ANALYZING STRATEGIC BEHAVIOR IN BUSINESS AND ECONOMICS

A GAME THEORY PRIMER

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Analyzing Strategic Behavior in Business and Economics

Preface

Standard optimization analysis involves finding the most efficient solution to well-defined objective function subject to one or more side constraints. A manager's ability to maximize a firm's value on behalf of shareholders, for example, may be hamstrung by an inability to raise finance capital, shortages of skilled labor, disruptions in the flow of critical raw materials, social or political unrest in overseas markets, capacity constraints, insufficient warehouse space, labor unrest, pollution emission standards, government regulation, proscriptions against certain types of business activities, antitrust legislation, and so on. Unfortunately, this approach to finding optimal solutions to managerial decision-making problems often ignores the competitive realities of the marketplace.

Business decisions are rarely made in a competitive vacuum. Consider, for example, the decision by senior management of a publicly-owned corporation to launch an advertising campaign in the expectation of increasing market share and profits. It commits substantial resources to the expectation of increasing sales, profit, and market share. But, what else should this company factor into its calculations? For one thing, its rivals in the marketplace will not stand idly by and watch their customer switch brand loyalties. They will respond aggressively to recapture, if not expand, their market shares of the market. This countermove may lead to even greater spending by all firms, but no appreciable change in existing market shares. In the end, the bottom lines of all firms may suffer. When the actions of a firm affect, and are affected by, the actions of rivals, it is important to ask whether a managerial decision takes you to a place that you want to be, or that you don't want to be.

Managers who are able to put themselves in the shoes of rivals are more likely to successfully achieve the firm's objectives than those who do not. Managers must be able to distinguish between those situations in which conflict is the best course

of action, and those in which the best result entails cooperation. The purpose of this text is to introduce students to the fundamentals of game theory, which is the formal study of strategic behavior. Game theory is not a cookbook of recipes on how to deal with every strategic situation. It is, however, a tool kit for analyzing situations involving move and countermove.

Prerequisites

Most of the economics presented in this book is at the introductory level. For this reason, this book assumes that the reader has taken a course in the principles of microeconomics. More advanced economics courses, such as managerial economics, industrial organization, and international trade are helpful, but by no means mandatory. Chapter 13, for example, explores the possible effects of export subsidies on intraindustry trade. The purpose of this chapter is not to educate the reader in the theories of international trade. Rather, it is meant to show how continuous strategies and best-response functions can enhance our understanding of commercial policy and international trade flows.

Although the presentations of most of the topics presented in this text are diagrammatic, it is not possible to explore some important game theoretic concepts without the use of basic mathematics and statistics. In part II, for example, simple differential calculus is used to identify players' best-response functions. In parts III and IV, such basic statistical concepts as expected value, standard deviation, and conditional probabilities are used in games involving incomplete and imperfect information. On the brighter side, this book is axiomatic in nature and presentation. There are no formal proofs and formal training in real analysis and set theory is not required.

Organization

This book is organized according to the information available to decision makers and the order of play. Sections I and II of the book deal with static and dynamic games in which the players have complete information about the strategies and payoffs. Section III discusses static and dynamic games under conditions of incomplete information in which the payoffs from alternative strategy profiles are uncertain. Section IV examines dynamic games with imperfect information in which the players are uncertain about the prior moves of rivals.

Depending on the target audience and the curriculum, chapters 1–10, 16, and 18 constitute the core of an introductory course in game theory and require little or no formal training in mathematics or statistics. Chapters 11–17 in section I expands the earlier analysis of static games with complete information by introducing the continuous strategies and best response functions. A rudimentary understanding of optimization analysis is required.

Sections III and IV build upon concepts presented earlier in the book. These sections relax the assumptions of complete and perfect information and explore some

real-world applications of game theoretic concepts, such as incentive contracts and auctions. The material presented in these chapters requires a familiarity with such basic statistical concepts as risk and uncertainty, which are reviewed in chapter 19. Although somewhat more challenging, these topics can be mastered by most students with a small measure of patience and perseverance.

Note to the Instructor

An Instructors Manual, including answers to selected end-of-chapter exercises and test bank, and PowerPoint presentations is available free of charge to instructors who adopt this text. For more information, contact textbooks@rowman.com.

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CHAPTER ONE

Introduction to Game Theory

Introduction

Many of us think of a game as a recreational activity involving two or more players, such as chess, gin rummy, football, or the computer game *Call of Duty*, which involves both winners and losers. In business, we often speak of the winning "team" as the company with best return on equity or largest market share. Unlike chess, however, success in business sometimes results from cooperation to achieve a mutually beneficial outcome.

Game theory is the formal study of decision making in strategic situations involving move and countermove. Game theory can deepen our understanding of strategic situations involving win-win situations when cooperation is possible. It also helps us to identify best responses when cooperation is not possible.

How well we perform in situations involving move and countermove depends on several factors, including a player's strategic skills, understanding of the rules, and information about a rival's resources, goals, and intentions. Master chess players, for example, do not simply react to moves, but attempt to unravel an opponent's strategy and tactics. It would be shortsighted for a manager to lower price to boost sales without first anticipating how competitors may react to a loss in market share, revenues, and profits. It would be negligent for a national leader to ignore the potential consequences of a change in foreign policy that invites a terrorist attack or risks plunging a country into war.

Strategic Behavior

Game theory is the most important tool in the economist's analytical kit for analyzing strategic behavior. **Strategic behavior** involves situations in which the decisions of

individuals and groups affect, and are affected by, the decisions of other individuals and groups. In other words, the decision-making process is mutually interdependent.

Much of economic theory assumes that decision makers attempt to achieve the best outcome subject to constraints that limit our options. Firms, for example, attempt to maximize shareholder value subject to limited financial, human, and nonhuman resources. Analyzing the decision-making process is simplified when we assume that these decisions have little or no measurable effect on the behavior of rival firms. In the real world, however, this assumption is not just naïve; it can jeopardize a company's very survival.

Game theory represents a significant improvement over earlier attempts to analyze strategic behavior. Although managers have much to learn from game theory, it is not a cookbook that provides a recipe for dealing with every strategic situation. Game theory attempts to systematically analyze situations in which the outcomes are mutually interdependent.

Short History of Game Theory

One of the earliest attempts to analyze strategic behavior can be traced to the work of French economist Antoine Augustin Cournot (28 August 1801–31 March 1877). Cournot (1838) sought to explain the output-setting decisions of duopolies. His analysis was modified five decades later by Joseph Bertrand (11 March 1822–5 April 1900), whose work (Bertrand, 1883) emphasized the role of strategic behavior in product pricing. In the twentieth century, the contributions of Cournot and Bertrand to an understanding of imperfect competition were extended by Edward Chamberlin (18 May 1899–16 July 1967), Joan Robinson (31 October 1903–5 August 1983), Heinrich von Stackelberg (31 October 1905–12 October 1946), Paul Sweezy (10 April 1910–27 February 2004), and others, although their efforts were handicapped by their reliance on standard economic and optimization methodologies.

In the 1920's, French mathematician Émile Borel (7 January 1871–3 February 1956) published several papers on the theory of games. By examining the role of bluffing and second-guessing in poker games with incomplete information, Borel sought to identify the existence of dominant strategies, which he believed would have military and economic applications. Although he is credited with the first modern formulation of mixed strategies and suggested a minimax equilibrium for two-player games with three or five possible strategies, he did not develop his ideas very far. Because of this, most historians recognize the Hungarian-born mathematician John von Neumann (28 December 1903–8 February 1957) as the father of modern game theory.

The brilliant and versatile von Neumann began his work on game theory by modeling the behavior of poker players. In 1928 he proved his famous minimax theorem, which demonstrates that in zero-sum games players with perfect information will adopt a strategy that minimizes their maximum losses. Recognizing the importance of game theory to economics, von Neumann teamed up with German-born economist Oskar Morgenstern (24 January 1902–26 July 1977) to develop his ideas more fully.

The result was the publication in 1944 of the modern game theory classic, *Theory of Games and Economic Behavior*.

Although von Neumann and Morgenstern emphasized the role of cooperation in economic behavior, Princeton mathematician John Forbes Nash Jr. (13 June 1928–) believed that strategic behavior was essentially rivalrous. In his twenty-seven page doctoral dissertation and several papers published in the early 1950s, Nash identified in games with a finite number of strategies the existence a "fixed point" equilibrium in which rational players adopt their best response to the strategies adopted by rivals. This seminal result later became known as a Nash equilibrium. According to Nash, business managers, for example, will cooperate with rivals when it suits them, but will violate implicit or explicit agreements whenever it is in their best interests to do so.

The ideas developed by Nash transformed game theory from a highly focused tool for analyzing zero-sum situations into a more general approach for analyzing strategic behavior involving both competition and cooperation. Although game theory was initially developed for use by economists, its usefulness to such diverse fields as sociology, politics, warfare, and diplomacy became immediately apparent. Game theory has even been applied to problems in evolutionary biology.

Since the 1970s, game theory has fueled a revolution in economic thought. In the 1990s, game theory captured the public's imagination when it was used to design an auction to allocate licenses for the "narrow-band" frequencies used by mobile telecommunication services such as cellular phones, pagers, and other wireless devices. These auctions both efficiently allocated Federal Communications Commission licenses and generated billions of dollars for U.S. government coffers.

Lexicon of Game Theory

In game theory, a decision maker is referred to as a **player**. Players' decisions have consequences, which we refer to as payoffs. A **payoff** is the expected gain or loss that results from a player's strategy choices.

Games can have zero-sum or non-zero-sum payoffs. In a **zero-sum game**, one player's gain is another player's loss, such as wagering on a hand in poker. In a **non-zero-sum game**, the sum of the players' gains and losses does not equal zero. In non-zero-sum games, the players can be all winners or all losers.

There are several features common to all games. Games have rules that define the order of play. Moves are based on strategies. A **strategy** is a game plan for achieving a player's objective. A player's strategy may consist of a single move, or multiple moves. It may involve pure or mixed strategies. A **pure strategy** is a complete and nonrandom game plan in which each player's move is the best response to the actual or anticipated move of a rival. By contrast, a **mixed strategy** involves randomly mixing pure strategies. In mixed strategy games, moves and payoffs are probabilistic.

The complete description of the players' strategies is called a **strategy profile**. In static games, strategy profiles will be summarized within curly brackets. Suppose, for example, that the managers of rival firms A and B are considering charging a *high price*

or a *low price*. This game has four possible strategy profiles: {*High price, High price*}, {*High price, Low price*}, {*Low price, High price*}, and {*Low price, Low price*}. The first entry refers to the strategy adopted by A and the second entry is the strategy adopted by B. Each strategy profile results in payoffs, which will be summarized in parentheses. Suppose that the payoff to each firm from a *high-price* strategy is $1 million. These payoffs would be summarized as ($1 million, $1 million).

There are two basic types of games. In a **static game**, players do not know the other players' moves until all moves have been made. A type of static game is a **simultaneous-move game** in which all players move at the same time. For example, in the children's game "Rock, paper, scissors" the two players simultaneously show a closed fist (rock), an open hand (paper), or a separated index and middle finger (scissors). The winner is determined by the rule: rock breaks scissors, scissors cut paper, and paper covers rock.

In static games, it is not necessary for players to move at the same time. We could, for example, isolate the players who reveal their strategy choices to an impartial referee, who declares a winner. Only then do the players learn of their opponents' moves.

By contrast, the players in a **dynamic game** (also known as a *sequential-move game*) alternate moves. In a two-player dynamic game, for example, player A moves first, followed by player B, followed by player A or B, and so on. Chess is an example of a sequential-move game.

Finally, games are defined by the number of times they are played. A **one-time game** is played once. A **repeated game** is played multiple times. If you and a friend agree to play a single game of backgammon, you are playing a one-time game. On the other hand, the best two out of three is a repeated game.

Rational versus Actual Behavior

In game theory, we generally assume that players behave rationally. By **rational behavior** we mean that players make decisions that are in their own self-interest. Sometimes the objective is to maximize expected measurable payoffs, such as profits, revenues, and market share, or to minimize expected payoffs, such as jail time following the commission of a crime. Sometimes rational choices are based on maximizing subjective personal satisfaction, such as when an individual receives positive utility from the well-being of others.

In order to make rational choices, players must have complete information about payoffs, strategy choices, and the preferences of other players. Even when decision makers have a shared understanding of the strategic environment within which games are played, preconceptions, misperceptions, and biases influence players' strategy choices. Herbert Simon (1957) recognized the limitations imposed on purely rational behavior in situations characterized by less-than-complete information and computational complexity. Simon noted that decision-makers act both rationally and emotionally depending on their cognitive limitations and the time available to