Preface

The study of economics, political science, and the social sciences more generally is an attempt to understand the ways in which people behave and make decisions, as individuals and in group settings. The goal is often to apply our understanding to the analysis of questions pertinent to the functioning of societies and their institutions, such as markets, governments, and legal institutions. Social scientists have developed frameworks and rigorous models that abstract from reality with the intent of focusing attention on the crux of the issues at hand, while ignoring details that seem less relevant and more peripheral. We use these models not only to shed light on what we observe but also to help us predict what we cannot yet see. One of the ultimate goals is to prescribe policy recommendations to the private and public sectors, based on the simplistic yet rigorous models that guide our analysis. In this process we must be mindful of the fact that the strength of our conclusions will depend on the validity of our assumptions, in particular those regarding human behavior and the environment in which people act.

Game theory provides a framework based on the construction of rigorous models that describe situations of conflict and cooperation between *rational* decision makers. Following the tradition of mainstream decision theory and economics, rational behavior is defined as choosing actions that maximize one's payoff (or some form of payoff) subject to the constraints that one faces. This is clearly a caricature of reality, but it is a useful benchmark that in many cases works surprisingly well. Game theory has been successfully applied to many relevant situations, such as business competition, the functioning of markets, political campaigning, jury voting, auctions and procurement contracts, and union negotiations, to name just a few. Game theory has also shed light on other disciplines, such as evolutionary biology and psychology.

This book provides an introduction to game theory. It covers the main ideas of the field and shows how they have been applied to many situations drawn mostly from economics and political science. Concepts are first introduced using simple motivating examples, then developed carefully and precisely to present their general formulation, and finally used in a variety of applications.

The Book's Origins and Intended Audience

As with many textbook authors, it was never my intention to write a textbook. This book grew out of lecture notes that I used for an advanced undergraduate game theory course that I taught at Stanford University from 1997 through 2004. Over the years I was convinced by some colleagues and a persistent executive editor to take those notes and expand them.

Given its origins, the book is aimed at more advanced undergraduates in economics. In writing the book I tried hard to be precise—as one ought to be with a more advanced textbook—while at the same time being reader friendly. Relative to the advanced course that I taught, I added many more examples, both easier and harder than the ones I had used in my class.

I was somewhat frustrated by the books that were available at the time I taught: some were too loose and others were too dense. As a consequence the ideas in this textbook are first presented in a way that most students with minimal mathematical training can follow; they are then further developed to meet the needs and address the curiosity of students who are more rigorously trained. Concepts are presented rigorously but illustrated using examples with varying degrees of complexity from easier to harder. I am therefore quite confident that first-year graduate students in economics and political science will find the book useful as well, especially as a backdrop to more demanding graduate-level textbooks.

This text is meant to be self-contained. Many examples should help the reader absorb the concepts of decision making and strategic analysis. Because precise logical reasoning is at the center of game theory, and of this textbook, a degree of mathematical maturity will be useful to comprehend the material fully. That said, it is not assumed that the reader has a strong mathematical background. A mathematical appendix covers most of what would be needed by someone with a relatively rigorous high school training. Calculus and knowledge of some basic probability theory are required to follow all of the material in this book, but even without this knowledge many of the basic examples and constructions can be appreciated.

The Book's Structure and Suggested Use

The book contains five parts:

- *Part I (Chapters 1–2)—Rational Decision Making:* This part presents the basic ideas of the *rational choice paradigm* used in economics and adopted by many other social science disciplines. Students who have had a basic microeconomics course can easily skip this part of the book.

- *Part II (Chapters 3–6)—Static Games of Complete Information:* The most fundamental aspects of game theory and "normal-form" games are developed in this part of the book. It starts with the notions of dominated and dominant strategies, moves on to consider the consequences of assuming rationality and common knowledge of rationality, and ends with the celebrated concept of Nash equilibrium. All the concepts are first introduced using "pure" (non-stochastic) strategies, and the more demanding concept of mixed strategies is introduced toward the end of this part.

- *Part III (Chapters 7–11)—Dynamic Games of Complete Information:* This part extends the static framework developed earlier to be able to deal with games that unfold over time. The "extensive-form" game is introduced, as well as the concepts of sequential rationality and subgame-perfect equilibrium. These concepts are then used to explore multistage and repeated games, as well as bargaining games. Applications include collusion between price-setting firms, the development of institutions that support anonymous trade, and legislative bargaining.

- *Part IV (Chapters 12–14)—Static Games of Incomplete Information:* This is where the analysis becomes more demanding. This part expands the concepts introduced in Part II to be able to tackle situations in which players are not exactly aware of the characteristics of the other players with whom they interact. The concepts of Bayesian games and Bayesian Nash equilibria are carefully developed and applied to such important contexts as adverse selection, jury voting, and auctions. Some of the more advanced treatments of auctions, and the chapter on mechanism design, are intended for graduate students and very rigorously trained undergraduates.

- *Part V (Chapters 15–18)—Dynamic Games of Incomplete Information:* The last part of the book extends Part IV to deal with games in which information unfolds over time. The idea of sequential rationality is extended to Bayesian games, and equilibrium concepts such as perfect Bayesian and sequential equilibrium are defined and illustrated. Applications include signaling games, the development of reputation, and information-transmission games.

As this outline illustrates, the book contains much more material than can be taught in a quarter or semester undergraduate course. Since it is not suited for an easy "math-free" course, I envision it being used in one or more of the following three courses:

- *Intermediate undergraduate game theory:* Such a course, most likely aimed at undergraduates who either have been exposed to intermediate microeconomics or are comfortable with logical analysis, would include Chapters 3–5 and 7–8. Depending on the instructor's preferences, and the students' level of preparation, some parts of Chapter 6, as well as Chapters 9–12 could be used, and possibly even parts of Chapters 15–16. Students who have not been exposed to rational choice theory will benefit from covering Chapters 1–2.

- *Advanced undergraduate game theory:* This is the course I taught at Stanford. It was aimed at undergraduates who had had intermediate microeconomics with calculus, and were familiar with probabilities and random variables. It included all of the material described for the intermediate course, as well as Chapter 6, most parts of Chapters 9–12, and parts of Chapters 13 and 15–16.

- *Graduate game theory:* This book would not be suited for an advanced graduate course on game theory, for which there are several excellent texts, such as Myerson (1991), Osborne and Rubinstein (1994), and most notably Fudenberg and Tirole (1991). It would be quite useful, however, for first-year Ph.D. students in economics and political science who are covering a first course on game theory. The topics would cover everything described in the advanced undergraduate course, as well as all of Chapters 12 and 15–16 and parts of Chapters 13–14 and 17–18.

Regardless of the way in which the book is used, all the topics are motivated with simple examples that illustrate the main concepts, many of which are used to slowly and carefully explain the main ideas. The easiest examples are tailored to appeal to students in an intermediate undergraduate class, while some examples will be suited only for the most advanced undergraduates as well as for graduate students. The book contains over 150 exercises, which should be more than enough to drive the various points home. About half the exercises have solutions that are freely accessible online, while solutions to the rest are available only to instructors. For more information, visit this book's page on the Princeton University Press web site at http://press.princeton .edu/titles/10001.html.

The Book's Style

The book is casual yet precise in tone, and sometimes a bit demanding. Where mathematical concepts and notation are introduced, they are explained, and where applicable the reader is referred to the mathematical appendix. Given that I trust instructors to assign the book to its intended audience, I expect most students not to need the appendix. However, because my intention is for a curious reader to be able to use the book without an instructor, the mathematical appendix may come in handy.

Many authors struggle with the fact that the English language does not have a singular pronoun that is sex neutral. I have noticed that in recent years many authors have been careful to use a mix of male and female players, and some have decided to tip the balance toward the female pronoun. Alas, I don't trust myself to be careful enough to catch all the uses of "he" and "she" were I to attempt to use both, and I am sure that I would sometimes make an error. Hence I decided to be old fashioned and use the singular male pronoun. I hope that readers will not find this practice insensitive.

Acknowledgments

One person is responsible for me choosing an academic career: Yossi Greenberg. Yossi introduced me to game theory and planted the seed of academic curiosity deep in the soil of my mind. I continued learning game theory from Binyamin Shitovitz and Dov Monderer as an undergraduate, and in graduate school I had the pleasure and privilege of learning so much more game theory from Eric Maskin and Drew Fudenberg. I owe my passion for the subject to the wonderful professors I have had during the years of my training.

Teaching curious students at Stanford only fueled that passion further. Many wonderful students passed through the game theory course that I taught, some of whom have continued on to their own academic careers and from whom I am now learning new things. One student has had a particularly important impact on this book. In 2003 Wendy Sheu took her excellent written notes from my class, with all my examples, definitions, and tangent comments, and typed them up for me. These notes formed the skeleton of the lecture notes that I used over the next three years, and from those notes came this textbook—after many more hours than I am willing to admit to myself.

While I was developing the notes at Stanford, I had the good fortune of employing two excellent Ph.D. students as my teaching assistants, David Miller and Dan Quint, who have both offered many valuable suggestions that improved the notes. In addition, Victor Bennett, Peter Hammond, Igal Hendel, Matt Jackson, and Steve Matthews have kindly agreed to use parts of this book in its earlier stages and have provided valuable feedback. Several anonymous reviewers selected by Princeton University Press offered excellent direction and comments. The final manuscript of this textbook was read by Orie Shelef, whose careful reading is second to none and whose thoughtful comments proved to be invaluable.

Of course, the editors at Princeton University Press played an important role in making this book a reality. Tim Sullivan's relentless pursuits convinced me to embark on the journey of transforming class notes into a textbook. After Tim left the Press, Seth Ditchik provided the necessary encouragement to make me follow through on my commitment. There were many days, and even more nights, when I regretted that

decision, although I am now pleased with the outcome. I was once told that there are three things one should do in the course of one's life: have a child, plant a tree, and write a book.[1] I must thank Tim and Seth for helping me scratch the third and last item off that list! I am also thankful to Peter Strupp and his team at Princeton Editorial Associates for providing outstanding copyediting and production services that improved the book tremendously.

Last but not least, I am grateful to my wife, Irit, whose help and encouragement touch my work in so many ways. Her sharp mind, exceptional drive, and superb organizational skills are an inspiration. Without her constant support I surely would accomplish only a fraction of what I manage to do. And when I think of game theory, I can't deny that my two sons, Nadav and Noam, constantly teach me that when it comes to strategy, there is still so much more that I have to learn!

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1. Some attribute this saying to the Cuban national hero, poet, and writer José Marti.