GAME THEORY AND STRATEGIC DECISION MAKING

In the oligopoly theory we explored some of the strategic output and pricing decisions that firms must often make. We saw how firms must take into account the likely responses of its competitors when it makes these decisions.

There are many questions about market structure and firm behaviour that we have not yet addressed. For example:

- Why do firms collude in some markets and compete aggressively in others?
- How do some firms manage to deter entry by potential competitors?
- And how should firms make pricing decisions when demand conditions are changing or new competitors are entering the market?

To answer these questions, we will use game theory to extend our analysis of strategic decision making. The application of game theory has been an important development in microeconomics.

Definitions

A Game is any situation in which players (participants) make strategic decisions—i.e. they take into account each other's actions and responses.

Strategic decisions result in payoffs to the players. Payoffs are outcomes that generate benefits or rewards and these benefits or rewards could be in the form of profits, prices, utility, dividends etc.

A payoff is a value associated with a possible outcome.

Strategy is a rule or plan of action for playing a game which results in a payoff.

Optimal strategy is a strategy that maximises a player's expected payoff.

NON-COOPERATIVE VERSUS COOPERATIVE GAME

Economic games that firms play can either be cooperative or non-cooperative.

In cooperative games players can negotiate binding contracts that allow them to plan joint strategies.

- An example of a cooperative game is the bargaining between buyer and seller over the price of a rug. If the rug costs $100 to produce and the buyer values the rug at $200, a cooperative solution to the game is possible. An agreement to sell the rug at any price between $101 and $199 will maximise the sum of the buyer's consumer surplus and the seller's profit while making both parties better off.

- Another example of a cooperative game would involve two firms negotiating a joint investment to develop a new technology (assuming neither firm would have enough know-how to succeed on its own). If the firms can sign a binding contract to divide the profits from their joint investment, a cooperative outcome that makes both parties better-off is possible.

In a non-cooperative game negotiation and enforcement of binding contracts are not possible.

- An example of a non-cooperative game is the case where two competing firms take each other's behaviour into account when independently setting prices. Each firm knows that
by undercutting its competitor it can capture more market share. But it also knows that in doing so, it risks setting off a price war.

- Another example of a non-cooperative game is the auction. Each bidder must take the likely behaviour of the other bidders into account when determining an optimal bidding strategy.

NB: the fundamental difference between cooperative and non-cooperative games lies in the contracting possibilities. In cooperative games binding contracts are possible and in non-cooperative games they are not.

We will be concerned mostly with non-cooperative games. In any game, however, the most important aspect of strategic decision making is understanding your opponent’s point of view, and (assuming your point of view is rational) deducing his or her likely responses to your actions. This point may seem obvious—of course one must understand an opponent’s point of view. In simple games people often ignore or misjudge opponents’ positions and the rational responses that those positions imply.

**DOMINANT STRATEGIES**

The following are the questions that we need to answer:

- How can we decide the best strategy for playing a game?
- How can we determine a game’s likely outcome?

We need something to help us determine how the rational behaviour of each player will lead to an equilibrium solution. Some strategies may be successful if competitors make certain choices but fail if they make other choices. Other strategies, however, may be successful regardless of what competitors do.

We begin with the concept of a **dominant strategy**—one that is optimal no matter what the opponent does.

The following example illustrates this in a duopoly setting.

- Suppose Firms A and B sell competing products and are deciding whether to undertake advertising campaigns
- Each firm will be affected by its competitor’s decision.
- The possible outcomes of the game are illustrated in the payoff matrix below.
- The payoff matrix summarises the possible outcomes of the game; the first number in each cell is the payoff to Firm A and the second number is the payoff to Firm B.
- If both firms decide to advertise Firm A will make a profit of 10 and Firm B a profit of 5. If Firm A advertises and B does not, Firm A will earn 15 and Firm B zero (0). The table also shows the outcomes for the other two possibilities.
- **What strategy should each firm choose?** First consider Firm A. Firm A should advertise because no matter what firm B does, Firm A does best by advertising. If Firm B advertises A earns 10 if it advertises but only 6 if it doesn’t. If Firm B does not advertise, A earns 15 if it advertises but only 10 if it doesn’t.
- Advertising is therefore the dominant strategy for Firm A. The same is true for Firm B: No matter what Firm A does Firm B does best by advertising.
- Assuming that both firms are rational, we know that the outcome for this game is that **both firms will advertise**.
- When every player has a dominant strategy we call the outcome of the game an **Equilibrium in Dominant Strategies**.
• Such games are straightforward to analyse because each player’s optimal strategy can be determined without worrying about the actions of the other players.

**Table 1: Payoff Matrix for an Advertising Game**

<table>
<thead>
<tr>
<th>Firm B</th>
<th>Advertise</th>
<th>Don't Advertise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advertise</td>
<td>10, 5</td>
<td>15, 0</td>
</tr>
<tr>
<td>Firm A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Don’t Advertise</td>
<td>6, 8</td>
<td>10, 2</td>
</tr>
</tbody>
</table>

Unfortunately, not all games have dominant strategies for all players. To see this we change the advertising game slightly. The payoff matrix is the same as above except for the bottom right hand corner—if neither firm advertises, Firm B earns a profit of 2 and Firm A earns a profit of 20.

• Now Firm A has no dominant strategy. Its optimal decision depends on what Firm B does. If Firm B advertises, Firm A does best by advertising; but if Firm B does not advertise, Firm A does best by not advertising.
• Now suppose both firms must make their decisions simultaneously. What should Firm A do?
• To answer this question Firm A must put itself in B’s shoes. What decision is best from B’s point of view and what is B likely to do?
• The answer is clear: Firm B has a dominant strategy-advertise, no matter what Firm A does. If Firm A advertises, B earns 5 by advertising and zero (0) by not advertising. If A does not advertise B earns 8 if it advertises and only 2 if it doesn’t. Therefore Firm A can conclude that Firm B will advertise.
• This means that Firm A should advertise and thereby earn a profit of 10 instead of 6.
• The *equilibrium is that both firms will advertise*. It is a logical outcome of the game because Firm A is doing the best it can, given Firm B’s decision; and Firm B is doing the best it can given Firm A’s decision.
To determine the likely outcome of a game, we have been seeking self enforcing or stable strategies. Dominant strategies are stable, but in many games, one or more players do not have a dominant strategy. We therefore need a more general equilibrium concept.

Nash equilibrium is a set of strategies (or actions) such that each player is doing the best they can given the actions of its opponents. Because each player has no incentive to deviate from it Nash Strategy, the Nash strategies are stable. In Table 2 above the Nash strategy is that both firms should advertise. In other words given the decision of its competitor, each firm is satisfied that it has made the best decision possible, and so has no incentive to change its decision.

In the Nash Equilibrium each firm is earning the largest profit it can given the prices of its competitors, and thus has no incentive to change its price. It is helpful to compare the concept of a Nash Equilibrium with that of equilibrium in dominant strategies.

Dominant Strategies: I am doing the best I can no matter what you do. You are doing the best you can no matter what I do.

Nash Equilibrium: I am doing the best I can given what you are doing. You are doing the best you can given what I am doing.

NB: Dominant strategy equilibrium is a special case of Nash equilibrium. In Table 2 above there is a single Nash Equilibrium—both firms advertise. In general a game need not have a single Nash Equilibrium. Sometimes there is no Nash Equilibrium, and sometimes there are several (i.e. sets of strategies are stable and self enforcing). The following examples will help clarify this.
The product Choice Problem
- Consider the following product choice problem.
- Two breakfast cereal companies face a market in which two new variations of cereal can be successfully introduced—provided that each variation is introduced by only one firm.
- There is a market for a new “crispy” cereal and a market for a new “sweet” cereal, but each firm has resources to introduce only one new product.

Table 3: Product Choice Problem

<table>
<thead>
<tr>
<th></th>
<th>Firm 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crispy</td>
<td>-5, -5</td>
</tr>
<tr>
<td>Sweet</td>
<td>10, 10</td>
</tr>
</tbody>
</table>

- The payoff matrix for the two firms looks like Table 3 above.
- In this game each firm is indifferent about which product it produces—so long as it does not introduce the same product as its competitor. If coordination were possible the two firms would probably agree to divide the market.
- But what if the firms must behave non-cooperatively?
- Suppose that somehow—perhaps through a news release—Firm 1 indicates that it is about to introduce the sweet cereal, and that Firm 2 after hearing this announces its plan to introduce the crispy one.
- Given the action that it believes its opponent is taking, neither firm has an incentive to deviate from its proposed action. If it takes the proposed action its payoff is 10, but if it deviates and its opponent’s action remains unchanged—its payoff is -5.
- Therefore the strategy set given by the bottom left hand corner of the payoff matrix is stable and constitutes a Nash Equilibrium. Given the strategy of its opponent, each firm is doing the best it can and has no incentive to deviate.
- Note that the upper right hand corner of the payoff matrix is also a Nash Equilibrium, which might occur if Firm 1 indicated that it was about to produce the crispy cereal.
- Each Nash Equilibrium is stable because once the strategies are chosen; no player will unilaterally deviate from them.
- Without further information we have no way of knowing which equilibrium (crispy/sweet versus sweet/crispy) is likely to result—or if either will result.
- Both firms have strong incentive to reach one of the two (2) Nash Equilibria, however, if they both introduce the same product they will both lose money.
- The fact that the two firms are not allowed to collude does not mean that they will not reach Nash Equilibrium. As an industry develops, understandings often evolve as firms “signal” each other about the paths the industry is to take.
Maximin Strategies

- The concept of a Nash Equilibrium relies heavily on individual rationality. Each player's choice of strategy depends not only on his own rationality, but also on the rationality of his opponent. This can be a limitation as the example in Table 4 shows.
- In this game, two firms compete in selling file encryption software. Because both firms use the same encryption standard, files encrypted by one firm's software can be read by the other firm—an advantage for consumers.
- Nonetheless, Firm 1 has a much larger market share because it entered the market earlier and its software has better user interface. Both firms are now considering an investment in a new encryption standard.
- Note that investing is the dominant strategy for Firm 2 because by doing so it will do better (earning 10 million instead of zero) regardless of what Firm 1 does. Thus Firm 1 should expect Firm 2 to invest. In this case Firm 1 would also do better by investing (and earning $20 million) than by not investing (and losing $10 million).
- Clearly, the outcome (invest, invest) is a Nash Equilibrium for this game, and you can verify that it is the only Nash Equilibrium.
- NB: Firm 1's managers had better be sure that Firm 2's managers understand the game and are rational. If Firm 2 should happen to make a mistake and fail to invest, it would be extremely costly to Firm 1.
- Consumer confusion over incompatible standards would arise, and Firm 1, with its dominant market share would lose $100 million.
- **If you were Firm 1 what would you do?**

  - If you tend to be cautious—and you are concerned that managers of Firm 2 might not be fully informed or rational—you might choose to play "don't invest". In that case the worst that can happen is that you will lose $10 million; you no longer have a chance to lose $100 million.
  - Such a strategy is called a maximin strategy because it maximises the minimum that can be earned.
  - If both firms used maximin strategies the outcome would be that Firm 1 does not invest and Firm 2 does. A maximin strategy is conservative and it is not profit maximising. Firm 1, for example, loses $10 million instead of earning $20 million.
  - Note that if Firm 1 knew for certain that Firm 2 was using a maximin strategy, it would prefer to invest and earn $20 million instead of following its own maximin strategy of not investing.
Table 4: Maximin Strategy

Firm 2

<table>
<thead>
<tr>
<th></th>
<th>Don’t Invest</th>
<th>Invest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Don’t Invest</td>
<td>0, 0</td>
<td>-10, 10</td>
</tr>
<tr>
<td>Invest</td>
<td>-100, 0</td>
<td>20, 10</td>
</tr>
</tbody>
</table>

PRISONERS’ DILEMMA

What is the Nash equilibrium for the Prisoner’s Dilemma? Table 5 below shows the outcome for the Prisoners’ Dilemma. The ideal outcome is the one in which neither prisoner confesses, so that both get two years in prison. Confessing is the Dominant Strategy for each prisoner—it yields a higher payoff regardless of the strategy of the other prisoner. Dominant strategies are also maximin strategies.

Table 4: Prisoners’ dilemma (Maximin Strategy)

Prisoner B

<table>
<thead>
<tr>
<th></th>
<th>Confess</th>
<th>Don’t Confess</th>
</tr>
</thead>
<tbody>
<tr>
<td>Confess</td>
<td>-6, -6</td>
<td>-1, -10</td>
</tr>
<tr>
<td>Don’t Confess</td>
<td>-10, -1</td>
<td>-2, -2</td>
</tr>
</tbody>
</table>

Prisoner’s Dilemma Applications

The most studied game in business is the prisoners’ dilemma. It illustrates a fundamental tension between conflict and cooperation. Both prisoners would like to cooperate to minimize their sentences (lower right corner below), but face a large temptation to turn in the other. Consequently it is difficult to maintain such a cooperative agreement. In the jargon of game theory, we say that such an outcome is not an equilibrium of the game.
Table 6: Prisoners' Dilemma Applications

<table>
<thead>
<tr>
<th>Jesse's Actions</th>
<th>Confess</th>
<th>Don't confess</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frank's Actions</td>
<td>Confess</td>
<td></td>
</tr>
<tr>
<td>Both receive 5 years in jail</td>
<td>Jesse 10 years, Frank goes free</td>
<td></td>
</tr>
<tr>
<td>Don't confess</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frank 10 years, Jesse goes free</td>
<td>Both receive 2 years in jail.</td>
<td></td>
</tr>
</tbody>
</table>

Equilibrium is reached in the upper left corner: each competitor is doing the best it can given what its opponent is doing. Neither competitor can unilaterally make himself better off. Note that this is not an **efficient** outcome—the inefficiency is analogous to an unconsummated wealth creating transaction.

Table 7: Pricing dilemma

<table>
<thead>
<tr>
<th>Coke's Actions</th>
<th>Price Low</th>
<th>Price High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pep's Actions</td>
<td>Price Low</td>
<td>Both receive low profits; Pepsi makes very high profits; Coke makes very low profits</td>
</tr>
<tr>
<td>Price High</td>
<td>Coke makes very high profits; Pepsi makes very low profits</td>
<td>Both receive high profits</td>
</tr>
</tbody>
</table>

Table 8: Advertising dilemma

<table>
<thead>
<tr>
<th>RJR Actions</th>
<th>Advertise Heavily</th>
<th>Advertise Lightly</th>
</tr>
</thead>
<tbody>
<tr>
<td>PM Actions</td>
<td>Both receive low profits</td>
<td>P-M makes very high profits; RJR makes very low profits</td>
</tr>
<tr>
<td>Advertise Heavily</td>
<td>P-M makes very high profits; RJR makes very low profits</td>
<td>Both receive high profits</td>
</tr>
<tr>
<td>Advertise Lightly</td>
<td>Both receive low profits</td>
<td>Both receive high profits</td>
</tr>
</tbody>
</table>


Discussion Question: How did the Tobacco Companies profits change following the government's ban of over-the-air cigarette advertising?

Table 9: Free Riding

<table>
<thead>
<tr>
<th></th>
<th>Shirk</th>
<th>Work Hard</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Student &quot;Joe&quot;</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shirk</td>
<td>Both receive C's; neither works very hard on this assignment</td>
<td>Both receive B's; Joe works hard but Sally does not</td>
</tr>
<tr>
<td>Work Hard</td>
<td>Both receive B's; Sally works hard but Joe does not</td>
<td>Both receive A's; both work very hard on this assignment</td>
</tr>
</tbody>
</table>

Assume that both students rank the outcomes as follows:

1. A Grade of B and no work is better than
2. A Grade of A and hard work which is better than
3. A Grade of C and not working which is better than
4. A Grade of B and hard work.

With this set of preferences, they reach a Nash equilibrium where each does not work and both get C's even though they would jointly prefer A's and working hard. Like all the prisoner's dilemma games, this illustrates the fundamental conflict between competition and cooperation.

Discussion Question: Describe a prisoner's dilemma in which either you or your company have been caught and tell me what you did to get out of it.

How to escape from a Prisoner’s Dilemma

The main message of the prisoners' dilemma is to not get caught in one. Realize that being in a dilemma means that there are unconsummated wealth creating transactions, and that getting out of a dilemma is analogous to consummating them.

- Communicate, but this violates section 1 of the Sherman Act. Often phone records are used in court as evidence that the firms were communicating with one another. "Wire fraud" is much easier to prove than price fixing.
- Alternatively, communicate indirectly:
  - Price leadership. The Dept of Justice is investigating the tire manufacturers in the US for anticompetitive pricing. Apparently Goodyear is the price leader in the industry.
  - Use "Focal Points". Example: $0.35 for candy bars; even 1/4 quotes on NASDAQ.
  - Announce "Most Favoured Customer" style agreements,
  - Announce price increases.

Commitment as a way out of a prisoner’s dilemma:

Develop a reputation for "punishing" aggressive rival behaviour, i.e. following a rival’s price cut, you price even lower. This is sometimes referred to as commitment To analyze such games, look
ahead, and then reason back. A rival will look ahead and realize that if he cuts price, it will provoke an aggressive response, i.e. punishment. If it believes it will be punished, it will not pursue such a course of action.

The more severe the threatened punishment, the less likely rivals will price low. However, the more severe the punishment, the less credible it is. What if you actually have to use it? If firm 1 does price low, then firm 2 would do better by not punishing firm 1, i.e. the threat is not credible. Establishing credible threats is very difficult.

- In the bargaining section of the class, we will examine 8 ways to establish credibility.
- Best strategies for repeated prisoner's dilemma games:

Economist Axelrod ran a tournament among economists to see which strategy would win a repeated prisoners dilemma. He ran computer simulations to determine the winner. Tit-for-Tat was the winning strategy. Axelrod identified 5 factors that characterized successful strategies:

- Be nice: no first strikes.
- Be forgiving: do not try to punish competitors too much.
- Be provocable: respond immediately to competitor aggressive moves.
- Don’t be envious: focus only on your own slice of the profit pie, not the size of your competitor’s slice.
- Be clear: make sure your competitors can easily interpret your actions.

How to avoid getting caught in a prisoner's dilemma:

Change the structure of the game by making your product less sensitive to rival's prices. Be creative. The goal here is to change the structure of the game so that the mutually advantageous outcome is a Nash Equilibrium.

- Seek a competitive advantage: make your company less sensitive to the pricing of rivals.
- Seek an unfilled niche; "Become a monopolist."
- Differentiate your product with design improvements, service, or advertising.
- Seek a cost advantage.
- Develop unique distribution channels.