We’ve already used game theory to discuss oligopoly in a couple of different ways. First, we had a simplified (two-action) simultaneous game, which showed how the pricing of duopolists can take the form of a Prisoners’ Dilemma (PD). Second, we introduced three more sophisticated models of duopoly: Cournot, Bertrand, and Stackelberg. However, none of these models were really dynamic, because they didn’t take place over time. (Stackelberg is a two-stage model, but it does not repeat over many periods.) Many competitors face each other week after week, month after month, year after year. The fact of repeated interaction can dramatically affect the likelihood of cooperative pricing. (“Cooperative pricing” is the term Besanko, et al., use to refer to quasi-collusive behavior in which firms do not explicitly try to cartelize, but implicitly may end up acting like a cartel anyway.)

I. Repeated Games

In the one-period analysis of duopoly, we concluded that the firms cannot successfully collude. In the PD version of the problem, for example, picking the low price is a dominant strategy, even though both firms would be better off if they picked the high price.

Do these results change if the firms play the game repeatedly? Could the firms manage to cooperate by using the threat of punishment in future plays of the game?

Suppose the PD version of the duopoly problem is repeated a finite number of times -- say, 10 times. It turns out that the firms still cannot manage to collude successfully, because doing so involves making non-credible promises or threats that are ruled out by subgame perfection. Consider the very last (10th) play of the game. In that game, the outcome will be exactly the same as in the one-shot game, because there is no longer any future in which to enforce threats or promises. Both players can predict this outcome of the 10th play of the game. Now consider the 9th play of the game. Here, as well, the outcome will be just as in the one-shot game. The players could make threats or promises about behavior in the 10th play -- but the threats and promises are pointless, because the result of the 10th play is a forgone conclusion. All the remaining games fall down like a line of dominoes. Subgame perfection tells us that in a finitely repeated PD, the outcome will be the same as in the one-shot game for every play of the game.

What happens if the game is repeatedly an infinite number of times? It turns out that in this case, collusion can sometimes be sustained as a Nash Equilibrium. Because there is always a future, it's always possible -- for any play of the game -- to make threats and promises based on future plays.

One method of sustaining collusion in an infinitely repeated PD is to use a trigger strategy. A trigger strategy says to cooperate until the other player cheats, and then cheat.
for a long period of time if the other player cheats. An extreme trigger strategy would say to cooperate until the other player cheats, and then cheat forever after if the other player cheats. This strategy is a called the “Grim” strategy.

If both players adopt a trigger strategy, and if the players care enough about the future relative to the present, then an equilibrium with collusion can be sustained. Suppose a player is thinking of cheating. If he cheats, he'll get a one-time large profit (from having the low price while the other player has the high price for one play of the game), followed by a stream of small profits (from both players setting the low price for the rest of time). If he continues to cooperate, he'll get a stream of medium profits (from both players setting the high price forever). Which outcome is better? The answer depends on how much the firms discount the streams of future profits, as well as the relative sizes of the different payoffs. If the players aren't too impatient, mutual cooperation can be a Nash Equilibrium.

To be more specific, suppose we have the Duopoly Cartelization game described earlier, with slightly different numbers:

<table>
<thead>
<tr>
<th></th>
<th>High Price</th>
<th>Low Price</th>
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<tbody>
<tr>
<td>High Price</td>
<td>100, 100</td>
<td>0, 150</td>
</tr>
<tr>
<td>Low Price</td>
<td>150, 0</td>
<td>60, 60</td>
</tr>
</tbody>
</table>

Let $\delta$ stand for the one-period rate of time discounting. In a business context, it’s usually the case that $\delta = 1/(1 + r)$, where $r$ is the interest rate. (However, we will modify this below.) Suppose you’re player 1, and you know that player 2 is using the Grim strategy. You know that if you cooperate, you’ll get 100 every period from now on. So your expected payoff is:

$$100 + 100\delta + 100\delta^2 + 100\delta^3 + \ldots = 100/(1 - \delta)$$

If you defect, you’ll get 150 now, and then 70 every period from then on. So your expected payoff is:

$$150 + 60\delta + 60\delta^2 + 60\delta^3 + \ldots = 90 + 60/(1 - \delta)$$

So it’s better to cooperate than defect if:

$$100/(1 - \delta) > 90 + 60/(1 - \delta)$$

$$40/(1 - \delta) > 90$$

$$40 > 90(1 - \delta)$$

$$40 > 90 - 90\delta$$

$$90\delta > 50$$

$$\delta > 50/90 = .5556$$
That is, it makes sense to cooperate if you care enough about the future relative to the present ($\delta$ is sufficiently large). And it seems reasonably likely that this statement will be true, because few firms would discount the future by 45%.

But is it reasonable to think that a game will go on forever, as we had to assume to make this approach work? No. But we can still use this approach if there's a certain probability that the game will end after any given play of the game. The term $\delta$ should be reinterpreted to include the probability that the game will end during any given period. Naturally, that means $\delta$ will be lower; firms will discount future streams of income more if there is a lower chance of getting them. But for sufficiently far-sighted firms, collusion is still a possible equilibrium.

Example: OPEC. In the 1970s, OPEC succeeded for a while in maintaining a cartel. But eventually the cartel collapsed, in part because of cheating by member nations, in part because of competition from oil producers in the North Sea and Southwestern U.S.

Example: Railroads in the 19th century. They repeatedly attempted to set high shipping rates in order to escape the cut-throat competition that was severely limiting their profits. But these agreements rarely lasted more than a few weeks, because the railroads couldn't resist the incentive to cut special deals with large shippers.

In general, the historical record shows that collusive agreements are possible but (unfortunately for the firms, fortunately for the consumers) extremely fragile and difficult to maintain. One of the main reasons is that it’s difficult for a cartel member to tell whether a drop in its sales is attributable to temporary demand fluctuations or other members cheating. Thus, a temporary drop in sales because of consumer choices can be mistaken for cheating, leading to a round of punishment under the trigger strategy agreement.

There are other strategy combinations, other than the grim strategy, that can be used to support a cooperative outcome. The most famous of these is the Tit-for-Tat strategy. Tit-for-Tat works like this: (1) In the first play of the game, cooperate. (2) In subsequent plays of the game, do what your competitor did in the previous play of the game. Thus, if your competitor cheated, you cheat; if he cooperated, you cooperate. This creates incentives for the other party similar to those created by the grim strategy. If your competitor defects, he will gain a short-term gain, but then will suffer losses (relative to the cooperative outcome) later on. Unlike the grim strategy, Tit-for-Tat allows forgiveness; essentially, your competitor has to let himself be “taken advantage of” for one period in order to re-establish cooperation.

What makes Tit-for-Tat so compelling? It might seem like Grim and Tit-for-Tat generate the same result of cooperation. But for a variety of reasons, such as the fluctuating demand issue discussed above, it’s possible to “misread” cooperation as cheating from time to time. A Grim strategy suffers more from misreads because it does not allow for
forgiveness. Tit-for-Tat is also “nice” because it starts by cooperating, which allows the cooperation to get off the ground. And it’s “provocable,” meaning that it protects itself by refusing cooperation once the player gets burned.

But Tit-for-Tat is not necessarily the “perfect” solution for firms that wish to cooperate. Why? Imagine there is no clear first period in which competition began. In that case, we could imagine two Tit-for-Tat players bouncing back and forth between cooperation and defection (Firm 1 cooperates while Firm 2 defects, and then Firm 1 defects because Firm 2 defected while Firm 2 cooperates because Firm 1 cooperated, ad infinitum). So it might make sense to adopt a strategy that is more forgiving, such as allowing two defections before defecting itself (Tit-for-Two-Tats). But on the other hand, a more forgiving strategy might be more vulnerable to hawkish players who wish to reap short-term gains, because the temporary gain from defection will be larger (lasting two periods instead of one).

II. Factors that Affect Oligopoly Pricing Behavior

If everything were very clear and certain, as it has been in our simplified models, then cooperative pricing could be pretty easy. But various factors create problems for would-be cooperators. The most important one, mentioned earlier, is fluctuating demand.

In general, cooperative outcomes are easiest to attain when: (a) it is easy to tell when defection has taken place, (b) it is easy to tell who defected, and (c) the short-run gain is relatively small compared to the difference between the cooperative and uncooperative outcomes. The factors that make cooperative outcomes more difficult generally thwart (a), (b), or (c).

A. More firms in the industry. The more firms there are, the larger is the short-run gain relative to the difference between the cooperative and uncooperative outcomes. Why? Because the gain from a higher industry price is spread among all the firms in the industry. A firm with a small market share will therefore get a smaller share of the benefits from cooperation. Also, the short-run gain from defection is larger for a smaller firm, because the gains from defection result from diverting customers from other firms’ share of the market (if your share is smaller, then the sum of the remaining firms’ shares is larger).

B. Slower reaction time. The longer it takes for other firms to react to a defection, the greater will be the short-run gains from defection (because they’ll last longer before the retaliation takes effect). There are several things that can slow down reaction time: (a) If orders are typically done in large quantities with lower frequency (“lumpy orders”), then there will be a longer lag-time before other firms can retaliate. (b) If prices are non-public, it takes longer for other firms to find out about defection and react to it. There may be many relatively invisible aspects of price, such as terms of credit, that make listed prices unreliable for monitoring defection. (c) If the number of buyers is relatively small, it will often take longer for other firms to discover defection. This is because buyers are one of the primary conduits of information about other firms’ behavior.
C. **Demand fluctuations.** As discussed earlier, the more volatile is demand, the more prices will fluctuate whether or not firms are cooperating. As a result, it becomes more difficult for firms to know for sure that other firms are defecting, since a drop in demand may explain the lower quantities the firm is able to sell.

D. **Asymmetries among firms.** The more different firms are from each other, the harder it is for firms to coordinate on a single “focal point.” For example, if duopolists have the same marginal cost, they would both calculate the same monopoly price, and that would be an obvious price for them to choose (even without communicating with each other). But if they have different marginal costs, they will favor different cooperative prices. What one firm perceives as a cooperative action, given its lower marginal cost, might be perceived as a non-cooperative action by a firm with a higher marginal cost. Also, for reasons noted in section A above, if firms differ in market share, smaller firms will typically have a greater incentive to defect. A larger firm might choose not to match a smaller firm’s lower price because it has more to lose from doing so (a bigger “people pay less” effect).

E. **More price-sensitive buyers.** The more sensitive buyers are to price, the more customers a firm will attract by defecting. This increases the short-run gain from defection relative to the difference between the cooperative and uncooperative outcomes. There are various things that can make buyers more or less price-sensitive, but one especially important one is the degree of product differentiation. The more homogeneous is the product, the more price sensitive buyers will be, because they can easily switch over to another firm’s product if it cuts price. Because of the fact that product differentiation makes buyers less price-sensitive and thereby eases cooperative pricing, firms may deliberately differentiate their products for strategic reasons.

F. **No clear price leader.** The advantage of having one large firm in the market set prices that other firms follow is that the price leader’s price provides a clear focal point for other firms to follow. Without a clear leader, there may not be a focal price.