14.01SC Principles of Microeconomics, Fall 2011
Transcript – Lecture 16: Oligopoly I



PROFESSOR: Economics-- oligopoly. Which is basically trying to move towards the most realistic modeling of markets that we can. We've talked about two extreme versions of modeling markets. One is perfect competition, which is the extreme case of perfect entry and exit. Free entry and exit. Perfect consumer information. An idealized market. We know that doesn't really exist in practice anywhere.

The second extreme was monopoly, which we do see in practice in some places. In particular, when there's natural monopolies. We do see that. But that's still doesn't describe most markets.

Most markets are better described as oligopolies. These are markets where there's more than one market player, yet where each firm is large enough to actually affect the price. So an oligopoly market is where there'll be a small number of firms in the market with substantial barriers to entry from additional firms. An oligopoly market where there's a small number of firms with enough barriers to entry that additional firms don't enter.

So the classic example of an oligopoly industry is the auto industry. Here's a market with a small number of dominant players. There's been some entry and exit over time, obviously, but it moves pretty slowly. By and large it's a market where there's very limited entry.

And the question is, how do firms behave in this market? Obviously it's not like perfect competition where they can lazily take a price out of the market and just produce based on that price. But it's also not the same as monopoly where they can just get to set the price and not worry about what other people do. They're in this in-between situation where they have price setting power. They have some market power but in a context where they have to worry about competitors.

And so in this context there are two different ways firms can behave. It's important to lay out to start. There's two different ways for firms to behave. They can behave cooperatively or non-cooperatively.

If they behave cooperatively we say that they form a cartel. So our cartel is what happens when oligopolistic firms, when firms in an oligopolistic market behave cooperatively to determine the outcome. We call that a cartel.

The classic example, of course, here being OPEC. The Organization of Petroleum Exporting Countries, which is a cartel that drives the price of oil. Those countries cooperate in how much oil they produce to move the price up or down according to what the group desires.

And what cartels do is essentially turn oligopolies into monopolies. So what cartelization does, what a cooperative equilibrium does is essentially say, let's all get together and behave as if we're one big monopoly by cooperating. And therefore, if you cooperate you can get all the wonderful things monopolies get: huge market power, huge markets et cetera.

But as we'll talk about next time, it turns out to be pretty hard to get a cooperative oligopoly. There's lots of reasons why it might fall apart. And that's why in most oligopolistic markets firms behave non cooperatively.

In most oligopolistic markets firms are behaving non-cooperatively. They're competing with each other, not cooperating. And that's what we're going to spend today analyzing is the case of non-cooperative oligopolies. Yeah?

AUDIENCE: [INAUDIBLE]?

PROFESSOR: Depends on the context. In the US, and I'll talk about this, in the US there's anti-trust legislation which can make it illegal in many contexts to cooperate. Obviously OPEC is not subject to some world legislation. But even in the US there can be implicit cartelization and implicit cooperation, and we'll talk about that.

It's a good question. So technically you're right. Technically it is illegal in the US in most contexts to form a cooperative, to form a cartel. Whether in practice those laws can be enforced is an interesting, legitimate question.

So today we want to focus on the case of non-cooperative oligopolies. And to do so we're going to turn to a new tool. And one of the fundamental tools of economics in the last 30 years which is game theory.

So today we're going to talk about game theory. Game theory is a tool of economics that was not really used early in economics but has come to dominate theoretical economics over the past 30 or 40 years.

And basically the way that game theory works is to think, literally, of oligopolistic firms as engaging in a game. So when you play, don't want to say play Monopoly, that's confusing terms. When you play Sorry! or whatever with someone, or play some online game with someone, you're competing to win. You're behaving non-cooperatively. You're competing to win.

So basically what the insights of game theory are that all the tools we used strategically to make decisions in playing games can actually be used in modeling how firms compete non-cooperatively in oligopolistic market. The key insight is that each firm will develop a strategy. Just as when you're playing chess you have some strategy going in, firms develop a strategy. And that based on that strategy they will determine their behavior.

And what is going to determine that behavior is going to be how firms' strategies combine to determine a market outcome. When firms come in with different strategies, or when a bunch of firms with strategies come in to compete with each other, what determines the market outcome.

And what that's going to depend on is something we call an equilibrium concept. Which is how do we measure-- essentially the equilibrium concept is in game theory terms, think about how do we determine when the game's over? How do we determine when we've decided on the outcome of the market. What's the equilibrium concept?

So when you're reading the rules of a new game the first thing you look for is how do you decide who wins. That's kind of like what the equilibrium concept is. It's what determines whether the game has ended. What determines whether you've reached equilibrium. Where you've reached a point where the market is stable and therefore the game has ended. Not ended in the sense the firm shut down, but ended in the sense that you know what everybody's doing. So it's not quite like winning or losing. It's more just like what determines when you're at the point where that market is at equilibrium.

Now the most famous concept is due to John Nash, who many of you heard of from the movie and book A Beautiful Mind, and that's called the Nash Equilibrium. A Nash equilibrium is the point at which no firm wants to change its strategy given what the other firms are doing. I'm going to say that again. A Nash equilibrium is the point where no firm wants to change its strategy given what the other firms are doing. It's a little bit bizarre, but we'll work it out.

In other words, more formally, the idea is that holding constant, given the strategies all your competitors use there's nothing that I can do to raise my profits further. Given the strategies all my competitors are playing, there's no strategy I can choose that will make me more profitable than the one I'm choosing. And likewise for every player in the market that will turn out to be true.

So have players sitting around a game board, going around the circle. Each player says, given what I know each of the rest you are doing, I'm doing the best thing I can. And they go around the circle and everybody says, OK, I'm at that point. You've reached a stable Nash equilibrium.

This was named, of course, for John Nash. You all know the story of John Nash. He was a famous, actually mathematician. We use his tools in economics, but he was a mathematician. Developed these incredible theories, and then developed schizophrenia, went crazy. But not before he developed some of the most important concepts in both mathematics and economics. The most important is the Nash equilibrium.

Now the best illustration we use of the Nash equilibrium is an example that we refer to as the prisoner's dilemma. And many of you will be familiar with this from more popular reading you've done in economics. But let me just go through it because it's important to understand it. The prisoner's dilemma.

The prisoner's dilemma the title comes from the old way they used to make police movies. Where the idea is you catch two guys at a crime. You can't put them away unless one of them fesses up.

So what you do is you put them each a separate room. And you say to the one, your buddy's cracked. He's going to he's going to sell you down the river. You better, I'm using all my '50s analogies, he's going to put you away for good. But if you admit that he's guilty and he did the crime, we'll let you off with a light sentence. Then they go to the other room and say the same thing to the other guy hoping they'll both rat on each other and they'll both get a sentence.

So basically the idea is, let's say that you walk into each room and you say to each person, look, we have enough evidence right here, and you show them, to send you each to prison for a year. We would have enough evidence to send you each to prison for a year. But we aren't sure about this other thing. If you'll admit that your friend did this other thing, then he'll go for five years and you'll go free.

And then we go to the friend and say the same thing. If you'll admit that your friend did the other thing he'll go five years and you'll go free. But if they both admit then they both go for two years. So if they both admit, they both go for two years.

Now the way to write this down, what we do here to explain this, is we write down what we call a payoff matrix. So write down a payoff matrix. So the idea is we have prisoner A here and prisoner B here. And they each have an option. They could remain silent or they can talk. Silent or talk.

Now if they both remain silent, if they both say I would never rat out my friend, I'm happy to go to jail for a year rather than rat out my friend, then they each get one year in jail. a equals 1, b equals 1. However if prisoner A rats out his buddy and prisoner B chooses not to rat out his buddy, then A gets-- so I'm sorry, if prisoner A talks and prisoner B remains silent. Prisoner A talks, prisoner B remains silent, then A gets zero but B get five years in prison.

On the other hand, if prisoner B rats out his friend, but a prisoner A is true and doesn't say anything, then prisoner A is going to get stuck with five years and prisoner B is going to get nothing. And if they both rat each other out then they both get two years. So people understand the payoff. Are there questions about the set-up here? This is complicated so got to make sure you understand the set-up.

Now, could someone tell me, if A and B could truthfully cooperate, what would be the optimal cooperative strategy? Yeah.

AUDIENCE: You both go for a year.

PROFESSOR: Right, you'd both be silent. So the optimal cooperative strategy is clear, which is to both be silent. So if the cop said, you know what, we'll let you guys get together and discuss what you want to do first-- which the cops would never be stupid enough to do-- but if they did and the guys can trust each other, then that's the optimal cooperative strategy.

What we call optimal in the language of game theory, we call that the dominant strategy. A dominant strategy is the best thing to do no matter what the other guy does is the dominant strategy. So the dominant cooperative equilibrium strategy is to both stay quiet. But what's the dominant, non-cooperative strategy? What is the dominant non-cooperative strategy?

So the ways with dominant strategy, we run through. Take prisoner A, ask the following. The dominant strategy is, is there a strategy that makes him better off regardless of what B does. Is there a strategy that makes A better off regardless of what B does. Let's go through.

If A remains silent, if B remains silent he gets a year. If B talks he gets five years. Now compare that to prisoner A strategy of talking. Well if he talks he's better off than if he doesn't talk, if B's remaining silent. If he talks he's better off than if he doesn't talk if B talks. That is regardless of what B does, he's better off talking. Regardless of what B chooses to do, his dominant strategy is to talk. Because if B is silent, he's better off if he talks. If B talks he's better off if he talks. So matter what B chooses to do, A is better off talking.

What about B? Well B, by the same logic, is always better off talking as well. No matter what A chooses to do, B is better off if he talks.

So where do we end up? What ends up as the Nash equilibrium? The Nash equilibrium is that both prisoners talk. The dominant strategy for both prisoners is to talk. And they both end up worse off than they could have if they could have cooperated. So the dominant non-cooperative strategy is to both talk, even though if they could get together they'd be better both not talking.

And this is basically how game theory works. Game theory math gets incredibly hard. And if you're interested, 14.12 is one of our most popular undergraduate courses, game theory. It's a great course where you take this and go run with it for a whole semester. It gets very complicated mathematically.

But the basic idea in game theory is pretty straightforward, which is just ask, are there dominant strategies that can be played by each player. If each player has a dominant strategy and those dominant strategies lead to a Nash equilibrium then you're done.

Here we're in a Nash equilibrium. Why are we in a Nash Equilibrium? Because given that A has talked, B's strategy, which is talking is the optimal thing to do. Given that B has talked, A's strategy which is talking is the optimal thing to do. So given what the other person's doing, each person is doing the right thing.

So you're in Nash equilibrium. Given that B has chosen to talk, A is talking. That's the profit maximizing thing to do. Given that A is talking, B is talking. That's the profit maximizing thing to do. So given the strategy the other player's chosen that's an equilibrium. Yeah.

AUDIENCE: If they both talk and got 10 years would that be the Nash equilibrium.

PROFESSOR: No if they both talk, the 10 years only happens if one talks and the other one doesn't.

AUDIENCE: No, I mean like, [INAUDIBLE].

PROFESSOR: Oh, if they both got 10 years? So let's ask that. Let's change this. Now let's just rework it. So now what's A's choice? Well A if he talks and B's silent, then he's better talking. But if he talks and B talks, he's worse talking. So then what he does depends on what B does. What B does is going to depend on what A does.

And we can't obviously see the Nash equilibrium here. Because there's no dominant strategy. What you do depends on what the other person does. So there's no dominant strategy. Dominant strategies only occur if there's something that you should do no matter what the other person does. So in this case were these are both 2, there is a dominant strategy, It's to talk. If those are both 10 there's no longer a dominant strategy so we can't quickly get the Nash equilibrium. It's a good question.

Now this is not just a cute example that you can use for prisoners, but actually explains firm behavior in many contexts. So the best example I like to think of of this is to think about advertising. So imagine if Coke and Pepsi, and imagine a world where Pepsi was as popular as Coke. That should never happen. Coke's way better. But imagine that was that world.

So imagine a world where if there's no advertising then basically Pepsi and Coke would split the market 50-50. Imagine that set up. So if Pepsi and Coke could agree not to advertise they'd split the market 50-50.

However, it's going to turn out that while that may be the dominant cooperative outcome, that's not the dominant non-cooperative outcome because each firm is better off advertising if the other one doesn't, or regardless.

So for example, imagine the following payoffs matrix. I'm just making this up. But here you have Pepsi and here you have Coke. And imagine the payoff matrix. And the payoff matrix is if they don't advertise, so Pepsi can choose not to advertise, or it can advertise.

So if they both don't advertise Pepsi gets 8 and Coke gets 8. I don't know what 8 is. 8 is billion dollars. I'm just making up numbers here, doesn't matter. So $8 billion each. If they both do advertise then they still end up splitting the market. Because basically they're just as good as each other. So they both spend all the money advertising and just back up where they would have started, except they've wasted all this money in advertising. So if they both advertise they each earn $3 billion instead of $8 billion. That is, they each split the market. They end up back where they would have started but they pissed away a bunch of money advertising along the way.

However if Coke advertised and Pepsi doesn't. Then almost everybody sees Coke, Coke, Coke everywhere and is like, Pepsi? Never heard of that. Coke makes $13 billion and Pepsi loses $2 billion. And likewise if Coke doesn't advertise but Pepsi does, people are like, I've never heard of Coke. I'm going to drink Pepsi. So Pepsi makes $13 billion and Coke makes minus $2 billion. Once again I just made numbers here so it would work, but these aren't real world examples.

So once again we can see there is a dominant cooperative strategy, which is they both should agree let's not advertise. But if they can cooperate, then in fact what's the Nash equilibrium? Let's work it through. And there's no shortcuts here. You've just got to work this through.

Let's look for Pepsi. Well Pepsi says if Coke doesn't advertise I'm better off advertising. If Coke does advertise, I'm better off advertising. So my dominant strategy is to advertise. Coke says, well gee, if Pepsi doesn't advertise I'm better off advertising. I make $13 billion instead of $8 billion. If Pepsi does advertise I make $3 billion instead of negative $2 billion. So I'm better off advertising too. So my dominant strategy is to advertise. So for both firms the dominant non-cooperative strategy is to advertise. So they both advertise and you end up in this equilibrium.

It's an example of how a non-cooperative equilibrium can lead to what we call a race to the bottom. You can think of it as a race to the bottom. In other words, if they could cooperate they could just be better off. But because they can't trust the other, there's this race to the bottom where they both end up worse off.

This is pretty striking. I thought they brought this out well in A Beautiful Mind, both the movie and the book, which is that all we've learned about economics so far is that competition is good, right? Competition is beneficial. Well here's a case, where in fact, at least in the firm's perspective, competition is bad. If they could just get together and cooperate they could make more money.

Now, in fact, this example is not so far-fetched. I don't know when it started but it was during your lifetimes. When you were young, hard liquors, scotch, bourbon, whisky, et cetera, did not advertise on television. You never saw a Johnny Walker ad or anything on television until, I don't know when it changed maybe five or six years ago. Maybe 10 years ago, I don't know. But certainly in your lifetimes.

That was not by government regulation. Many people thought there was a government regulation, they couldn't. That was not. That was a cooperative equilibrium where the makers of hard liquors got together and agreed not to advertise on TV. And they said it was in the "public interest" yada yada yada, but that wasn't. It was just they recognized the benefits of cooperating and not wasting money advertising on TV and competing with each other.

Well that broke down some number of years ago. And now you see whiskey ads and scotch ads and other things on television. And they've moved to this non-cooperative equilibrium where they're all losing money by having this advertising. So that's in advertising.

For me, once again, this is a hard thing, what intuition works for you. For me the intuition works best maybe from my scars from my dating life is thinking about personal decisions. So imagine that there's some girl named Allison. And Allison has a potential problem with her boyfriend. They've had a fight and now she's deciding whether or not to make up or break up.

Now we can think of this just like Coke and Pepsi. Allison is going to be thinking, well gee, if he wants to make up with me and I want to make up with him then we're both better off. But if I want to make up with him and he doesn't want to make up with me, that makes me look like a total idiot. Whereas if I break up with him preemptively, yes it would be sad if he wanted to stay with me, but at least if he wanted to break up with me I look better. So she preemptively breaks up with him.

John, her boyfriend, thinking the same thing, behaves in exactly the same way. So it could be that even though they both would be better off if they just said, look the honest truth is, we're both wrong, let's make up and we'll both be happy. Because they're so afraid of being the one being dumped, they end up breaking up.

Now we all know of examples like this from life, where people stupidly if they could have just cooperated had a better outcome because they're so afraid of being left with the short end of the stick, because they don't cooperate you end up with the worst outcome for both. That's an example of a non-cooperative equilibrium in real life.

Now in real life there is one aspect of oligopolistic non-cooperative equilibria that allow them to be enforced, however. That allow you to overcome the prisoner's dilemma. There's one thing that allows you to overcome the prisoner's dilemma and that's repeated games. Repeated games can help you overcome the prisoner's dilemma.

Now let's take the Coke and Pepsi example and let's imagine that they're making the advertising decision every period. Every period they have to make an independent advertising decision. They can advertise or not advertise every period. And imagine Coke says to Pepsi, I've got the following deal for you. I commit to not advertise as long as you don't, but the minute you advertise I'm going to advertise forever. So as long as you don't advertise I won't. But if you ever run an ad, the bet's off and I'm never going to cooperate with you. I'm going to advertise forever.

Let's think about Pepsi's choice in period one if Coke presents them with this deal. Let's think about Pepsi's choice if Coke presents them with this deal.

Well one thing is they could say, ha ha, great Coke, good job trusting me. I'm going to screw you in advertising period one. So Pepsi could say, great, Coke's laid down arms in period one. I'm going to go and advertise. I'll make $13 billion in period one because Coke's wimped out. And then I'll make $3 billion forever after, because forever after we're both going to advertise. But at least I' beat them up that first period.

However, if Pepsi says, wait a second, if Coke's really right, honest, then I can get an equilibrium where we make $8 billion forever. And certainly $8 billion forever a better deal than $13 billion one year and $3 billion forever. So in fact if Coke's willing to live up to that promise then that is a good deal. And actually we can turn this non-cooperative equilibrium into a cooperative equilibrium through the enforcement of a repeated game. Through the fact that this game gets played over and over and over again you can enforce a cooperative equilibrium.

We can come back to relationships again. If you're in a committed relationship and you know that if I say it's your fault over and over again, eventually person's going to leave. Then people say gee, I'm willing to take some of the blame and not always say it's your fault and we have a fight. Because I know that if I always say it's your fault ultimately that will break the relationship up and that makes me worse off then admitting it was my fault some of the time. It's the same logic. Yeah.

AUDIENCE: Is the point of the game to make more than the other guy or to make as much as possible?

PROFESSOR: Make as much as possible. That's a good point. I presume that the point is to make as much as possible. I'm ruling out cut off your nose to spite your face equilibria. So in other words, I'm assuming the goals is to maximize profits not relevant mark position. That's a good point. I should have made that assumption clear. It's the assumption we're always making whatever we confirm behavior is assuming it's profit maximization.

So repeated games can enforce a cooperative equilibria, essentially. Even in a non-cooperative set up. But it turns out this only works if the game goes on forever. This only works if the game is going to go on forever.

So, for example, imagine that Pepsi knows that in 10 years the US government is going to ban the advertisement of sugared sodas. The US government is going to finally say, look, people are too obese, no more advertising sugary sodas. Pepsi knows this. In 10 years that's going to happen.

Well Pepsi's thinking, gee, that means in year 10 I should advertise. In that last year I should advertise because Coke can't punish me the next year because no one can advertise the next year. So I know starting after 10 years we're both in this equilibrium because the government's going to enforce it. So in ninth year, right beforehand, right before that government ban I should advertise and Coke can't get me the next period because they don't have the tool to punish me.

Well Coke, of course, knows Pepsi is going to behave that way. So Coke says, wait a second, if Pepsi's going to behave that way then I better advertise in the ninth period too or I'm going to get hit with a minus $2 billion. So I'm going to advertise in the ninth period too.

Well Pepsi says, look, if Coke's going to advertise in the ninth period for sure, I may as well advertise in the eight period because Coke's going to advertise in the ninth period for sure. And by the same logic you can work it back that they'll both advertise right away and you'll end up with a non-cooperative equilibrium.

That is a repeated game that does not enforce the cooperative equilibrium. Because by working that logic backwards if it ends in some realistic time frame, then you better off just breaking it now rather waiting for that period where you're the one who loses. Yeah.

AUDIENCE: [INAUDIBLE] what if Pepsi [INAUDIBLE]?

PROFESSOR: Exactly. If they don't then you could imagine that if Pepsi knows this and Coke doesn't, then Pepsi's optimal strategy will be to cooperate to the next to last period then go ahead and screw Coke and then Coke will lose. But presuming symmetric information, repeated games cannot enforce these equilibria if they end.

So this is just an incredibly quick introduction to the fun that is game theory. We're going to go on now and do more rigorous versions of these models. But this is just to get you excited about the tools you can do with game theory with fun examples.

Game theory is about taking these fun examples and thinking a lot harder about a lot. What if there's asymmetric information? What if the game ends long enough in the future that you're willing to be patient? How far off in the future does the game have to end to still enforce the cooperate equilibrium?

What if there are three players? What if players move in different orders? What if one player goes first, the second player responds to that, is it different than if they go simultaneously? These are all really interesting issues that are very relevant to the real world firm behavior that you learn about game theory. So this is just to whet your appetite for that.

Having done that we're going to now turn, leave aside these more interesting dynamic issues and focus on a specific example of a non-cooperative oligopoly. Because, once again, this is all fun intuitively, but we want you to be able to work through a problem. And the way to work that through is we're going to have to move to a specific, simplified example.

And the example we're going to focus on is called the Cournot model. The Cournot model of non-cooperative oligopoly. The way we're going to do this here, is we're going to return to the example we had with the prisoner's dilemma. But instead of just facing two choices, talk or not talk, we're going to talk about firms facing a whole continuum of choices. Firms choosing how much they produce in a non-cooperative equilibria situation.

So, for example, let's take the example they use in the book. Let's imagine there's two airlines that fly between New York and Chicago, American and United. And let's imagine for simplicity those are the only two airlines. Because of the hub and spoke system we talked about last time, let's say all the gates in Chicago that are available to come from New York are taken by two airlines-- United and American. Those are your only two options flying New York to Chicago.

And the question we want to ask is, get in that world, how do United and American decide how many flights to run and what price to charge? If they're monopolies we'd know. If it was a perfect competition we'd know, but how do they decide this all oligopolistic.

The way we figure this out is by looking for the Nash equilibrium in this case, which we also call Cournot equilibrium. Which is basically the quantity is chosen by each firm such that holding all other firms' quantities constant. So each firm chooses quantity such that holding all other firm's quantities constant they are maximizing profits.

So I choose a quantity such that holding all the other firm's quantities constant I'm choosing a profit-maximizing quantity. And if each firm can choose a quantity that makes the market function where this is met, then you're in Cournot equilibrium. You're in Cournot equilibrium when each firm has decided, I'm happy. It's the same as the Nash concept. I'm happy with what I'm producing given what everybody else is producing. If everybody feels that way then you're in a Nash equilibrium or a Cournot equilibrium.

So to see this, this is not immediately intuitive. Let me just talk you through the steps of how you'd solve for this. How do you actually solve for a Cournot equilibrium? So basically what are the steps to solving?

Step one for solving a Cournot equilibrium is to create each firm's residual demand. So compute residual demand. We talked about residual demand curves earlier. Which is, that's the demand for my firm given the quantity absorbed by other firms in the market. In this case it's quantities absorbed by the one other firm in the market, but in general you do this with multiple players. So first you calculate residual demand.

Then having computed your residual demand you develop a marginal revenue function. You calculate your marginal revenue which will be a function of other firm's quantities. So your residual demand will lead you to calculate a marginal revenue function. It's a function of other firms' quantities.

You then do the same, do one and two for all firms. So for each firm you end up with a marginal revenue function and a function of all the firm's quantities. Step four is you have n equations and n unknowns and you solve.

So you develop a series of equation where each firm's marginal revenue function is a function of each other firms quantities. You get one equation like that for each firm. That leaves you n equations and n unknowns you solve. If you can solve it then you reach equilibrium. If you don't have a solution then there is no stable Nash equilibrium. But if you can solve that there is a Cournot equilibrium and you solve for it.

So what we're going to do here is I'm going to illustrate this to you graphically today and we'll work through some more of the math of it next time. So we'll start by doing this graphically.

So let's start by considering the case of American Airlines. Let's start with figure 16-1. Start by considering the case of American Airlines. And let's say that the demand curve in this market in our example we're going to do, let's say that the demand curve is of the form p equals 339 minus q.

So there's 339,000 flights that are demanded each month. Each month there are 339,000 flights demanded in the whole market. So 339,000 people want to go from New York to Chicago every month. And let's also assume the marginal cost is $147. I don't know where Perloff came up with these numbers, but let's just go with them. The specific numbers don't matter.

Now what would American Airlines do if it was a monopolist? If American Airlines was a monopolist, it would set marginal revenues which are 339 minus 2q by the same math we did before. You just multiply it through by q and then differentiate and you get 339 minus 2q equal to the marginal cost which is 147. So if it was a monopolist it would choose a quantity of 96 and it would choose a price of $243. A prices of $243 which we would just get out the demand curve. If the quantity is 96, the price is $243.

And that's what we see here. The marginal revenue curve intersects the marginal cost curve at a quantity of 96,000. You then go up to the demand curve to read off the price.

Remember for a monopolist you've got to still respect the demand curve. You get the demand curve to read off the price, that's $243. That's what American would do if they were monopolist. So if they were the only folks flying New York to Chicago, they fly 96,000 people a month at a price of $243,000.

However, now let's say American recognizes that United is in the market. And let's say American recognizes that United is going to deliver some amount of flights q sub u. They know American is going to do some amount of flights q sub u. They don't quite know yet what it is, but they know there's going to be some amount of flights q sub u. So the residual demand for American is q sub a equals total demand minus q sub u. That's their residual demand.

So, for example, let's say that American just guesses that United will fly 64,000 passengers. Let's say Americans says, look, I just know, I've got some corporate spy who's told me that United will fly 64,000 passengers. So what you want to do is then you just re-solve the problem but using residual demand.

So then you say, well if United is going to fly 64,000 passengers then my residual demand is that price equals 339 minus the quantity I sell, q sub a, minus q sub u, which I think is 64,000, which is 64. So my new residual demand is p equals 275 minus q sub a. That's my new residual demand. Because I thought United is going to sell 64,000. So instead of my demand being 339 minus q, now 275 minus q sub a. That's what's left.

So if I use this as my new demand function and re-solve, if this is my demand function, my marginal revenues are then 275 minus 2 qa. My marginal cost is the same which is 147. So instead of my equation being 339 minus 2q equals 147. Now it's 275 minus 2qa equals 147. If I do that I'm going to get a qa star of 64,000 flights.

I'm going to say, well look, if I was a monopolist I would have deliver 96,000 flights. But given that United is delivering 64,000, that's it's going to be optimal for me to also deliver 64,000. At 64,000 flights what's my price going to be? Well my price is 275 minus qa. So my price is going be to be $211.

If I think United is delivering 64,000 flights then I'm going to deliver 64,000 flights at a price of $211. So that's basically how American would function.

Now what's strange about this is American doesn't know how many flights United is going to deliver. There isn't such a thing. In fact, it's not like there's not some rule which says we're going to go 64,000. United is trying to figure this out too. So, in fact, simultaneously to American making this decision, United is making the same decision.

And they're going through the exact same math. They're saying, well gee, given how much American flies, how much should we fly? They're going through the same math. And in fact if we assume that both firms have to face the same marginal cost and the same demand curve, then in fact they're solving a symmetric problem. They are also creating a residual demand function, but instead of being qa equals d minus qu, now United is making qu equals d minus qa. They're making a parallel residual demand function and they are solving as well. And both firms, therefore, are ending up with choices of quantities that depend on the other firm's quantity.

And in particular what they're developing is what we call a best response curve. So figure 16-2, I skipped over figure 16-2. This just illustrates what happens when American thinks United is committing 64,000. Let's go through that in one second. Get through it mathematically.

This is an example where American knows United is doing 64,000 flights. So they say, well look, my residual demand is essentially this new line d super r. And that's what I choose on that new line. So that creates a new marginal revenue curve, mr super r. That new marginal revenue curve intersects marginal cost at 64,000 and that's why I fly only 64,000 flights at a price of $211. So you see here is one example of how given an amount United is flying, how American chooses how much to fly. Questions about that graphic that ties the math I did here?

What figure 16-3 does is say, look, we can actually do this for a whole host of possible production levels by the other firm. And we can develop what we call best response curves. Best response curves are, given what the other firm does, what should I do. So, for example, American's best response curve is given that-- so on the x-axis we have how many thousands of flights American's passengers are flying per quarter. On the y-axis how many thousands of flights United passengers are flying per quarter.

So, for example, if American decides to fly zero flights then United should fly 96 flights, right? Then United is a monopolist. So that's the point on the y-axis, to 96,0 point on the curve. With a 0 on the x-axis, 96 on the y-axis. If American decides to fly 0. United should fly 96. That's the monopoly case we just solved.

If American decides to fly 64, United should fly 64. That's the case we just solved as well. Likewise, American's best response curve is this steeper line. But it's the same thing. If United flies 0, American should fly 96 then at 0 on the y-axis, 96 on the x-axis. So if United flies 0 American should fly 96. If United flies 64, American should fly 64.

So you can actually, literally trace out these curves asking at every single point, given what the other guy's doing, what should I do. So we solved for two points on this curve. We solved for the other guy producing zero point, which is you produce 96. We solved for the other guy producing 64 point which is you produce 64. That same math can be used to solve for every point on this curve. Yeah?

AUDIENCE: [INAUDIBLE] 192 point.

PROFESSOR: The 192 point is it's the question is the following. At what point would American produce zero. How much when United have to produce for American to produce zero. Well they'd only produce zero if United was producing 192,000. Only at that point would they actually say, forget it, we're just going to produce zero.

That's what the 192 point means. Only if they knew United was producing all that much would they just drop out of the market. So that's the 192 intersection. A backwards way to read the curves.

But the bottom line, is essentially we can write these best response curves. They're basically the quantity I'm going to produce given the quantity the other firm produces. And the key thing is that these are symmetric in this example. Since the costs are the same and they both face the same market demand then these curves are symmetric.

What that means is that these curves are having figured out one you can automatically draw the other. A trick for solving these problems is that if you have a symmetric Cournot equilibrium you don't need to calculate the math to find each firm's best response curve. Once you calculate one you know the other firm's just a complement of it. So having calculated American's best response curve we could have automatically drawn the United best response curve as a complement of that.

The other key point is by drawing this diagram we can see the Cournot equilibrium. Remember Cournot equilibrium. Cournot equilibrium is where I'm happy with my quantity given what the other firm's doing. Given what the other firm's doing I can't make any more money. Once again, I don't care about market share, I just care about money. So given what the other firm's doing I can't make any more money.

Well that happens at 64,000 each. Because when American is producing 64,000, United is happy to produce 64,000. That's their profit maximizing choice. If United is producing 64,000 American's happy to produce 64,000. That's their profit maximizing choice. So that point of each producing 64,000 we are in a Nash or Cournot equilibrium. Both firms are happy given what the other firm is doing. Both firms are profit maximizing given what the other firm is doing.

Now basically, for example, another way to look at this is that you're only in equilibrium if you're on both firms' reaction curves. So, for example, American might say, look the equilibrium I like is where I do 96,000 flights and you none. So the equilibrium I like is on the x-axis the point 96, 0, where I do 96,000 flights and you United do none.

United says, however, no that's not optimal for me. Because if you're doing that, then you're charging a price of $243. So there's money to be made for me. I can come in and start stealing some of your flights. So that's not an equilibrium from my perspective. Might be an equilibrium from your perspective.

You're delighted you're a monopolist. But not from my perspective. At that price I'll come in and start stealing some your business. And I'm going to start stealing some of your business. As I steal your business you are going to have to move up your best response curve because your residual demand is shrinking.

And you'll only reach equilibrium when you're both happy with the outcome. If only one firm is happy with the outcome the other firm can always change its behavior, raise its price up or down or its quantity up or down to change the market share and change the outcome. So equilibrium will only be when you're at both firms best response curves. You'll only be at both firm's best response curves where they intersect.

Let's stop there I'm going to come back next time. Jessica we should have the same handout next time. Let's make sure this figure is in the handout next time as well. And we'll come back and talk about this last figure and we'll do the math behind it as well.