Industrial Economics

Dr.Tarek Safwat

CHAPTER 7
GAME THEORY

GAME THEORY

- Game theory helps us understand oligopoly and other situations where “players” interact and behave strategically.
- **Dominant strategy**: a strategy that is best for a player in a game regardless of the strategies chosen by the other players
- **Prisoners’ dilemma**: a “game” between two captured criminals that illustrates why cooperation is difficult even when it is mutually beneficial

GAME THEORY

- Game theory is the study of how people behave in strategic situations.
- Strategic decisions are those in which each person, in deciding what actions to take, must consider how others might respond to that action.

GAME THEORY

- Game theory is a branch of mathematical analysis developed to study decision making in conflict situations.
- It is an interdisciplinary approach – mathematics and economics.
- Game theory was founded by the great mathematician John von Neumann. He developed the field with the great mathematical economist, Oskar Morgenstern.

GAME THEORY

- Game theory analyzes the interactions between rational individuals or entities, known as players, who are pursuing their own self-interests.
- It explores various scenarios, known as games, where players make choices and receive outcomes based on the choices made by all participants.

GAME THEORY

- Because the number of firms in an oligopolistic market is small, each firm must act strategically.
- Each firm knows that its profit depends not only on how much it produces but also on how much the other firms produce.

KEY CONCEPTS OF GAME THEORY

- **Key Concepts:**
- A) Players: Game theory involves multiple players, each with their own preferences, strategies, and payoffs.
- B) Strategies: Players choose from a set of possible strategies, which determine their actions in the game.
- C) Payoffs: Payoffs represent the outcomes or rewards associated with different combinations of strategies chosen by the players.

PRISONERS' DILEMMA

- A game between two prisoners that shows why it is hard to cooperate, even when it would be beneficial to both players to do so.

PRISONERS' DILEMMA

- **The Prisoners' Dilemma**
  - Art and Bob been caught stealing a car: sentence is 2 years in jail.
  - Inspector wants to convict them of a big bank robbery: sentence is 10 years in jail.
  - Inspector has no evidence and to get the conviction, he makes the prisoners play a game.

PRISONERS' DILEMMA

- **Rules**
- Players cannot communicate with one another.
  - If both confess to the larger crime, each will receive a sentence of 3 years for both crimes.
  - If one confesses and the accomplice does not, the one who confesses will receive a sentence of 1 year, while the accomplice receives a 10-year sentence.
  - If neither confesses, both receive a 2-year sentence.

PRISONERS' DILEMMA

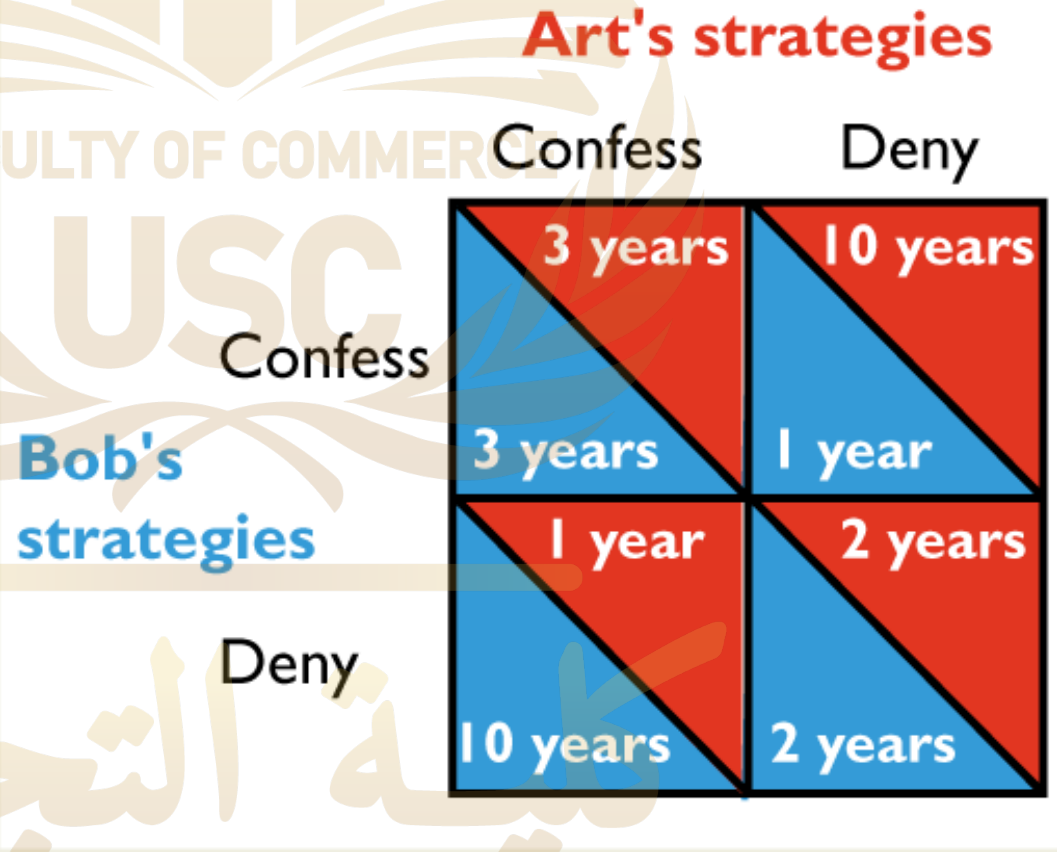
- **Strategies**
- The **strategies** of a game are all the possible outcomes of each player.
- The strategies in the prisoners' dilemma are:
  - Confess to the bank robbery
  - Deny the bank robbery

PRISONERS' DILEMMA

- **Payoffs**
- Four outcomes:
  - Both confess.
  - Both deny.
  - Art confesses and Bob denies.
  - Bob confesses and Art denies.
- A **payoff matrix** is a table that shows the payoffs for every possible action by each player given every possible action by the other player.

PRISONERS' DILEMMA

Table shows the prisoners' dilemma payoff matrix for Art and Bob.



Nash Equilibrium

Definition: A Nash Equilibrium occurs when each player chooses a strategy that gives him/her the highest payoff, given the strategy chosen by the other player(s) in the game. *("rational self-interest")*

Nash Equilibria occur when best responses line up

A GAME THEORY SIMULATION

- Let's say that an oligopoly industry consists mainly of two rival competitors (for example, A and B). The table below illustrates strategies and rewards, depending on whether the firms cooperate in price setting or not. After playing the game simulation, we notice the following outcome
- s:

	Firm B sets a high price	Firm B sets a lower price
Firm A sets a high price	Firm A's profit = $40 million Firm B's profit = $40 million	Firm A's profit = $10 million Firm B's profit = $60 million
Firm A sets a lower price	Firm A's profit = $60 million Firm B's profit = $10 million	Firm A's profit = $15 million Firm B's profit = $15 million

A GAME THEORY SIMULATION

- When firm A sets a high price, but firm B sets a lower price (the blue option in the table), then most consumers will purchase firm's B's products, and firm B will make a much higher profit than firm A. The opposite happens when firm B sets a high price, and firm A sets a lower price (the green option).
- If both firms set a high price, then neither firm will have a market share advantage, but the high price will generate a moderately high profit for each firm (the black option). This option often occurs when firms choose to cooperate (collude) and form a cartel. In most industrialized countries, anti-trust laws prohibit explicit cooperation.

A GAME THEORY SIMULATION

- If both firms set a low price (the red option), then neither firm will have a market share advantage. However, the low price reduces each firm's profits. This is beneficial for consumers, but not for firms. This non-cooperation situation occurs when firms engage in a price war. An outcome that stems from non-cooperation is called a Nash equilibrium. The Nash equilibrium in the above table is that both firms end up with a profit of $15 million.

1. PRISONER'S DILEMMA IN PRICE COMPETITION

- **Industry Example: Airline Ticket Pricing**
- Two airlines dominate a route, say Airline A and Airline B.
- Both can either set high prices (cooperate) or low prices (compete aggressively).

1. PRISONER'S DILEMMA IN PRICE COMPETITION

	Airline B: High Price	Airline B: Low Price
Airline A: High Price	A: High profits, B: High profits	A: Low profits, B: High profits
Airline A: Low Price	A: High profits, B: Low profits	A: Low profits, B: Low profits

1. PRISONER'S DILEMMA IN PRICE COMPETITION

	Airline B: High Price	Airline B: Low Price
Airline A: High Price	A: $20M, B: $20M	A: $5M, B: $30M
Airline A: Low Price	A: $30M, B: $5M	A: $10M, B: $10M

1. PRISONER'S DILEMMA IN PRICE COMPETITION

- If both airlines choose low prices, they enter a price war, earning low profits.
- If both choose high prices, they maximize profits but risk regulatory scrutiny for collusion.
- Airlines often get stuck in the low-price, low-profit equilibrium due to lack of trust.

1. PRISONER'S DILEMMA IN PRICE COMPETITION

- **High Price, High Price:**
- Both airlines cooperate and set a high price. Profits: $20M for each airline.
- This is the best collective outcome but risks regulatory attention if collusion is suspected.
- **High Price, Low Price:**
- One airline charges a high price while the other undercuts with a low price.
- The low-price airline captures most of the market: $30M for the low-price airline and only $5M for the high-price airline.
- **Low Price, Low Price:**
- Both airlines compete aggressively by setting low prices.
- Profits drop for both: $10M each, a worse outcome than cooperation.

. PRISONER'S DILEMMA IN PRICE COMPETITION

- Dominant Strategy: Setting a low price is the safer choice for both airlines because it avoids being undercut (earning $5M if the other airline sets a low price).
- Nash Equilibrium: Both airlines set low prices, earning $10M each. This is a suboptimal outcome compared to the cooperative $20M each.

R&D INVESTMENT GAME

- **Industry Example: Pharmaceutical Companies**
- Firms like Pfizer and Moderna decide how much to invest in R&D for vaccines.
- High R&D investment may lead to innovation, but it’s costly.
- If both invest heavily, profits may diminish due to competition.
- If one invests and the other doesn’t, the innovator captures the market.

R&D INVESTMENT GAME

	Moderna Invests	Moderna Doesn't Invest
Pfizer Invests	Moderate profits for both	Pfizer gains monopoly profits
Pfizer Doesn't Invest	Moderna gains monopoly profits	Both firms earn low profits

R&D INVESTMENT GAME

	Moderna Invests	Moderna Doesn't Invest
Pfizer Invests	Pfizer: $50M, Moderna: $50M	Pfizer: $80M, Moderna: $20M
Pfizer Doesn't Invest	Pfizer: $20M, Moderna: $80M	Pfizer: $30M, Moderna: $30M

R&D INVESTMENT GAME

- **Both Invest:**
- Both Pfizer and Moderna invest heavily in R&D.
- They split the market, earning $50M each due to shared market dominance.
- **One Invests, One Doesn't:**
- The company that invests captures a monopoly position, earning $80M, while the non-investing firm earns only $20M.
- Incentive to be the sole investor creates a competitive dynamic.

R&D INVESTMENT GAME

- **Neither Invests:**
- Without R&D investment, both firms earn $30M through existing products, but they risk losing market share to competitors in the long run.

R&D INVESTMENT GAME

- **Dominant Strategy:** Investing in R&D is risky because of high costs, but not investing risks losing market dominance.
- **Nash Equilibrium:** Both firms invest in R&D, earning $50M each. This is suboptimal compared to a cooperative strategy where only one invests while both share the rewards.

Types of Cooperation/Collusion

Collusion: An agreement among sellers to act jointly in their common interest.

Explicit Collusion: Firms agree to joint profit-maximizing outputs (illegal in Canada)

Examples: OPEC oil

If a single firm cheats, it increases its profits. If cheating grows, the collusion fails

QUESTION 1: PRICE COMPETITION EXAMPLE

- **Airline A and Airline B dominate a route. They can choose between setting high prices or low prices. The payoff matrix below shows the profits for each airline (in millions of dollars).**

	Airline B: High Price	Airline B: Low Price
Airline A: High Price	A: $20M, B: $20M	A: $5M, B: $30M
Airline A: Low Price	A: $30M, B: $5M	A: $10M, B: $10M

QUESTION 1: PRICE COMPETITION EXAMPLE

- Questions:
- 1. Define the Nash equilibrium for this game. Explain your reasoning.
- 2.Which strategy maximizes the combined profits for both airlines? Why might this outcome not occur in practice?
- 2. How does this game reflect the Prisoner's Dilemma?

QUESTION 1: PRICE COMPETITION EXAMPLE

- **1. Nash Equilibrium:**
- The Nash equilibrium occurs when neither airline can improve its profit by unilaterally changing its pricing strategy.
- If Airline A sets a low price, Airline B's best response is also to set a low price (earning $10M).
- If Airline B sets a low price, Airline A's best response is also to set a low price (earning $10M).
- Nash Equilibrium: Both set low prices (A: $10M, B: $10M).

QUESTION 1: PRICE COMPETITION EXAMPLE

- **2. Maximizing Combined Profits:**
- Combined profits are maximized when both set high prices (A: $20M, B: $20M).
- However, this outcome is unstable because each airline has an incentive to undercut the other for higher individual profits.

QUESTION 1: PRICE COMPETITION EXAMPLE

- **3. Reflecting the Prisoner's Dilemma:**
- Cooperation (high prices) leads to the best collective outcome but is difficult to sustain without collusion.
- Fear of being undercut forces both to choose low prices, resulting in a suboptimal outcome for both.

QUESTION 2: PROBLEM-SOLVING (R&D INVESTMENT EXAMPLE)

- **Two pharmaceutical companies, Pfizer and Moderna, are deciding whether to invest heavily in R&D for a new vaccine. The payoff matrix (profits in millions) is shown below:**

	Moderna Invests	Moderna Doesn't Invest
Pfizer Invests	Pfizer: $50M, Moderna: $50M	Pfizer: $80M, Moderna: $20M
Pfizer Doesn't Invest	Pfizer: $20M, Moderna: $80M	Pfizer: $30M, Moderna: $30M

QUESTION 2: PROBLEM-SOLVING (R&D INVESTMENT EXAMPLE)

- **Questions:**

1. Identify the dominant strategy for Pfizer. Does Moderna have a dominant strategy? Justify your answers.
2. What is the Nash equilibrium in this game? Show your reasoning.
3. If the two companies could cooperate, what strategy would maximize their combined profits? Why might this be difficult to achieve in practice?

QUESTION 2: PROBLEM-SOLVING (R&D INVESTMENT EXAMPLE)

- 1. Dominant Strategy for Pfizer:
- Pfizer earns $50M (if Moderna invests) or $80M (if Moderna doesn't) when it invests, compared to $20M or $30M if it doesn't.
- Dominant Strategy for Pfizer: **Invest.**
- Moderna faces a similar payoff structure, so its dominant strategy is also to **Invest.**

QUESTION 2: PROBLEM-SOLVING (R&D INVESTMENT EXAMPLE)

- 2. Nash Equilibrium:
- Both firms investing is the Nash equilibrium (Pfizer: $50M, Moderna: $50M).
- Neither firm can improve its payoff unilaterally by deviating from this strategy.
- 3.Maximizing Combined Profits:
- Combined profits are maximized when one firm invests and the other doesn't (e.g., Pfizer: $80M, Moderna: $20M).
- Achieving this requires explicit coordination, which is unlikely in competitive markets.