Collusion and Cartels

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Defining Collusion:

A secret agreement between two or more parties for a fraudulent, illegal, or deceitful purpose. These are “cooperative” outcomes in the sense that firms agree to act together.

Why do firms want to achieve a cooperative outcome?

They earn higher profits!

Some famous recent examples of collusion
(we’ll see more when we cover antitrust issues):

Lysine (mid-1990’s)

From Wikipedia:

The lysine price-fixing conspiracy was an organized effort during the mid-1990s to raise the price of the animal feed additive lysine. It involved five companies that had commercialized high-tech fermentation technologies, including American company Archer Daniels Midland (ADM), Japanese companies Ajinomoto and Kyowa Hakko Kogyo, and Korean companies Sewon America Inc. and Cheil Jedang Ltd. A criminal investigation resulted in fines and three-year prison sentences for three executives of ADM who colluded with the other companies to fix prices. The foreign companies settled with the United States Department of Justice Antitrust Division in September through December 1996. Each firm and four executives from the Asian firms pled guilty as part of a plea bargain to aid in further investigation against ADM. The cartel had been able to raise lysine prices 70% within their first nine months of cooperation.

The investigation yielded $105 million in criminal fines, a record antitrust penalty at the time, including a $70 million fine against ADM. ADM was fined an additional $30 million for its participation in a separate conspiracy in the citric acid market and paid a total fine of $100 million. Three former high-ranking ADM executives were convicted in September 1998 after a ten-week jury trial. Buyers of lysine in the United States and Canada sued and recovered $80 to $100 million in damages from the five cartel members, and ADM paid $38 million to settle mismanagement suits by its shareholders.

The lysine cartel was the first successful prosecution of an international cartel by the U.S. Department of Justice in more than 40 years. Since then, the DoJ has discovered and prosecuted scores of international cartels.

Matt Damon Movie: The Informant

`http://www.imdb.com/video/imdb/vi2750218777/`

Vitamins Inc. (also mid-1990's)

From a NY Times article (October 10, 1999):

The scope of the conspiracy boggles the mind. For a full decade, top executives at some of the world's largest drug companies met secretly in hotel suites and at conferences. When Federal investigators were closing in, they moved to the homes of high-level European executives.

Working together in a coalition they brazenly called “Vitamins Inc.,” they carved up world markets and carefully orchestrated price increases, in the process defrauding some of the world's biggest food companies, including Kellogg, Coca-Cola and Nestle.

It was, in the words of Joel I. Klein, head of the Justice Department's antitrust division, “the most pervasive and harmful criminal antitrust conspiracy ever uncovered.”

In May, after the conspiracy collapsed, those involved agreed to pay nearly $1 billion to settle Federal antitrust charges, by far the largest criminal fines in American history. And further penalties could come in Europe and elsewhere. The companies involved have pleaded guilty to the Government's charges, but they have refused to discuss details of the case beyond what the authorities originally charged.

A Collusion Example

Let's play a game:

- I'm auctioning off $ 40.
- Write a bid (your payoff is thus 40-bid) on a piece of paper.
- Can't go over $40.00 (Duke policy prohibits me from harvesting money from students).
- Highest unique bid wins (if two people bid 35, the person who bids 34 wins).
- Talk as much as you want with each other.
- I will secretly send the payment, but announce it in class.

Self-enforcing Collusion:

Non-cooperative strategies that achieve cooperative results.

We extend the basic static Cournot game to an infinitely-repeated game.

Firms stand to gain the difference between the static Cournot outcome and the monopoly outcome (in total). Thus, we should be able to make each firm at least as well off under collusion as we can under non-cooperative Nash-in-quantities strategies in a one-shot game.

When we move to infinitely-repeated games, we find that collusive output levels constitute a subgame perfect equilibrium.

Steps:

1. non-cooperative (static Nash-in-quantities) strategies

2. collusive (cooperative) monopoly equilibrium

3. incentives to deviate from the cooperative outcome

Ex: One-shot game with

$$p = 1 - q_1 - q_2$$

1. find the best-response function and equilibrium profits for non-cooperative static Cournot. These are:

$$q_1(q_2) = \frac{(1 - q_2)}{2}$$

$$q_1 = q_2 = \frac{1}{3}$$

$$Q = \frac{2}{3}$$

$$p = \frac{1}{3}$$

$$\pi_i = \frac{1}{9}$$

2. find the best outcome under cooperative behavior. This will mean splitting the profits that result if we act like a monopolist.

Note that we have assumed: CRS, identical costs (= 0). In this case,

$$q_1 = q_2 = \frac{1}{4}$$

$$Q = \frac{1}{2}$$

$$p = \frac{1}{2}$$

$$\pi_i = \frac{1}{8}$$

(remember they split market shares 50-50).

3. Check deviations from the cooperative outcome
(Is it a Nash equilibrium?)

In the one-shot game, we should always deviate from the cooperative solution. (Just like the prisoner's dilemna.)

Look at F.O.C.:

Firm 1 plays collusive (cooperative) strategy ($q_1 = \frac{1}{4}$).
F.O.C. for firm 2 is:

$$\max \pi_2 \rightarrow (1 - \frac{1}{4} - q_2)q_2 = 0$$

This has solution $q_2^* = \frac{3}{8}$.

Firm 2 receives profits $\pi_2 = \frac{3}{8}^2 \approx 0.14$ given prices are
$p = 1 - q_1 - q_2 = 1 - \frac{1}{4} - \frac{3}{8} = \frac{3}{8}$.

Two-Period Game

Firms will play for two periods.

- Period 1: Firms Compete in Quantities. Receive π^1.
- Period 2: Firms Compete in Quantities. Receive π^2.

Suppose I have the strategy "I will play $q = 1$ (keep your profits at zero) in the second period, if you don't play Monopoly in the first period." Will this work to sustain collusion?

- Collude:
  Payoffs are:
  $$\frac{1}{8} + \frac{1}{8} = \frac{1}{4} = 0.25$$
- Defect in Period 1, Revert to being punished by Cournot Eqm in period 2:
  $$\frac{9}{64} + 0 = \frac{9}{64} \approx 0.14$$

So I choose to cooperate with monopoly in the two periods, if, if I believe my opponents strategy.

Is Punishment in Period 2 Credible?

- In period 2, will I actually want to produce q_1?

- Moreover, would I play $q_1 = \frac{1}{4}$ in period 2, if we cooperate in period 1.

Infinitely Repeated Games (Supergames)

What happens when both firms live forever?

We need a discount factor (Tirole calls this δ).

Maximize discounted profits:

$$\Pi_i = \sum_{t=1}^{\infty} \delta^{t-1} \pi_i^t$$

And adopt "trigger strategies". These say that in each period, I play cooperative as long as all players have always cooperated in the past. However, as soon as any player deviates in any period, I play noncooperative strategy forever. (Sometimes called 'grim' punishment.)

When is this strategy a subgame perfect equilibrium?

Tirole goes through the proof for this. The answer is: a trigger strategy is a subgame perfect equilibrium if δ is sufficiently large. I.e., we have to care about the future “enough.” Otherwise, punishing in the future does not deter us from cheating today.

Result: with infinitely-repeated games, we get more equilibria!

Bertand Model

Suppose that we have a Bertrand Game with N competitors, with monopoly profits of π^M.
Trigger Strategies:

- Cooperate: Receive $\frac{\pi^M}{N}$ each period, forever.

$$
\begin{aligned}
&\frac{\pi^M}{N} + \delta \frac{\pi^M}{N} + \delta^2 \frac{\pi^M}{N} + \cdots \\
=&\frac{\pi^M}{N} \frac{1}{1-\delta}
\end{aligned}
$$

  (geometric series, remember...)

- Defect: Undercut p^M by a penny, and get the entire market. Receive π^M, then zero forever.

$$
\begin{aligned}
&\pi^M + \delta 0 + \delta^2 0 + \cdots \\
=&\pi^M
\end{aligned}
$$

When can we sustain cooperation?

$$\frac{\pi^M}{N}\frac{1}{1-\delta} \text{ vs. } \pi^M$$

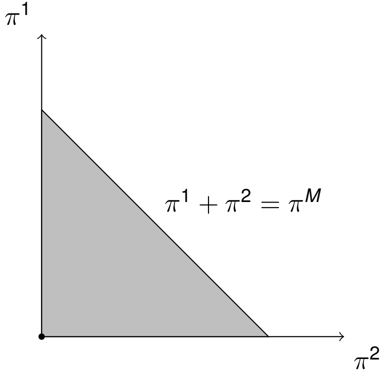
which happens when:

$$(1-\delta) > N$$

So, for instance, given $\delta = 0.5$, we can never sustain collusion at monopoly level using these trigger strategies...

Folk Theorem

A general theorem, the so-called "Folk" Theorem, is that any set of payoffs π^1 and π^2, such that $\pi^1 + \pi^2 \leq \pi^M$, can be sustained in an infinitely repeated game as $\delta \to \infty$.



Asymettric Costs

- Remember Stephen's discussion of Quebec gas retailers. These had different marginal costs, either due to owning a refinery, or having an onsite convenience store.
- Suppose two firms, marginal costs $\bar{c}$ and $\underline{c}$, where $\bar{c} < \underline{c}$.
- What it the condition to keep each firm inside the collusive agreement? (the so-called "Incentive Compatibility" Condition in Mechanism Design)
  - High Cost ($\bar{c}$):

$$(p^M - \bar{c})\frac{q^M}{2}\frac{1}{1-\delta} \geq (p^M - \bar{c})q^M$$

  - Low Cost ($\underline{c}$):

$$(p^M - \underline{c})\frac{q^M}{2}\frac{1}{1-\delta} \geq (p^M - \underline{c})q^M + (\bar{c} - \underline{c})Q(\bar{c})\frac{1}{1-\delta}$$

Asymettric Costs: Ctd.

- What is $(\bar{c} - \underline{c})Q(\bar{c})\frac{1}{1-\delta}$, Bertrand with a lower cost than my rival, forever.
- Which Incentive constraint is harder to satisfy? The incentive constraint for the low cost retailer.
- What can we do?
- Perhaps give the low cost retailer more market share, say instead of 50-50, 70-30. The IC conditions would become:
  - High Cost ($\bar{c}$):

$$(p^M - \bar{c})q^M \times 0.30\frac{1}{1-\delta} \geq (p^M - \bar{c})q^M$$

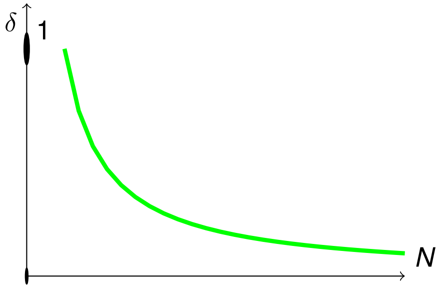
  - Low Cost ($\underline{c}$):

$$(p^M - \underline{c})q^M \times 0.70\frac{1}{1-\delta} \geq (p^M - \underline{c})q^M + (\bar{c} - \underline{c})Q(\bar{c})\frac{1}{1-\delta}$$

Concentration and Possibility of Collusion

- What is the relationship between collusion and the number of firms? Notice we need:

$$(1 - \delta) \geq N$$



Information Lags, Infrequent Interaction

- What about the effect of frequent versus infrequent interaction?
- Think of δ as the number of periods that you can earn profits before other firms can respond.
- Higher likelihood of collusion when information is quickly disseminated, or when orders flow in regularly.
- The question of detecting defection in a cartel is the task of Green and Porter (1983).

Additional Factors

Two more issues may affect these results.

1. Entry. If firms enter, what happens to our ability to collude? (There is on-going research on this.) A basic result is that if firms enter faster than demand increases, it's harder to sustain collusion. Why? Future payoffs are smaller.
2. Exogenous shocks to demand. If demand is stochastic, we can have situations where the firms cannot tell whether one player cheated, or demand went down. (Green and Porter Model) We can also have business cycle effects. When demand is growing (before a boom) it's easy to sustain collusion. When demand is falling (beginning of a recession) it's hard. (Rotemberg and Saloner Paper)

Collusion with hidden demand:

- One of the funny aspects of the collusion models we've seen is that there is never any use of the "grim trigger". Firms always collude if the discount parameter is high enough, or they don't. We never see defection and punishment.
- We often see long periods of cooperation interrupted by price wars.
  - 1955 Price War in Cars: 5 percent drop in pricing of cars, 55 percent increase in sales.
  - Joint Executive Cartel: Railroad cartel for Chicago to New York railroad routes: price wars interrupted by by high prices.
- Suppose we can't see demand exactly: we can't tell who has cheated, or if cheating has happening at all: we might have a problem of detecting defections in collusion.
- Notice that these price wars are a "smoking gun" for looking for evidence of collusion: don't happen in competitive markets.

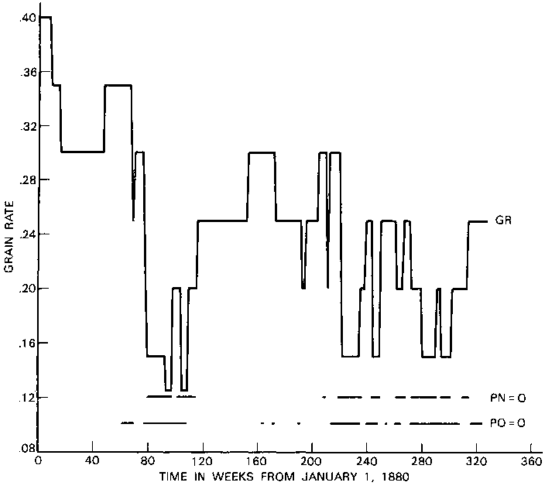
Joint Executive Cartel

- Active in the 1880's.
- Cartel controls shipments by rail from Chicago to the Atlantic Seaboard.
- Most of the shipments are grain.
- Notice that competition comes from the Great Lakes: these are shutdown during the winter.
- Records of meetings between cartel members: used a trigger strategy to punish deviations from the Cartel.
- Entry of new railroads in 1880 and 1886: accommodated into the cartel.

Joint Executive Cartel Ctd.

FIGURE 1

PLOT OF GR, PO, PN AS A FUNCTION OF TIME



Model with Hidden Demand

- Bertrand Competition.
- Demand Process (Low and High Demand States):

$$D^*(p) = \begin{cases} D(p) & \text{with probability } \alpha \\ 0 & \text{with probability } 1-\alpha \end{cases}$$

- Monopoly price p^M, and profits π^M.
- Suppose I don't sell anything:
  - My opponent cheated and the demand state is high.
  - The demand state is low.
- There is signal extraction problem.

Punishment and Accommodation

- Suppose I use the “Grim Trigger”: if I sell $q = 0$ at p^M, I assume that my cartel partner has defected, and in the punishment phase, set $p = 0$ forever.
- Then with probability α each period, I will enter the punishment phase, and remain there forever. So collusion unravels for sure.
- An issue here is that having a punishment phase, $T = \infty$, the number of periods that I punish for, is too much. My cartel-mates will stay in line with a T that is much smaller.

Incentive Constraint

- Suppose I use a "Forgiving Trigger": if I sell $q = 0$ at p^M, I assume that my cartel partner has defected, and in the punishment phase, set $p = 0$ for T periods, before reverting to p^M (cooperation phase).
- The incentive constraint for my partner has to do with the value of staying in the cartel versus defecting.
- Value of being in the cartel (net present value): V^+ (collusive phase), and V^- (punishment phase). Need the difference to be large enough to keep defections from happening.

Value Function

- V^+ collusive phase:

$$V^+ = \underbrace{(1-\alpha)(\frac{\pi^M}{2} + \delta V^+)}_{\text{High Demand}} + \underbrace{\alpha(\delta V^-)}_{\text{Low Demand}} \tag{1}$$

- V^- punishment phase:

$$V^- = \delta^T V^+ \tag{2}$$

- Keeping firms from colluding:

$$V^+ \geq (1-\alpha)(\underbrace{\pi^M}_{\text{One Period of Defection}} + \underbrace{\delta V^-}_{\text{Punishement}}) + \alpha(\delta V^-)$$

- Let's put this stuff together

$$(1-\alpha)(\frac{\pi^M}{2}+\delta V^+)+\alpha(\delta V^-)\geq(1-\alpha)(\pi^M+\delta V^-)+\alpha(\delta V^-)$$
$$\rightarrow\frac{\pi^M}{2}+\delta V^+\geq\pi^M+\delta V^-$$
$$\delta(V^+-V^-)\geq\frac{\pi^M}{2}$$

- Rexpress the value function:

$$V^+ =(1-\alpha)(\frac{\pi^M}{2}+\delta V^+)+\alpha(\delta V^-)$$
$$V^+ =(1-\alpha)(\frac{\pi^M}{2}+\delta V^+)+\alpha(\delta^{T+1}V^+)$$
$$(1-(1-\alpha)\delta+\alpha\delta^{T+1})V^+=(1-\alpha)(\frac{\pi^M}{2})$$
$$V^+=\frac{(1-\alpha)}{(1-(1-\alpha)\delta+\alpha\delta^{T+1})}\frac{\pi^M}{2}$$

- Now let's look at the defection constraint (IC Condition):

$$\delta(V^{+} - V^{-}) \geq \frac{\pi^{M}}{2}$$
$$2(1-\alpha)\delta + (2\alpha - 1)\delta^{T+1} \geq 1$$

- Now, we find the smallest T, smallest punishment phase, that keeps this IC Condition holding, since this will maximize the profits of the firms in this industry. What the smallest T? Because lower T means a higher value V^{+} from collusion.
- Example: $\alpha = 0.1$ and $\delta = 0.8$. Let's see this:

$$1 = 2 \times 0.90 \times 0.80 + (0.2 - 1)0.8^{T+1}$$
$$-0.44 = -0.8 \times 0.8^{T+1}$$
$$log(0.44) - log(0.8) = (T+1)log(0.8)$$
$$T = 1.69$$

So the punishment phase is for 2 periods.

What would happen under Cournot Competition Instead?

- What are profits from collusion: $\frac{\pi^M}{2}$?
- What are profits from defection: π^M?
- What are profits from punishment phase?
- What is V^+?
- What is V^-?
- What is the IC Condition.

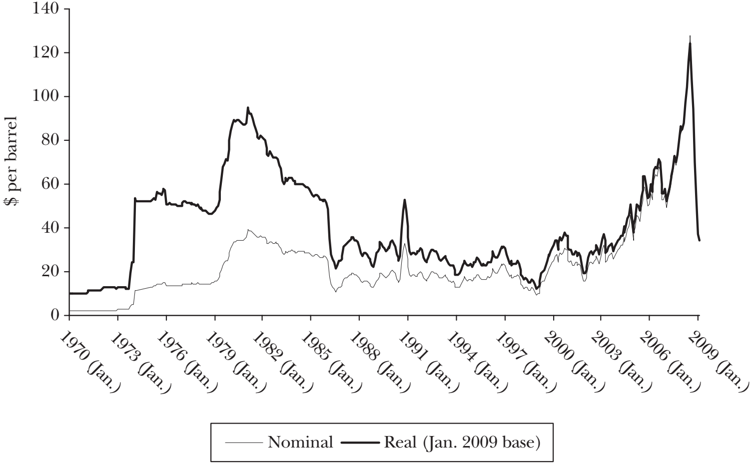
Outline

OPEC Cartel: Outline

1. Background and History of OPEC.
2. How OPEC is organized.
3. Monopolization.
4. Carbon Externalities and Cartel Effect.
5. Cartel Effect on Efficiency: Allocation of Market Shares.

Oil Prices

Figure 1
Historical Crude Oil Price Movements



Source: U.S. Energy Information Administration,
⟨http://tonto.eia.doe.gov/country/timeline/oil_chronology.cfm⟩.
Note: Prices shown are for Saudi light crude oil from 1970–74 and are U.S. refiner acquisition cost of imported crude oil thereafter.

Oil Industry

- Oil is about 13 percent of commodity trade. Large Global Market.
- Very Inelastic Demand -0.3 in the long-run, -0.1 in the short run. Hard to replace fuel consuming equipment: think of changing the car fleet to more efficient vehicles.
- Very Inelastic Supply: 0.3 in the long-run, about 0.05 in the short-run. Oil exploration and drilling takes a long time to set up.
- Very different marginal costs of supply, going from about $ 10 a barrel in Saudi Arabia, to over $100 in the Alberta Tar Sands.
- Basically a Global Market for Oil, and many different products (Kerosene to Diesel), that are tightly linked in terms of prices.

Oil Industry: Demand Shock

- Suppose that there is a 5 percent drop in world production: Libya goes offline.
- Effect on prices:
  - Elasticity of demand and supply in the short run is $0.05 + 0.10 = 0.15$.
  - So the change in prices is:

$$
\begin{aligned}
\frac{\%\Delta Q}{\%\Delta P} &= 0.15 \\
\%\Delta Q &= 0.15\%\Delta P \\
10 &= 0.15\%\Delta P \\
\%\Delta P &= 66
\end{aligned}
$$

- Now you see the enormous incentive to withhold production off the market.

Oil Producing Countries

Table 1

Twenty Largest Oil Companies, Ranked by Production, 2007

Rank	*Company*	*Country*	*State ownership (%)*	*Production (thousand barrels/day)*	*Proved reserves (million barrels)*
1	**Saudi Aramco**	**Saudi Arabia**	100	10,413	264,200
2	**NIOC**	**Iran**	100	4,401	138,400
3	Pemex	Mexico	100	3,474	12,187
4	CNPC	China	100	2,764	22,447
5	Exxon Mobil	US		2,616	11,074
6	**KPC**	**Kuwait**	100	2,600	101,500
7	**PDV**	**Venezuela**	100	2,570	99,377
8	BP	UK		2,414	10,073
9	**INOC**	**Iraq**	100	2,145	115,000
10	Rosneft	Russia	75.16	2,027	17,513
11	Petrobras	Brazil	32.2	1,918	9,581
12	Shell	UK/Netherlands		1,899	4,887
13	**Sonatrach**	**Algeria**	100	1,860	11,400
14	Chevron	US		1,783	7,523
15	ConocoPhillips	US		1,644	6,541
16	**Adnoc**	**UAE**	100	1,574	52,800
17	Lukoil	Russia		1,552	12,572
18	Total	France		1,509	5,778
19	**NNPC**	**Nigeria**	100	1,414	21,700
20	**Libya NOC**	**Libya**	100	1,368	30,700

Source: Petroleum Intelligence Weekly, December 4, 2008.
Note: Affiliates of OPEC members appear in bold type. The "proved reserves" shown in the final column of the table refers to that portion of known oil deposits that can be economically extracted at prevailing prices using available technology. Most of the oil in any given deposit will never be produced and therefore does not count as proved reserves because it would be too costly to effect complete recovery.

Oil Producing Countries Ctd.

	Marginal Production Cost	
Russia	Arctic	120
Russia	Onshore	18
Europe	Biodiesel	110
Europe	Ethanol	103
Canada	Sand	90
Brazil	Ethanol	66
Brazil	Offshore	80
United States	Deep-water	57
United States	Shale	73
Angola	Offshore	40
Ecuador	Total	20
Venezuela	Total	20
Kazakhstan	Total	16
Nigeria	Deep-water	30
Nigeria	Onshore	15
Oman	Total	15
Qatar	Total	15
Iran	Total	15
Algeria	Total	15
United Arab Emirates	Total	7
Iraq	Total	6
Saudi Arabia	Onshore	3

Oil Industry: Marginal Costs

- Notice the large differences in marginal costs between producers.
- As well, certain countries have large shares of the global oil market: Saudi Arabia, Iran, Iraq and so on.
- OPEC Members versus Non-OPEC members: why are their reserves (proven) so different?
- Nine out of ten of the U.S. recessions since World War II were preceded by a spike up in oil prices.

OPEC: Structure and History

- 1960's: Marketing Agency for Oil Producing Countries.
- 1971-1974: OPEC learns how restrict oil production.
- 1974-Present: Monitoring prices through production quotas for Cartel Members. Also surveillance of investment among cartel members: $\rightarrow$ remember the contrast between pricing and capacity investment in talking about the distinction between Cournot and Bertrand Competition.
- Cartel Members:
  Iran, Iraq, Kuwait, Saudi Arabia, Venezuela, Qatar, Libya, the United Arab Emirates, Algeria, Nigeria, Ecuador, Angola.
- Importantly, these Cartel Members control most of the marginal; i.e. quickly changeable production, for oil, since they hold back on production.
- Low Investment Budgets: about $40 billon a year, versus about $75 billion a year for private western companies (which have much lower production).

OPEC: How it works.

- Regular Meetings of Cartel Members.
- Cartel Members Allocated Production Quotas (how are these allocated).
- No monetary transfers between members (imagine Iraq paying Iran to withhold production for instance).
- Saudi Arabia and U.A.E. are by far the largest members.
- Hard to separate out changes in prices due to defecting cartel members, changes in production of non-cartel members, and changes in demand (China's demand spikes).
- Not a clear punishment mechanism, other than cartel members defecting from their quota allocation.

OPEC: Asymmetries

- Large Differences in Marginal Cost.
- Differences in Global Market Share, compare Saudi Arabia versus Ecuador.
- Differences in how “Budget Constrained” Different Countries are: think of Venezuala versus U.A.E.’s.
- Will the Cartel hold if I pull out?
- Let’s look at the FOC for country i, incentive to defect from quota (holding Cartel Fixed):

$$\frac{\partial \pi_i}{\partial Q_i} = \underbrace{P_i(\bar{Q}) - c_i}_{\text{Markup}} + \underbrace{\frac{\partial P}{\partial Q} s_i \bar{Q}}_{\text{Effect on Global Price}}$$

  where s_i is the market share, and $\bar{Q}$ is total world production.
- Small Members of OPEC defect all the time.
  DEFECTION CONSTRAINT

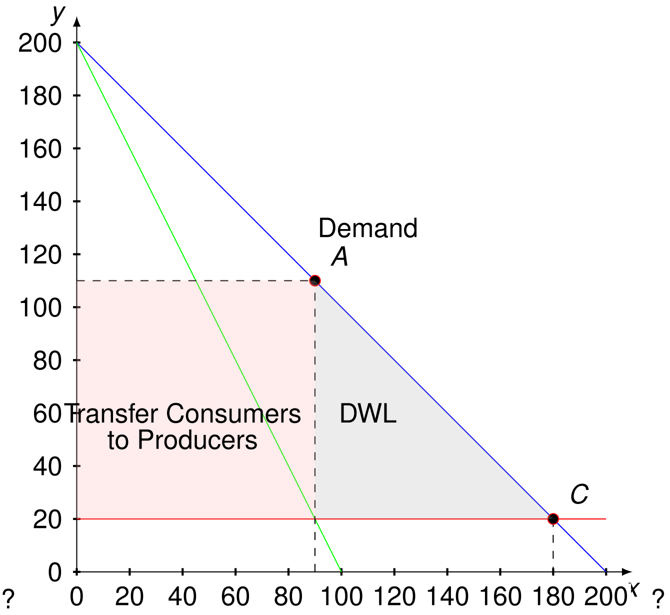
Big Effects of OPEC

1. Higher Prices for Oil.
2. High Profits for OPEC Members.
3. OPEC and Climate Change.
4. Productive Efficiency of OPEC.

High Price of Oil

- Suppose the demand curve for oil is $Q = 200 - P$.
- Marginal Cost is MC=$ 20.
- What is the effect of the cartel?

High Price of Oil



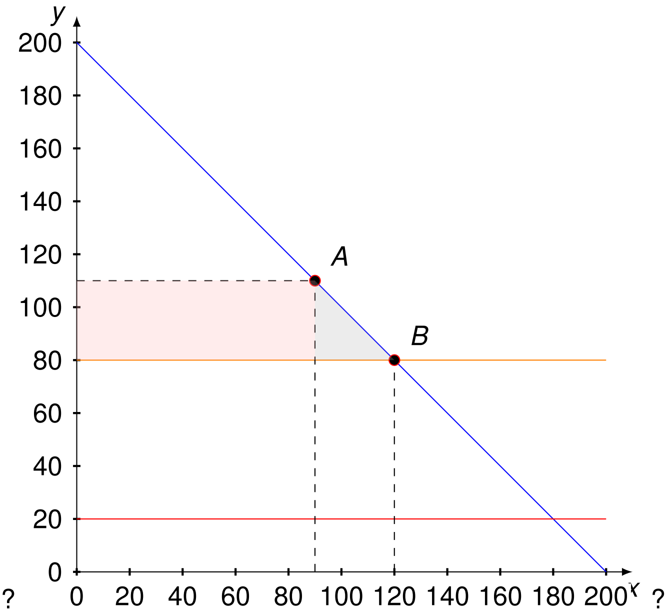
Political Economy of OPEC

- Large Transfers to Oil Producing Countries.
- What do we think about this?
  - Generally Oil Exporters are poorer.
  - Poorly Managed, Norway being the exception.

Climate Change and OPEC

- Suppose that there is a Marginal External Cost of Oil of $ 60 Per Barrel.
- What is socially optimal production?
- Marginal Social Cost: $MSC = MC + MEC = 20 + 60 = 80$.
- Socially efficient production at $Q = 120$ instead of $Q = 200$.
- Notice that you can't worry about the effect of OPEC on prices, and think that we need a Carbon Tax on Oil at the same time...

Climate Change and OPEC



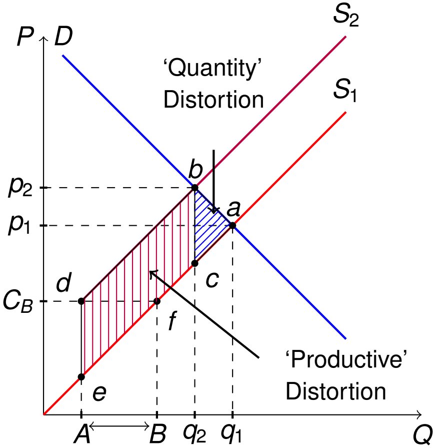
Productive Efficiency Effects of OPEC

- Notice that the main effect of prices is a little ambiguous.
- What about the distortion on production?

Productive Efficiency Effects of OPEC

- Notice that the main effect of prices is a little ambiguous.
- What about the distortion on production?
- Say the average cost is $ 70 per barrel, but Saudi Arabia could produce for the world market for $ 20 per barrel: what is the cost side effect here?

Productive Efficiency Effects of OPEC



Note: The cartel operates assets on S_1 with costs below C_B up to B, while the competitive supply is S_1 above C_B. $A - B$ Indicates the reduction in production from the cartel.

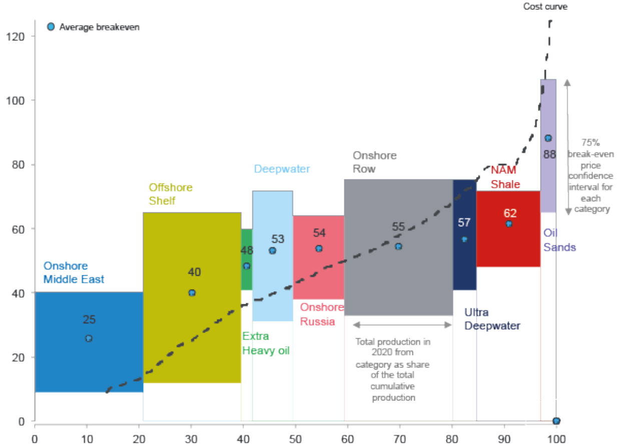
Figure: Welfare Analysis of Quantity and Productive Distortions

Data

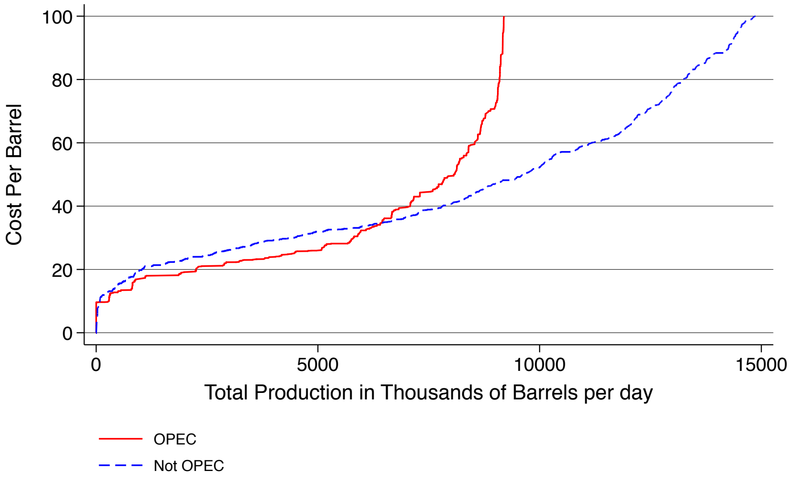
- We have some data from Rystad on 28,000 oil fields in the world.
- This information is used for building models that forecast the price of oil over time.
- Let me show you some pictures.

Data: OPEC Share

Notice the decline in share in the early 80's.

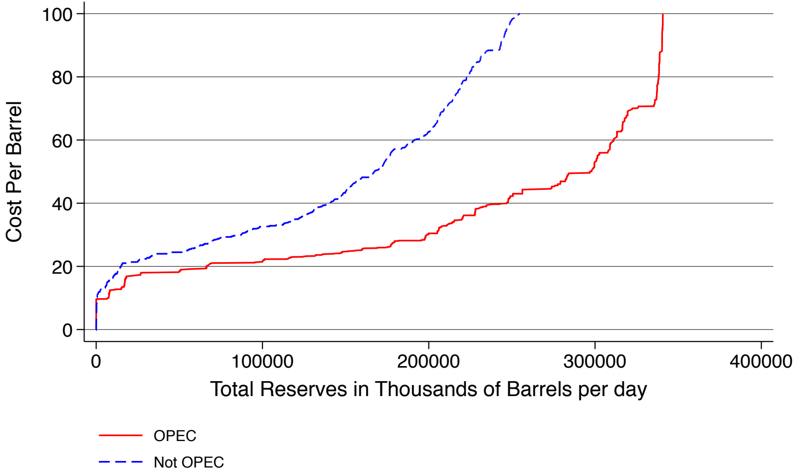


Data: Production in OPEC and Not



Source: Rystad Energy

Data: Reserves in OPEC and Not

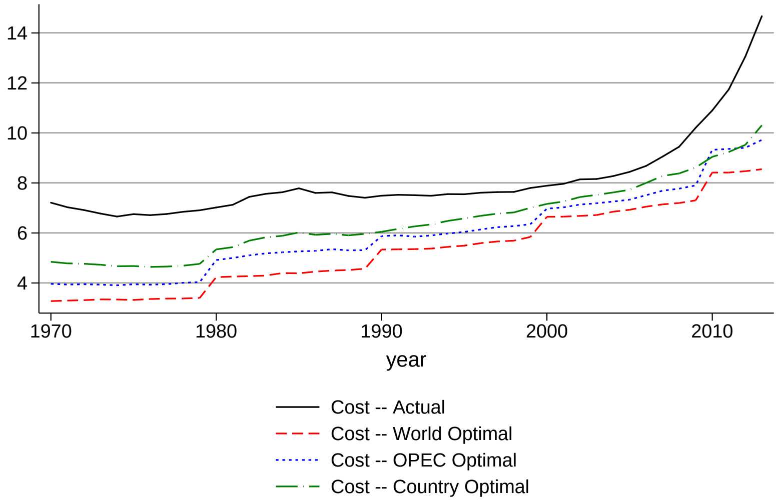


Source: Rystad Energy

What would cost minimizing — social planner's solution do?

- How would we do the social planner's problem?
- Minimize costs by tapping the cheapest wells first.
- Let's see what this implies from 1970 to 2015.

Actual and Counterfactual Cost Paths



Actual and Counterfactual Share of Oil in the Middle East