Dynamic oligopoly theory

Collusion – price coordination

Illegal in most countries

- Explicit collusion not feasible
- Legal exemptions

Recent EU cases

- Gas – approx. 1.1 billion Euros in fines (2009)
- Car glass – approx. 1.4 billion Euros (2008)
- Elevators – approx. 800 million Euros (2007)

Tacit collusion

Hard to detect – not many cases.

Repeated interaction

Theory of repeated games

Deviation from an agreement to set high prices has

- a short-term gain: increased profit today
- a long-term loss: deviation by the others later on

Tacit collusion occurs when

long-term loss > short-term gain

Model

Two firms, homogeneous good, $C(q) = cq$

Prices in period t: (p_{1t}, p_{2t})

Profits in period t: $\pi^1(p_{1t}, p_{2t})$, $\pi^2(p_{1t}, p_{2t})$

History at time t: $H_t = (p_{10}, p_{20}, \ldots, p_{1,\,t-1}, p_{2,\,t-1})$

A firm's strategy is a rule that assigns a price to every possible history.

A subgame-perfect equilibrium is a pair of strategies that are in equilibrium after every possible history: Given one firm's strategy, for each possible history, the other firm's strategy maximizes the net present value of profits from then on.

T – number of periods

T finite: a unique equilibrium

period T: $p_{1T} = p_{2T} = c$, irrespective of H_T.

period $T - 1$: the same

and so on

T infinite (or indefinite)

At period τ, firm i maximizes

$$\sum_{t=\tau}^{\infty} \delta^{t-\tau} \pi^i (p_{1t}, p_{2t}), \qquad \delta = \frac{1}{1+r}$$

The best response to (c, …) is (c, …).

But do we have other equilibria?
Can $p > c$ be sustained in equilibrium?

<u>Trigger strategies</u>: If a firm deviates in period t, then both firms set $p = c$ from period $t + 1$ until infinity.

[Optimal punishment schemes? Renegotiation-proofness?]

Monopoly price: $p^m = \arg\max\, (p - c)D(p)$
Monopoly profit: $\pi^m = (p^m - c)D(p^m)$

A trigger strategy for firm 1:

- Set $p_{10} = p^m$ in period 0
- In the periods thereafter,
  - $p_{1t}(H_t) = p^m$, if $H_t = (p^m, p^m, \ldots, p^m, p^m)$
  - $p_{1t}(H_t) = c$, otherwise

If a firm *collaborates*, it sets $p = p^m$ and earns $\pi^m/2$ in every period.

The *optimum deviation*: $p^m - \varepsilon$, yielding $\approx \pi^m$ for one period.

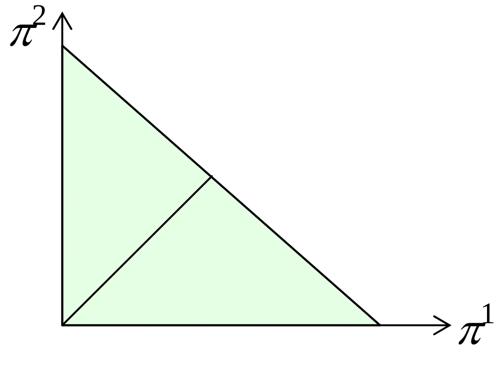
An equilibrium in trigger strategies exists if:

$$\frac{\pi^m}{2}(1 + \delta + \delta^2 + \ldots) \geq \pi^m + 0 + 0 + \ldots$$

$$\Leftrightarrow \frac{1}{2}\frac{1}{1-\delta} \geq 1 \Leftrightarrow \delta \geq \frac{1}{2}$$

The same argument applies to collusion on any price $p \in (c, p^m]$. $\Rightarrow$ Infinitely many equilibria.

The Folk Theorem.



Collusion when demand varies

Demand stochastic.

Periodic demand is

low: $D_1(p)$ with probability ½

high: $D_2(p)$ with probability ½

$D_1(p) < D_2(p), \forall p$.

The demand shocks are *i.i.d.*

Each firm sets its price after having observed demand.

What are the best collusive strategies for the two firms? Trigger strategies: A deviation is followed by $p = c$ forever.

What are the best collusive prices? One price in low-demand periods and one in high-demand periods: p_1 and p_2.

$\pi_s(p)$ – total industry profit in state s when both firms set p.

With prices p_1 and p_2 in the two states, each firm's expected net present value is:

$$V = \sum_{t=0}^{\infty} \delta^t \left[\frac{1}{2} \frac{D_1(p_1)}{2}(p_1 - c) + \frac{1}{2} \frac{D_2(p_2)}{2}(p_2 - c) \right]$$

$$= \frac{1}{4(1-\delta)} [D_1(p_1)(p_1 - c) + D_2(p_2)(p_2 - c)]$$

$$= \frac{\pi_1(p_1) + \pi_2(p_2)}{4(1-\delta)}$$

The best possible collusive price in state s is:

$$p_s^m = \arg\max\,(p - c)D_s(p),\ s = 1, 2.$$

$$\pi_s^m = (p_s^m - c)D_s(p_s^m),\ s = 1, 2.$$

If the firms can collude on these prices, then:

$$V = \frac{\pi_1^m + \pi_2^m}{4(1-\delta)}$$

A deviation in state s receives a gain equal to: π_s^m

For (p_1^m, p_2^m) to be equilibrium prices, we must have:

$$\pi_s^m \leq \tfrac{1}{2}\pi_s^m + \delta V \iff \pi_s^m \leq 2\delta V$$

The difficulty is state 2 (high-demand), since $\pi_1^m < \pi_2^m$.

The equilibrium condition becomes:

$$\pi_2^m \leq 2\delta \frac{\pi_1^m + \pi_2^m}{4(1-\delta)}$$

$$\iff \delta \geq \frac{2}{3 + \frac{\pi_1^m}{\pi_2^m}} \equiv \delta_0$$

$$0 < \frac{\pi_1^m}{\pi_2^m} < 1 \Rightarrow \frac{1}{2} < \delta_0 < \frac{2}{3}$$

But what if $\delta \in [\frac{1}{2}, \delta_0)$? Can we still find prices at which the firms can collude?

The problem is again state 2. We need to set p_2 so that

$$\pi_2(p_2) \leq 2\delta \frac{\pi_1^m + \pi_2(p_2)}{4(1-\delta)}$$

$$\Rightarrow \pi_2(p_2) = \frac{\delta}{2-3\delta}\pi_1^m$$

$$\tfrac{1}{2} \leq \delta < \tfrac{2}{3} \Rightarrow \tfrac{\delta}{2-3\delta} \geq 1 \quad \Rightarrow \quad \pi_2 \geq \pi_1$$

So: prices below monopoly price in high-demand state – during boom. Could even be that $p_2 < p_1$.

But is this a price war?

More realistic demand conditions:
Autocorrelation – business cycle.
Collusion most difficult to sustain just as the downturn starts.

Haltiwanger & Harrington, *RAND J Econ* 1991
Kandori, *Rev Econ Stud* 1991

Bagwell & Staiger, *RAND J Econ* 1997

[Exercise 6.4]

Empirical studies of collusion

- the railroad cartel
    - Porter *Bell J Econ* 1983
    - Ellison *RAND J Econ* 1994

- collusion among petrol stations
    - Slade *Rev Econ Stud* 1992

- collusion in the soft-drink market: prices and advertising
    - Gasmi, *et al., J Econ & Manag Strat* 1992

- collusion in procurement auctions
    - Porter & Zona *J Pol Econ* 1993 (road construction)
    - Pesendorfer *Rev Econ Stud* 2000 (school milk)

Infrequent interaction

Suppose the period length doubles.

$$\delta \rightarrow \delta^2$$

Collusion feasible if:

$$\delta^2 \geq \frac{1}{2} \quad \Leftrightarrow \quad \delta \geq \frac{1}{\sqrt{2}} \approx 0.71$$

Multimarket contact

Market A: Frequent interaction, period length 1.
Collusion if $\delta \geq ½$.

Market B: Infrequent interaction, period length 2.
Collusion if $\delta^2 \geq ½$.

(How could frequency vary across markets?)

What if both firms operate in both markets?
Can the firms obtain collusion in both markets even in cases where $\delta^2 < ½ < \delta$?

A deviation is most profitable when both markets are open.

Deviation yields: $2\pi^m$
Collusion yields:
$[\pi^m/2]$ every period, plus
$[\pi^m/2]$ every second period (starting today)

Collusion can be sustained if:

$$\frac{\pi^m}{2}[1 + \delta + \delta^2 + \ldots\ ] + \frac{\pi^m}{2}[1 + \delta^2 + \delta^4 + \ldots\ ] \geq 2\pi^m$$

$$\Leftrightarrow \ \frac{1}{2}\frac{1}{1-\delta} + \frac{1}{2}\frac{1}{1-\delta^2} \geq 2$$

$$\Leftrightarrow \ 4\delta^2 + \delta - 2 \geq 0 \ \Leftrightarrow \ \delta \geq \frac{\sqrt{33}-1}{8} \approx 0.59$$