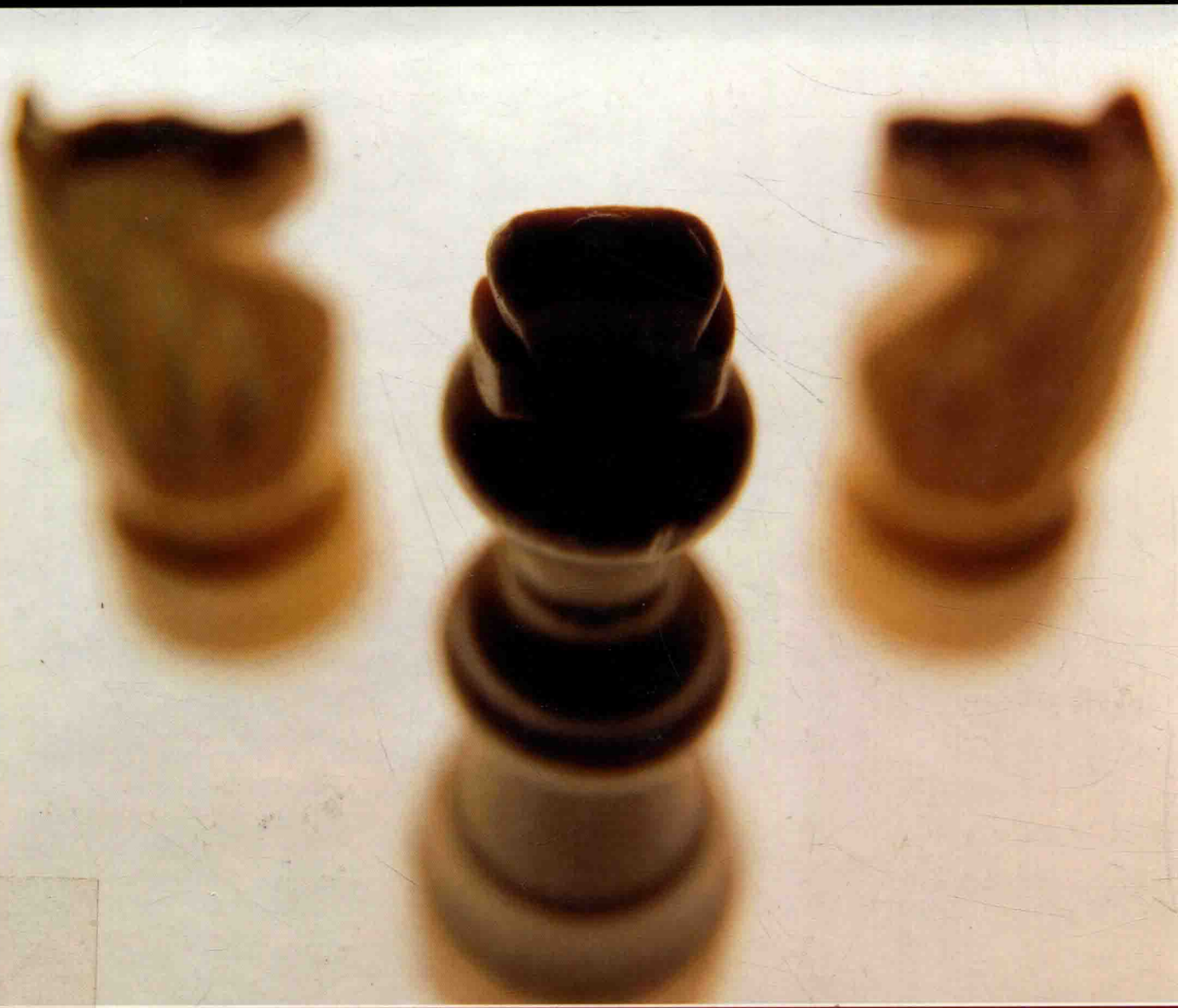
Game Theory

A Non-Technical Introduction to the Analysis of Strategy



Roger A. McCain

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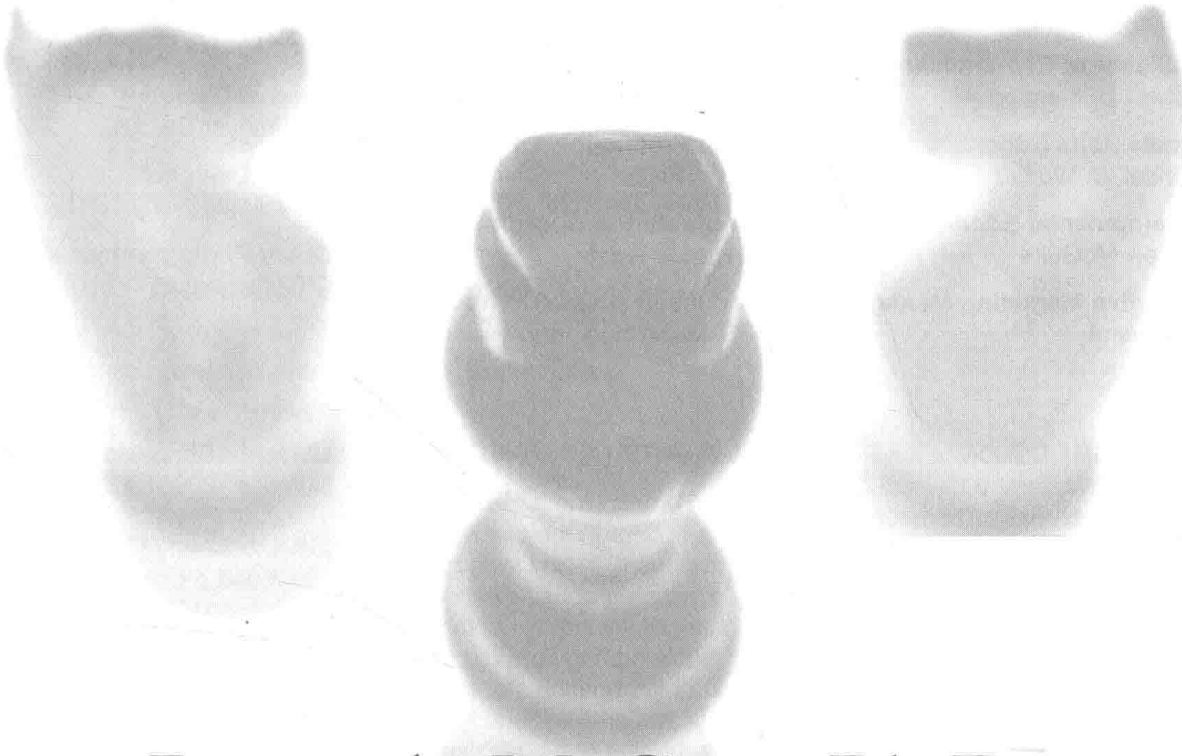

Roger A. McCain, Ph.D.
Professor of Economics
Drexel University

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Roger A. McCain

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Preface

Game theory is a field of study that was developed in the latter half of the twentieth century. Today, more than ever before, game theory attracts attention for its wide range of applications ranging from business, auctions, and elections to military strategy, biology, and gambling. Game theory received much attention because of the 1994 Nobel Memorial Prize in Economics and the hit 2001 movie based on the life of John Nash, who shared that prize. It is also appreciated as a powerful means of understanding human society. Game theory originated as a branch of mathematics, but research in game theory has included experimental as well as mathematical methods from the first. Thus, game theory has grown to be an interdisciplinary field with applications in economics, political science, philosophy, business, and international relations, among others. Two decades ago, the student who wanted a nontechnical introduction to game theory might have picked up Morton Davis' little book, *Game Theory: a Nontechnical Introduction*, and for intuitive and suggestive applications might have read Schelling's *Strategy of Conflict*. In the intervening years game theory has grown in many ways, but I believe that most of the very important ideas in the field can still be introduced in the same intuitive, nontechnical style that those books exemplify, and that is the purpose of this book.

Thus, the objectives of this textbook are to be interdisciplinary, accessible, clear, and explicit. I aim to teach with examples, beginning each concept with an example and using the example to motivate more general considerations rather than the reverse. I also want to avoid calculus and keep algebra to a minimum. All of these objectives involve trade-offs. As an economist, I have a particular affinity for economic and business examples. I have attempted to control this by including noneconomic as well as economic and business examples in every chapter (except two) and on most topics. An interdisciplinary approach leads naturally to examples that draw on a wide variety of disciplines and other areas: for example, I have examples based on naval conflict (mostly fictionalized), musical comedy, and sports.

Text Organization

Although the book is intended to be elementary, the first two chapters take up the relationship between normal form and extensive form games, a topic not even covered in most other texts. I do this for two reasons. The first (and most important) reason is that, in my opinion, the extensive form is far more intuitive and corresponds more closely to the average person's concept of a game. Thus, under the objective of making the text explicit, I did not feel that I

could leave that key relationship implicit. The second reason for taking up the relationship between extensive form and normal form games is that it is often a source of confusion, even in professional-level work. The concept that links extensive form games and normal form games, contingency and contingent strategies, is important in itself and should be a contribution to the students' education even if it were not needed for other purposes in a textbook of game theory.

In Chapter 3 I expand the concept of a prisoner's dilemma, and use the term *social dilemma*. This term is common in Europe and is increasingly common in North America. I think it is a useful term in that it allows us to distinguish between the prisoner's dilemma as a specific example and the more general kind of situation it is an example of. One other departure in that chapter is an example of a game with a dominant strategy equilibrium that is also the cooperative solution. Almost all discussions of dominant strategy equilibrium focus on the social dilemmas, but I think it's important for the student to know that a dominant strategy equilibrium does not have to be inefficient and may indeed be efficient. This is another instance of making explicit what most other textbooks leave implicit.

In Chapters 4 and 5 I introduce the Nash equilibrium in two-person games. The examples in Chapter 4 are fairly novel ones, and I think they illustrate the range of possibilities in Nash equilibrium more systematically than a survey of the classical cases alone would do. In Chapter 5, this includes such familiar two-by-two games as Battle of the Sexes and Chicken, along with the discussion of zero-sum games and the maximin criterion. Moreover, depending on the instructor's purposes, Chapter 5 might be skipped or postponed until some other chapters have been covered.

Some game theory texts have chapters or fairly extensive discussion on three-person games, while others do not. I believe there are two major advantages in discussing three-person games at some length. On one hand, they provide the student with some practice in dealing with games of more than two persons that are still simple enough to be expressed as tables of numbers. I think this is valuable itself. It also gives an opportunity to introduce some of the kinds of phenomena that can arise in multiperson games but not in two-person games. Most other texts do not take full advantage of this. The "spoiler example" is almost the only example of distinct three-person game phenomena found in most texts. In my judgment, however, the most important new phenomenon in three-person games is the possibility that coalitions may form, even in noncooperative games. Conformism, with consequent herding behavior, and nonlinear crowding games are also worth study in three-person games but impossible in two-person games. Thus I regard Chapter 6 as a key chapter.

Since this text is intended for students who may not have background or completed prerequisites in probability and statistics, it seems necessary to introduce some probability concepts, and that is the purpose of Chapter 7. Chapter 8 deals with mixed strategies. Mixed strategies are very counterintuitive and difficult for the average student (in my experience), and I have tried to highlight some of the cognitive difficulties of this topic.

Chapter 9, "Advanced Topics in Noncooperative Equilibrium" is an optional chapter. It begins with the iterative elimination of dominant strategies. This is not an advanced concept in itself, but belongs here because it is closely connected to the distinction of strong and weak dominance, which can be tricky. The chapter then goes on to introduce correlated equilibrium, an alternative to the Nash equilibrium concept that has been a topic of research in the last two decades. I believe it is not found in any other introductory textbook, but I think it belongs here for three reasons. First, it provides a much more satisfactory concept of fully rational behavior in coordination games than the Nash equilibrium does, especially when there is time for "cheap talk" or other arrangements. Second, it illustrates the power of mixed strategies, especially in coalitions in noncooperative games. Third, it provides an answer to "The Blonde Problem" from the movie *A Beautiful Mind*. The movie (and its defects) has just had too much impact to ignore, and it plays a part in several chapters. Another example, from the musical *Guys and Dolls*, further illustrates the point. The examples also serve to illustrate the need for thoroughness, and not to neglect such possibilities as coalitions and mixed strategies.

Chapter 10, on oligopoly pricing models, is also optional and is intended mainly for business and economics students and will probably be skipped by others. It likely suffers more than any other chapter from the avoidance of calculus. In particular, it gives a treatment of Cournot equilibrium in the form of a tabular game in normal form. Many economists will find that strange, but it allows for a far closer parallel to many other game theory examples, including the Edgeworth model. Students will have some difficulty with the differences between the two approaches, but this is another instance where I believe it is better to make the differences explicit by a parallel treatment. The chapter then goes on to develop a very simplified example of a mixed strategy pricing game along lines derived from Ghemawat's recent work. The appendices introduce the familiar calculus-based Cournot and a somewhat more rigorous version of the Ghemawat model along with the smattering of calculus and mathematical statistics that they require. The appendices together might be the equivalent of yet another chapter in the classroom

Chapter 11, on *N*-person games, focuses mainly on some simplifying assumptions that are widely used in applications, especially in economics. Here again, the point is to make explicit what may be implicit in other writing. There is also one minor terminological novelty. One of the two simplifying assumptions uses the representative agent approach, which is very familiar in economics. The other is the use of the term *state variable* to apply to games other than differential games. While this is novel, I think it is a sound extension of the received terminology. We need some term to refer to variables like price, interest, and the frequency of choosing a particular mode of transportation as they play their role in large group interactions.

Chapters 12 and 13 address cooperative solutions to games: in particular, the solution set and the core. This may seem old-fashioned. Most of the competitive textbooks do not discuss cooperative solutions, and one that does it discusses them only at a very advanced level. Also,

noncooperative concepts have been far more dominant in recent research, perhaps because of the increasing role of economists in the development of game theory. Economists tend to distrust anything cooperative. Cooperative solutions are a bit more difficult than Nash equilibrium, but I think they are needed in this text for three reasons. First, there are still some appropriate cases for application of the core and the solution set, even though these concepts have not been central to recent research. Cooperative solutions are the right answers and we should teach them. Second, the student needs some understanding of cooperative solutions in order to have a complete understanding of social dilemmas and other Nash equilibria that are contrasted with cooperative solutions. (This applies especially to the solution set.) Third, sequential games that are noncooperative in themselves may have cooperative stages, so that cooperative solutions may play a part in the backward solution of a sequential game. Chapter 12 is intentionally interdisciplinary and thus includes political and international as well as economic and business examples. Chapter 13 is more directed to economic applications and will probably be skipped in courses that are not aimed at economics majors. It would be possible to skip Chapter 13 or both chapters without much loss of continuity for those who prefer to focus quite narrowly on noncooperative solutions.

Chapter 14 introduces sequential games and the subgame perfect equilibrium concept. Chapter 15 applies the principles from Chapter 14 to the study of nested and imbedded games. This is an innovation and I believe it has two major benefits. First, it provides further examples and applications of subgame perfect equilibrium, extending the student's understanding of this somewhat counterintuitive topic. This could be done by other kinds of examples as well, of course. But, second, it introduces the possibility that people may take action to change the rules of the (nested) game. This leads to an interpretation of game theory that is more open to evolution and human creativity, on the one hand, and leads naturally into political applications and mechanism design, on the other. In a terminological innovation, nested games (which are subsets of other games) are distinguished from imbedded games; that is, nested games are proper subgames and thus must be equilibrial in the case of a subgame perfect equilibrium.

Chapters 16 and 17 introduce repeated play, with Chapter 16 assuming a definite endpoint and Chapter 17 assuming indefinite repetition. These chapters conclude the core of the book, which is composed of Chapters 1 through 8, 11, and 14 through 17.

Chapter 18 touches on mechanism design and applications in the law, and includes a discussion of credible threats by authorities, including monetary authorities. This chapter is not meant as a comprehensive survey either of mechanism design or of game theoretic approaches to monetary authority, but rather to make the student aware of the existence of such studies within game theory. Probably two more advanced courses (if not more) would be required for the student who hopes to master these topics!

Chapter 19 attempts to introduce the main ideas in the game-theoretic analysis of voting, perhaps the most important application in the book. It begins with Bowen's analysis of

single-peaked preferences in voting, which seems largely lost, and stresses the contrast between strategic and naïve voting and the lack of any voting scheme that always meets standards of reasonableness. This is more of a practical issue than a mathematical one, and the Arrow Theorem is not stressed as the chapter relies largely on examples.

Chapter 20 discusses experimental studies. This very large literature is sampled in a way that is very selective but I hope representative. This chapter stresses the tension between bounded and ideal rationality and between self-interested and other motivations in the experimental literature. Chapter 21 discusses the application to auctions, certainly a key body of applications in the coming-of-age of applied game theory. It should follow the chapter on experiments since experimental studies have played a key role in applied auction theory. The book concludes with a chapter on game theory and evolution, both biological and social. This chapter also looks back to the chapters on experiments and on indefinitely repeated play.

To teachers of game theory I would say one final thing. Game theory is fun to teach and to learn. I hope you enjoy it as much as I do.

Roger A. McCain

Key Text Features

- **To best understand this chapter** Each chapter begins with an introductory box outlining which chapters the student should have already covered. This allows for greater flexibility in assigning chapters, since the box clarifies what can be skipped and what cannot.

- **Heads Up** The "Heads Up" box, positioned toward the beginning of each chapter, introduces the key chapter concepts in order to prepare students for what lies ahead.

- **Definition Boxes** New terms are introduced with boxed definitions that reinforce the text and also provide a handy study tool.

- **Summary** Each chapter ends with a chapter summary that enables students to review the general concepts of the chapter.

- **Exercises and Discussion Questions** A series of exercises at the end of each chapter can be used by students to test what they've learned, or by instructors to work through in-class problems with students.

Key Supplements

- **Instructor's Manual** To assist instructors in teaching the game theory course, an instructor's manual is available that gives an overview of each chapters' objectives, tips for organizing the course (including classroom activities), and answers to end-of-chapter questions.
- **Web site** The text's Web site can be located at *http://mccain.swlearning.com*. The site includes access to Econ Applications Web site, South-Western's acclaimed internet resources. Instructors can also gain password-protected access to quiz questions and answers for each chapter.
- **Economic Applications Web site (e-con@pps) http://econapps.swlearning.com** Complimentary access to South-Western's ***e-con@pps Web*** site is included with every new copy of this textbook.* This site includes a suite of highly acclaimed and content-rich dynamic Web features developed specifically for economics classrooms: EconNews Online, EconDebate Online, and EconData Online. Organized and searchable by key economic topic for easy integration into your course, these regularly updated features are pedagogically designed to deepen students' understanding of theoretical concepts through hands-on exploration and analysis of the latest economic news stories, policy debates, and data.
- Students buying a used book can purchase access to the site at *http://econapps.swlearning.com.*

Acknowledgements

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Index of Examples by Topic Area

* End of chapter exercises only.

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† Many examples in other categories could be thought of as economics examples, since game theory often follows neoclassical economics in assuming that people are rational in the sense that they maximize something. However, these are example models or issues in economics, and not applied otherwise.

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* End of chapter exercises only.

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* End of chapter exercises only.

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* End of chapter exercises only.

‡ Examples in this category have no specific application, or use the application primarily to illustrate an aspect of game theory, or have wider applications, or have been used in experimental studies, or all of these.

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* End of chapter exercises only.

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