is a cartel in order to avoid buyer resistance to a price increase.

- Kumara, Marshall, Marx, and Samkharadze (IJIO 2015)
- Procurement setting - After receiving bids, the procurer decides whether to award the contract to the firm with the lowest bid or, at a cost, re-run the auction with the inclusion of another firm.
- Prior to the initial auction, two firms are given the opportunity to cartelize and either publicly reveal the cartel ("merger") or keep it hidden.
- The firms have private information regarding their costs which influences whether they form a cartel.

How does enforcement affect how collusion operates?

Equilibrium is characterized for which it is more profitable to keep the cartel hidden.

- Suppose the cartel is publicly known.
 - ▶ The buyer is less inclined to believe that a high bid is due to high cost.
 - ▶ It is then more likely to re-run the auction and invite more bidders.
- Suppose the cartel is hidden.
 - ▶ A high bid may be accepted because the buyer believes it is due to high cost.

Buyer resistance may induce even a lawful cartel to remain hidden.

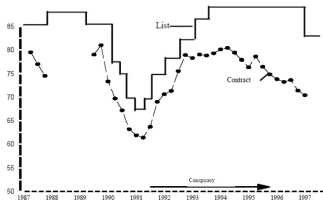
How does enforcement affect price?

Questions

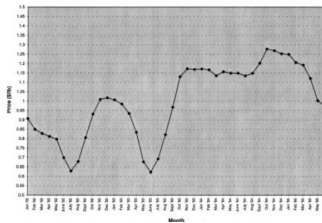
- How does enforcement impact the price level?
- How does enforcement impact price dynamics over the cartel life cycle?
- How does enforcement impact price variability including responsiveness to cost and demand shocks?

How does enforcement affect price?

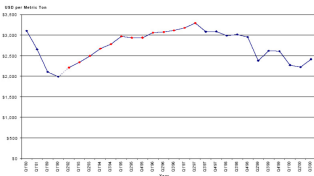
Property of price paths of unlawful cartels: Gradual price increase



Citric Acid

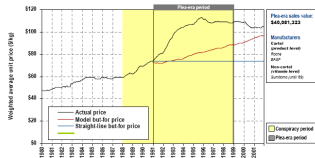


Lysine



Graphite Electrodes

Figure 12-18: Beta Carotene 10% Cold Water Soluble USP price and but-for price



Vitamins (Beta Carotene)

How does enforcement affect price?

Property of price paths of unlawful cartels: Low price variability

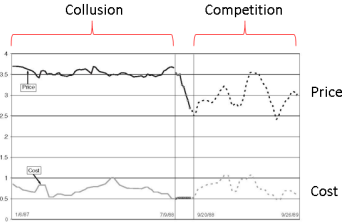
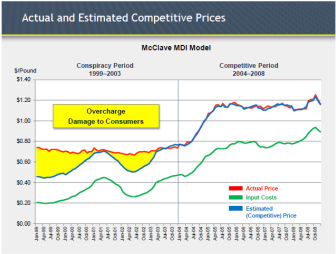


Fig. 1. Frozen perch prices and costs: 1/6/67-9/26/89.

Frozen Perch

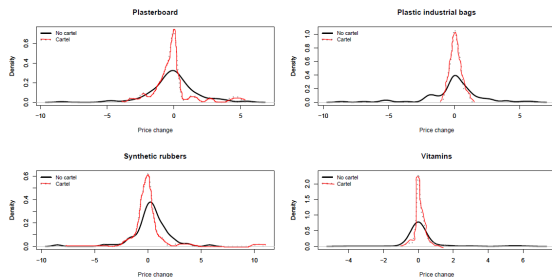


Urethane

How does enforcement affect price?

Property of price paths of unlawful cartels: Low price variability

- In 8 out of 11 German cartels, price variability was significantly lower when firms were colluding



Distribution of price changes
Black - competitive periods; Red - collusive periods
von Blackenburg et al (2011)

How does enforcement affect price?

- Properties of price paths of unlawful cartels
 - ▶ Gradual price increase
 - ▶ Low price variability (compared to competition)
 - ▶ Price need not decline after cartel collapse
- Are these properties unique to when the cartel is illegal?

How does enforcement affect price?

What constrains the collusive price path? A cartel may not set a higher price because it is

- unstable - ICC is binding
- unprofitable - ICC is not binding
 - ▶ concerned that further price increases may create suspicions that there is an unlawful cartel
 - ▶ monopoly price or constrained by the price of the next best substitute or non-cartel suppliers
 - ▶ buyer resistance
- uncertainty over how high a price is stable - will the ICC be satisfied?

How does enforcement affect price?

Literature

- Horizon
 - ▶ Static - joint profit maximizing behavior.
 - ▶ Dynamic - infinite horizon for which ICCs may bind.
- Enforcement technology
 - ▶ Exogenous
 - ★ Fixed probability or
 - ★ Probability of detection exogenously depends on firms' behavior (e.g., prices)
 - ▶ Endogenous
 - ★ Probability of detection is derived by solving the inference problem faced by buyers and the competition authority

How does enforcement affect price?

Literature

		Enforcement Technology	
		Exogenous	Endogenous
Horizon	Static	Block, <u>Nold</u> , and <u>Sidak</u> (JPE 1981)	<u>Besanko and Spulber</u> (EJ 1989, AER 1990) <u>LaCasse</u> (RJE 1995)
	Dynamic	McCutcheon (1997) <u>Cyrenne</u> (RIO 1999) Harrington (RJE 2004, IER 2005) Harrington and Chen (IJIO 2006)	

How does enforcement affect price?

Static model with endogenous monitoring technology

- Game of incomplete information between firms and competition authority (or customers)
 - ▶ Firms act as a perfect cartel
 - ▶ Competition authority/customers are uncertain whether firms are colluding but know how firms price if they are colluding
 - ▶ Common cost is private information to firms
 - ▶ High price may be due to high cost or that firms are colluding
- Issues
 - ▶ When does a competition authority/customers investigate?
 - ▶ How does detection impact pricing?
 - ▶ To what extent can a cartel avoid detection?

How does enforcement affect price?

Dynamic model with exogenous monitoring technology

- n firms offering symmetrically differentiated products.
- Grim trigger strategy (punishment is infinite version to static Nash equilibrium)
- Per-period probability ρ of discovery and conviction which imposes a per firm penalty F .

How does enforcement affect price?

- Cartel charges highest \hat{p} such that the ICC holds:

$$\begin{aligned} & \pi_1(\hat{p}, \dots, \hat{p}) + \delta [(1 - \rho)V^c + \rho V^{nc} - \rho F] \\ \geq & \max_{p_1} \pi_1(p_1, \hat{p}, \dots, \hat{p}) + \delta (V^{nc} - \rho F) \end{aligned}$$

where

$$V^c = \frac{\pi_1(\hat{p}, \dots, \hat{p}) + \delta \rho (V^{nc} - F)}{1 - \delta(1 - \rho)}$$
 is the collusive value

V^{nc} is the non-collusive value

- As ρ or F increase, V^c declines which reduces the LHS of the ICC and tightens ICC \Rightarrow lowers collusive price.

How does enforcement affect price?

Caveat: Under some circumstances, enforcement can lower punishment payoffs and thereby loosen the ICC and allow for a *higher* price.

- Cyrenne (RIO 1999)
 - ▶ Modifies imperfect monitoring setting of Green and Porter (1984) to allow for detection when a price war occurs.
- Perfect monitoring version
 - ▶ Probability of detection is higher when a firm deviates: $\rho^{dev} > \rho^{co}$

$$\begin{aligned} & \pi_1(\hat{p}, \dots, \hat{p}) + \delta [(1 - \rho^{co})V^c + \rho^{co}V^{nc} - \rho^{co}F] \\ & \geq \max_{p_1} \pi_1(p_1, \hat{p}, \dots, \hat{p}) + \delta (V^{nc} - \rho^{dev}F) \end{aligned}$$

- ▶ If ρ^{dev} / ρ^{co} is sufficiently high then the RHS declines more than the LHS which loosens the ICC \Rightarrow lowers collusive price.
- But wouldn't the initial raising of price from the competitive to the collusive level similarly result in a high probability of detection?

How does enforcement affect price?

- Standard collusive theory fails to provide
 - ▶ transitional pricing dynamics
 - ▶ reduced price variability
- Objectives of a cartel
 - ① Raise price
 - ② Maintain the internal stability of the cartel.
 - ③ Avoid creating suspicions that a cartel has formed.
- Need to take account of how cartel behavior influences detection.

How does enforcement affect price?

Harrington (IER 2005, RJE 2004)

- If the cartel is detected then a firm pays a penalty X^t and receives static NE profit $\hat{\pi}$ in all future periods.
- X^t is sensitive to firms' prices and duration

$$X^t = \beta X^{t-1} + \gamma x(P^t)$$

- ▶ $x(P^t) > 0$ and is non-decreasing, $\gamma > 0$.
- ▶ $1 - \beta \in (0, 1)$ is the depreciation rate.

How does enforcement affect price?

- Probability of detection in period t is

$$\phi(\underline{P}^t, \underline{P}^{t-1}) = \hat{\phi}(f(\underline{P}^t) - f(\underline{P}^{t-1})).$$

where \underline{P}^t is the vector of firms' prices in period t ,

- $f(\underline{P}^t)$ is a summary statistic of firms' prices
 - ▶ $f(P, \dots, P) = P$
 - ▶ If $\underline{P}'' \leq \underline{P}'$ (component-wise) then $f(\underline{P}'') \leq f(\underline{P}')$.
 - ▶ Examples: Average price, weighted average price, median price
- $\hat{\phi}$ describes how the probability of detection depends on the change in summary statistic of firms' prices
 - ▶ If $x \geq y$ then $\hat{\phi}(x) \geq \hat{\phi}(y)$ [non-decreasing in price increases]
 - ▶ $\hat{\phi}(x) \geq \hat{\phi}(0) \forall x$ [minimized at a zero price change]

How does enforcement affect price?

- State variables: P^{t-1}, X^{t-1}
- Punishment path: Deviation from the collusive price path results in a Markov Perfect Equilibrium: $V_i^{mpe}((P^t, \dots, P_i, \dots, P^t), \beta X^{t-1})$.
- Cartel's problem: $V(P^{t-1}, X^{t-1}) =$

$$\begin{aligned} & \max_P \pi(P) + \delta \phi(P, P^{t-1}) [(\hat{\pi} / (1 - \delta)) - \beta X^{t-1} - \gamma_X(P)] \\ & + \delta [1 - \phi(P, P^{t-1})] V(P, \beta X^{t-1} + \gamma_X(P)) \end{aligned}$$

subject to

$$\begin{aligned} & \pi(P) + \delta \phi(P, P^{t-1}) [(\hat{\pi} / (1 - \delta)) - \beta X^{t-1} - \gamma_X(P)] \\ & + \delta [1 - \phi(P, P^{t-1})] V(P, \beta X^{t-1} + \gamma_X(P)) \geq \\ & \max_{P_i} \pi(P_i, P) + \delta \phi((P | P_i), P^{t-1}) [(\hat{\pi} / (1 - \delta)) - \beta X^{t-1}] \\ & + \delta [1 - \phi((P | P_i), P^{t-1})] V_i^{mpe}((P | P_i), \beta X^{t-1}). \end{aligned}$$

How does enforcement affect price?

- Long-run steady-state price, P^* :

$$\pi'(P^*) - \frac{\delta \hat{\phi}(0) \gamma x'(P^*)}{1 - \delta \beta (1 - \hat{\phi}(0))} = 0.$$

- In the steady state, a marginal increase in price
 - ▶ raises profit by $\pi'(P^*)$
 - ▶ raises the expected present value of the penalty by

$$\frac{\delta \hat{\phi}(0) \gamma x'(P^*)}{1 - \delta \beta (1 - \hat{\phi}(0))}$$

where $\hat{\phi}(0)$ is steady-state probability of detection.

- If $x'(P^*) = 0$ then monopoly price.

How does enforcement affect price?

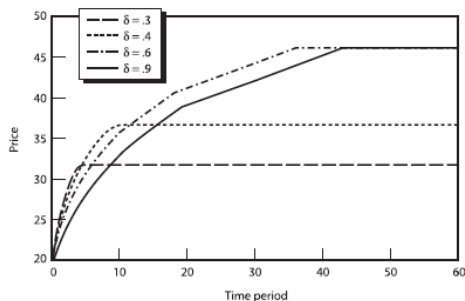
Suppose ICCs are not binding.

- Equilibrium price path is increasing over time.
 - ▶ To reduce the likelihood of detection, price is gradually raised to its steady-state level.
 - ▶ While accumulated penalties are growing, the probability of incurring them would be increased by lowering price so price does not decline.
 - ★ When ICCs are binding, price may need to decline as penalties accumulate.

How does enforcement affect price?

Suppose ICCs are binding.

- When δ is higher, ICCs are loosened which allows higher prices.
- When δ is higher, the cartel is more patient so it raises price at a slower rate in order to reduce the likelihood of detection.



- Enforcement may cause more patient cartels to lower price in the short-run.

How does enforcement affect price?

A step towards endogenizing the enforcement technology in a dynamic setting.

- Harrington and Chen (IJIO, 2006)
- Common and stochastic linear cost function,

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

where c^t is a random walk,

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

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

- Cost shock provides a competitive rationale for why price increases and is high.

How does enforcement affect price?

Detection technology

- 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 .

How does enforcement affect price?

Moments of buyers' beliefs in period t

- Finite memory of k periods:

$$\{\eta^{t-k}, \dots, \eta^{t-1}\}$$

where $\eta^\tau \equiv P^\tau - P^{\tau-1}$.

- Use the sampling moments so buyers' distribution on η^t is

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

where

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

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

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

How does enforcement affect price?

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:

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

where f is the Normal density function.

- ml^t is the maximum likelihood

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

How does enforcement affect price?

- Detection depends on relative likelihood:

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

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

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

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

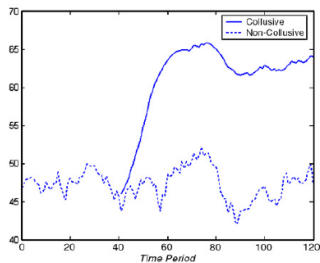
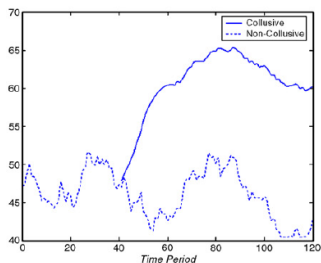
How does enforcement affect price?

- Solve the cartel's dynamic problem (non-binding ICCs)
- Generate price path.
 - ▶ Specify initial values for the state variables.
 - ▶ Run model for 40 periods when firms are competing (so buyers form "competitive" beliefs)
 - ▶ "Turn on" collusion in period 41.

How does enforcement affect price?

Property: Transition phase in which price gradually rises.

Property: Stationary phase in which price variance is low.



How does enforcement affect price?

Low price variability under collusion

Average Variance of Price Changes

Cost Variance	Non-collusion, σ_{nc}^2	Collusion, σ_c^2	$\sigma_{nc}^2 / \sigma_c^2$
$\sigma_\varepsilon^2 = 1$	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

Cartel avoids large price changes to make price changes seem "reasonable" to buyers.

How does enforcement affect price?

Impact of illegality and enforcement on the collusive price path:

- 1 Price is gradually increased.
- 2 Steady-state price is lower as long as penalties are increasing in price.
- 3 Higher discount factor results in initially lower prices but, as with lawful cartels, raises the long-run price.
- 4 Price is less responsive to cost shocks and thus less variable (Harrington and Chen, IJIO, 2006)

How would an unlawful cartel respond to screening?



“First of all: I didn't do anything, and secondly: everybody did the same!”