Implicit Collusion

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Collusion

- In order to increase profits, firms have an incentive to collude
  - Settle on the monopoly price and share quantities
  - Refrain from entering each other's market
  - Share common subsidiaries and fix monopoly prices...
- Explicit collusion (market monopolization) has been outlawed in the US and Canada since the late XIXth century (Sherman Act (1890), Clayton Act (1914))
- In Europe, cartels existed until 1945.
- Cartels still exist but in an attenuated form (OPEC, shipping conferences, Webb Pomerene export associations)

Implicit collusion

- Cartels are inherently unstable: if all other firms settle on the monopoly price, each individual firm has an incentive to choose $p^m - \epsilon$ and capture the whole market
- In explicit collusion agreements, sanctions against this behavior are clearly defined and enforced (by law)
- If explicit cartels are outlawed, collusion can only arise in a dynamic environment, where firms are punished for their behavior today by punishments tomorrow.

Dynamic punishments

- Friedman (1972): first discussion of Nash reversion and conditions for stability of agreements
- Green and Porter (1984): collusion with imperfect monitoring
- Rotemberg and Saloner (1986): collusion and exogenous shocks

Cartel size and stability

- What is the optimal cartel size? (Salant, Switzer and Reynolds (1988))
- Formation of market sharing agreement (Belleflamme and Bloch (2004))

The stage game

- Suppose that two firms agree to set the monopoly price p^m and share the monopoly profit π^m.
- If both firms cheat, they compete in a Bertrand market and obtain a profit $\pi = 0$

	Comply	Cheat
Comply	$(\frac{\pi^m}{2}, \frac{\pi^m}{2})$	$(0, \pi^m)$
Cheat	$(\pi^m, 0)$	$(0, 0)$

Equilibria

- If the game is only played once, it is a prisoner's dilemma. *The only equilibrium is for both firms to cheat*
- If the game is played a finite number of periods, the only equilibrium is for both firms to cheat every period with payoffs $(0,0),(0,0),....,(0,0)$
- If the game is played infinitely often, the equilibrium where all players play Nash every period with payoffs $(0,0),(0,0),....,(0,0)$ remains an equilibrium, but there are other equilibria.

The grim trigger strategy equilibrium

- Consider the following strategy:
  - Start by playing ”comply”
  - If both players have played ”comply” from periods 1,2,...,t-1, play ”Comply” at period t
  - If it is not the case that both players have played ”comply” from periods 1,2,...,t-1, play ”Cheat” at period t
- These strategies are called ”grim trigger strategies” or Nash reversion strategies
- Once the players enter the punishment phase, it is unrelenting. They continue to punish each other ad infinitum.

Conditions for existence

- The grim trigger strategies form an equilibrium if and only if

$$\sum_{t=0}^{\infty} \delta^t \frac{\pi^m}{2} \geq \pi^m + \sum_{t=1}^{\infty} \delta^t 0,$$

or

$$\frac{\pi^m}{2(1-\delta)} \geq \pi^m, \delta \geq \frac{1}{2}$$

- If δ is too low, the firms always prefer to cheat and get the instantaneous profit π^m. They don't value the future enough to be sensitive to the dynamic punishment scheme.
- During the punishment phase, both firms play a Nash equilibrium. Hence, the equilibrium of the repeated game is subgame perfect. After each history, players are acting optimally.

Collusion in a Cournot duopoly

- Consider a linear Cournot duopoly with $P = 1 - Q$ and $c = 0$.
- The monopoly price is $p = \frac{1}{2}$. Monopoly quantity is $q = \frac{1}{2}$ and each firm produces $\frac{1}{4}$ with a profit $\pi = \frac{1}{8}$
- In the Cournot game, both firms produce $\frac{1}{3}$ for a profit $\frac{1}{9}$
- If one firm complies and produces $\frac{1}{4}$, the best response of the offer firm is to produce $\frac{3}{8}$. The price then becomes $p = 1 - \frac{3}{8} - \frac{1}{4} = \frac{3}{8}$ and profits $\frac{3}{32}$ and $\frac{9}{64}$.
- The condition for existence of a collusive equilibrium is:

$$\frac{1}{8}\frac{1}{1-\delta} \geq \frac{9}{64} + \frac{1}{9}\frac{\delta}{1-\delta}, \delta \geq \frac{9}{17} > \frac{1}{2}$$

- It is easier to sustain collusion if firms are price competitors than if they are quantity competitors.

Collusion with incomplete information

- In models of collusion, punishments are never observed as they are off equilibrium
- In reality, price wars occur. How can you justify them?
- In the model, price wars occur because firms imperfectly monitor each other's production and mistake a drop in demand with an increase in output.
- Imperfect monitoring does not arise when firms share geographical markets or rotate bids. In that case, only monopolistic behavior is observed.

Assumptions on the industry

- The industry is stable over time (no entry, no exit)
- Output is the only decision variable
- Information about prices is public, about quantities produced is private
- The information used to monitor the cartel is imperfectly correlated with the firms' conduct.

Notations

- Let $\pi_i(x_i, p)$ be the profit of rim i as a function of price p and output x_i, β discount rate
- Firms maximize $E[\sum_{t=0}^{\infty} \beta^t \pi_i(x_{it}, p_t)]$
- $p_t = \theta_t p(\sum_{i=1}^{n} x_{it})$
- θ_t are iid distributed with cdc F and $E\theta = 1$

Strategies and equilibrium

- A strategy specifies
  - a quantity produced at period 0, x_{i0}
  - at each period $t \geq 1$, a quantity x_{it} as a function over the history of prices $p_0, p_1, .., p_{t-1}$
- A sub game perfect equilibrium is a vector of strategies $(s_1^*, .., s_n^*)$ such that, at each period t, for all histories firms choose an optimal action given the strategies of the other firms.

Grim trigger strategy

- We consider a trigger strategy with two parameters: a threshold price $\overline{p}$ and a number of periods T
- Let $(y_1, ..., y_n)$ be the cooperative production level and $(z_1, ..., z - n)$ the Cournot production level
- A time period t is normal if
  - $t = 0$
  - $t - 1$ was normal and $p_{t-1} \geq \overline{p}$
  - $t - T$ was normal and $p_{t-T} < \overline{p}$
- Otherwise, period t is reversionary
- Play $x_{it} = y_i$ if t is normal
- Play $x_{it} = z_i$ if t is reversionary

Characterization of equilibrium

- Fix T and $\overline{p}$. We compute the maximal cooperative outcome y_i which can be sustained by the trigger strategy.
- For any individual output level r, $V_i(r)$ is the expected profit of firm i
- $w_i = \sum j \neq i y_j$
- $\gamma_i(r) = E_\theta \pi_i(r, \theta p(w_i + r))$
- $\delta_i = E_\theta \pi[z_i, \theta p(\sum_j z_j)]$

The Bellman equation

$$
\begin{aligned}
V_i(r) &= \gamma_i(r) + \beta \Pr[\overline{p} \leq \theta p(r + w_i)] V_i(r) \\
&+ \beta \Pr[\theta p(r + w_i), \overline{p}][\sum_{t=1}^{T-1} \beta^t \delta_i + \beta^T V_i(r)]
\end{aligned}
$$

- Let $\Pr[\theta p(r + w_i), \overline{p}] = F(\frac{\overline{p}}{p(r+w_i)})$
- Then

$$
V_i(r) = \frac{\gamma_i(r) - \delta_i}{1 - \beta + (\beta - \beta^T)F(\frac{\overline{p}}{p(r+w_i)})} + \frac{\delta_i}{1 - \beta}.
$$

Equilibrium

- In equilibrium, y_i is chosen to maximize $V_i(\cdot)$ for fixed w_i:

$$V'(y_i) = 0.$$

- Prices drop when θ is low: the cartel collapses during low demand episodes
- Prices fluctuate, as prices rise again to the collusive level after T periods.

Prices and fluctuations

- Is collusion more likely during booms or recessions?
- According to Green and Porter, collusion collapses in recessions
- On the other hand, incentives to cheat are typically higher during booms
- In the IO folklore, cartels collapse during recessions, but data suggest otherwise.

Equilibrium with demand fluctuations

- N firms producing a homogeneous product
- Inverse demand: $P(Q_t, \epsilon_t)$ increasing in ϵ
- ϵ is distributed on a compact interval $[\underline{\epsilon}, \overline{\epsilon}]$ according to a cdf F
- At the beginning of t, *all firms learn* ϵ_t.
- Each firm chooses a price p_t

The collusive equilibrium

- Each firm selects the monopoly price $p^m(\epsilon_t)$, produces $\frac{1}{N}$ of the monopoly quantity $Q^m(\epsilon_t)$ and obtains a profit $\Pi^m(\epsilon_t)$
- By deviating, the firm selects a price $p^m - \eta$ and captures the whole market, resulting in a profit $N\Pi^m(\epsilon_t)$
- After a deviation, firms revert to the Nash equilibrium, charge a price equal to marginal cost and earn zero profit.
- Let K be the punishment incurred after a deviation.
- Collusion occurs if and only if $Pi^m(\epsilon_t) \geq N\Pi^m(\epsilon_t) - K$ or

$$\Pi^m(\epsilon_t) \leq \frac{K}{N-1},$$

Collusion

- For any K define implicitly the threshold value ϵ^* by:

$$\Pi^m(\epsilon^*) = \frac{K}{N-1} \tag{1}$$

- If $\epsilon_t \leq \epsilon^*$, compliance occurs and firms get a payoff of $\Pi^m(\epsilon_t)$. If $\epsilon_t > \epsilon^*$, compliance only occurs if $\Pi^m \leq \Pi^m(\epsilon^*)$, so pick $\Pi^m = \Pi^m(\epsilon^*) = \frac{K}{N-1}$.
- For a fixed ϵ^*, compute the punishment as

$$K = \frac{\delta}{1-\delta}[\int_{\underline{\epsilon}}^{\epsilon^*} \Pi^m dF(\epsilon) + (1 - F(\epsilon^*)\Pi^m(\epsilon^*). \tag{2}$$

- An *equilibrium* is a fixed point (K, ϵ^*) of the two mappings (1) and (2)

Properties of equilibrium

- If $\epsilon_t > \epsilon^*$, the profit is constant for all ϵ_t. This must mean that quantities are increasing in ϵ_t and prices decreasing in ϵ_t: prices are lower during booms.
- If $\epsilon_t \leq \epsilon^*$, profits and quantities are increasing in ϵ_t.
- If N increases and δ decreases, ϵ^* falls.
- Punishments are never observed in equilibrium, there are no fluctuations from cooperative to noncooperative equilibrium.

Robustness

- There are no restrictions on demand, but marginal cost is constant
- If marginal cost is increasing, firms may not defect by lowering the price but by increasing the price! (Bertrand competition with increasing marginal cost is not well defined)
- If cost is quadratic and demand linear the results still hold, and higher ϵ correspond to lower prices.

Cournot versus Bertrand

- If firms compete in quantities rather than prices, there are two differences
  - Defecting means choosing the best response to the quantities chosen by the other firms
  - The punishment equilibrium involves a positive profit for all fins
  - In the linear model, higher ϵ increase the probability of defection, but this is not a general result.

Empirical analysis: the cement industry

Dependent variable	price cement/index	price cement /constr
constant	$0.025^{***}(0.01)$	$0.038^{***}(0.07)$
GNP	$-0.438^{**}(.236)$	$-0.875^{**}(.161)$
R^2	.1	.48

The Railroad Cartel

TABLE 4—RAILROADS IN THE 1880's

	Estimated Nonadherence	Rail Shipments (Million bushels)	Fraction Shipped by Rail	Total Grain Production (Billion Tons)[a,b]	Days Lakes Closed 4/1–12/31[a]
1880	0.00	4.73	22.1	2.70	35
1881	0.44	7.68	50.0	2.05	69
1882	0.21	2.39	13.8	2.69	35
1883	0.00	2.59	26.8	2.62	58
1884	0.40	5.90	34.0	2.98	58
1885	0.67	5.12	48.5	3.00	61
1886	0.06	2.21	17.4	2.83	50

[a]Obtained from the Chicago Board of Trade (1880–86).
[b]This total is constructed by adding the productions of wheat, corn, rye, oats, and barley in tons.

The Stigler effect and the cartel formation puzzle

- Suppose that demand is $P = 1 - Q$
- Each firm produces at 0 marginal cost.
- Each firm makes a profit $\pi = \frac{1}{(n+1)^2}$
- If k firms merge, they obtain a profit $\frac{1}{k(n-k+2)^2}$ each while each outsider gets $\frac{1}{(n-k+2)^2}$.
- The Stigler effect: firms want other firms to merge or form cartels. As a consequence, no cartel will form!

Cartels

- Consider an open membership game (d'Aspremont et al. (1983)) where firms choose whether or not to belong to a cartel.
- The *only equilibrium is for firms to remain singletons*
- In order to guarantee that firms form cartels, one needs to assume cost synergies, or that cartels become first movers in a Stackelberg game, or that cartels form among firms with lower marginal cost, or that cartels form a dominant firm with competitive fringe..
- (You must give an advantage to a cartel)

Cartels

- Salant Switzer and Reynolds (1978) define the ”minimal profitable cartel size” as k such that $\pi^I(k) = \pi(1)$ or $\frac{1}{(n+1)^2} = \frac{1}{k(n-k+2)^2}$.
- In practice, $k \simeq 0.8n$
- In the δ model, any cartel size $k \geq k^*$ is an equilibrium,
- In the γ model, no cartel is an equilibrium
- In the sequential coalition formation game, the unique SPE is for the firts $n - k^*$ firms to remain singletons, and the last k^* firms to form a cartel (Bloch, 1996 and Ray and Vohra, 1999). Easy intuition but hard proof!

Market sharing agreements

- Belleflamme and Bloch (2004) consider a network model which is close to the cartel formation model.
- Firms are located on geographic markets.
- They can form bilateral market sharing agreements where they refrain from entering each other's market.
- This is considered a serious problem in the EU (Solvay case, Maersk SAS, etc...)

The model of market sharing agreements

- Reduced form: profit in market i depends on the number of competitors on market i, $\pi(n_i)$.
- This may correspond to oligopolistic markets, or to procurement auctions..
- Typically, one assumes $\pi(\cdot)$ decreasing.
- If a firm is present on markets $i = 1, ...I$, it gets

$$\Pi = \sum_i \pi(n_i).$$

- Each firm is identified to one market (firm i, market i) which is the "home" market.

Properties of profit functions

- Profit functions are decreasing, $\pi(n_i) < \pi(n_{i-1})$
- Profit functions are convex, $\pi(n_i) - \pi(n_{i+1}) < \pi(n_{i-1}) - \pi(n_i)$
- profit functions are log-convex, $\frac{\pi(n_i)-\pi(n_{i+1})}{\pi(n_{i+1})} < \frac{\pi(n_{i-1})-\pi(n_i)}{\pi(n_i)}$.
- These assumptions are satisfied in Cournot oligopolies (under standard assumptions) and in private value auctions.

Stable market sharing agreements

- When two firms i and j form an agreement, they lose access to each other's market (i.e. lose $\pi(n_i)$ or $\pi(n_j)$), but increase profit on their home market (from $\pi(n_j+1)$ to $\pi(n_j)$, or $\pi(n_i+1)$ to $\pi(n_i)$).
- When markets are symmetric, firms form market sharing agreements if and only if $n_i = n_j$.
- In fact, in a stable network, firms form complete components of different sizes. The size of each component is at least m^* where m^* is the minimal integer for which $\frac{\pi(n-m^*)}{\pi(n-m^*+1)} \geq 2$. (we know that $\pi(1) \geq 2\pi(2)$.
- hence firms form complete cliques of market sharing agreements.

Efficient market sharing agreements

- Industry profits are maximized when all firms join in a single component.
- Social welfare is maximized in the empty network.

Asymmetric markets

- When markets are asymmetric, the situation becomes very different:
- The complete network may not be stable if firms are too asymmetric
- The empty network may be stable when firms are very asymmetric
- Stable networks may fail to exist
- A network with incomplete component may be stable: the small firm may have MSA with the two large firms, but they do not have a MSA.