



The Collusion Chasm:
Reducing the Gap Between Antitrust
Practice and Industrial Organization
Theory

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Antitrust Practice and Collusion

- United States
 - Section 1 of the Sherman Act (1890)
 - "Every contract, combination in the form of trust or otherwise, or conspiracy, in restraint of trade or commerce among the several States, or with foreign nations, is declared to be illegal."
 - Practice
 - "By operationalizing the idea of an agreement, antitrust law clarified that the idea of an agreement describes a process that firms engage in, not merely an outcome that they reach. Not every parallel pricing outcome constitutes an agreement because not every such outcome was reached through the process to which the law objects: a negotiation that concludes when the firms convey mutual assurances that the understanding they reached will be carried out." [Jonathan Baker (1993)]



- European Union

- Article 81 of the Treaty of the European Communities (1999)

- "The following shall be prohibited as incompatible with the common market: all agreements between undertakings, decisions by associations of undertakings and concerted practices which may affect trade between Member States and which have as their object or effect the prevention, restriction or distortion of competition within the common market ..."

- Practice

- "Today pure market 'parallel behavior' without any attempt from the firms involved to communicate with each other or establish practices which help sustain collusion would probably not be judged by the Court of First Instance and the European Court of Justice as a concerted practice within the meaning of Article 81." [Massimo Motta (2004)]



- Brands of collusion according to antitrust practice

- Explicit collusion

- Definition: Coordination through direct communication.

- Legal status: Always illegal.

- Tacit collusion

- Definition

- "Tacit collusion ... describes the process, not in itself unlawful, by which firms in a concentrated market might in effect share monopoly power, setting their prices at a profit-maximizing, supracompetitive level by recognizing their shared economic interests and their interdependence with respect to price and output decisions." [U.S. Supreme Court (1993)]

- "Concerted practices" is defined by the European Court of Justice as "a form of coordination between undertakings which, without having reached the stage where an agreement properly so-called has been concluded, knowingly substitutes practical cooperation between them for the risks of competition."

- Legal status: Generally legal.



- What is the role of economics with respect to competition policy regarding collusion?
 - Merger policy
 - Identifying mergers that may make collusion more likely.
 - Identifying industry traits conducive to collusion.
 - Concerned with both explicit and tacit collusion.
 - Cartel policy
 - Identifying "prosecutable" cases of collusion, which effectively means explicit collusion.
 - Identifying industry traits conducive to explicit collusion.
 - Distinguishing explicit collusion from tacit collusion and competition.
 - Focus today is on cartel policy.



- State of economic theory

- Standard questions

- What industry traits are conducive to collusion?

- How does one distinguish collusion from competition?

- *Where is the distinction between explicit and tacit collusion?*

- There is a gap between antitrust practice - which distinguishes explicit and tacit collusion - and economic theory - which (generally) does not.



- Questions to be addressed:

- How does economic theory define collusion?
- What does explicit collusion look like?
 - How do hard-core cartels act?
 - How often do they meet?
 - What do they talk about?
- How can we model the distinction between explicit and tacit collusion?
- What results on explicit and tacit collusion can we glean from the existing body of theoretical work on collusion?
- How can we make progress in understanding explicit and tacit collusion?



Theoretically Defining Collusion

- IO economists say "collusion" is present when:
 - price exceeds some competitive benchmark.
 - the optimality of each firm's price depends on the anticipated aggressive response of other firms if they were to act differently.
 - this anticipated response is not attributable to a change in the other firms' environment (or beliefs over that environment).



- Infinitely repeated games

- Stage game Nash equilibrium is the competitive benchmark.
- In an infinitely repeated game, subgame perfect equilibria that are distinct from repetition of stage game Nash equilibria are deemed "collusive".
- Classic mechanism: Each firm prices above the stage game Nash equilibrium because pricing lower depresses future profit as other firms respond by pricing lower.
- Collusion is well-defined and, in principle, identifiable.



- Supergames that are not infinitely repeated

- Suppose the game is not infinitely repeated because

- the strategic form evolves - structural variables such as durable capital, intertemporal demand effects (durable goods, switching costs, etc.), learning-by-doing, inventories, etc.
 - beliefs over the strategic form evolve - there is incomplete information.

- Relevant competitive benchmark is Markov Perfect Equilibrium.

- A Markov Perfect Equilibrium is a subgame perfect equilibrium in which each firm's strategy depends only on that part of the history that affects the strategic form or beliefs over it.
 - Equilibria that are distinct from a Markov Perfect Equilibrium are deemed "collusive".



- Example: Alternating price [Maskin and Tirole (1988)]

- Model

- Duopoly price game with homogeneous goods.
 - Constant and common marginal cost.
 - Infinite number of periods.
 - Set of feasible prices, A , is finite.
 - Firms alternate choosing price
 - In odd periods, firm 1 chooses its price while firm 2 is locked into its price from the previous period.
 - In even periods, firm 2 chooses its price while firm 1 is locked into its price from the previous period.

- Markov strategy

- Only "relevant" part of the history is the price selected in the previous period.
 - A Markov strategy is of the form: $R(\cdot) : A \rightarrow A$.

- *Theorem:* If firms are sufficiently patient and the set of prices is sufficiently fine then there exists \underline{p} such that $R^*(\cdot)$ is a symmetric Markov Perfect Equilibrium where:

$$R^*(p) = \begin{cases} p^m & \text{if } p \leq \underline{p} \text{ and } p \geq p^m \\ \underline{p} & \text{if } p \in (\underline{p}, p^m) \end{cases}$$

and p^m is the joint profit-maximizing price.

- This looks like collusion
 - Outcome path is p^m .
 - Undercutting the monopoly price induces the other firm to respond aggressively by pricing at \underline{p} .



- Other examples

- Durable goods

- Current demand depends on past sales.
 - With a MPE competitive benchmark, history should matter only through its impact on the stock of existing customers.
 - A low price by a competitor last period may induce a low price this period by reducing current demand.

- Private information on (persistent) cost

- Current beliefs on a rival's cost may depend on the rival's price last period.
 - A lower price last period by one's rival may reduce a firm's expectation on the rival's current price and bring forth a lower price response.

- In a collusive context, these responses might be interpreted as a punishing price war.



□ Challenges

- Can we define what it means to respond *too strongly* to a change in the state variables?
- Can we disentangle structural interdependence from behavioral interdependence?



- Conclusions

- When the strategic form is exogenous then

- competition implies that firm behavior should be independent of past behavior.

- equilibria with such dependence can be classified as collusive.

- When the strategic form is endogenous then

- Markov Perfect Equilibrium tells us what part of the history should matter

- but not *how much* it should matter.

- Can we distinguish collusion and competition when we can't even define what we mean by collusion?



Explicit Collusion in Practice

- Questions
 - How often do hard-core cartels meet?
 - What do they talk about?
 - How are they organized?
- Frequency of cartel meetings

Industry	Years	Frequency of Meetings
Vitamins	1989-1999	Quarterly
Carbon graphite products	1999-2000	Monthly
Citric acid	1991-1995	Every two months
Lysine	1992-1995	Quarterly
Sodium gluconate	1993-95	Monthly




- What are they talking about?

- Refined sugar (1927-36)

- "The unavoidable conclusion ... is that the initial agreement was incomplete, in the sense used in the theory of the firm. Collusive agreements are incomplete for the usual reason that it is impossible to anticipate, enumerate and work through all contingencies. ... The weekly meetings allowed the refiners to 'complete the contract' ..."
[Genesove and Mullin (2001)]

- Points of discussion


- Price
 - Allocation of supply
 - Punishments and side payments
 - Monitoring and compliance

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- Coordinating on price
 - Citric acid (1991-95)
 - Discussions of demand and cost trends.
 - Firms agreed to a standard price and allowed each firm to offer a 3% discount to their five biggest customers.
 - Electrical and mechanical carbon and graphite products (1990-2000)
 - Set general price
 - Set prices for large customers
 - Set prices that would undercut non-cartel competitors
 - Conclusions
 - There is more to coordinating on a single price.
 - But could this have been done tacitly? Would price leadership have been sufficient?

- Coordinating on market allocation of supply
 - Allocating market shares
 - Citric acid (1991-95): Collusive market shares were set at each firm's historical market share over 1988-90.

Cartel Member	Market Share
Haarman & Reimer/Bayer	34.0%
Archer Daniels Midland	27.5%
Jungbunzlauer	24.0%
Hoffman-La Roche	15.0%

- Lysine (1992-95)
 - Prior to the entry of ADM, the suppliers of lysine had been colluding.
 - ADM built a large low-cost plant and entered the industry aggressively.
 - By early-mid 1992, ADM's global market share was 1/3.
 - Representatives of ADM approached the other firms about colluding and proposed that ADM's market share be 1/3.

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- Allocating territories - Seamless steel tubes (1990-95)
 - Collusion among four European and four Japanese manufacturers.
 - Agreed that firms should refrain from selling in the home countries of the other cartel members.
 - In shared markets, they would meet to designate which company was to win a particular job by bidding an agreed upon price, with the others to submit higher phantom bids.
 - Allocating customers - Linen supply (1994-2002)
 - Firms agreed not to compete for each other's customers.
 - Agreed to notify each other when such customers were contemplating switching suppliers and to submit intentionally high price quotes or refraining from submitting price quotes.



- Conclusions

- Central problem to collusion is allocating supply.
- Inability to agree on market shares is often a source of collusion breakdown.
 - Lysine (1992-95)
 - First phase of collusion (November 1992 - March 1993): Firms agreed on price but did not reach an agreement as to market share. After three months, the agreement broke down.
 - Second phase of collusion (late 1993 - 1995): Agreement on shares occurred in late 1993 and thereafter collusion worked.
- Coordinating a market allocation is likely to require explicit communication.




- Monitoring and compliance

- Citric acid (1991-95)

- Each firm submitted monthly sale volumes to a representative of Hoffman-La Roche who would then distribute the information among the other cartel members.
 - At their bi-monthly meetings, there would be a discussion of the latest cartel sales report towards monitoring the agreement.
 - They would discuss any problems with the cartel's operation such as accusations about cheating.

- Other examples

- Lysine (1992-95) - Each month, the five companies telephoned or mailed their lysine sales to an employee of Ajinomoto who prepared a spreadsheet that was handed out at the quarterly maintenance meetings.
 - Graphite electrodes (1992-97) - Created the Central Monitoring System in 1995 which called for Tokai Carbon to collect data from the other members and compare actual sales with the agreed-upon market shares.

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- Refined sugar (1927-36) - evaluated claims of cheating
 - Provided a mechanism by which firms can judge whether cheating has in fact occurred.
 - Cheating may be subtle; not a lower price but rather a more favorable provision in some contractual term.
 - The Sugar Institute served as a court and thereby made monitoring less noisy.
 - Conclusions
 - Communication among firms can result in more effective monitoring.
 - Some punishments can be avoided by discussing suspected episodes of cheating.



- Asymmetric punishments and side payments

- Inter-firm sales and asymmetric punishments

- Vitamins A and E (1989-99) - A firm that was substantially above its quota would have to purchase vitamins from those below their quotas.

- Other examples

- Citric acid (1991-95)

- Graphite electrodes (1992-97)

- Side payments - School milk auctions in Florida (1980-91)

- Market shares fluctuated widely.

- Evidence of side payments which allowed the cartel member with the lowest cost to be the designated bidder.

- Conclusions

- Asymmetric punishments may be more effective in deterring cheating (and be renegotiation-proof).

- Side payments may result in a Pareto superior outcome.

- Like with market allocation, asymmetric treatment may required explicit communication.



- Organizational structure and review of cartel meetings

- Graphite electrodes

- "Top guy" meetings were attended by chief executives at which price levels were set.

- Meetings with lower level officers (such as sales managers) would organize details and exchange information.

- Vitamins


- "Summit" conferences were held for a few days once each year.

- These were attended only by high-ranking corporate officials, just below the level of CEO.

- They decided upon prices and market shares.

- These meetings were followed four months later by the next level of managers. They would review profit and determine whether any members were above or below quota.

- Regional managers met each quarter to report prices and sales volumes in order to monitor and enforce compliance.

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- Hard-core cartels can be highly organized and engage in non-trivial communication in order to
 - agree upon a collusive outcome (prices, allocation of supply, capacity).
 - monitor an agreement which includes exchanging information and judging possible violations.
 - punish infractions.



Theories of Explicit Collusion

- Objective is to develop a theory of explicit collusion and tacit collusion.
 - When is explicit collusion likely to emerge?
 - What industry traits are conducive to explicit collusion?
 - How can we distinguish explicit collusion from tacit collusion and from competition?
- Why would firms ever explicitly collude?
 - Explicit collusion makes firms liable for antitrust penalties, while tacit collusion (generally) does not.
 - A simple revealed preference argument tells us that either:
 - they cannot tacitly collude or
 - they can but they expect to earn higher profit from explicit collusion that more than compensates for the expected penalties.




- Questions to be addressed by theory:
 - When is tacit collusion difficult?
 - When is explicit collusion (significantly) more profitable than tacit collusion?
- Direct communication provided by explicit collusion can perform two functions:
 - Coordination
 - Explicit collusion allows firms to coordinate on a better outcome (equilibrium selection).
 - A distinction between explicit and tacit collusion is how an equilibrium is reached.
 - Information sharing
 - Explicit collusion provides a rich message space that allows for more profitable outcomes.
 - Firms can share information about cost, demand, etc.



Coordination

- With respect to what do firms need to coordinate?
 - If firms are symmetric then price leadership ought to be sufficient to achieve a symmetric outcome. Explicit collusion may be unnecessary.
 - In fact, firm asymmetries are ubiquitous, vast, and relevant to the stability of collusive arrangements.
 - There is a lot more to collusion than coordinating on a single price.
- Allocation of supply
 - Model
 - Homogeneous goods price game with n firms.
 - Common constant marginal cost, c .
 - Joint profit-maximizing price of p^m .
 - Infinitely repeated game with history being common knowledge (perfect monitoring).
 - Firm heterogeneity in discount factors, $0 < \delta_1 \leq \dots \leq \delta_n < 1$.


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- Maximal punishment strategy (grim trigger strategy) equilibria
 - An outcome is defined by a common price and an allocation of demand at that price.
 - Equilibrium strategy profile:

$$\rho_i^1 = p'$$

$$\rho_i^t = \begin{cases} p' & \text{if } p_j^\tau = p' \forall \tau \leq t-1, \forall j \\ c & \text{otherwise} \end{cases}$$

$t = 2, 3, \dots; i = 1, 2, \dots, n.$

where firm i 's quantity at a price of p' is q_i' .

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- (Ad hoc) definitions of explicit and tacit collusion
 - Tacit collusion: firms can only coordinate on price.
 - Explicit collusion: firms can coordinate on price and firm quantities.
 - Best collusive outcome under tacit collusion
 - Equilibrium conditions:

$$\frac{(p' - c) \left(\frac{D(p')}{n} \right)}{1 - \delta_i} \geq (p' - c) D(p') \quad \forall i \Leftrightarrow \delta_i \geq \frac{n - 1}{n},$$

Result: p' is an equilibrium price iff

$$\min \{ \delta_1, \dots, \delta_n \} \geq \frac{n - 1}{n}.$$

- Collusion is more difficult when firms are more heterogeneous.

□ Best collusive outcome under explicit collusion

■ Equilibrium conditions:

$$\frac{(p' - c) q'_i}{1 - \delta_i} \geq (p' - c) D(p') \quad \forall i \Leftrightarrow q'_i \geq (1 - \delta_i) D(p').$$

■ Result: p' is an equilibrium price iff

$$\left(\frac{1}{n}\right) \sum_{i=1}^n \delta_i \geq \frac{n-1}{n}.$$

■ Intuition

□ Relatively impatient firms can only be induced to collude by offering them a relatively high market share.

□ There must be relatively patient firms willing to accept a relatively low market share.

■ Collusion is no more difficult when firms are more heterogeneous.



- Summary of results

- If $\min \{\delta_1, \dots, \delta_n\} \geq \frac{n-1}{n}$ then tacit collusion is stable.

- If $(\frac{1}{n}) \sum_{i=1}^n \delta_i \geq \frac{n-1}{n} > \min \{\delta_1, \dots, \delta_n\}$ then tacit collusion is not stable but explicit collusion is.

- If $\frac{n-1}{n} > (\frac{1}{n}) \sum_{i=1}^n \delta_i$ then even explicit collusion is not stable.

- Impact of asymmetry on collusion

- The accepted wisdom is that collusion is more difficult when firms are more asymmetric.

- Here we find that:

- tacit collusion is indeed more difficult when firms are more asymmetric.

- explicit collusion is more likely when firms are (moderately) asymmetric.

- A (tentative) new "wisdom" might be:

- competition occurs when asymmetries are severe

- explicit collusion occurs when asymmetries are modest.

- tacit collusion occurs when asymmetries are minimal.




- Asymmetric punishments


- Relevancy of asymmetric punishments.

- Asymmetric punishments have been used by actual cartels.
 - Asymmetric punishments can support better collusive outcomes.
 - However, it may be harder to coordinate on asymmetric punishments.

- Model [Harrington and Skrzypacz (2004)]

- Infinitely repeated duopoly game in which firms make simultaneous price decisions.
 - Demand
 - Fixed market demand at m discrete units.
 - Stochastic firm demand: $\varphi(b; p_1, p_2)$ is the probability that firm 1 sells b units given its price is p_1 and its rival's price is p_2 .

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- φ is continuously differentiable with respect to p_1 and p_2 .
[smoothness]
 - $\varphi(b;p',p'')=\varphi(m-b;p'',p')$ [symmetry]
 - $\partial\varphi(b;p,p)/\partial p_1+\partial\varphi(b;p,p)/\partial p_2=0$ [local invariance]
 - For example, it holds when φ depends only on the price difference, $p_1 - p_2$, as with the discrete choice model.
 - Cost functions are common and linear.
 - Imperfect monitoring
 - Firms' prices are private information.
 - Quantities (or market shares) are common knowledge.
 - Strongly symmetric public equilibrium
 - Conditions only on publicly observed market shares.
 - For each history, firms have the same continuation payoff.
 - Punishments are necessarily symmetric such as price wars.

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- *Impossibility Result.* The set of strongly symmetric Nash equilibrium outcomes for the infinite horizon game coincides with the set of symmetric Nash equilibrium outcomes for the stage game.
 - Symmetric punishments cannot sustain any symmetric collusive outcome, for any discount factor.
 - Intuition
 - Suppose punishment occurs when market share is too skewed.
 - Marginally undercutting the collusive price raises the probability that its market share is high but lowers the probability that the other firm's market share is high.
 - For small price cuts, these two effects exactly offset each other.
 - *Possibility Result.* Collusion is stable with asymmetric punishments.
 - *Tentative conclusion.* Explicit collusion is more likely when stable collusion requires asymmetric punishments.



Information Sharing

- Introduction

- Suppose firms have private information.
 - Cost or valuations (in auction context)
 - Demand information
 - Prices or quantities for monitoring purposes
- How might this private information be signalled?
 - With tacit collusion: a firm's price or an announcement on price.
 - With explicit collusion: a rich message space with focal meaning.



- Modeling direct communication
 - Exchanging information on cost or demand in a posted-price setting
 - Cost or demand signals are private information.
 - The selection of price (or quantity) is preceded by a cheap talk stage.
 - Exchanging information valuations in a single-unit auction setting.
 - Bidders' valuations are private information.
 - Pre-auction mechanism
 - Elicits cartel members' valuations.
 - Member with the highest valuation bids with other members submitting phantom bids (or not participating).
 - If the ring's representative wins then side payments may be paid to the other ring members.



- Model [Athey and Bagwell (2001, 2004)]

- Homogeneous goods price-setting game with two firms.


- Demand is perfectly inelastic and divisible:

$$D(p) = \begin{cases} 1 & \text{if } p \leq r \\ 0 & \text{if } r < p \end{cases}$$

- 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.

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- Stage game without communication (tacit collusion)
 - Nature chooses each firm's cost.
 - Firms make simultaneous price decisions.
 - Stage game with communication (explicit collusion)
 - Nature chooses each firm's cost.
 - Each firm makes an announcement from $\{L, H, N\}$.
 - Firms make simultaneous price decisions and propose a market allocation (when they charge identical prices).
 - Infinite horizon game
 - A firm's information set is
 - its past cost realizations.
 - realized announcements, prices, and market allocation proposals of both firms.
 - Focus on perfect public equilibria.



- First-best outcome

- Description


- If one firm has low cost and the other does not then the low-cost firm prices at r and the high cost firm prices above r .
 - If both firms have the same cost then both price at r with the allocation of supply being irrelevant.
 - Implementation of this outcome requires that firms truthfully reveal their cost types.


- Tension between efficiency and cartel stability.

- A high cost firm may want to signal it has low cost in order to have positive sales.
 - To induce a high cost firm to provide an accurate cost report, the collusive price may need to be set relatively low.
 - Though a mechanism may exist to induce truthful revelation of firms' costs, it may not be optimal for firms to use it when it requires low prices.



- Relating the characterization of the best (most profitable) equilibrium to explicit and tacit collusion.
 - Suppose the best equilibrium has uninformative messages.
 - Explicit collusion is then no more profitable than tacit collusion.
 - Firms should not explicitly collude unless there is coordination failure.
 - Suppose the best equilibrium has informative messages.
 - Explicit collusion may be more profitable than tacit collusion.
 - What is the best equilibrium when firms cannot send messages?
 - Explicit collusion is preferred only if the incremental profit gain exceeds expected penalties.

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- *Result #1:* If cost persistence is high relative to firms' patience then the incremental value of explicit collusion (over tacit collusion) is zero.
 - Properties of the best equilibrium.
 - Messages are uninformative.
 - Both firms charge the same price and equally share market demand.
 - First-best outcome is not achieved.
 - Intuition
 - When cost persistence increases, it becomes more valuable to a firm to signal that it has low cost.
 - Inducing truthful revelation either requires firms to be more patient or to set lower prices.
 - When firms are not very patient, the preference is to forego efficiency in order to support higher collusive prices.

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- *Result #2*: If patience is high relative to cost persistence then the incremental value of explicit collusion is weakly positive.
 - Properties of equilibrium
 - Messages are informative.
 - Only the lower cost firm produces.
 - First-best outcome is achieved.
 - Mechanism uses intertemporal market share favors
 - If a firm announces high cost and the other firm announces low cost then the latter prices at r and the other firm prices above r (and sells zero).
 - 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.
 - A firm that says it is low cost when it is high cost then foregoes future market share when it might be low cost and thus it is more valuable to have high market share.
 - However, one has to be concerned with the incentives of a firm that is supposed to provide a market share favor.



- Tacit collusion with *iid* cost and sufficiently patient firms.
 - A firm prices at r when it has high cost and prices just below r when it has low cost.
 - Tacit collusion achieves productive efficiency and close to optimal pricing.
 - Explicit collusion does not yield higher profit than tacit collusion.
- *Tentative conclusion*: Explicit collusion is more likely when firms' costs are less persistent over time.



Research Challenges

- Gap between practice and theory
 - Antitrust practice makes a distinction between explicit and tacit collusion.
 - Most collusive theories do not distinguish between explicit collusion and tacit collusion.
- What we need to do to close this gap:
 - Develop models of how hard-core cartels behave.
 - Develop frameworks within which we can explore the effects of direct communication.



Research Questions Related to Explicit Collusion

- Frequency of meetings
 - Why do cartels meet so frequently?
 - Can we develop a theory of endogenous meetings?
 - Answers to these questions could lead to predictions about the frequency of price changes under explicit collusion.
- Market allocation
 - What determines how asymmetric firms allocate supply?
 - When are pre-collusive market shares used?
 - When is the market allocation persist over time?
 - What determines whether firms allocate market share or customers or territories?



- Information sharing to help monitoring

- Practice

- In the citric acid cartel, firms hired an international accounting firm to independently audit sales reports.
 - In many cartels, firms self-reported sales data.

- When do firms have the incentive to accurately report sales data?

- Explicit collusion could reduce the noisiness of monitoring. When is the incremental gain from a more informative signal large?

- Detection of collusion

- Firms that explicitly collude have to worry about being discovered and penalties levied. Tacitly colluding firms do not.


- When is detection of explicit collusion more difficult?

- Harrington and Chen (2004) show that detection is less likely when cost is more variable and, therefore, explicit collusion is more likely.



Developing a Framework for Comparing Explicit and Tacit Collusion

- Questions to be addressed:
 - When can collusive outcomes be achieved without direct communication?
 - When is direct communication especially valuable?
 - How is observed behavior different when firms coordinate their behavior by engaging in direct communication?

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- Theoretical challenges in modeling explicit and tacit collusion
 - Coordination - modelling equilibrium selection.
 - Information sharing
 - An equilibrium framework can compare what collusive outcomes are achievable by equilibria when there is pre-play communication (explicit collusion) and when there is not (tacit collusion).
 - With a multiplicity of equilibria, there is still a coordination issue.
 - A babbling equilibrium always exists.
 - Though market signaling could, in principle, allow tacit collusion to be as effective as explicit collusion, there is still a coordination issue - will firms draw the right inferences from, say, price announcements?



- Non-equilibrium methods

- Agent-based computational models with generic learning rules.

- Neural nets

- Reinforcement learning

- Q-learning

- Useful for modelling tacit collusion.

- When can agents collude without direct communication?

- What does collusive behavior look like when there is no direct communication?

- What is the behavioral pattern preceding a collusive outcome?

- How does behavior respond to cost and demand shocks?



- Experimental methods

- General approach


- Define two treatments: tacit collusion and explicit collusion.
 - Find the difference in average price and profit.
 - Contrast this difference across environments - when is it large?

- Approach #1: Big communication difference

- Tacit collusion treatment: No communication - only selection of price.
 - Explicit collusion treatment: Communication of any type of messages precedes selection of price.

- Approach #2: Modest communication difference


- Tacit collusion treatment: Price selection is preceded by sending messages regarding price.
 - Explicit collusion treatment: Price selection is preceded by sending messages regarding price and firms' quantities (market allocation).


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- Industry traits to vary
 - Number of firms
 - Degree of asymmetries among firms (cost, capacity, etc.)
 - Degree of cost and demand fluctuations
 - How does the difference in average price between the explicit collusion and tacit collusion treatments depend on the characteristics?
 - Existing experimental work
 - Plenty of work exploring the possibility of collusion but very little contrasting explicit and tacit collusion.
 - One experiment finds that tacit collusion may be possible but costly [Cason and Davis (1995)]
 - Firms may not be able to coordinate without explicit communication or doing so tacitly through the market may involve price wars.
 - "In contrast to no-communication sessions, sellers are less likely to engage in a price war before organizing price increases."



Can Economic Theory Tell Us What *Should* Be Illegal?

- Antitrust practice has led to a (murky) definition of illegal collusion.
 - "The correct standard is that there must be evidence that tends to exclude the possibility of independent action. ... there must be direct or circumstantial evidence that reasonably tends to prove that [the parties] had a conscious commitment to a common scheme designed to achieve an unlawful objective." [Monsanto Co. v. Spray-Rite Service Corp., 1984]
 - Direct communication is illegal.
 - Some forms of tacit collusion – parallelism plus – are illegal.
- But is this definition an appropriate one?
 - Is it well-grounded in terms of welfare analysis?
 - Is it practical?

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- Judge Richard Posner argues that tacit collusion can, in some instances, be thought as a contractual arrangement and thus warrants prosecution:
 - "... one seller communicates his 'offer' by restricting output, and the offer is 'accepted' by the actions of his rivals in restricting their outputs as well. It may therefore be appropriate in some cases to instruct a jury to find an agreement to fix prices if it is satisfied that there was a tacit meeting of the minds of the defendants on maintaining a noncompetitive pricing policy."
 - Is such an antitrust policy tenable?
 - Judge Stephen Breyer from the *Clamp-All* case (1988):
 - "Courts ... have almost uniformly held ... that ... individual pricing decisions (even when each firm rests its own decision upon its belief that competitors will do the same) do not constitute an unlawful agreement. That is not because such pricing is desirable (it is not), but because it is close to impossible to devise a judicially enforceable remedy for "interdependent" pricing. How does one order a firm to set its prices without regard to the likely reactions of its competitors?"

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- What is required of a meaningful definition of illegal collusion?
 - It should involve a *verifiable* practice that results in supracompetitive prices.
 - It should be possible to develop an *enforceable* remedy.
 - Can we do better than to make illegal the practice of “direct communication that contributes to supracompetitive prices”?