Econ 1101
Spring 2013

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4/24/2013

Announcements

- Make sure you go to the recitation and participate in the platform debate!
- **Final exam**: Tuesday, May 14th, 6.30-8.30pm
  - If you have exam conflict, there is a makeup final on Thursday, May 16th, 10am-12pm
  - Registration deadline for the makeup
    - Tuesday, May 7th at 4pm
    - To register, email headgrader@gmail.com
- No homework due this week!

Agenda

- Introduction to Game Theory
  - Prisoner’s Dilemma
  - Nash Equilibrium
  - Battle of the Sexes
  - Sequential-choice game and modifications
  - Extra: Split or Steal and Penalty Kick
- Introduction to Oligopoly
  - Duopoly
  - When is cooperation likely?
    - Competition Policy in the US and in Europe
  - Application of Game Theory: An Arms Race for Nuclear Weapons

Oligopoly / Game Theory

- So far, we have worked through the two extreme types of market structure – Perfect Competition and Monopoly
- We have also covered one structure “in between” – Monopolistic Competition – which seemed to be more like what we can observe in the real world.
- Now, we are going to look at another concept lying “in between” – this time though, instead of having large number of producers, we will only have a few firms, of relatively large size.
  - Oligopoly -> a market structure with few sellers (from Greek: *oligoi* – “few” and *polein* – “to sell”)
  - With only few sellers, how do they interact?

Consider OPEC
(the cartel of oil producing nations)

- The group can benefit if each country holds back oil production to keep the price high – so each country within the cartel gets a production quota.
- But a single country can also benefit from deviating from the agreement and secretly selling more than the quota amount at the high price.
- How does it all work out?
  - – Game Theory is a useful tool!

What is Game Theory?

- No, we will not learn how to become the best at playing Starcraft.
- From Wikipedia:
  - *Game theory is the study of strategic decision making. More formally, it is the study of mathematical models of conflict and cooperation between intelligent, rational decision-makers*
- Roger Myerson's (2007 Nobel Prize winner) dedication in his graduate textbook on game theory:
  - *For (…) With the hope that a better understanding of conflict may help create a safer and more peaceful world*
- Random fact: a bulk of cutting-edge research on game theory is being done at universities in… Israel.

Famous example: **Prisoner's Dilemma**

- Scenario: Two thugs have been caught on an attempt to steal public belongings.
- The evidence is not that strong against them though, so a smart inspector brings them in for questioning and locks them in separate rooms.
- Each thug chooses between the two actions:
  - Confess or Remain Silent
- The outcome depends on what both of them do.
- Let's look at the Payoff Matrix…

Prisoner’s Dilemma

- Payoff Matrix – tells us how years in jail (negative) depend upon both players’ actions jointly.

		Little John	
		Confess	Stay Silent
Robin Hood	Confess	LJ gets 5 RH gets 5	LJ gets 7 RH gets 0
	Stay Silent	LJ gets 0 RH gets 7	LJ gets 1 RH gets 1

- Strategy: a rule for how a player behaves in the game

Look at the incentives for Robin Hood

- Suppose he thinks that Little John is staying silent…
  - His optimal action is to ______________________________

- Suppose he thinks that Little John is going to confess…
  - His optimal action is to ______________________________

Look at the incentives for Robin Hood

- Suppose he thinks that Little John is staying silent…
  - His optimal action is to confess
- Suppose he thinks that Little John is going to confess…
  - His optimal action is to confess

What about Little John?

- Suppose he thinks that Robin Hood is staying silent…
  - His optimal action is to ______________

- Suppose he thinks that Robin Hood is going to confess…
  - His optimal action is to ______________

What about Little John?

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Nash Equilibrium

- A pair of actions of both players where:
  - Player 1’s strategy is optimal for him/her, taking as given how Player 2 behaves,
  - Player 2’s strategy is optimal for him/her, taking as given how Player 1 behaves.
- In this game, the unique Nash Equilibrium is:
  –
- This equilibrium is particularly compelling because it is special. Each choice made is a Dominant Strategy.
- Dominant Strategy: A strategy that is optimal regardless of what the other player does.

Nash Equilibrium

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  - Player 1's strategy is optimal for him/her, taking as given how Player 2 behaves,
  - Player 2's strategy is optimal for him/her, taking as given how Player 1 behaves.
- In this game, the unique Nash Equilibrium is:
  - **Robin Hood confesses AND Little John confesses**
- This equilibrium is particularly compelling because it is special. Each choice made is a <u>Dominant Strategy</u>.
- Dominant Strategy: A strategy that is optimal regardless of what the other player does.

Analysis of the Nash Equilibrium

- As we have seen, a Nash Equilibrium is some stable set of mutual behaviors, where none of the players has an incentive to change anything.
- Subsequently, we are interested in investigating how efficient the Nash Equilibrium outcome is from the perspective of both players of the Prisoner’s Dilemma.
- Equilibrium outcome is:
  - Both confess and land in jail for 5 years
- Notice that this is NOT optimal!
  - If neither of them confessed, then each would only get 1 year in jail.
  - If they could cooperate (e.g. commit themselves somehow to not confessing) then both parties would be strictly better off.

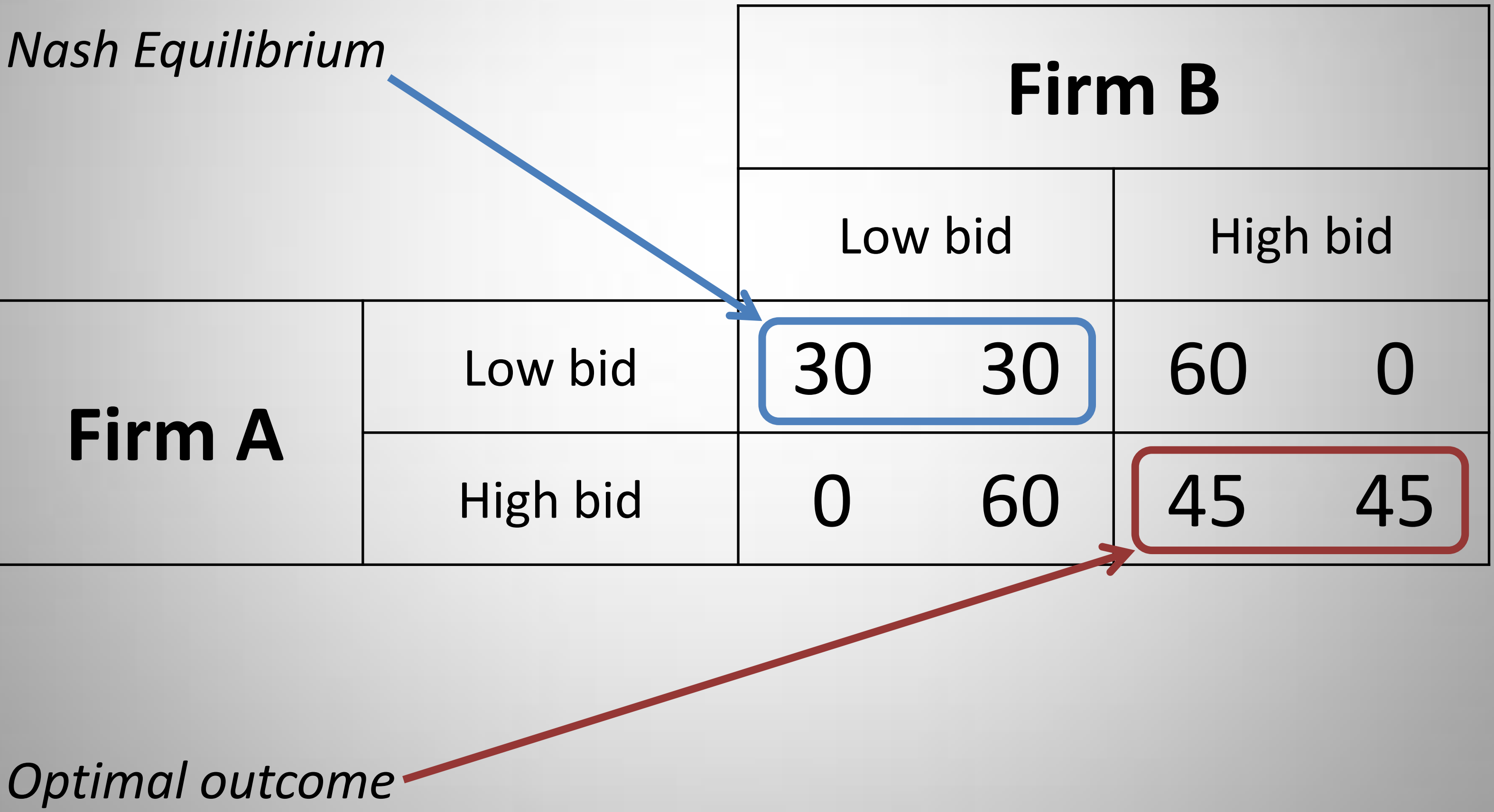
Various applications

- Prisoner’s Dilemma is a simple, yet extremely useful game in various real-world applications.
- We have already mentioned briefly the modeling of behavior of the members of a cartel…
- Another application – a public tender:

Assume two companies send their offers for a public tender. Initial contract is worth 60.

		Firm B			
		Low bid		High bid	
Firm A	Low bid	30	30	60	0
	High bid	0	60	45	45

Public tender



Nash Equilibrium

		Firm B	
		Low bid	High bid
Firm A	Low bid	30 30	60 0
	High bid	0 60	45 45

Optimal outcome

How about a 3-choice game?

		#2					
		Choice A		Choice B		Choice C	
#1	Choice A	0	0	10	3	10	3
	Choice B	3	10	0	0	8	8
	Choice C	3	10	8	8	0	0

How about a 3-choice game?

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		Choice A		Choice B		Choice C	
#1	Choice A	0	0	10	3	10	3
	Choice B	3	10	0	0	8	8
	Choice C	3	10	8	8	0	0

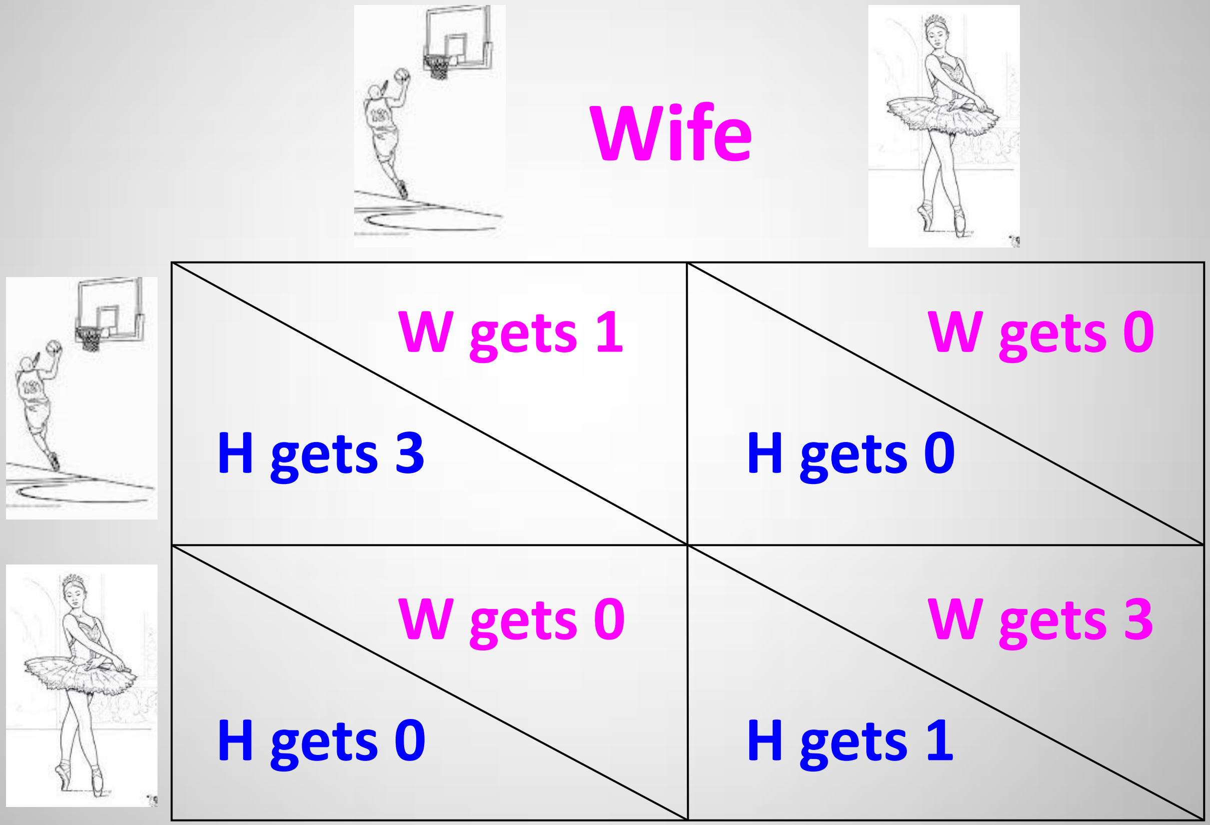
Let’s take a look at some example

Using our previous setup to describe the movie scene

Nash Equilibria are again suboptimal from the perspective of a group (both students)

		Grad student 2					
		Blonde		Brunette 1		Brunette 2	
Grad student 1	Blonde	0	0	10	3	10	3
	Brunette 1	3	10	0	0	8	8
	Brunette 2	3	10	8	8	0	0

Battle of the Sexes



Wife

Husband

	W gets 1 H gets 3	W gets 0 H gets 0
	W gets 0 H gets 0	W gets 3 H gets 1

- Let’s figure out the optimal strategies and Nash equilibrium:
  - Suppose H thinks that W is going to attend basketball…
    - The optimal response is to attend ___________
  - Suppose H thinks that W is going to attend ballet…
    - The optimal response is to attend ___________
  - Suppose W thinks that H is going to attend basketball…
    - The optimal response is to attend ___________
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    - The optimal response is to attend ballet

Battle of the Sexes

- Hence, the Battle of the Sexes has two Nash Equilibria:
  - Husband and wife both attend basketball game
  - Husband and wife both attend ballet performance
- We cannot say much more, in particular we don’t know which equilibrium will be chosen.
- Can you think of a solution to this situation?
- Can we achieve somehow a better, more stable equilibrium arrangement that will be equally satisfactory to both sides?

Different setup (1)

- Let’s change the game so that the action is now sequential:
  - Wife moves first. Then sends a text message to her husband informing him about her decision. What is the equilibrium outcome now assuming that the guy makes, obviously, a rational decision taking her choice into consideration?

Different setup (2)

- Let’s change the game so that the action is now sequential:
  - Wife moves first. Then sends a text message to her husband informing him about her decision. What is the equilibrium outcome now assuming that the guy makes, obviously, a rational decision taking her choice into consideration?
    - Both will end up watching ballet
- This is a so-called **First Mover Advantage**

Yet another setup

- Let's change it one more time. Like above, the wife picks the show first and sends her husband a text message with the info…
- But before she chooses what to attend, the husband makes a deal with all his basketball buddies that if any of them ever hears that he went to see a ballet performance during an NBA game, they will all defriend him on Facebook.
  - Suppose the husband really likes having Facebook friends and if he is defriended by them, he suffers **a loss of 10**.
- After this modification the payoff matrix looks like this:

Battle of the Sexes with facebook

Wife

		
Husband 	W gets 1 H gets 3	W gets 0 H gets 0
	W gets 0 H gets 0-10=-10	W gets 3 H gets 1-10=-9

- Now we want to work out the equilibrium, provided that each player is forward-looking and assumes the other player will act rationally, given the choices already made by the other player.
  - Hint: to solve this game, we need to work backwards and look at the endgame.
- Suppose the husband's deal with his basketball buddies holds and the wife knows about it.
- Then, regardless of the wife's choice, in the endgame the husband will choose ___________
- Anticipating the husband's eventual choice, the wife will choose ___________

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- Suppose the husband's deal with his basketball buddies holds and the wife knows about it.
- Then, regardless of the wife's choice, in the endgame the husband will choose basketball
- Anticipating the husband's eventual choice, the wife will choose basketball

- Finally, anticipating how the wife will react to the deal with his friends, the husband will definitely make it.
- This move on the husband’s part is something like the famous example of Cortez burning his ships after landing in Mexico in 1519. He was playing a game with his soldiers. Fighting the Aztec Indians then became a better option for the army than retreating back to the ships.
- This is a taste of game theory.
  – More than being fun and interesting, it is a powerful tool for social scientists to study important strategic interactions.

Golden Balls – Split or Steal

- Let’s apply what we know about game theory to analyze behavior of people on a British game show – Golden Balls.
- After a series of elimination rounds, four players are eliminated down to two.
- The two remaining players must now play a game of “split or steal” to determine how much money they each go home with.
- If both pick split, they split the total winnings. If one picks split and the other picks steal, the person who steals gets all of the winnings. If both pick steal, they both leave with nothing.

Split or Steal?

		Person A	
		Split	Steal
Person B	Split	½ of winnings ½ of winnings	All of winnings 0
	Steal	0 All of winnings	0 0

Split or Steal?

- We see that if Person A picks “Steal”, Person B is indifferent, technically, between “Split” or “Steal”. However, we can easily assume that the payout for Person B is negative if he picks “Split” when Person A picks “Steal,” since he will also have a psychologically negative experience being cheated on.

A Game of Split or Steal

		Kaley	
		Split	Steal
Sam	Split	31,315 31,315	62,630 0
	Steal	0 62,630	0 0

Another Game of Split or Steal

		Abraham	
		Split	Steal
Nick	Split	6800 6800	13,600 0
	Steal	0 13,600	0 0

Links

Kaley vs Sam:

https://www.youtube.com/watch?v=hbS_1s985NA

Abraham vs Nick:

https://www.youtube.com/watch?v=S0qjK3TWZE8

Extra: Penalty Kick

- Can you find a Nash Equilibrium in the following game (known as the Penalty Kick or Matching Pennies)?
  - Hint: There always exists at least one Nash Equilibrium

A striker can kick in the left or right corner. A keeper can defend left or right corner.

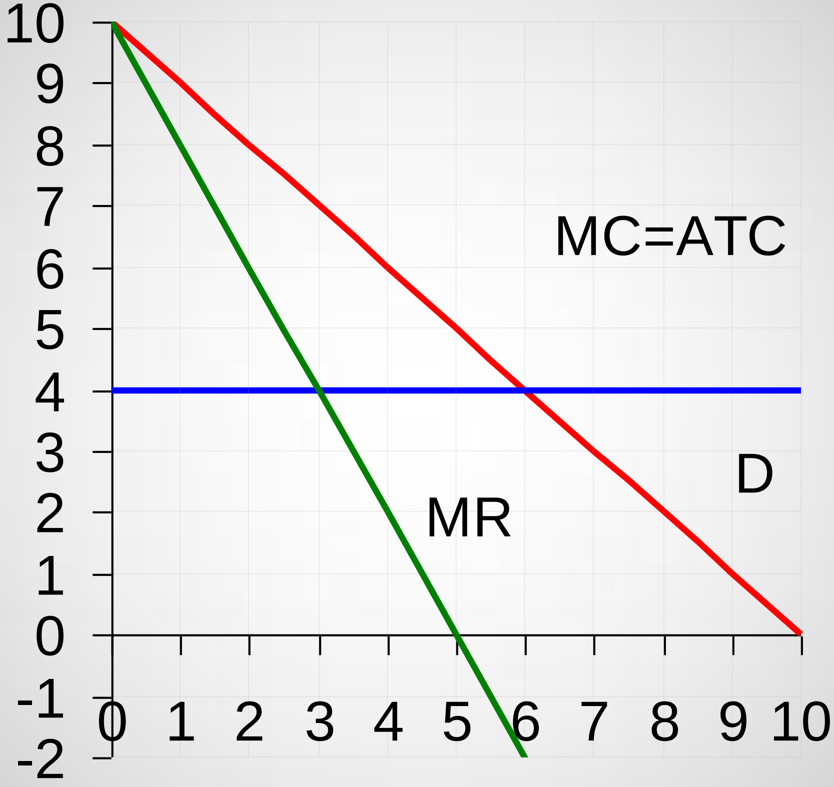
		Goalkeeper			
		Left		Right	
Striker	Left	-1	1	1	-1
	Right	1	-1	-1	1

Recall the initial motivation

- So far, we have worked through the two extreme types of market structure – Perfect Competition and Monopoly.
- We have also cover one structure “in between” – Monopolistic Competition – which seemed to be more like what we can observe in the real world.
- Now, we are going to look at another concept lying “in between” – this time though, instead of having large number of producers, we will only have a few firms, of relatively large size.
  - Oligopoly -> a market structure with few sellers (from Greek: *oligoi* – “few” and *polein* – “to sell”).
  - With only few sellers, how do they interact?

Duopoly in our sample economy

- Suppose two producers, Huey and Dewey, decide to enter this market:



- With perfect competition, we get: Q=___, P=___
- With monopoly, we get: Q=___, P=___
- What happens with duopoly?

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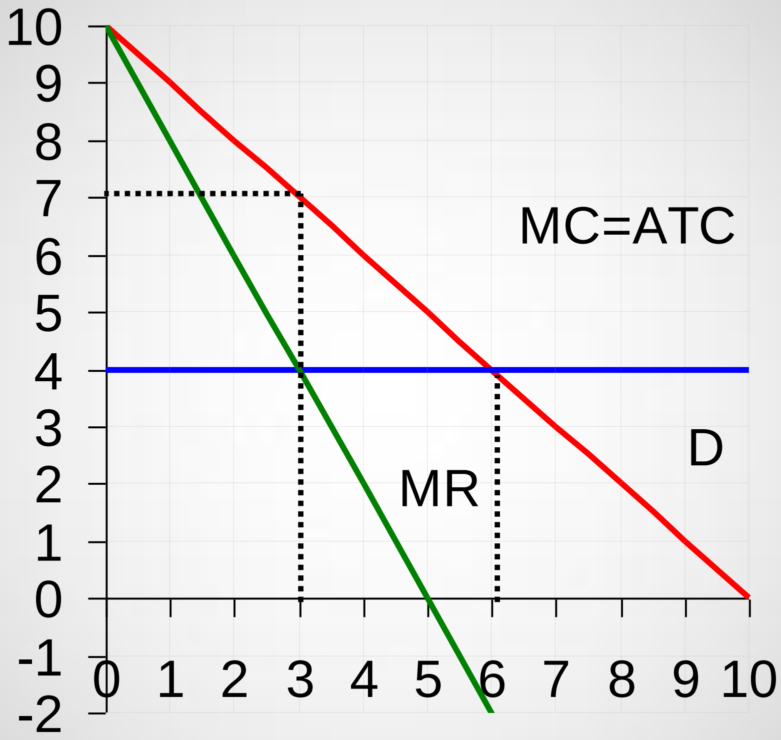


- With perfect competition, we get: Q = 6, P = 4
- With monopoly, we get: Q = 3, P = 7
- What happens with duopoly?
  - It depends. Let’s take a look at some cases.

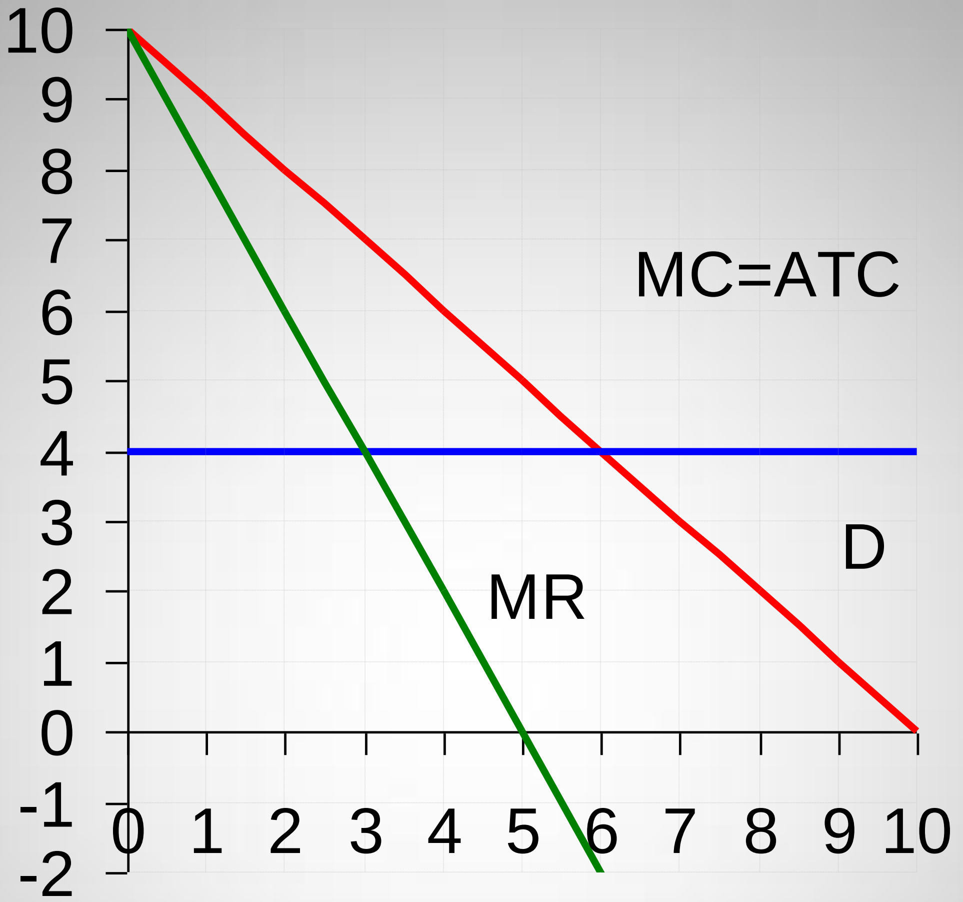
First, some assumptions:

1. Each producer has to post prices and stick to them for the entire day.
2. Prices have to be round numbers.
3. Buyers buy from the lowest-price firm. If prices are the same, then the sellers split the market.
4. For now, we consider two possible prices: $5 and $6.

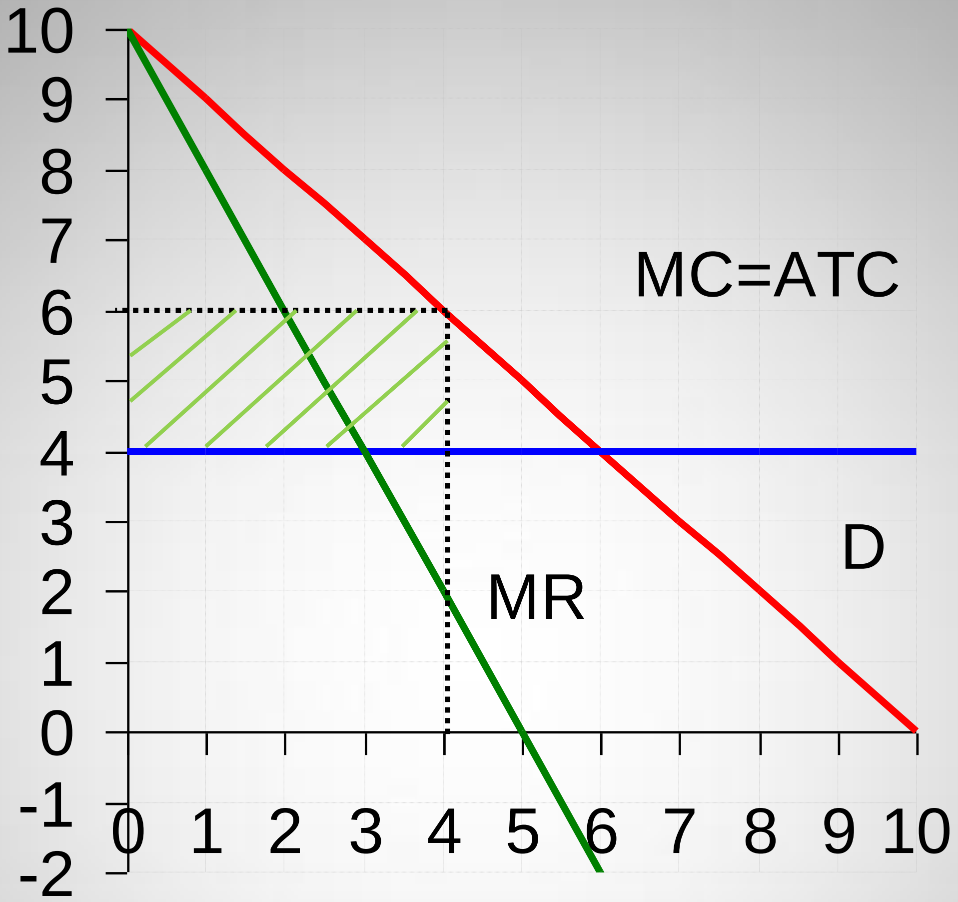
- Suppose we have the scenario above. Let's work out what happens.
- We will need to map this into the prisoner's dilemma payoff matrix from the previous lecture.

Payoff matrix for this problem (1)

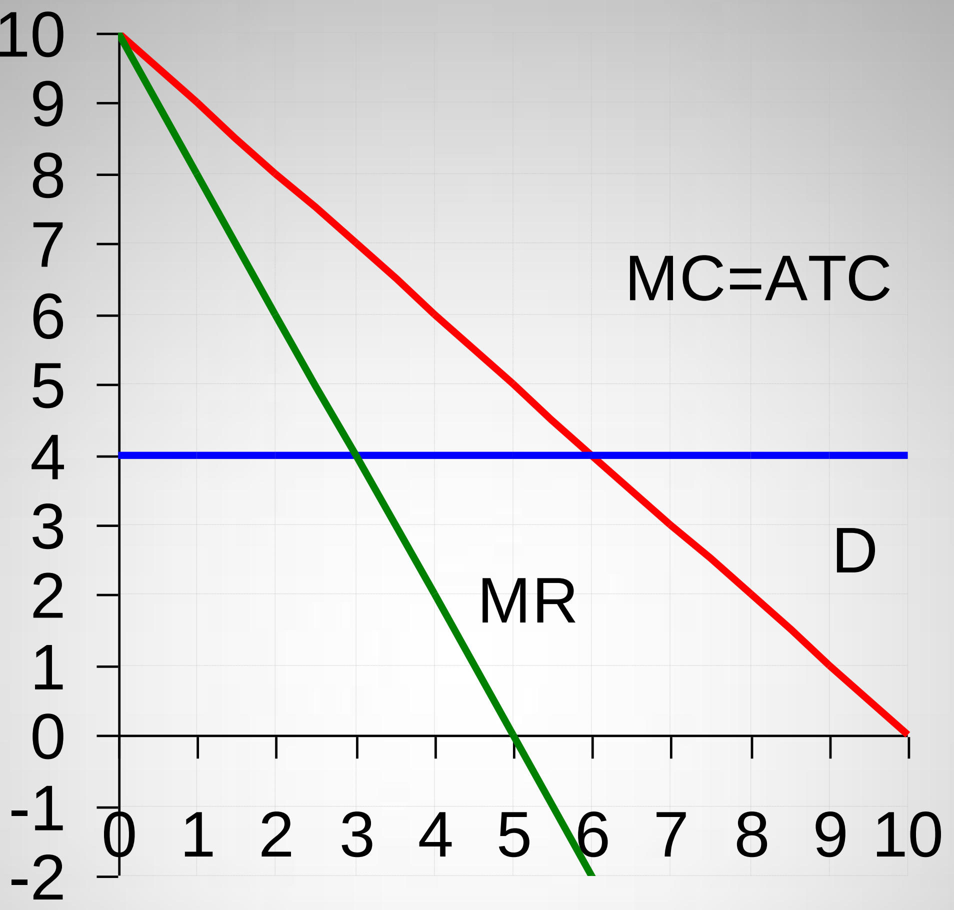
		Dewey	
		P = 6	P = 5
Huey	P = 6	D gets ? H gets ?	D gets ? H gets ?
	P = 5	D gets ? H gets ?	D gets ? H gets ?



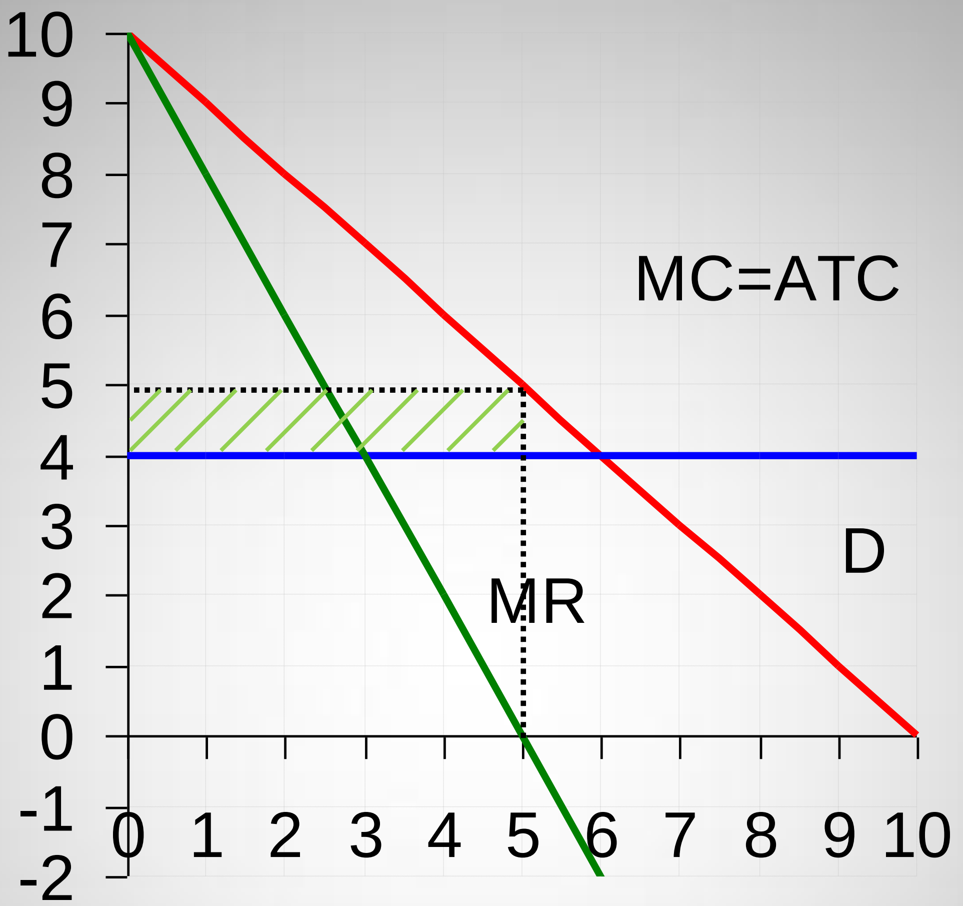
- Suppose both set P = 6. Then, total quantity is Q = 4 and they split the market 50/50, so q = 2 for each of them.
- Consequently, profit of each is ____



- Suppose both set P = 6. Then, total quantity is Q = 4 and they split the market 50/50, so q = 2 for each of them.
- Consequently, profit of each is $4
  - We can put this in the payoff matrix when both set P = 6.



- Suppose both set P = 5. Then, total quantity is Q = 5 and they split the market 50/50, so q = 2.5 for each of them.
- Consequently, profit of each is ____

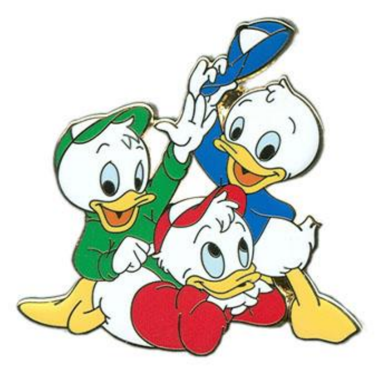


- Suppose both set P = 5. Then, total quantity is Q = 5 and they split the market 50/50, so q = 2.5 for each of them.
- Consequently, profit of each is $2.50
  - We can put this in the payoff matrix when both set P = 5.

- How about if one of them sets P = 5 and the other P = 6 ?
- Suppose Huey sets P = 6 and Dewey sets P = 5
- Suppose Dewey sets P = 6 and Huey sets P = 5

- How about if one of them sets P = 5 and the other P = 6 ?
- Suppose Huey sets P = 6 and Dewey sets P = 5
  - Huey gets $0,
  - Dewey gets $5.
- Suppose Dewey sets P = 6 and Huey sets P = 5
  - Huey gets $5,
  - Dewey gets $0.
- Now we can fill out the entire payoff matrix.

Payoff matrix for this problem (2)



		Dewey	
		P = 6	**P = 5**
Huey	**P = 6**	**D gets 4** **H gets 4**	**D gets 5** **H gets 0**
	P = 5	**D gets 0** **H gets 5**	**D gets 2.5** **H gets 2.5**

Solution to this problem

- So, looking at this payoff matrix we can see that both Huey and Dewey will charge $5 and this is a Nash Equilibrium for this game.
- Moreover, this is a Dominant Strategy for both players.
- What could happen if Huey and Dewey had some way to cooperate?

What about other prices?

- P = 7 is the monopoly price. But…
  - … for the same reason that $6 will not be part of the Nash Equilibrium, this does not work. Firms will just charge $5.
- P = 4? (if the other firm sets the price at $5, wouldn’t you want to respond by going to $4?)
  - No, because you will not make any profit then.
- So the unique Nash Equilibrium is…
  - Both charging $5.

- This is the most simple model of duopoly – it's called the Bertrand model – where both firms choose their price level simultaneously.
  - Notice that if we drop the assumption that prices have to be round numbers, the profits will actually be driven down to 0 in Nash Equilibrium.
- An alternative is the so-called Cournot model: where both producers simultaneously choose quantity, rather than price.
  - This allows the model to predict that the oligopoly will actually have its output and price in between monopoly and perfect competition.
  - We will not however discuss the details of that model.
- These two models are alternatives and can be applied separately to different industries.

Stackelberg model

- This model also analyzes duopoly, but this time in a sequential framework.
- One firm is a leader and moves first by choosing a quantity level.
- The other firm is a follower and will maximize its profit taking what the leader did as given.
- The leader, before making a move, predicts that the follower will adjust to its quantity and takes that into consideration.
  - This is just like in the husband/wife/Facebook example
- Eventually, the Stackelberg model places itself somewhere “in between” Bertrand and Cournot in terms of price, quantity and surplus.

What if this game is repeated every day, forever?

- It is possible then to sustain cooperation with a constant threat to revert back to the price war.
- Monopoly price: P = 7
- Market Q = 3
- If each sells q = 1.5, then the profit for each is (7-4) x 1.5 = 4.5
- Threat: if ever the other firms sets P <7, then we can punish it by setting P = 4 afterwards.
- Look at incentives:
  - Take as given that the other guy is setting P = 7.
  - If we match, we both get 4.5 today.

- If we set P = 6, we will get the whole market of Q = 4. We make the profit (6-4) x 4 = 8.
- It’s a short term gain!
- But then its over…
- So we can compare:

	Cooperate forever	Cheat today
Today	4.50	8.00
Tomorrow	4.50	0.00
Next day	4.50	0.00
Day after that	4.50	0.00
…	4.50	0.00

- If one cares about the future, cooperation is sustainable

- The choice seems pretty obvious in most cases.
- However, if you are desperate for cash now or you believed the world was going to end last year (as the Mayas had predicted), we might have observed a breakdown of cooperation.
- What if there are more sellers?
- Suppose we have 3 sellers:
  - Huey, Dewey and Louie.
  - Cooperation involves establishing a joint monopoly: each sets price at $7, they divide Q = 3 equally and the profit of each one is (7-4) x 1 = $3.

- Returns to cooperation and cheating with 3 firms (split monopoly 3 ways):

	Cooperate forever	Cheat today
Today	3.00	8.00
Tomorrow	3.00	0.00
Next day	3.00	0.00
Day after that	3.00	0.00
…	3.00	0.00

- Compare that with the 2-firm case (split monopoly 2 ways):

	Cooperate forever	Cheat today
Today	4.50	8.00
Tomorrow	4.50	0.00
Next day	4.50	0.00

- Gain from cheating the same as before.
- But the gain from cooperating is smaller…
  - Hence, cheating on the 3-way agreement is more likely.

- In general, cartels are more likely to work if:
  1. Interaction is frequently repeated and participants care about the future.
  2. There is a strong commitment device (e.g. penalties that cannot be avoided).
  3. The fewer players, the better.
  4. If other players can react more quickly (if information about what each other is doing goes back and forth quickly).
  5. Cooperation more likely with a more favorable legal environment.

Current law is not favorable to cartels

- US Antitrust Law:
  - 1890 Sherman Act outlaws price fixing
  - If you are found to be part of a conspiracy to fix price, you can go to jail.
- Europe: Regulated by the European Commission
  - If you are interested, you can see these web pages for more info
    - http://ec.europa.eu/competition/index_en.html
  - We can see some examples of cartel cases that have been prosecuted
    - http://ec.europa.eu/competition/cartels/overview/index_en.html

Some other illegal practices among oligopolies

- Resale Price Maintenance
  - – Producer obliging its retailers to sell the product at some fixed, usually higher price.
    - Does it really limit competition?
- Predatory Pricing
  - – Cutting down your own prices (often below MC) in order to drive a competitor out of the market
- Product tying
  - – Offering multiple products to retailers exclusively together, in a bundle.
- For detailed discussion refer to Mankiw, Ch. 17

Application: Cold War

- Potential Prisoner’s Dilemma situation for a first strike nuclear attack

		Soviet Union	
		First Strike	**Don’t Attack**
U.S.	**First Strike**	**USSR gets –100** **U.S. gets - 100**	**USSR. gets–1000** **US. gets 200**
	Don’t Attack	**USSR gets 200** **U.S. gets –1000**	**USSR gets 0** **U.S. gets 0**

- The unique NE is ______________________________

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		First Strike	Don’t Attack
U.S.	First Strike	USSR gets –100 U.S. gets - 100	USSR. gets–1000 US. gets 200
	Don’t Attack	USSR gets 200 U.S. gets –1000	USSR gets 0 U.S. gets 0

- The unique NE is first strike for both countries

- Suppose instead that each party can credibly commit to launch a massive retaliatory attack on warning. So if one party launches a first strike, nuclear winter results. The payoffs now look like (where -∞ mean “minus infinity”):

		Soviet Union	
		First Strike	**Don’t Attack**
U.S.	**First Strike**	**USSR gets –∞** **U.S. gets –∞**	**USSR. gets –∞** **US. gets –∞**
	Don’t Attack	**USSR gets –∞** **U.S. gets –∞**	**USSR gets 0** **U.S. gets 0**

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		Soviet Union	
		First Strike	Don’t Attack
U.S.	First Strike	USSR gets –∞ U.S. gets –∞	USSR. gets –∞ US. gets –∞
	Don’t Attack	USSR gets –∞ U.S. gets –∞	USSR gets 0 U.S. gets 0

N.E.

- The unique Nash Equilibrium is now <u>Don’t Attack</u>
- This is the concept of mutually-assured destruction (MAD) which results in a kind of stability.
- Requires both to keep up in an arms race (if one is more powerful than the other then MAD can break down).
- Requires rationality on both parts.
- Hence, this is a useful theory to think about Soviet/US Cold War interactions.
- Not very useful though for thinking about North Korea and Iran…

Arms Control (chapter 17 in Mankiw)

- Model of an “Arms Race”

		Soviet Union	
		Arm	**Disarm**
U.S.	**Arm**	**USSR at risk** **U.S. at risk**	**USSR at risk, weak** **US. gets safe, powerful**
	Disarm	**USSR safe, powerful** **U.S. at risk, weak**	**USSR safe** **U.S. safe**

- Again, we see the usual Prisoner’s Dilemma, where the unique equilibrium is when both choose to Arm.
- Again, if the two countries could cooperate, both would be better off if both disarm.
- How about signing an arms control agreement?
  - Both parties would be better off.
  - **But it is crucial for both sides to be able to verify compliance of the other party!**