Price-Fixing and Repeated Games

Collusion and cartels

- What is a cartel?
  - attempt to enforce market discipline and reduce competition between a group of suppliers
  - cartel members agree to coordinate their actions
    - prices
    - market shares
    - exclusive territories
  - prevent excessive competition between the cartel members

Collusion and cartels 2

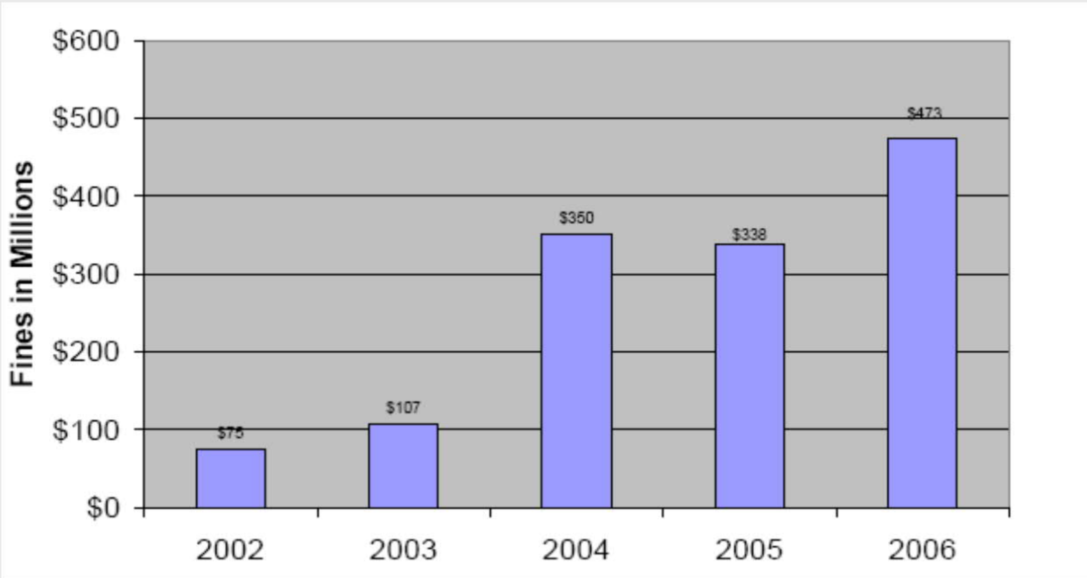
- Cartels have always been with us; generally hidden
  - electrical conspiracy of the 1950s
  - garbage disposal in New York
  - Archer, Daniels, Midland
  - the vitamin conspiracy
- But some are *explicit* and difficult to prevent
  - OPEC
  - De Beers
  - shipping conferences

Recent events

- Recent years have seen record-breaking fines being imposed on firms found guilty of being in cartels. For example
  - illegal conspiracies to fix prices and/or market shares
  - €479 million imposed on Thyssen for elevator conspiracy in 2007
  - €396.5 million imposed on Siemens for switchgear cartel in 2007
  - $300 million on Samsung for DRAM cartel in 2005
  - Hoffman-LaRoche $500 million in 1999
  - UCAR $110 million in 1998
  - Archer-Daniels-Midland $100 million in 1996

Recent cartel violations 2

- Justice Department Cartel Fines grew steadily since 2002



Cartels

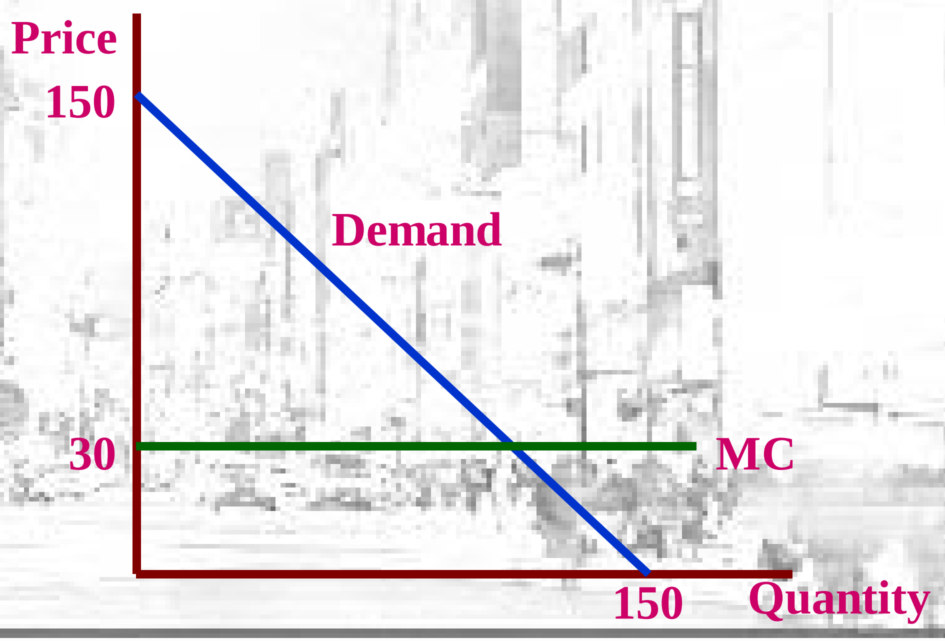
- Two implications
  - cartels happen
  - generally illegal and yet firms deliberately break the law
- Why?
  - pursuit of profits
- But how can cartels be sustained?
  - cannot be enforced by legal means
  - so must resist the temptation to cheat on the cartel

The incentive to collude

- Is there a real incentive to belong to a cartel?
- Is cheating so endemic that cartels fail?
- If so, why worry about cartels?
- Simple reason
  - without cartel laws legally enforceable contracts *could* be written
    De Beers is tacitly supported by the South African government
    - gives force to the threats that support this cartel
      - not to supply any company that deviates from the cartel
- Investigate
  - incentive to form cartels
  - incentive to cheat
  - ability to detect cartels

An example

- Take a simple example
  - two identical Cournot firms making identical products
  - for each firm MC = $30
  - market demand is P = 150 - Q
  - $Q = q_1 + q_2$



The incentive to collude

Profit for firm 1 is: $\pi_1 = q_1(P - c)$

$$= q_1(150 - q_1 - q_2 - 30)$$

$$= q_1(120 - q_1 - q_2)$$

To maximize, differentiate with respect to q_1:

Solve this for q_1

$$\partial\pi_1/\partial q_1 = 120 - 2q_1 - q_2 = 0$$

$$q^*_1 = 60 - q_2/2$$

This is the *best response function* for firm 1

The best response function for firm 2 is:

$$q^*_2 = 60 - q_1/2$$

The incentive to collude 2

- Nash equilibrium quantities are $q^*_1 = q^*_2 = 40$
- Equilibrium price is P* = $70
- Profit to each firm is (70 – 30)x40 = $1,600.
- Suppose that the firms cooperate to act as a monopoly
  - joint output of 60 shared equally at 30 units each
  - price of $90
  - profit to each firm is $1,800
- But
  - there is an incentive to cheat
    - **firm 1's output of 30 is not a best response to firm 2's output of 30**

The incentive to cheat

- Suppose that firm 2 is expected to produce 30 units
- Then firm 1 will produce $q^d_1 = 60 - q_2/2 = 45$ units
  - total output is 75 units
  - price is $75
  - profit to firm 1 is $2,025 and to firm 2 is $1,350
- Of course firm 2 can make the same calculations!
- We can summarize this in the pay-off matrix:

The Incentive to cheat 2

Both firms have the incentive to cheat on their agreement

This is the Nash equilibrium

		Firm 2	
		Cooperate (M)	Deviate (D)
Firm 1	Cooperate (M)	(1800, 1800)	(1250, 2250)
	Deviate (D)	(2250, 1250)	**(1600, 1600)**

The incentive to cheat 3

- This is a prisoners' dilemma game
  - mutual interest in cooperating
  - but cooperation is unsustainable
- However, cartels do form
- So there must be more to the story
  - consider a dynamic context
    - firms compete over time
    - potential to punish "bad" behavior and reward "good"
  - this is a ***repeated game*** framework

Finitely repeated games

- Suppose that interactions between the firms are repeated a finite number of times know to each firm in advance
  - opens potential for a reward/punishment strategy
    - "If you cooperate this period I will cooperate next period"
    - "If you deviate then I shall deviate."
  - once again use the Nash equilibrium concept
- Why might the game be finite?
  - non-renewable resource
  - proprietary knowledge protected by a finite patent
  - finitely-lived management team

Finitely repeated games 2

- Original game but repeated twice
- Consider the strategy for firm 1
  - first play: cooperate
  - second play: cooperate if firm 2 cooperated in the first play, otherwise choose deviate

		Firm 2	
		Cooperate (M)	Deviate (D)
Firm 1	Cooperate (M)	(1800, 1800)	(1250, 2250)
	Deviate (D)	(2250, 1250)	(1600, 1600)

Finitely repeated games 3

- This strategy is unsustainable
  - the promise is not credible
    - at end of period 1 firm 2 has a promise of cooperation from firm 1 in period 2
    - but period 2 is the last period
    - dominant strategy for firm 1 in period 2 is to deviate

		Firm 2	
		Cooperate (M)	Deviate (D)
Firm 1	Cooperate (M)	(1800, 1800)	(1250, 2250)
	Deviate (D)	(2250, 1250)	(1600, 1600)

Finitely repeated games 4

- Promise to cooperate in the second period is not credible
  - but suppose that there are more than two periods
    - with finite repetition for T periods the same problem arises
      - in period T any promise to cooperate is worthless
      - so deviate in period T
      - but then period T – 1 is effectively the "last" period
      - so deviate in T . . . and so on
- Selten's Theorem
  - "If a game with a unique equilibrium is played finitely many times its solution is that equilibrium played each and every time. Finitely repeated play of a unique Nash equilibrium is the equilibrium of the repeated game."

Finitely repeated games 5

- Selten's theorem applies under two conditions
  - The one-period equilibrium for the game is *unique*
  - The game is repeated a finite number of times
- Relaxing either of these two constraints leads to the possibility of a more cooperative equilibrium as an alternative to simple repetition of the one-shot equilibrium
- Here, we focus on relaxing the second constraint and consider how matters change when the game is played over an infinite or indefinite horizon

Repeated games with an infinite horizon

- With finite games the cartel breaks down in the "last" period
  - assumes that we know when the game ends
  - what if we do not?
    - some probability in each period that the game will continue
    - indefinite end period
    - then the cartel might be able to continue indefinitely
      - in each period there is a likelihood that there will be a next period
      - so good behavior can be rewarded credibly
      - and bad behavior can be punished credibly

Valuing indefinite profit streams

- Suppose that in each period net profit is π_t
- Discount factor is R
- Probability of continuation into the next period is ρ
- Then the present value of profit is:
  - $PV(\pi_t) = \pi_0 + R\rho\pi_1 + R^2\rho^2\pi_2 + \ldots + R^t\rho^t\pi_t + \ldots$
  - valued at "probability adjusted discount factor" $R\rho$
  - product of discount factor and probability of continuation

Trigger strategies

- Consider an indefinitely continued game
  - potentially infinite time horizon
- Strategy to ensure compliance based on a *trigger strategy*
  - cooperate in the current period so long as all have cooperated in every previous period
  - deviate if there has ever been a deviation
- Take our earlier example
  - period 1: produce cooperative output of 30
  - period *t*: produce 30 so long as history of every previous period has been (30, 30); otherwise produce 40 in this and every subsequent period
- Punishment *triggered* by deviation

Cartel stability

- Expected profit from sticking to the agreement is:
  - $PV^M = 1800 + 1800R\rho + 1800R^2\rho^2 + \ldots = 1800/(1 - R\rho)$
- Expected profit from deviating from the agreement is
  - $PV^D = 2025 + 1600R\rho + 1600R^2\rho^2 + \ldots = 2025 + 1600R\rho/(1 - R\rho)$
- Sticking to the agreement is better if $PV^M > PV^D$
  - this requires $1800/(1 - R\rho) > 2025 + 1600R\rho/(1 - R\rho)$
  - or $R\rho > (2.025 – 1.8)/(2.025 – 1.6) = 0.529$
    - if $\rho = 1$ this requires that the discount rate is less than 89%
    - if $\rho = 0.6$ this requires that the discount rate is less than 14.4%

Cartel stability ?

- This is an example of a more ge
- Suppose that in each period
  - profits to a firm from a collusive a
  - profits from deviating from the agre
  - profits in the Nash equilibrium are π^N
  - we expect that π^D
- Cheating on the c   as:

$$R\rho > \frac{\pi^D - \pi^C}{\pi^D - \pi^N}$$

- The cartel is stable
  - if short-term gains from cheating are low relative to long-run losses
  - if cartel members value future profits (low discount rate)

There is always a value of R < 1 for which this equation is satisfied

This is the short-run gain

This is the long-run loss from cheating on the cartel

Trigger Strategy Issues

- With infinitely repeated games
  - cooperation is sustainable through self-interest
- But there are some caveats
  - examples assume speedy reaction to deviation
    - what if there is a delay in punishment?
      - trigger strategies will still work but the discount factor will have to be higher
  - harsh and unforgiving
    - particularly relevant if demand is uncertain
      - **decline in sales might be a result of a "bad draw" rather than cheating on agreed quotas**
      - **so need agreed bounds on variation within which there is no retaliation**
      - **or agree that punishment lasts for a finite period of time**

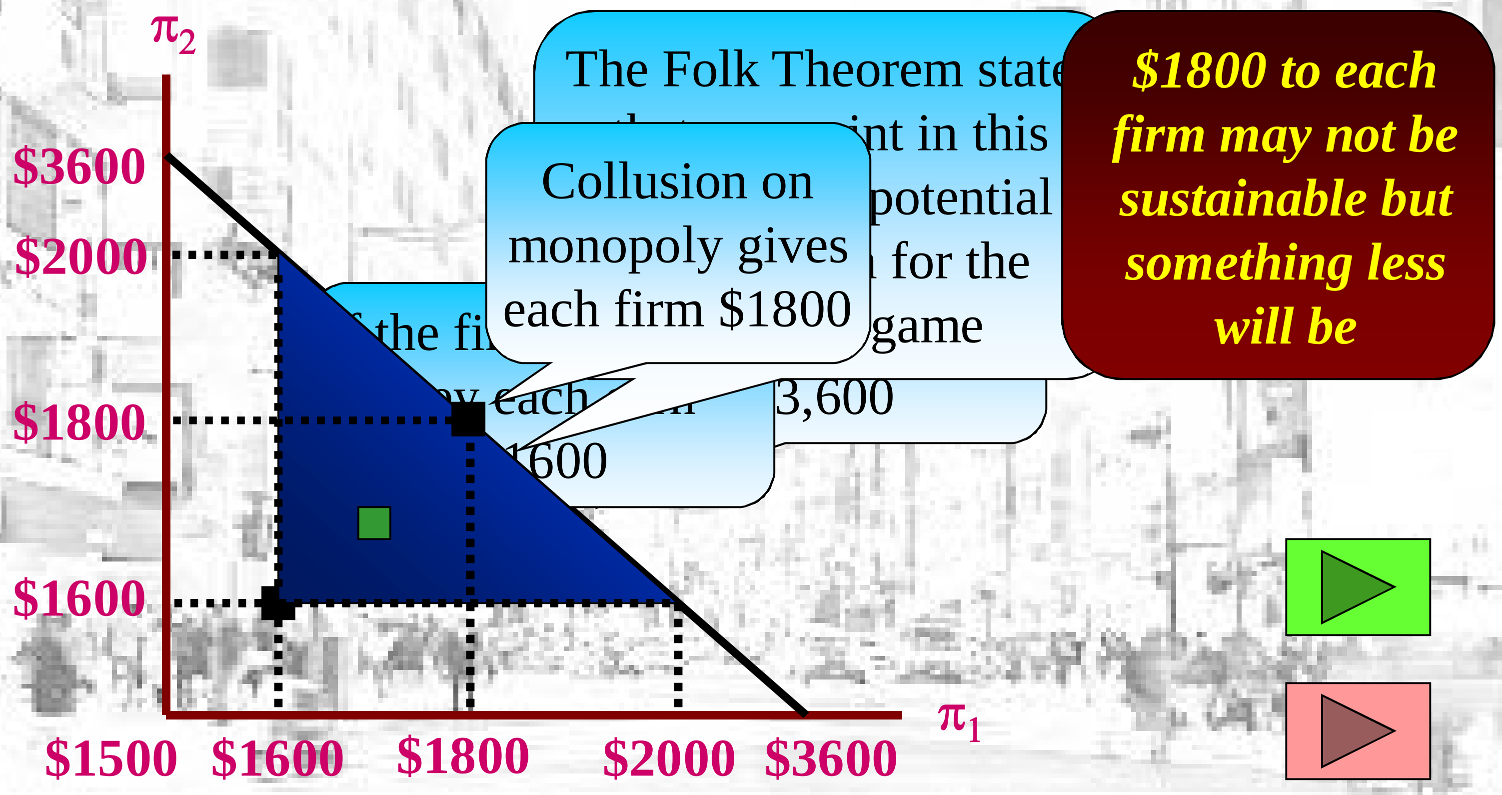
The Folk theorem

- Have assumed that cooperation is on the monopoly outcome
  - this need not be the case
  - there are many potential agreements that can be made and sustained – the Folk Theorem

Suppose that an infinitely repeated game has a set of pay-offs that exceed the one-shot Nash equilibrium pay-offs for each and every firm. Then any set of feasible pay-offs that are preferred by all firms to the Nash equilibrium pay-offs can be supported as subgame perfect equilibria for the repeated game for some discount factor sufficiently close to unity.

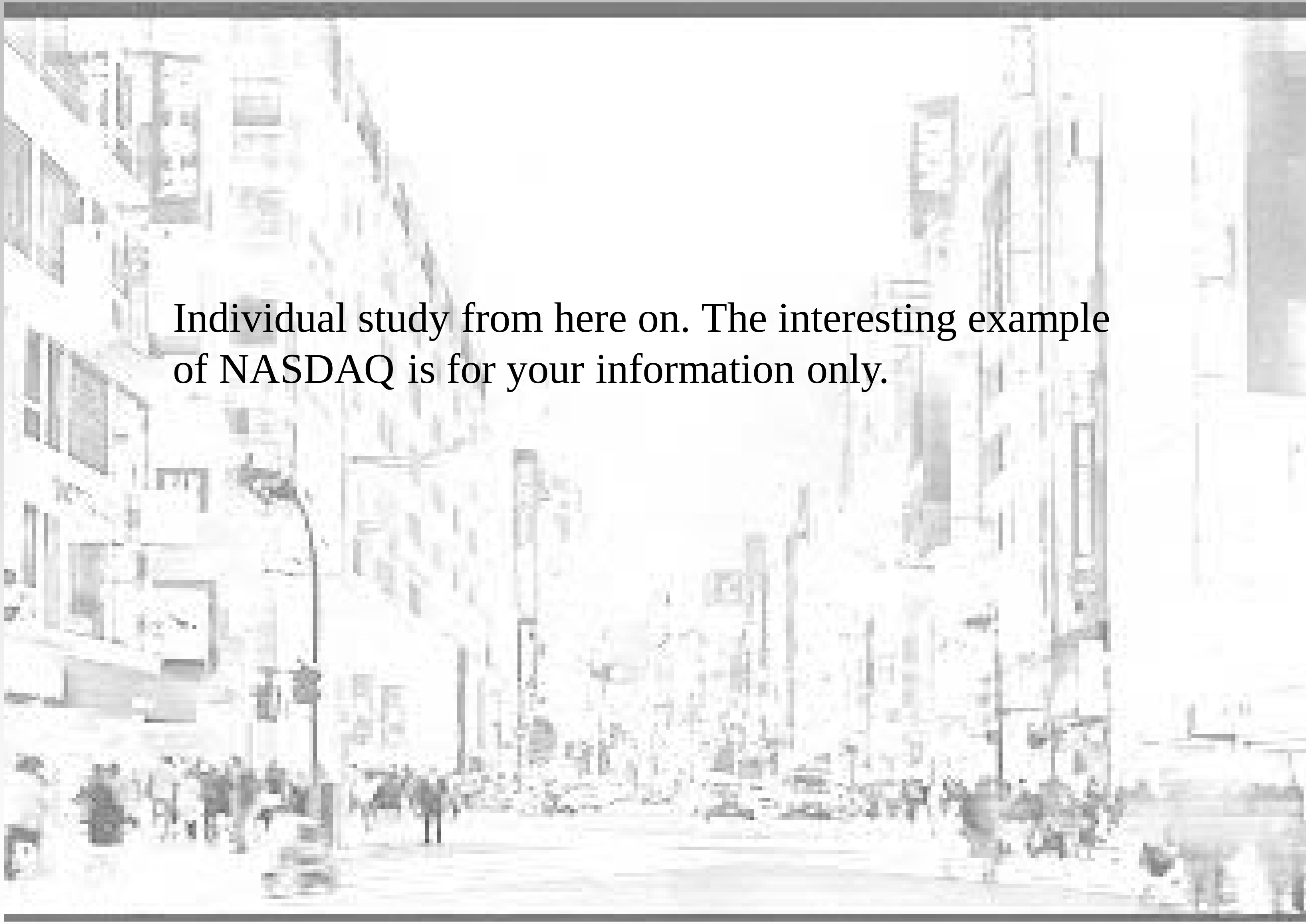
The Folk theorem 2

- Take example 1. The feasible pay-offs describe the following possibilities



Balancing temptation

- A collusive agreement must balance the temptation to cheat
- In some cases the monopoly outcome may not be sustainable
  - too strong a temptation to cheat
- But the folk theorem indicates that collusion is still feasible
  - there will be a collusive agreement:
    - that is better than competition
    - that is not subject to the temptation to cheat



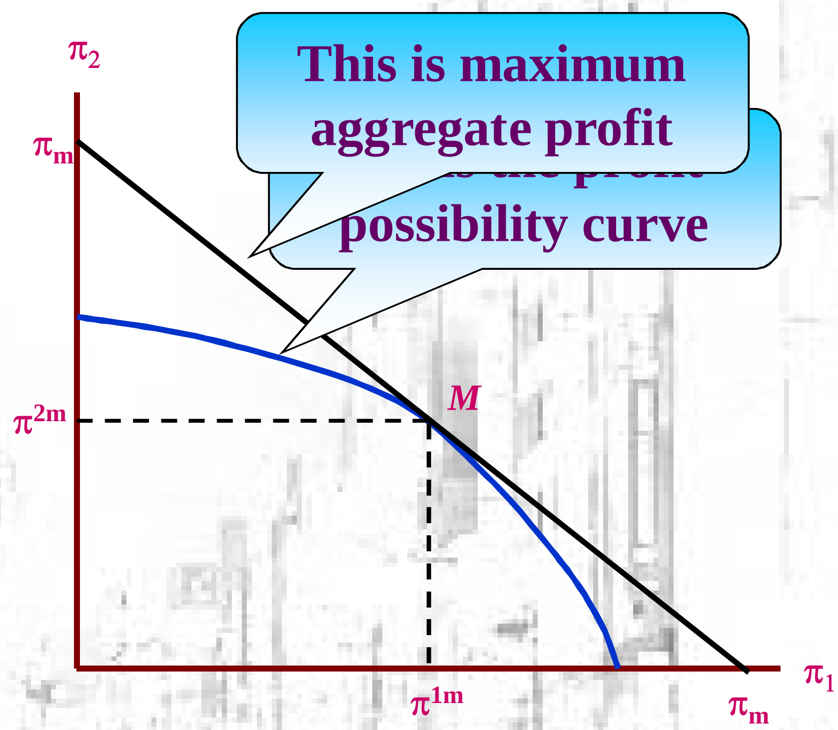
Individual study from here on. The interesting example of NASDAQ is for your information only.

Introduction

- Collusion is difficult to detect
  - no detailed information on costs
  - can only infer behavior
- Where is collusion most likely?
  - look at the cartel member's central problem
    - **cooperation is necessary to sustain the cartel**
    - **but on what should the firms cooperate?**
  - take an example
    - **duopolists with different costs**

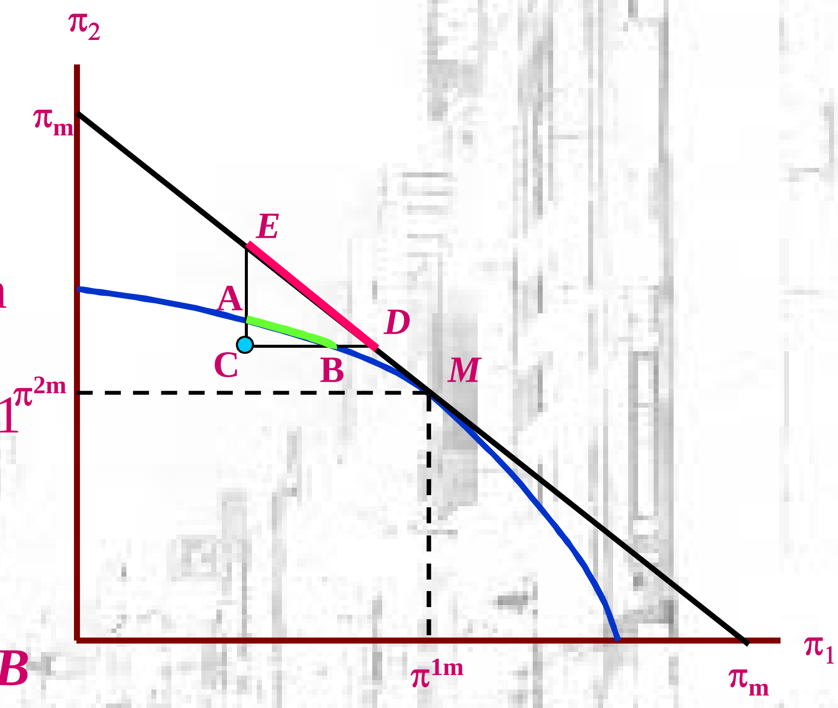
An Example of Collusion

- Suppose there are two firms with different costs
- ***Profit-possibility frontier*** describes maximum non-cooperative joint profit
- Point ***M*** is maximum joint profit
  - **π^{1m} to firm 1**
  - **π^{2m} to firm 2**
  - **π_m in total**



Example of Collusion 2

- Suppose that the Cournot equilibrium is at C
- Collusion at *M* is not feasible
  - firm 2 makes less than at ***C***
  - A side-payment from 1 to 2 makes collusion feasible on DE
- With no side-payment collusion confined to ***AB***



Market Features that Aid Collusion

- Potential for monopoly profit
  - demand relatively inelastic
  - ability to restrict entry
    - common marketing agency
      - ***persuade consumers of advantages of buying from agency members***
        - ***low search costs***
        - ***security***
    - trade association
      - ***control access to the market***
        - ***persuade consumers that buying from non-members is risky***
        - ***use marketing power***

Features Aiding Collusion 2

- Low costs of reaching a cooperative agreement
  - small number of firms in the market
    - lowers search, negotiation and monitoring costs
    - makes trigger strategies easier and speedier to implement
  - similar production costs
    - avoids problems of side payments
      - ***detailed negotiation***
      - ***misrepresentation of true costs***
  - lack of significant product differentiation
    - again simplifies negotiation – don't need to agree prices, quotas for every part of the product spectrum

Features Aiding Collusion 3

- Low cost of maintaining the agreement
  - use mechanisms to lower cost of detecting cheating
    - *basing-point pricing*
  - use mechanisms to lower cost of detecting cheating
    - ***most-favored customer clauses***
      - ***guarantees rebates if new customers are offered lower prices***
    - ***meet-the-competition clauses***
      - ***guarantee to meet any lower price***
      - ***removes temptation to cheat***
      - ***look at a simple example***

Meet-the-competition clause

- the one-shot Nash equilibrium is (Low, Low)
- meet-the-competition clause removes the off-diagonal entries
- now (High, High) is easier to sustain

		Firm 2	
		High Price	Low Price
Firm 1	High Price	12, 12	5, 14
	Low Price	14, 5	6, 6

Features Aiding Collusion 4

- Frequent market interaction
  - makes trigger strategy more effective
- Stable market conditions
  - makes detection of cheating easier
  - with uncertainty need a modified trigger strategy
    - punish only for a set period of time
    - punish only if sales/prices fall outside an agreed range

An Example: Collusion on NASDAQ

- NASDAQ is a very large market
- Traders typically quote two prices
  - “ask” price at which they will sell stock
  - “bid” price at which they will buy stock
    - ***at the time of the analysis prices quoted in eighths of a dollar***
    - ***prices determined by the “inside spread”***
      - ***lowest ask minus highest bid price***
  - profit on the “spread”
    - ***difference between the ask and the bid price***
  - competition should result in a narrow spread
    - ***but analysis seemed to indicate wider spreads***
      - ***inside spreads had high proportion of “even eighths”***

Collusion on NASDAQ 2

- Suggestion that this was evidence of collusion
  - NASDAQ dealers engaged in a repeated game
  - past and current quotes are public information to dealers
  - so dealers have an incentive to cooperate on wider spreads
- Look at an example

Collusion on NASDAQ 3

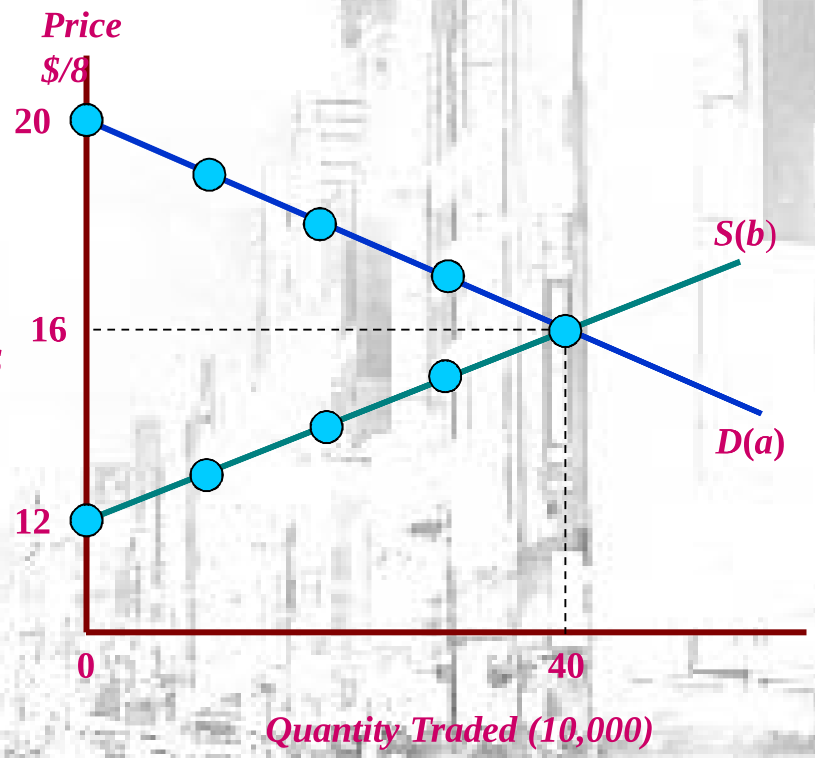
- Suppose that there are N dealers in a stock
  - dealer i has an ask price a_i and a bid price b_i
  - inside ask a is the minimum of the a_i
  - inside bid b is the maximum of the b_i
  - inside spread is $a - b$

Collusion on NASDAQ 4

- Since inside spread is *a – b*
  - **demand for shares of stock by those who want to purchase at price a is D(a)**
  - **supply of shares of stock by those who wish to sell at price b is S(b)**
  - **both measured in blocks of 10,000 shares**
  - **assume D(a) = 200 – 10a; S(b) = -120 + 10b**

Collusion on NASDAQ 5

- Two other assumptions
  - *1. dealers set bid and ask prices to equate demand and supply*
    - *do not buy for inventory*
  - *so 200 – 10a = -120 + 10b*
  - *which implies b = 32 – a*
  - *only (ask, bid) combinations that we need consider are [(20, 12), (19, 13), (18, 14), (17,15), (16, 16)]*
- *2. Dealer not quoting inside spread gets no business; others share orders equally*



Collusion on NASDAQ 6

- Value of this stock v defined as price that equates public demand and public supply
  - $v = 16$ (or \$2.00)
  - quantity of 400,000 would be traded
- Aggregate profit is
  - revenue from selling at more than v
  - revenue from buying at less than v
  - □ $\pi(a, b) = (a - v)D(a) + (v - b)S(b)$
  - Recall that $D(a) = S(b)$ so that $b = 32 - a$ so that
  - □ $\pi(a) = (a - b)(200 - 100a) = (2a - 32)(200 - 10a)$ **or**
  - □ $\pi(a) = 20(a - 16)(20 - a)$

Collusion on NASDAQ 7

- This gives the profits:

Is this sustainable or is there an incentive to defect and quote a lower ask and higher bid?

Ask Price a	*Bid Price b = 32 – a*		($'000)
20		0	0
19	13	10	75
18	14	20	100
17	15	30	75
16	16	40	0

Profit is maximized at an ask of 18 and bid of 14

Collusion on NASDAQ 8

- We have the pay-off matrix

		Norman Securities (ask, bid)		
		(18, 14)	(17, 15)	(16, 16)
All Other Market Makers (ask, bid)	(18, 14)	(100(N-1)/N; 100/N)	(0, 75)	(0, 0)
	(17, 15)	(75, 0)	(75(N – 1)/N; 75/N)	(0, 0)
	(16, 16)	(0, 0)	(0, 0)	(0, 0)

Collusion o…

We now have a prisoners' dilemma game

Is (18, 14) sustainable in an indefinitely repeated game?

Norma… …)

All Other Market Makers (ask, bid)	(18, 14)	(17, 15)
(18, 14)	(100(N-1)/N; 100/N)	(0, 75)
(17, 15)	(75, 0)	(75(N – 1)/N; 75/N)

Collusion on NASDAQ 10

Suppose that the probability of repetition from period to period is ρ and the discount factor is R

The pay-off to Norman from cooperation is:

$$PV_c = (1 + \rho R + \rho^2 R^2 + \ldots)100/N = 100/(N(1 - \rho R)$$

The pay-off to cheating with a trigger strategy is:

$$PV_d = 75 + (\rho R + \rho^2 R^2 + \ldots)75/N = 75 + 75\,\rho R\,/(N(1 - \rho R)$$

Cheating does not pay if: $pR = \rho > \dfrac{3N-4}{3N-3}$

Collusion on NASDAQ 11

- At the time of the original analysis there were on average 11 dealers per stock
  - with $N = 11$ we need $\rho R > 0.966$
  - with $N = 13$ we need $\rho R > 0.972$
  - collusion would seem to need a very high ρ and high R
    - ***but the time period between trades is probably less than an hour***
    - ***so ρ is approximately unity***
    - ***and the relevant interest-rate is a per-hour interest rate***
    - ***so in this setting ρR being at least 0.99 is not unreasonable***
- Collusion would indeed seem to be sustainable
- No collusion was actually admitted but corrections to trading procedures were agreed.

Antitrust Policy & Collusion

- Ideally, antitrust policy can act to deter cartel formation
- To do this, authorities must investigate/monitor industries and, when wrongdoing is found, prosecute and punish
  - However, the authorities can not monitor every market.
  - So, for any cartel, there is only a probability that it will be investigated and discovered
  - Assume: Probability of investigation is a;

    Probability of successful prosecution *given* investigation is s

    Punishment if successfully prosecuted if fine, F

Antitrust Policy & Collusion 2

- Combining our investigation and prosecution assumptions with our earlier model of collusion yields the following expected profit for each cartel member

$$V^C = \frac{\pi^M - asF + \dfrac{as\rho}{1-\rho}}{1 - \rho(1 - as)}$$

- In our earlier analysis $a = s = F = 0$. It is clear in examining the above equation that an increase in either the probability of investigation a, or in the probability of successful prosecution s, or in the punishment | fine F, will ***decrease*** expected cartel profits and so make cartel formation less likely

- MORAL: Policy against cartels works by deterring their formation in the first place and not perhaps so much as by breaking them up once they happen

Antitrust Policy & Collusion 3

- Which tool the authorities should rely most on— ***a***, ***s***, or ***F***— depends on a number of factors.
- Even a small fine may do the trick if the probability of detection and prosecution ***as*** is high enough.
- However, monitoring, investigating, and prosecuting are expensive whereas fines are relatively costless to impose. This suggests that optimal policy will cut back on expensive detection efforts and balance this by imposing heavy fines for those cartels that are detected.

Cartel Detection

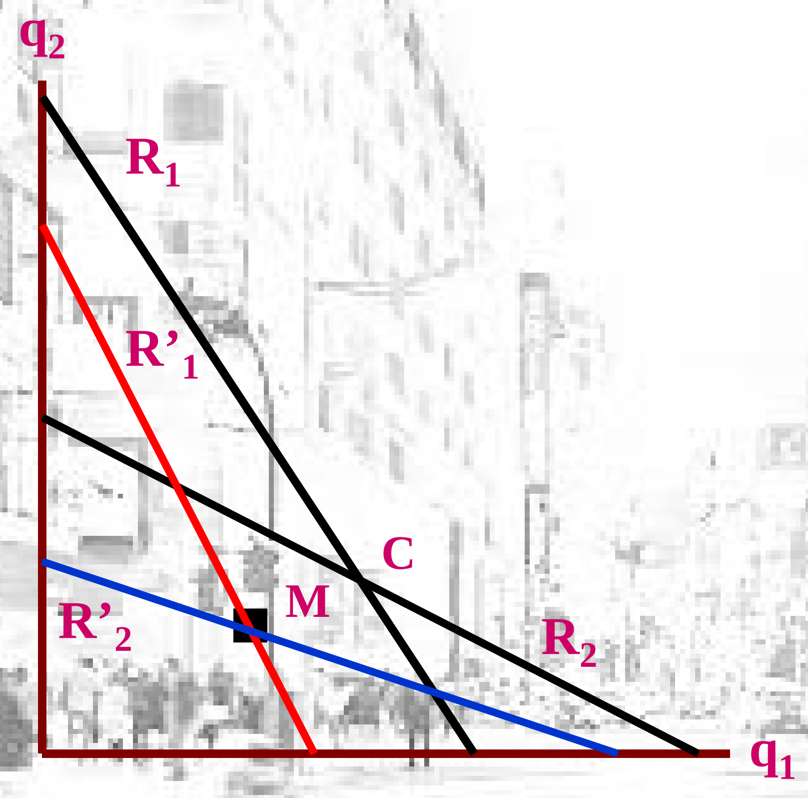
- Cartel detection is far from simple
  - most have been discovered by "finking"
  - even with NASDAQ telephone tapping was necessary
- If members of a cartel are sophisticated they can hide the cartel: make it appear competitive

Cartel Detection 2

- ***"the indistinguishability theorem"*** (Harstad and Phlips 1991)
  - ICI/Solvay soda ash case
    - **accused of market sharing in Europe**
    - **no market interpenetration despite price differentials**
    - **defense: price differentials survive because of high transport costs**
    - **soda ash has rarely been transported so no data on transport costs are available**
- The Cournot model illustrates this "theorem"

Cartel Detection 2

Indistinguishability Theorem



- start with a standard Cournot model: C is the non-cooperative equilibrium
- assume that the firms are colluding at M: restricting output
- M can be presented as non-collusive if the firms exaggerate their costs or underestimate demand
- this gives the apparent best response functions R'_1 and R'_2
- M now "looks like" the non-cooperative equilibrium

Cartel detection 3

- Cartels have been detected in procurement auctions
  – bidding on public projects; exploration
  – the electrical conspiracy using "phases of the moon"
    - those scheduled to lose tended to submit identical bids
    - but they could randomize on losing bids!
- Suggested that losing bids tend not to reflect costs
  – correlate losing bids with costs!
- Is there a way to beat the indistinguishability theorem?
  – Osborne and Pitchik suggest one test

Cartel Detection 4

- Suppose that two firms
  - compete on price but have capacity constraints
  - choose capacities before they form a cartel
- Then they anticipate competition after capacity choice
  - collusive agreement will leave the firms with excess capacity
  - uncoordinated capacity choices are unlikely to be equal
    - ***one firms or the other will overestimate demand***
  - so both firms have excess capacity but one has more excess

Cartel Detection 5

- So, firms enter into collusive agreement with different amounts of spare capacity
- If so, collusion between the firms then leads to:
  – firm with the smaller capacity making higher profit per unit of capacity
  – this unit profit difference increases when joint capacity increases relative to market demand

An example: the salt duopoly

Brit[illegible] t were suspected of operating a cartel

BS is the smaller firm and makes more profit per unit of capacity

	1980	1981	1982	1983	1984
BS Profit	7065	7622	10489	1015[illegible]	[illegible]
WP Profit	7273	7527	6841	629[illegible]	[illegible]
BS profit per unit of capacity	8.6	9.3	12.7	12.3	13.2
WP profit per unit of capacity	6.6	6.9	6.3	5.8	5.7
Total Capacity/Total Sales	1.5	1.7	1.7	1.9	1.9

The profit difference grows with capacity

BS capacity: 824 kilotons; WP capacity: 1095 kilotons

But will this test be successful if it is widely known and applied?

Basing Point Pricing

Birmingham Steel Company

Antitrust Policy: Leniency/Amnesty

- Play the cartel members against each other by offering amnesty or leniency to the firm that provides evidence to indict the others
- However, the possibility of avoiding penalties increases the ex-ante value of joining a cartel
- May lead to the formation of more cartels even as more a caught and prosecuted

Evidence on Leniency

- Only real world data is on cartels that were caught, which is not a random sample
- Hinloopen and Soetevent (2006) test leniency programs in a laboratory experiment
- They found that leniency
  - Made cartel formation more difficult
  - Made defection more likely
  - Made defecting firms defect more
- All of which worked to lower prices