Students' ECONOMIC FORUM

A monthly publication from South Indian Bank

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GAME THEORY

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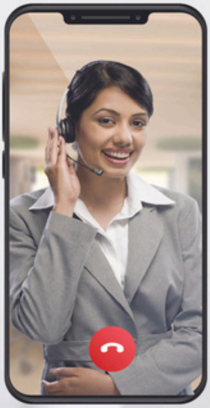

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"Game theory says that the true source of uncertainty lies in the intentions of others"

- Peter L. Bernstein

The 'SIB Students' Economic Forum' is designed to kindle interest in the minds of the younger generation. We highlight one theme in every monthly publication. Topics of discussion for this month is "GAME THEORY"

What Is Game Theory?

- Game Theory is a branch of mathematics and economics that studies strategic interactions where the outcomes depend on the actions of multiple decision-makers (players). It seeks to predict and explain how these players will behave in different situations.
- Scope: The scope of game theory extends across various fields such as economics, political science, psychology, sociology, and even biology. It is used to model competitive situations like markets, auctions, voting systems, and negotiations.

Historical Context:

- Origins: The roots of game theory can be traced back to early 20th-century mathematicians like Émile Borel and John von Neumann.
- Development: In 1944, John von Neumann and Oskar Morgenstern published "Theory of Games and Economic Behavior," which is considered the foundational text of modern game theory.
- Evolution: The field further evolved with contributions from John Nash, who introduced the concept of Nash Equilibrium in the 1950s, expanding the applicability of game theory to non-cooperative games.
- Modern Applications: Over the years, game theory has been applied to a variety of domains including evolutionary biology, computer science (algorithmic game theory), and international relations.

How Game Theory Works:

- Strategic Interactions: The core of game theory is the study of strategic interactions, where each player's payoff depends not only on their own decisions but also on the decisions of others.
- Rationality: It assumes that all players are rational, meaning they aim to maximize their own payoffs.
- Information: The availability and distribution of information play a crucial role. Games can be classified based on whether players have perfect information (all players know everything about the game) or imperfect information.
- Equilibrium Concepts: Game theory often focuses on finding equilibrium points, where no player has an incentive to unilaterally change their strategy. The most well-known equilibrium concept is the Nash Equilibrium.

Key Concepts and Terminology:

Game: In game theory, a game is a formalized representation of a situation where the outcome depends on the actions of two or more players. It involves a set of rules, possible moves (strategies), and outcomes (payoffs). Examples:

- Chess: A classic example where two players move pieces according to fixed rules with the goal of checkmating the opponent's king.
- Market Competition: Companies deciding on pricing strategies in a competitive market.
- Public Goods Provision: Individuals deciding whether to contribute to a common good (like clean air) that everyone benefits from.

Players: Players are the decision-makers in the game. They can be individuals, firms, nations, or any entities making strategic choices.

Rational Players: Assume to act in a way that maximizes their own payoff.

Cooperative vs. Non-Cooperative: Players can either work together to achieve a common goal (cooperative) or act independently in their own interest (non-cooperative).

Symmetric vs. Asymmetric: In symmetric games, players have identical strategies and payoffs, while in asymmetric games, players have different strategies and payoffs.

Strategy: A strategy is a complete plan of action a player will take given the set of circumstances that might arise within the game.

Types:

- Pure Strategy: A specific predetermined action a player will follow.
- Mixed Strategy: A probabilistic approach where a player chooses among possible moves according to certain probabilities.

Payoff

- Concept: Payoff is the reward a player receives from arriving at a particular outcome in the game. It reflects the utility, profit, or other benefits the player gains.
- Measurement: Payoffs can be quantified in different forms such as money, utility points, or any other metric that represents the player's preferences. The payoff matrix is often used to illustrate the payoffs for different strategies.

Information Set

- Importance in Sequential Games
  - Definition: An information set is a collection of decision points accessible to a player at a particular stage of the game, indicating the information available when making a decision.
  - Importance: In sequential games, players make decisions at different points in time. The information set helps determine what actions are feasible based on the knowledge of previous moves. This is crucial for planning strategies in dynamic contexts like chess or negotiation processes.

Equilibrium

- Concept: Equilibrium in game theory is a state where all players have chosen their strategies and no player can benefit by changing their strategy unilaterally. It represents a stable state where expectations are met.
- Types:
  - Nash Equilibrium: The most well-known type, where each player's strategy is optimal given the strategies of other players.
  - Dominant Strategy Equilibrium: Exists when a player's best strategy remains the same regardless of what the opponents do.
  - Subgame Perfect Equilibrium: An extension of Nash Equilibrium applicable to dynamic games, where players' strategies constitute a Nash Equilibrium in every subgame.

The Nash Equilibrium:

- Definition: The Nash Equilibrium, named after the mathematician John Nash, is a fundamental concept in game theory. It refers to a situation in a game where each player's strategy is optimal given the strategies chosen by all other players. In other words, no player has an incentive to unilaterally deviate from their chosen strategy.
- Significance:
  - It provides a key solution concept for analyzing strategic interactions in games.
  - Nash Equilibrium predicts stable outcomes in situations where players are rational and aware of each other's strategies.
  - It serves as a benchmark for understanding strategic decision-making in various contexts, including economics, politics, and social interactions.

Applications of Game Theory:

Economics

- Market Behavior
  - Game theory is extensively used to model and analyze market behavior, particularly in oligopolistic and monopolistic markets where firms interact strategically. It helps in understanding pricing decisions, product differentiation, and market entry strategies.
  - Example: In a duopoly market, firms may engage in price competition or collusion, leading to different market outcomes depending on their strategies.

Auctions

- Auctions are strategic environments where bidders compete to acquire goods or services. Game theory provides insights into bidder behavior, auction design, and revenue maximization strategies for auctioneers.
- Example: In a first-price sealed-bid auction, bidders must decide how much to bid based on their valuation of the item and their beliefs about other bidders' valuations.

Business

- Competitive Strategies
  - Game theory helps businesses analyze competitive situations and devise optimal strategies to gain a competitive edge. It is used to model scenarios such as price wars, product differentiation, and strategic alliances.
  - Example: Firms in an oligopoly may use game theory to anticipate competitors' reactions to price changes and adjust their pricing strategies accordingly.

Project Management

- Decision Making
  - Game theory is applied in project management to model decision-making processes involving multiple stakeholders with conflicting objectives. It helps in optimizing resource allocation, scheduling, and risk management.
  - Example: In a construction project with multiple contractors, game theory can be used to determine the optimal allocation of resources to minimize costs and delays.

Consumer Product Pricing

- Pricing Strategies
  - Game theory provides insights into pricing strategies adopted by firms in competitive markets. It helps firms analyze consumer behavior, demand elasticity, and strategic interactions with competitors when setting prices.
  - Example: Airlines use game theory to optimize pricing strategies for seats based on factors such as demand forecasting, competitor pricing, and capacity constraints.

Types of Game Theory

Cooperative vs. Non-Cooperative Games

- Cooperative Games: Players can form coalitions and make binding agreements for mutual benefit.
- Example: Labor union negotiations for wage contracts.
- Non-Cooperative Games: Players act independently, pursuing self-interest without agreements.
  - Example: Cournot duopoly competition.

Zero-Sum vs. Non-Zero-Sum Games

- Zero-Sum Games: Total payoff remains constant; gains by one player equal losses by others.
  - Example: Poker.
- Non-Zero-Sum Games: Total payoff varies; cooperation can lead to mutual benefits.
  - Example: Prisoner's Dilemma.

Simultaneous vs. Sequential Move Games

- Simultaneous Move Games: Players decide simultaneously without observing others' choices.
  - Example: Battle of the Sexes.
- Sequential Move Games: Players act in a predetermined order, observing previous actions.
  - Example: Chess.

One Shot vs. Repeated Games

- One Shot Games: Single round of interaction with no repeated play.
  - Example: Rock-paper-scissors.
- Repeated Games: Multiple rounds allow learning, cooperation, and retaliation.
  - Example: Iterated Prisoner's Dilemma.

Examples of Game Theory:

The Prisoner's Dilemma: Scenario: Two suspects must choose to cooperate or betray each other. Analysis: Both have an incentive to betray, leading to suboptimal outcomes.

Dictator Game: Scenario: One player splits money with another who has no say. Analysis: Despite self-interest suggesting keeping all money, dictators often share, showing considerations like fairness.

Volunteer’s Dilemma: Scenario: Some must take a costly action for collective benefit. Analysis: Self-interest may lead to free-riding, risking loss of collective benefit.

The Centipede Game: Scenario: Players decide to continue or end the game for payoffs. Analysis: Optimal strategy involves trust and continued play, but fear of game's end can lead to suboptimal outcomes.

Game Theory Strategies:

Maximax Strategy

- Definition: The maximax strategy is a decision-making strategy where a player maximizes their potential payoff by selecting the option with the highest possible outcome under the assumption that their opponents will also make choices that maximize the player's payoff.
- Example: In a game of investment where a player can choose between risky and safe investments, the maximax strategy involves choosing the option with the highest potential return, assuming the opponents will not take actions to reduce this payoff.

Maximin Strategy

- Definition: The maximin strategy is a decision-making strategy where a player maximizes their minimum possible payoff by selecting the option that guarantees the highest minimum outcome, regardless of the actions of the opponents.
- Example: In a negotiation scenario where a player can choose between accepting a guaranteed minimum payment or risking a potentially higher but uncertain payoff, the maximin strategy involves selecting the option with the highest guaranteed minimum outcome.

Dominant Strategy

- Definition: A dominant strategy is a strategy that yields the highest payoff for a player regardless of the choices made by other players. If a dominant strategy exists for a player, it is always the best strategy to choose.
- Example: In a prisoner's dilemma game, where two suspects can either cooperate or betray each other, betraying is a dominant strategy for each player because it yields a higher payoff regardless of the other player's choice.

Pure Strategy

- Definition: A pure strategy is a strategy in which a player chooses a single action or decision with certainty, without randomizing or mixing actions.
- Example: In a game of rock-paper-scissors, if a player always chooses "rock" as their move, without any variation or randomness, they are employing a pure strategy.

Mixed Strategy

- Definition: In a mixed strategy, a player selects from multiple options with specific probabilities, effectively randomizing their choices. Example: In a matching pennies game, a player may flip a coin with a 60% chance of heads and a 40% chance of tails, showcasing a mixed strategy.

Limitations of Game Theory

- Assumptions of Rationality: Game theory assumes perfect rationality, which may not reflect real-world decision-making influenced by emotions and biases.
- Incomplete Information: Models often assume complete information, neglecting real-world uncertainties and asymmetries.
- Simplification of Complex Situations: Game theory simplifies complex scenarios, potentially overlooking important factors like social norms and cultural differences.
- Computational Challenges: Some games are computationally intractable, limiting the practical applicability of game theory.
- Limited Predictive Power: While insightful, game theory may not always accurately predict real-world outcomes due to unexpected behavior and external factors.
- Ethical Considerations: It may raise ethical concerns, especially in competitive scenarios, where fairness and justice are at stake.
- Assumption of Self-Interest: Game theory assumes self-interest, but real-world decisions may involve altruistic motives and social preferences.
- Static Player Behavior: Players in game theory are typically assumed to have fixed strategies, neglecting dynamic and adaptive behavior seen in reality.

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