# 7. Game theory

## The concept

Game Theory, a branch of applied mathematics, is used by economists to explain competition among firms in oligopoly and monopolistic competition. It is a mathematical analysis of strategic behaviour. The players are the rival businesses in an industry where strategic games are commonly played as firms seek advantage over rivals. Firms decide on their strategies, taking into consideration what their opponents' strategies are likely to be. Mathematical analysis of strategic behaviour, known as Game Theory, helps us to understand the decisions made by firms.

Game Theory is a mathematical analysis of businesses' competitive strategies.

Some common competitive games are outlined in this section and the strategies of each player are analysed by comparing the payoffs of those strategies. A payoff is what a player receives from the outcome of a game once players have made their decisions. Payoffs can be summarised in small matrices.

In each game, firms will try to use a dominant strategy, a strategy that, no matter what their rivals do, will bring them the best payoff. Each firm will need to deduce its rivals' likely responses to their own strategies, for the best results.

A dominant strategy is a strategy that, no matter what their rivals do, brings them the best payoff.

## The duopoly game

We read in Chapter 3.1 that price competition is not common in an oligopoly. This is because, if a firm's strategy is to cut its price to lift sales, its rivals will do the same to defend their share of the industry's sales. The result is likely to be lower prices and lower profits for each firm. So how do firms set their prices?

Price fixing is illegal, but firms in an oligopoly sometimes find ways of colluding anyway. To understand how oligopoly firms charge a similar price, we will limit our study to a duopoly, an oligopoly with only two firms. To do a similar analysis for a market supplied by more than two firms is more complicated, but the principles are the same. Collusion is not effective, in addition to being illegal in the structure of laws prevailing in Australia.

If both duopolists charge a high price they will both make high profits. The dilemma for both companies, having made a collusive agreement to both charge a high price, is whether to comply with that agreement, or to cheat. If one undercuts the other's price, it will get more customers, winning those customers from its rival. Its rival's response will be to also charge a lower price. After some trial and error by both companies, an equilibrium will emerge, as each decide on the strategy that delivers their best outcome. The equilibrium position will occur when both companies charge a competitively low price.

Even if the equilibrium is for players to comply with the agreement, they will probably cheat at some point. An actual case study can illustrate this. In the case study, the players are countries rather than companies. The Organisation of Petroleum Exporting Countries (OPEC) is based on an agreement by oil-rich, Middle Eastern countries to hold back oil production in order to keep crude oil prices high. However, there are several examples of countries cheating on this agreement. When Kuwait expanded its production in defiance of the agreement, Iraq invaded Kuwait in 1990 and set fire to its oil wells, sparking American intervention codenamed Desert Shield. Also, in 2018 Iran accused Saudi Arabia and Russia of breaking the OPEC agreement by increasing oil production.

We will now use game theorists' mathematical analysis for the duopoly game. Our fictional example is of two newspapers servicing the same small city, The Express and The Clarion, both issued daily. Imagine that payoffs in the table below are calculated by both players, with full knowledge of their own costs and educated guesses about their rival's costs. These are summarised in the matrix below. Payoffs from The Clarion's strategies show the change in profit after equilibrium, in green, and The Express' in purple. The payoffs if both firms cheat are shown in the top left box, and in the bottom right if both comply. The matrix shows outcomes, or payoffs, as percentage changes in income.

| Payoff matrix | | The Express' strategies | |
|---|---|---|---|
| | | Cheat | Comply |
| The Clarion's strategies | Cheat | + 5%/+ 5% | + 40%/- 10% |
| | Comply | - 10%/+ 40% | + 20%/+ 20% |

To choose The Clarion's best strategy outcomes, focus on the green numbers only. First, look at The Express' first column, "cheat". If The Express cheats, The Clarion's profit will increase by 5% if it also cheats but will decrease by 10% if it complies. Since a 5% rise in profit is preferable to a 10% decrease, The Clarion's best strategy, if The Express cheats, is to also **cheat**. See (1) in the table below.

| | Strategy | Cheat | Comply |
|---|---|---|---|
| The Clarion's strategies | Cheat ✓ (3) | + 5% ✓ (1) | – 40% ✓ (2) |
| | Comply | - 10% | + 20% |

Next, to choose The Clarion's responses if The Express complies, look at The Express' second column. If The Clarion also complies, it's profit will fall by 40% if it cheats and will increase by 20% if it complies. Since a 40% increase is better than 20%, The Clarion's best strategy, if The Express complies, is to **cheat**. See (2) in the table above.

The Clarion's strategy in both cases is to cheat. This, then, is its **dominant strategy** because it is its best strategy no matter what The Express does. See (3) in the table above.

To choose The Express' best strategy outcomes, focus on the purple numbers only. First, look at The Clarion's first row, "cheat". If The Clarion cheats, The Express' profit will increase by 5% if it also cheats and fall by 10% if it complies. The Express' best strategy, in the case of The Clarion cheating, is to also cheat. See (1) in the table below.

| Payoff matrix | | The Express' strategies | |
|---|---|---|---|
| | | Cheat ✓ (3) | Comply |
| The Clarion's strategies | Cheat | + 5% ✓ (1) | - 10% |
| | Comply | + 40% ✓ (2) | + 20% |

Next, look at The Clarion's second row. If The Clarion complies, The Express' profit will increase by 40% if it cheats but by only 20% if it complies. In this case The Express' better strategy is again to **cheat**. See (2) in the table above.

The Express also has a dominant strategy–it's best strategy no matter what The Clarion does – which is to **cheat**. See (3) in the table above.

The dominant strategies for both firms is the same, and so the market will settle into an equilibrium, a dominant strategy equilibrium.

**Eco Term**

A dominant strategy equilibrium occurs when each player plays its dominant strategy.

## Nash equilibrium

In terms of the matrix reproduced below, both firms choose the box in the top left-hand corner. That means that both publishers will cheat, in other words they will compete rather than comply with an agreement to collude. **They both have the same dominant strategy**, which is to cheat, and neither has anything to gain by changing to a better strategy. This can be checked by looking at the alternative strategies to each other's plays. If The Express cheats, The Clarion's response to cheat (a 5% increase in profit) pays better than to comply (a 10% drop in profit). If The Clarion cheats, The Express also cheats because the alternative pays less (a -10% profit change compared to a 5% profit increase). A Nash equilibrium exists.

| Payoff matrix | | The Express' strategies | |
|---|---|---|---|
| | | Cheat | Comply |
| The Clarion's strategies | Cheat | + 5% ✓/+ 5% ✓ | + 40% ✓/– 10% |
| | Comply | - 10%/+ 40% ✓ | + 20%/+ 20% |

A Nash equilibrium is named for its originator, John Nash, the subject of the film "A Beautiful Mind" in which Nash was played by Russell Crowe. Nash shared the Nobel Prize for Economics in 1994 for his Game Theory.

**Eco Term**

A Nash equilibrium exists when each player's strategy is the best response to the other players' strategies, and each has no incentive to change their strategy.

## The price game

Let us imagine Qantas and Virgin airlines each pricing the Sydney to Melbourne 8.00 am flights. They do not produce identical services. Virgin, for example, try to have a more fun approach to their customers' flight experience in order to differentiate their product from Qantas, an established company when Richard Branson entered Virgin into the airline market in the year 2000.

The two airlines fly similar aeroplanes for these flights. They both have good knowledge of the costs of supplying their own flight services, but not exact details of each other's costs. Let's say that Qantas and Virgin consider charging either $100 or $120 for an 8.00 am return flight to Sydney from Melbourne. They would both have to calculate their likely profits from a single seat. Note that the amounts shown in the table below are fictional.

| Payoff matrix | | Qantas' prices | |
|---|---|---|---|
| | | Charge $100 | Charge $120 |
| Virgin's prices | Charge $100 | $30/$30 | $50/$10 |
| | Charge $120 | $10/$50 | $40/$40 |

Working through Virgin's responses to Qantas' strategies, the first column shows that Virgin would choose to charge $100 if Qantas did, as a $30 profit per seat is better than $10, and the second column shows that Virgin would choose $50 over $40, charging $100, if Qantas charged $120. Virgin has a dominant strategy, then, which is to charge $100 no matter which price Qantas chooses.

| Payoff matrix | | Qantas' prices | |
|---|---|---|---|
| | | Charge $100 | Charge $120 |
| Virgin's prices | Charge $100 ✓ | $30 ✓/$30 | $50 ✓/$10 |
| | Charge $120 | $10/$50 | $40/$40 |

The first Qantas row in the table below shows that it will choose $30 over $10 if Virgin charged $100 per seat, thus charging the lower price itself. The second row shows that Qantas would also charge $100, preferring /$50 to /$40 if Virgin charged $120. Qantas too has a dominant strategy, to charge $100 no matter what price Virgin might choose.

| Payoff matrix | | Qantas' prices | |
|---|---|---|---|
| | | Charge $100 ✓ | Charge $120 |
| Virgin's prices | Charge $100 | $30/$30 ✓ | $50/$10 |
| | Charge $120 | $10/$50 ✓ | $40/$40 |

Looking at the strategies chosen by both, in the table below, and focussing on the four boxes highlighted in yellow in the table below, the top left is the only box that both airlines choose with two ticks in the same box. That combination of strategies will bring the market to equilibrium.

| Payoff matrix | | Qantas' prices | |
|---|---|---|---|
| | | Charge $100 ✓ | Charge $120 |
| Virgin's prices | Charge $100 ✓ | $30 ✓/$30 ✓ | $50/ ✓/$10 |
| | Charge $120 | $10/$50 ✓ | $40/$40 |

The equilibrium position is a dominant strategy equilibrium because it is the result of both players following their dominant strategy. It is also a Nash equilibrium because neither player can do better with a different strategy. It seems that the bottom right box is a better outcome for both, but we have already decided that there is a better strategy in response to each of the other player's strategies. Virgin won't choose to charge the higher price if Qantas does, because the alternative, a $50 profit, is better. The same argument applies to Qantas.

Profits could be higher for both if they make an enforceable agreement to each charge $120. However, not only is an enforceable agreement illegal in most countries, the duopoly game described above suggests that duopolists are unlikely to collude, given that the dominant strategy for each is to cheat.

A different game is illustrated by a real event involving these two airlines, not a price war but a capacity war that erupted in 2012-2013. In 2012 Virgin began a discounting war with Qantas in order to grab a bigger share of the corporate and government business class market. It made immediate gains in that market, and then, in order to consolidate these gains, bought more aeroplanes to increase its capacity to fly more routes. Qantas responded immediately, to win back their lost market share. Alan Joyce, Qantas CEO, explained that his airline's profit maximising position was to keep its 65% of the market, and so Qantas also bought more aeroplanes and increased its flights.

It is instructive to look at one more price game scenario, both for practice and to illustrate the fact that there is not always a dominant strategy, there is not always an equilibrium and if there is an equilibrium it will not necessarily be a Nash equilibrium.

In the case shown in the payoff matrix below, two firms, Firm 1 and Firm 2, each firm chose a high or low price in response to the other firm's decisions. The numbers refer to an increase in profit. It is a good idea to work it through yourself. There is more practice in the focus questions to follow.

| Payoff matrix | | Firm 2 | |
|---|---|---|---|
| | | Low | High |
| Firm 1 | Low | 60/80 ✓ | 40 ✓/70 |
| | High | 70 ✓/60 | 30/70 ✓ |

Neither firm has a dominant strategy, there is no Nash equilibrium as there is no one box in which the two firms choose the same strategy, and the there is no equilibrium position between the firms.

## The advertising game

Advertising is an effective strategy and will increase a firm's revenue, at least for a while. The Decore shampoo television advertisement, from 1988 to 1992, was wildly successful, and each campaign broadcast resulted in higher sales for a while, However, the product itself seems to have been unpopular as sales always fell off quite soon.

Advertising announces its product and its product differentiation. New customers try the product and so move their custom from rival firms. Each time an oligopolist starts an advertising campaign, it wins market share from its competitors. But then its competitors respond with competitive strategies of their own, usually advertising, to regain their lost market share. The end result is higher costs and therefore lower profits for each company. Television advertising in particular is extremely expensive.

However, the first company to advertise does win some market share and usually keeps it. That is the advantage of moving first. Such an advantage can be achieved by strategies other than advertising, such as the release of a new product or a new technology, or by increasing output. The advantage gained from these competitive strategies is achieved by being the first to move – to release a new product, to increase capacity or to advertise.

## Focus Questions

14. (a) What is the purpose of game theory?

(b) Explain the difference between a dominant strategy equilibrium and a Nash equilibrium.

15. (a) Complete the following payoff matrices. Note any Nash equilibria or dominant strategies. Label the vertical columns Firm A and the horizontal rows Firm B. Start by looking at Firm A's responses to each of Firm B's choices and tick their best ones, then tick Firm B's best responses to Firm A's choices.

(i)

| | |
|---|---|
| 9, 9 | 1, 10 |
| 10, 1 | 2, 2 |

(ii)

| | |
|---|---|
| 7, 6 | 5, 5 |
| 4, 5 | 6, 4 |

(iii)

| | |
|---|---|
| 8, 7 | 4, 6 |
| 6,5 | 7, 8 |

(iv)

| | |
|---|---|
| 5, 6 | 2, 7 |
| 4, 3 | 3, 4 |

(b) Summarise the lesson for duopolists to learn from the "advertising game".

16. Summarise the four market forms in the table below.

| | Perfect Competition | Monopolistic competition | Oligopoly | Monopoly |
|---|---|---|---|---|
| Features | | | | |
| Close Australian examples | | | | |