

GAME THEORY AND THE LAW

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and RANDAL C. PICKER
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Reviewed by
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**STRATEGIC BEHAVIOR AND THE LAW:
A GUIDE FOR LEGAL SCHOLARS TO
GAME THEORY AND THE LAW
AND OTHER GAME THEORY TEXTS**

Game theory appears increasingly in the analysis of legal rules and institutions. *Game Theory and the Law*, by Douglas G. Baird, Robert H. Gertner, and Randall C. Picker, is the most comprehensive and encompassing treatment of this approach. What follows offers legal scholars a review of the book, a brief overview of the use in law of game-theoretic approaches, and an annotated guide to other leading texts about game theory.

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I. INTRODUCTION

The awarding of the 1994 Nobel Prize in economics to three game-theorists (John Harsanyi,¹ John Nash,² and Reinhard Selten³) is the latest indication that game theory is prevalent and important.⁴ As one popular article describes it: "Game theory uses equations to model the behavior of decision-makers whose choices affect one another."⁵ Recently, the use of game theory in law has grown at an increasing rate.⁶ Game theory models now frequently appear, for example, among papers presented at the annual meetings of the American Law and Economics Association. And the pages of the leading law and economics journals⁷ further reflect the rising prominence of game-theoretic reasoning.

Topics in law that have recently been viewed through a game-theoretic lens include alternative dispute resolution,⁸ bargaining obligations under the NRLA,⁹ burdens of production in civil litigation,¹⁰ Chapter 11 bankruptcy and out-of-court debt restructurings,¹¹ civil procedure,¹² comparative negligence,¹³

1. See, e.g., John Harsanyi, *Games with Incomplete Information Played by 'Bayesian' Players, I: The Basic Model*, 14 MGMT. SCI. 159 (1967); *Games with Incomplete Information Played by 'Bayesian' Players, II: Bayesian Equilibrium Points*, 14 MGMT. SCI. 320 (1967); *Games with Incomplete Information Played by 'Bayesian' Players, III: The Basic Probability Distribution of the Game*, 14 MGMT. SCI. 486 (1968).

2. See, e.g., John Nash, *Equilibrium Points in n-Person Games*, 36 PROC. NAT'L ACAD. SCI. U.S. 48 (1950); *Non-Cooperative Games*, 54 ANNALS MATHEMATICS 286 (1951).

3. See, e.g., Reinhard Selten, *Reexamination of the Perfectness Concept for Equilibrium Points in Extensive Games*, 4 INT'L J. GAME THEORY 25 (1975); *The Chain-Store Paradox*, 9 THEORY & DECISION 127 (1978).

4. See, e.g., Amanda Bennett, *Along With Its High Honor, Nobel Award In Economics Influences Future Research*, WALL ST. J., Oct. 11, 1994, at B1, B4; *Nobel in Economics is Awarded to Three for Pioneering Work in Game Theory*, WALL ST. J., Oct. 12, 1994, at B12.

5. Rob Norton, *A New Tool to Help Managers*, FORTUNE, May 30, 1994, at 136.

6. In his 1990 review of the first edition of Eric Rasmusen's text, *Games and Information: An Introduction to Game Theory*, Ian Ayres predicted just such a trend in the game-theoretic approach to legal analysis. Ian Ayres, *Playing Games with the Law*, 42 STAN. L. REV. 1291, 1317 (1990) (book review).

7. These are the *Journal of Law & Economics*, *Journal of Legal Studies*, *International Review of Law & Economics*, and *Journal of Law Economics & Organization*.

8. Jennifer Gerarda Brown & Ian Ayres, *Economic Rationales for Mediation*, 80 VA. L. REV. 323, 329 (1994).

9. Keith N. Hylton, *An Economic Theory of the Duty to Bargain*, 83 GEO. L.J. 19 (1994).

10. Bruce L. Hay & Kathryn E. Spier, *Burdens of Production in Civil Litigation: An Economic Perspective*, Harvard Law School (Feb. 1994, presented Apr. 1994 at the Law & Economics seminar at Stanford Law School).

11. Michelle J. White, *Corporate Bankruptcy as a Filtering Device: Chapter 11 Reorganizations and Out-of-Court Debt Restructurings*, 10 J.L. ECON. & ORG. 268 (1994).

12. See, e.g., Seth J. Chandler, *Reconsidering the Duty to Settle*, 42 DRAKE L. REV. 741 (1993); Bruce L. Hay, *Effort, Information, Settlement, Trial*, 24 J. LEGAL STUD. 29 (1995); Samuel Issacharoff & George Loewenstein, *Second Thoughts About Summary Judgment*, 100 YALE L. J. 73 (1990); Kathryn E. Spier, *Pretrial Bargaining and the Design of Fee-Shifting*

compensatory remedies for contract breach,¹⁴ contingent fees,¹⁵ contractual mistake,¹⁶ corporations,¹⁷ discovery,¹⁸ divestitures,¹⁹ divided entitlements and fractional property rights,²⁰ endogenous determination of the sequence of moves in litigation,²¹ environmental law,²² hearsay,²³ legal preference to make entitlements contingent on the result of *ex post* balancing tests,²⁴ methods for overcoming signalling problems in settlement negotiations,²⁵ the sanctioning of frivolous suits,²⁶ structural adjudication,²⁷ the role of lawyers in litigation,²⁸ traditional judicial reluctance to enforce liquidated damages,²⁹ and workouts

Rules, 25 RAND J. ECON. 197 (1994).

13. Tai-Yeong Chung, *Efficiency of Comparative Negligence: A Game Theoretic Analysis*, 22 J. LEGAL STUD. 395 (1993).

14. Alan Schwartz, *The Myth that Promisees Prefer Supercompensatory Remedies: An Analysis of Contracting for Damage Measures*, 100 YALE L. J. 369 (1990).

15. James D. Dana, Jr. & Kathryn E. Spier, *Expertise and Contingent Fees: The Role of Asymmetric Information in Attorney Compensation*, 9 J.L. ECON. & ORG. 349 (1993).

16. Eric Rasmusen & Ian Ayres, *Mutual and Unilateral Mistake in Contract Law*, 22 J. LEGAL STUD. 309 (1993).

17. Ian Ayres, *The Possibility of Inefficient Corporate Contracts*, 60 U. CIN. L. REV. 387 (1991).

18. Robert D. Cooter & Daniel L. Rubinfeld, *An Economic Model of Discovery*, 23 J. LEGAL STUD. 435 (1994); Robert D. Cooter & Daniel L. Rubinfeld, *The New Discovery Rules—An Economic Analysis*, UC Berkeley, Boalt School of Law (Oct. 1994, presented at the Conference on the Law and Economics of Litigation Reform at Georgetown University Law Center).

19. Margaret Meyer et al., *Organizational Prospects, Influence Costs, and Ownership Changes* 1 J. ECON. & MGMT. STRATEGY 9 (1992).

20. Ian Ayres & Eric L. Talley, *Solomonic Bargaining: Dividing A Legal Entitlement to Facilitate Coasean Trade*, 104 YALE L.J. 1027 (1995). See also Eric L. Talley, *Property Rights, Liability Rules, and Coasean Bargaining Under Incomplete Information*, John M. Olin Program in Law and Economics Working Paper No. 114, Stanford Law School (August 1994).

21. Andrew F. Daughety & Jennifer F. Reinganum, *Endogenous Sequencing in Models of Settlement and Litigation*, 9 J.L. ECON. & ORG. 314 (1993).

22. See, e.g., Adam L. Aronson, Note, *From "Cooperator's Loss" to Cooperative Gain: Negotiating Greenhouse Gas Abatement*, 102 YALE L.J. 2143 (1993).

23. Richard D. Friedman, *Toward A Partial Economic, Game-Theoretic Analysis of Hearsay*, 76 MINN. L. REV. 723 (1992).

24. Jason Scott Johnston, *Bargaining Under Rules versus Standards*, 11 J.L. ECON. & ORG. (forthcoming 1995).

25. Robert H. Gertner & Geoffrey P. Miller, *Settlement Escrows*, 24 J. LEGAL STUD. 87 (1995).

26. A. Mitchell Polinsky & Daniel L. Rubinfeld, *Sanctioning Frivolous Suits: An Economic Analysis*, 82 GEO. L.J. 397 (1993).

27. Robert D. Cooter, *Structural Adjudication and the New Law Merchant: A Model of Decentralized Law*, 14 INT'L REV. L. & ECON. 215 (1994).

28. Ronald J. Gilson & Robert H. Mnookin, *Disputing Through Agents: Cooperation and Conflict Between Lawyers in Litigation*, 94 COLUM. L. REV. 509 (1994).

29. Eric L. Talley, *Contract Renegotiation, Mechanism Design, and the Liquidated Damages Rule*, 46 STAN. L. REV. 1195, 1220, 1222 (1994).

to avoid legal bankruptcy.³⁰ In addition, game theory played a crucial role in designing the recent auction rules adopted by the FCC for assigning licenses to wavelengths for such personal communication services as cordless pocket phones, portable faxes, and wireless computer networks.³¹

In the midst of this proliferation of game-theoretic technology among legal academics comes *Game Theory and the Law*. Written by, respectively, the Dean of the University of Chicago law school, a University of Chicago business school professor, and a University of Chicago law school professor, it is the first nontechnical, modern introduction to how (noncooperative) game theory can be applied specifically to legal analysis.³² The central, motivating premise of the book is that legal applications of game theory can be understood with a minimum of formal mathematical prerequisites. Ideas and concepts are introduced by simple, numerical examples that assume only moderate familiarity with high school algebra. The book presents the organizing principles underlying a set of prototypical games, their solutions, and their applications to legal decision-making. The games introduced include: the assurance game, the battle of the sexes, the beer-quiche game, the game of chicken, the game of matching pennies, and the (infinitely and finitely repeated) prisoner's dilemma. Because noncooperative game theory has become the predominant language of modern economics, the book contains definitions (both in the main body and in a glossary) of such game-theoretic terms as *dominant strategy*, *Nash equilibrium*, *common knowledge*, *mixed strategy*, *backwards induction*, *subgame perfect equilibrium*, *information set*, *off-the-equilibrium path belief*, *sequential rationality*, *reputation*, *Bayesian equilibrium*, and *perfect Bayesian equilibrium*. Specific topics covered include alternative representations of games, different solution concepts, credibility of promises or threats (the commitment problem), asymmetric information

30. Alan Schwartz, *Bankruptcy Workouts and Debt Contracts*, 36 J.L. & ECON. 595 (1993); Claire Finkelstein, Note, *Financial Distress as a Noncooperative Game: A Proposal for Overcoming Obstacles to Private Workouts*, 102 YALE L.J. 2205 (1993).

31. John McMillan, *Selling Spectrum Rights*, 18 J. ECON. PERSPECTIVES 145 (1994), provides an excellent account of this case study in the success of modern game theory applied to policy. He explains the rationale for the features of the particular auction format proposed by Professors Paul R. Milgrom and Robert Wilson, experimentally tested by Professor Charles Plott, and essentially adopted by the FCC. As he states, "[w]hen the theorists met the policy-makers, concepts like Bayes-Nash equilibrium, mechanism design, incentive-compatibility constraints, and order-statistic theorems came to be discussed in the corridors of power." *Id.* at 146.

32. I share Robert H. Mnookin's view expressed on the back jacket of the book:

Baird, Gertner, & Picker make important contemporary research in game theory and information economics accessible to lawyers, law students, and legal academics; and the authors then creatively use this research to further our understanding of the way legal rules may affect how people behave. The wonder is that this book is a sophisticated, subtle, and intellectually rigorous guide while requiring none of the formal mathematical apparatus typically used in explorations of modern game theory.

games, “folk” theorems³³ for infinitely repeated games, and bargaining games.

II. A GUIDED TOUR OF *GAME THEORY AND THE LAW*

Game Theory and the Law is a user-friendly analysis of concrete, numerical examples, rather than a theoretical presentation of abstract concepts. The authors introduce and explain, with actual legal cases or hypotheticals, the salient issues of modern game theory. This breadth of coverage is remarkable. This is not just a textbook; it is also something of a research monograph, introducing many new models attributable to the authors alone.

The book consists of an introduction and eight chapters, each with bibliographic notes describing original sources in the literature. The introduction to understanding strategic behavior contains brief previews of the individual chapters.³⁴ These chapters can be organized into four pairs. The first pair deals with games of complete information, in which there is no private or asymmetric information among the players regarding each other’s feasible strategies or payoffs. Here the solution concepts of dominant strategy equilibria and Nash equilibria³⁵ are presented. The difference between Chapters 1 and 2 lies in the form of the game analyzed: “strategic” (or normal) form in one case and “extensive” form in the other. The next pair of chapters presents the economics of asymmetric information, with emphasis on information revelation or unraveling and signalling or screening. Here the notion of beliefs in games of imperfect information and the perfect Bayesian equilibrium solution concept are presented. The difference between Chapters 3 and 4 lies in the verifiability of the asymmetric information. The third pair of chapters analyze games that are more complicated versions of the games

33. These are so-named because when the first such results (concerning the conditions under which outcomes in a one-shot game could be realized as equilibria of a repeated game) were proved in the 1950s, they were not published and became part of the folklore of game theory. Since then, these results have been extended in many directions. See, e.g., Drew Fudenberg & Eric Maskin, *The Folk Theorem in Repeated Games with Discounting and with Incomplete Information*, 54 *ECONOMETRICA* 533 (1986).

34. For this reason, the review below is brief. Because this essay is for legal scholars and game theorists who are already interested in applications of game theory to the law, legal and game-theoretic terms explained in *Game Theory and the Law* are not defined below. There are several excellent law review articles that provide alternative presentations of games and define various solution concepts. See, e.g., Randall C. Picker, *Law and Economics: Intellectual Arbitrage*, 27 *LOY. L.A. L. REV.* 127 (1993); Martin Shubik, *Game Theory, Law, and the Concept of Competition*, 60 *U. CIN. L. REV.* 285 (1991); Ian Ayres, *Three Approaches to Modeling Corporate Games: Some Observations*, 60 *U. CIN. L. REV.* 419 (1991).

35. Nash, *supra* note 2.

covered thus far. These chapters illustrate the limits of backwards induction and simple models and discuss the concept of reputation and the folk theorems concerning repeated games. The last pair of chapters address noncooperative game-theoretic models of bargaining under private information.

Chapter 1 is about simultaneous-move or normal form games of complete information. Mostly developed in the 1950s, this has been termed "classical" game theory. Topics treated include the definition of the strategic form of a game in terms of players, strategies, and payoffs; the distinction between games of complete and incomplete information; the distinction between games of perfect and imperfect information; bimatrix games; strictly dominant strategies; iterated elimination of strictly dominated strategies; Nash equilibria; mixed strategies; and focal points. These are explored in the context of several famous games, including the prisoner's dilemma, the game of matching pennies, the battle of the sexes, and the tragedy of the commons. The first legal application is an examination of how alternative tort regimes, such as negligence with contributory negligence, strict liability with contributory negligence, or comparative negligence, all induce socially efficient precautions by motorists and pedestrians.³⁶ Other legal applications include analyses of collective action problems, law enforcement, and collective bargaining in labor and management negotiations.

Chapter 2 covers sequential-move or extensive form complete information games, which are models of multi-person dynamic interaction. Topics treated include backwards induction, credibility of threats or subgame perfection,³⁷ dynamic consistency, and information sets. These are explored in the context of several legal applications including enforcement of debt contracts, market preemption and strategic commitment in antitrust, warranty breach and mitigation of damages in contract law, and tax amnesty laws and extensions in Chapter 11 reorganizations.

Chapter 3 covers dynamic games of incomplete information. It starts by analyzing a game from *The Maltese Falcon*.³⁸ Topics treated include perfect Bayesian equilibrium, separating versus pooling equilibria, the distinction between verifiable and nonverifiable information, the unraveling result for verifiable information, common knowledge, observable, but nonverifiable information, and renegotiation. Legal applications include analyses of disclosure laws, long-term contracts, incomplete contracts, and relational contracts.

Chapter 4 covers games involving private, verifiable information. Topics treated include signalling, screening, types, Harsanyi's transfor-

36. See, e.g., STEVEN SHAVELL, *ECONOMIC ANALYSIS OF ACCIDENT LAW* (1987).

37. Selten, *supra* note 3.

38. *THE MALTESE FALCON* (Metro-Goldwyn-Mayer 1941).

mation,³⁹ equilibrium dominance refinements, adverse selection, and moral hazard. These are explored in the context of a beer-quiche breakfast game in a legal setting. Other legal applications include analyses of the Family and Medical Leave Act, the Worker Adjustment and Retraining Notification Act, contract default rules, and insurance or credit markets.

Chapter 5 covers repeated games, both those involving complete and private information. Topics include the so-called endpoint problem due to backwards induction in finitely repeated games, infinitely repeated games or supergames, discount factors, grim or trigger strategies, stationary games, tit-for-tat strategies, renegotiation-proof equilibria, and the well-known results, known as folk theorems.⁴⁰ Legal applications include analyses of the Statute of Frauds and such antitrust issues as tacit collusion, conscious parallelism, and reputation effects in entry deterrence via predatory pricing.

Chapter 6 covers games of collective action, embedded games, and the limits of using simple games. Topics treated include the revelation principle in mechanism design and excess momentum or excess inertia in the adoption of standards when there are network externalities. Legal applications include analyses of the Bankruptcy Code and the use of circuit breakers to limit herd behavior in speculative markets.

Chapter 7 covers noncooperative games of bargaining, such as Rubinstein's⁴¹ models with a sequence of alternating offers and infinite horizons. Legal applications include analyses of legal rules as exit options, laws governing corporate reorganizations, and collective bargaining under the NLRA.

Chapter 8 covers games of bargaining under private information in the context of civil procedure. Topics treated include simple models about suit and settlement in pre-trial bargaining, optimism versus asymmetric information models of sequential versus unitary trials for liability versus damages, biases in the selection of cases for litigation, and rules for discovery involving verifiable information.

Finally, a bibliography contains all of the references cited in the bibliographic notes at the end of each chapter. After each reference, the chapter number where that work is cited is indicated. The book concludes with an excellent glossary of legal and economic terms. This collection of key definitions is a wonderful resource, and readers who like to browse will appreciate this feature.

Given the large role asymmetric information games ("aigs") have played in recent legal and economic analysis, readers will no doubt be pleased to see

39. Harsanyi, *supra* note 1.

40. Fudenberg & Maskin, *supra* note 33.

41. Ariel Rubinstein, *Perfect Equilibrium in a Bargaining Model*, 50 *ECONOMETRICA* 97 (1982).

them amply covered in Chapters 3, 4, (parts of) 5, and 8. Chapter 3, in fact, makes the distinctions between verifiable, nonverifiable, unobservable, and observable (but nonverifiable) information in novel, clear and useful ways. (These distinctions are particularly important for legal analysis when comparing the information that courts are likely to have with the information that parties themselves have.) The treatment of contract renegotiation in Chapter 3 reflects nicely the general importance of renegotiation in games. Chapter 4's exposition of signalling games is particularly user-friendly because it does not get mired in the "cottage industry" of equilibrium refinements. Chapters 5 and 8 cover two of the most important aigs, namely repeated aigs and bargaining aigs.

There are, of course, several well-known shortcomings of applying game theory and information economics in legal analysis. These include the assumptions of common knowledge⁴² and common or shared (rational) conjectures, the nonuniqueness⁴³ (or nonexistence⁴⁴ of) equilibria, and the hyperrationality hypothesis. There are technical reasons for each of these problems. In the absence of assuming common knowledge about some defining element of a game, outside analysts or even the players themselves have no place to begin their inquiry as to what players are likely to do. Games of complete information assume common knowledge amongst players regarding every defining aspect of those games. Asymmetric information games relax this assumption by allowing players' types⁴⁵ to be private information. But, this comes at the cost of assuming the probability distribution of possible types is common knowledge. Common knowledge is a very

42. Intuitively, something is common knowledge among the players of a game if they all know it, they all know that they all know it, and so forth ad infinitum. For an excellent exposition about common knowledge, see John D. Geanakoplos, *Common Knowledge*, 6 J. ECON. PERSPECTIVES 53 (1992). Robert J. Aumann, *Agreeing to Disagree*, 4 ANNALS STAT. 1236 (1976), stated the first formal definition of common knowledge.

43. See Robert J. Aumann, *What Is Game Theory Trying to Accomplish?*, in FRONTIERS OF ECONOMICS 28 (Kenneth J. Arrow & Seppo Honkapohja eds., 1985) for the position that multiplicity is a problem only for prediction, which is not the sole goal of game theory.

44. Ayres, *supra* note 6 at 1310-15 discusses nonexistence and multiplicity of equilibria, the arbitrary nature of out-of-equilibrium beliefs (around which a whole cottage industry of various refinements has grown up), and the difficulty of performing comparative statics analysis when equilibria change discontinuously in response to parameter changes. The last issue has been ameliorated by the recent pathbreaking work on monotone comparative statics. For sufficient ordinal conditions to compare Nash equilibria of a family of noncooperative games, see Christina Shannon, *Complementarities, Comparative Statics, and Nonconvexities in Market Economies* (1992) (unpublished Ph.D. dissertation, Stanford University) extending a result in Paul R. Milgrom & D. John Roberts, *Rationalizability, Learning and Equilibrium in Games with Strategic Complementarities*, 58 ECONOMETRICA 1255 (1990).

45. The notion of a player's type includes that player's utility or preferences, costs, or available strategic choices.

strong informational assumption.⁴⁶ Indeed, the well-known no-trade theorem demonstrates that common knowledge of rationality and prior beliefs eliminates the rationale for speculative trading.⁴⁷ This seemingly paradoxical result has been nicknamed the “Groucho Marx theorem” because it implies that an investor will not trade with any other investor who is willing to trade with that first investor, much like Groucho would not date anyone who would agree to date him or join any club that would have him as a member.⁴⁸ Commonality of conjectures is related to multiplicity of equilibria. For most games, uniqueness of equilibria is the odd exception, rather than the rule. This has led to many principles for selecting among equilibria.⁴⁹ The paradigm of extreme rationality provides a benchmark, which it could be argued might be less of a prescriptive ideal than an irrational and unrealistic “fantasy” for human behavior.

The so-called rational actor faces a much more simplified world than we do. But that simplicity of analysis is both a virtue and a potential vice. Actual behavior is richer and more complex than any model of that behavior can or should be. But there have already been fruitful departures from the starting point of “homo economicus” or “femme economicus,” which enrich and enliven the “bare-bones” skeletal model of human actors. Some of these promising areas of research involve new advances in game theory (in particular) and decision theory (in general).⁵⁰ Of course, no book, regardless of how current, can keep abreast of the myriad directions in which game theory continues to expand. There are five particular directions into which game theory recently has expanded and will likely continue to expand in the future: experimental game theory, behavioral game theory, evolutionary game

46. For an exploration into the power of common knowledge at solving coordinated action problems, see Michael Suk-Young Chwe, *Game Theory and Global Rituals: Media, McDonald's, and Madonna*, Economics Department, University of Chicago (Presented July 1995, Stanford Institute for Theoretical Economics).

47. See Geanakoplos, *supra* note 42, for more on the no-speculation theorem. See also Paul R. Milgrom & Nancy L. Stokey, *Information, Trade and Common Knowledge*, 26 J. ECON. THEORY 17 (1982), for a statement and proof of the no-speculation result.

48. See Lynn A. Stout, *Agreeing to Disagree Over Excessive Trading*, 81 VA. L. REV. 751-4 (1995), for criticism of the misapplication of this result to conclude that rational investors cannot agree to disagree.

49. See, e.g., JOHN HARSANYI & REINHARD SELTEN, *A GENERAL THEORY OF EQUILIBRIUM SELECTION IN GAMES* (1988).

50. For an investigation into the consequences of relaxing the common knowledge of rationality assumption in game theory, see Robert J. Aumann, *Irrationality in Game Theory*, in *ECONOMIC ANALYSIS OF MARKETS AND GAMES: ESSAYS IN HONOR OF FRANK HAHN* 214, 218, 223 (Partha Dasgupta & Douglas Gale eds., 1992). See also Bruce Chapman, *More Easily Done than Said: Rules, Reasons and Rational Choice*, Law and Economics Working Paper Series - 41 (1995), University of Toronto (unpublished manuscript, on file with author) for the position that legal theory can help resolve problems in rational choice theory, particularly game theory and social choice theory.

theory, biform game theory, and psychological game theory. Experimental games involve actual play of games (usually by MBA students, economics majors, or Cal Tech undergraduates).⁵¹ Behavioral games recognize the cognitive limitations that decision-makers face.⁵² Obviously, experimental and behavioral games overlap significantly. Evolutionary games take into account boundedly rational behavior in learning how to play games.⁵³ Biform games combine features of noncooperative games (the currently dominant mode of analysis) and cooperative games (the once prevailing mode of analysis, that fell into relative neglect with the advent of asymmetric information extensive form games).⁵⁴ Psychological games incorporate belief-dependent emotions into game theory.⁵⁵ Psychological games have been applied to model suit, settlement, and trial;⁵⁶ the control of bureaucratic corruption and tax evasion;⁵⁷

51. See JOHN KAGEL & ALVIN ROTH, HANDBOOK OF EXPERIMENTAL ECONOMICS (1994), for an excellent survey of laboratory experiments of games involving bargaining (chapters 6 and 12), externalities (chapter 4), learning (chapter 8), and auctions (chapter 11). See Alvin Roth et al., *Bargaining and Market Behavior in Jerusalem, Ljubljana, Pittsburgh, and Tokyo: An Experimental Study*, 81 AM. ECON. REV. 1068 (1991), for the results of ultimatum bargaining experiments across four countries. For two well-known related studies of dictator and ultimatum games, see Elizabeth Hoffman & Matthew L. Spitzer, *Entitlements, Rights, and Fairness: An Experimental Examination of Subjects' Concepts of Distributive Justice*, 14 J. LEGAL STUD. 259 (1985), and *The Coase Theorem: Some Experimental Tests*, 25 J.L. & ECON. 73 (1982).

52. See DANIEL KAHNEMAN ET AL., JUDGMENT UNDER UNCERTAINTY: HEURISTICS AND BIASES (1982); RICHARD H. THALER, QUASI-RATIONAL ECONOMICS (1991); RICHARD H. THALER, THE WINNER'S CURSE: PARADOXES AND ANOMALIES OF ECONOMIC LIFE (1991). See also Thomas S. Ulen, *Rational Choice and the Economic Analysis of Law*, 19 LAW & SOC. INQUIRY 487 (1994), for a review of the Thaler books and their implications for Coasean bargaining, the debate over mandatory versus default rules in corporate and insurance law, and regulatory policy towards risky behavior. Finally, see Christine M. Jolls & Richard H. Thaler, Behavioral Law and Economics (presented May 1995 at the American Law and Economics Association) for numerous examples of a behavioral economics approach to legal analysis.

53. See Jack Hirshleifer & Juan Carlos Martinez Coll, *What Strategies Can Support the Evolutionary Emergence of Cooperation?*, 32 J. CONFLICT RESOL. 367 (1988).

54. See, e.g., Adam Brandenburger & Harbourne W. Stuart, Jr., Biform Games, Harvard Business School (Aug. 1994), which applies biform games to analyze monopolies, in particular, the game between Nintendo and Sega in the home video game market.

55. See Peter H. Huang, Psychological Game Theory and the Law: Incorporating Emotions Based on Beliefs About Strategic Behavior into Legal Analysis (October 1995).

56. See Peter H. Huang & Ho-Mou Wu, *Emotional Responses in Litigation*, 12 INT'L REV. L. & ECON. 31 (1992).

57. See Peter H. Huang & Ho-Mou Wu, *More Order without More Law: A Theory of Social Norms and Organizational Cultures*, 10 J.L. ECON. & ORG. 390 (1994).

negotiations over newly formed constitutions and property rights;⁵⁸ the preference-shaping role of law;⁵⁹ and the first year of law school.⁶⁰

As the technical difficulties underlying the above weaknesses are overcome and the novelty of game-theoretic models wears off, game theory will make further inroads into legal analysis.⁶¹ *Game Theory and the Law* ably succeeds in disseminating the know-how required to apply game theory to analyze legal rules and institutions. It will not alone enable readers unfamiliar with economics to write in the pure mathematician's style of definition, theorem, and proof in developing new game theory. But that is not its purpose. In addition, as noted elsewhere,⁶² game-theoretic models demonstrate what can happen, not what must happen. As such, they call for empirical studies to determine what does happen.

In conclusion, *Game Theory and the Law* offers the interested reader a unified methodology for the analytical modeling of strategic interactions between legal actors. The only remaining question is how large its audience is and will become. While the current audience of legal scholars for this book may be small, it will not only provide a valuable public good, but will also sow the seeds for its own larger future audience, even if it is used only in seminars at a few law schools.

III. ANNOTATED GUIDE TO OTHER RECENT GAME THEORY BOOKS

Although *Game Theory and the Law* is unique in being the first book to demonstrate how formal game theory can be systematically applied to the study of legal rules and institutions, several recent game theory books not specifically written for legal scholars can nonetheless profitably be read by them. This section provides an annotated guide to this growing, diverse literature.⁶³

58. See Peter H. Huang, *The Role of Passions and Norms in Bargaining Over Constitutions* (Feb. 1994) (unpublished manuscript presented at the Conference on Constitutions and Constitutionalism, Murphy Institute of Political Economy); Peter H. Huang & Ilana Roth, *Passions and Property Rights in Economic Transformations* (Sept. 1992) (unpublished manuscript presented in London at the European Association of Law and Economics meeting).

59. See Peter H. Huang, *Transformative and Focal Default Rules in Contract and Corporate Law and the Symbolic Role of Criminal Law* (July 1995) (unpublished manuscript).

60. See Peter H. Huang, *Does Being a 1L Foster Distrust and Preemptive Dishonesty?* (June 1995) (unpublished manuscript).

61. Two factors that might slow the rate at which legal scholars adopt game-theoretic modelling are unfamiliarity and political considerations. See Ayres, *supra* note 6, at 1315.

62. *Id.* at 1317.

63. It has recently become commonplace that books written for modern undergraduate intermediate microeconomics or first year MBA price theory or managerial economics courses include a chapter (or more) about game theory, especially, though not exclusively, in connection with oligopoly. See, e.g., MICHAEL R. BAYE & RICHARD O. BEIL, *MANAGERIAL ECONOMICS AND*

- Avinash Dixit & Barry Nalebuff, *Thinking Strategically: The Competitive Edge in Business, Politics, and Everyday Life*, 1990, W.W. Norton, ISBN # 0-393-96101-X. This is a paperback written for a broad, popular audience. It assumes less competence in mathematics, but also covers much less material than *Game Theory and the Law*. It is very readable, contains anecdotal stories and cases, and was a Book-of-the-Month Club Alternate Selection. There are references to sports, movies, and popular culture.
- William Poundstone, *Prisoner's Dilemma*, 1992, Anchor Books, ISBN # 0-385-41580-X. This paperback is also aimed at laypeople. It combines a biographical narrative of John von Neumann (one of the co-founders of modern game theory) with an intellectual history of the development of game theory. It also discusses criticisms of game theory, lessons from the game of chicken during the Cuban missile crisis, biological cooperation, and real-life dollar auction games.
- J. Keith Murnighan, *Bargaining Games: A New Approach to Strategic Thinking in Negotiations*, 1993, Morrow, ISBN # 0-688-10905-5. This hardcover book is also aimed at a lay audience. It focuses on applying lessons from game theory to real-world bargaining situations.
- John McMillan, *Games, Strategies, & Managers*, 1992, Oxford University Press, ISBN # 0-19-507430-0. This is a hardcover book written for the second year MBA student market and hence it contains a strong managerial emphasis. There are many wonderful real-world examples of game theory, especially those about negotiating, contracting, and bidding. Some of the more formal theory is presented in the Appendix. The book also has an excellent annotated bibliography.
- Philip O. Staffin, *Game Theory and Strategy*, 1993, Mathematical Association of America, ISBN #0-88385-637-9. This paperback offers a multidisciplinary introduction to game theory assuming only high school algebra. But it omits asymmetric information game theory, a topic important because of its many recent applications to economics and the law.
- H. Scott Bierman & Luis Fernandez, *Game Theory with Economic Applications*, 1993, Addison-Wesley, ISBN # 0-201-56298-7. This is a recent undergraduate paperback text that introduces game-theoretic modeling in economics. It has many applications, but it assumes knowledge of calculus, primarily simple differentiation. It was the first undergraduate textbook designed for economics majors who are not also mathematics majors.
- Roy Gardner, *Games for Business and Economics*, 1995, John Wiley, ISBN # 0-471-31150-2. This is the latest undergraduate text introducing game-theoretic modeling in business and economics. It is quite similar to Bierman & Fernandez, but differs by including some more mathematical sections as well as treatment of evolutionary stability, arbitration, multi-person bargaining games in coalition function form, and matching games. There are interesting chapter-ending sections on viewing current events from game-theoretic perspectives, appendices on experimental results of laboratory games, and a short, annotated bibliography.
- Elinor Ostrom, Roy Gardner, and James Walker, *Rules, Games, and Common-Pool Resources*, 1994, University of Michigan Press, ISBN # 0-472-96546-7. This paperback combines analytic tools from game theory with institutional analysis, laboratory experimental tests,

BUSINESS STRATEGY ch. 10 (1994); ROBERT H. FRANK, MICROECONOMICS AND BEHAVIOR 255-80 and 527-39 (2d ed. 1994); JACK HIRSHLEIFER & AMIHAI GLAZER, PRICE THEORY AND APPLICATIONS ch. 10, 469-71, 497-503 (5th ed. 1992); MICHAEL L. KATZ & HARVEY S. ROSEN, MICROECONOMICS ch. 15 and Appendix 15A (2d ed. 1994); B. PETER PASHIGAN, PRICE THEORY AND APPLICATIONS 397-405 (1994); ROBERT S. PINDYCK & DANIEL L. RUBINFELD, MICROECONOMICS ch. 13 (3rd ed. 1995); WILLIAM F. SAMUELSON & STEPHEN G. MARKS, MANAGERIAL ECONOMICS ch. 9 (1992); ANDREW SCHOTTER, MICROECONOMICS: A MODERN APPROACH chs. 7, 8, 11, 18 (1994); HAL R. VARIAN, INTERMEDIATE MICROECONOMICS: A MODERN APPROACH ch. 27 (3d ed. 1993).

and empirical field studies to explore how institutions endogenously develop to deal with common-pool resource problems.

- Eric Rasmusen, *Games and Information*, 1994, second edition, Blackwell, ISBN # 1-55786-502-7. This is a very user-friendly hardcover graduate or MBA level text that emphasizes the building of models and the importance of asymmetric information games. It contains many interesting applications, but it does assume knowledge of calculus. This edition includes problem sets with detailed solutions and new material on auditing, nuisance suits, renegotiation of contracts, financial market microstructure, signal jamming in entry deterrence, repossession, government procurement, and supermodular games. There is a helpful appendix containing mathematical terminology and the statements of useful theorems.
- Robert Gibbons, *Game Theory for Applied Economists*, 1992, Princeton University Press, ISBN # 0-691-00395-5. This is a paperback designed primarily for graduate students in economics, but it is also appropriate for advanced undergraduate economics or mathematics majors. It is written in a moderate, mathematical style of exposition, and has challenging exercises, but it is somewhat terse in exposition. It is primarily designed for those who intend to create their own game-theoretic models.
- Ken Binmore, *Fun and Games: A Text on Game Theory*, 1992, D. C. Heath and Company, ISBN # 0-669-24603-4. This is a hardcover text intended for undergraduates, but not necessarily economics majors. It is eclectic in coverage with its mathematical and philosophical sections. It assumes that hard-to-define quality of mathematical maturity and does not get to asymmetric information until the very end.
- Ken Binmore, *Game Theory and the Social Contract, volume 1: Playing Fair*, 1994, MIT Press, ISBN # 0-262-02363-6. This hardcover book provides a great exposition of game theory applied to political philosophy. It should be of interest not only to political theorists, but also to constitutional scholars. The book complements nicely the author's text, *Fun and Games*. The central thesis of this book is that game theory offers a systematic tool for investigating ethical issues. The author illustrates how modern noncooperative game theory is consistent with many ideas of Harsanyi and Rawls. There are many simple examples for, and minimal mathematical demands on, the reader.
- Ken Binmore, Alan Kirman, and Piero Tani, *Frontiers of Game Theory*, 1993, MIT Press, ISBN # 0-262-02356-3. This collection of seventeen examples of cutting edge research in game theory is divided into five areas: prediction, explanation, investigation, description, and prescription. There are both applied and theoretical contributions.
- Peter Morris, *Introduction to Game Theory*, 1994, Springer-Verlag, ISBN # 0-387-94284-X. This paperback is for advanced undergraduates and graduate students in mathematics and other quantitative disciplines, such as operations research and statistics. There is rigorous coverage of noncooperative and cooperative game theory, including game-playing algorithms and supergames.
- James W. Friedman, *Game Theory with Applications to Economics*, second edition, 1990, Oxford University Press, ISBN # 0-19-506355-4. This is a hardcover graduate textbook that presupposes a mathematical background and includes coverage of cooperative games. It is written by the author of numerous game-theoretic models of oligopolies.
- Jurgen Eichberger, *Game Theory for Economists*, 1993, Academic Press, ISBN # 0-12-233620-8. This recent hardcover graduate text is written at the level of Hal Varian's classic first year graduate textbook. It involves the use of several running examples throughout the book. It also covers cooperative games.
- Andreu Mas-Colell, Michael D. Whinston, & Jerry R. Green, *Microeconomic Theory*, 1995, Oxford University Press, ISBN # 0-19-507340-1. This is the most recent hardcover text for the first year graduate microeconomics sequence. Part 2 (chapters 7, 8, & 9) covers the minimal essentials of game theory, which every first year economics graduate student should know. The authors are leading researchers who have individually authored many key articles in different areas of game theory. There are many excellent and challenging exercises.

- David M. Kreps, *Game Theory and Economic Modelling*, 1991, Oxford University Press, ISBN # 0-19-828381-4. This paperback is written for economics graduate students and economists. It was a series of lectures given by the co-creator of much of current asymmetric information game theory. It can be fruitfully read by a fairly general audience. The perspectives regarding the use and weaknesses of asymmetric information game theory are interesting, but somewhat idiosyncratic. Overall, this expository monograph is worth reading.
- David M. Kreps, *A Course in Microeconomic Theory*, 1990, Princeton University Press, ISBN # 0-691-04264-0. This hardcover first-year graduate microeconomics text is especially strong on game theory, in particular, asymmetric information games. It is, however, very uneven and quite frequently chatty regarding tangential issues (usually in smaller type).
- Drew Fudenberg & Jean Tirole, *Game Theory*, 1991, MIT Press, ISBN # 0-262-06141-4. This mathematical textbook is the definitive book for second and later year economics graduate students. It presents complete proofs of just about every key result known as of its writing. Both of its authors have contributed much to modern noncooperative game theory.
- Roger B. Myerson, *Game Theory: Analysis of Conflict*, 1991, Harvard University Press, ISBN # 0-674-34115-5. This advanced hardcover graduate textbook is mathematical and treats cooperative games. The perspective towards game theory is that of applying mathematics to analyze social conflict and its resolution. It is written by one of the primary figures in the mechanism design literature. (See McMillan, *supra* note 31, at 158 for an example of mechanism design applied to auction design to suggest price preferences as a way to help designated bidders, such as small firms and firms owned by minorities and women, while simultaneously increasing revenue; Spier, *supra* note 12, at 203-10 for an example of mechanism design applied to provide a theoretical foundation for Rule 68; Talley, *supra* note 29, at 1220 for an example of mechanism design applied to contract law.)
- Martin J. Osborne & Ariel Rubinstein, *A Course in Game Theory*, 1994, MIT Press, ISBN # 0-262-15040-1. This is the latest graduate mathematical textbook. The emphasis is on game theory's foundations and interpretations of its key concepts. Complete proofs of all the results covered are presented. The novel aspects of this book include the material on finite automata models of bounded rationality. The authors have written together and separately many important articles on game theory.
- Peter Ordeshook, *A Political Theory Primer*, 1992, Routledge, ISBN # 0-415-90241-X. This paperback offers an introduction to game-theoretic modelling in political science and public choice. It is written by a Cal. Tech. political scientist, who specializes in what is known in political science as formal theory. It does not assume knowledge of calculus and treats extensive form games, asymmetric information, repeated games, and coalitions. It contains many games of elections and legislative processes.
- Peter Ordeshook, *Models of Strategic Choice in Politics*, 1989, University of Michigan Press, ISBN # 0-472-10122-6. This collection of fifteen papers applies game theory to the analysis of elections, legislative processes, and international relations. It offers a sample of the recent work in formal political theory. Having been written by and for political science researchers, this book employs mathematical notation freely. It convincingly demonstrates that the core of politics is strategic interaction between parties with differing interests.
- Peter Ordeshook, *Game Theory and Political Theory*, 1986, Cambridge University Press, ISBN # 0-521-131593-X. This paperback is already somewhat dated, but it surveys twenty years of game-theoretic models in analyzing political behavior, especially that in committees and elections. It is written in a user-friendly mathematical style and is appropriate as a textbook for graduate students in political science.
- James D. Morrow, *Game Theory for Political Scientists*, 1994, Princeton University Press, ISBN # 0-691-03430-3. This book provides an introduction to game theory for political science researchers, including applications to legislative rules, (international) deterrence, voting, and bargaining. It is truly designed to enable the reader upon working through it to construct her own game-theoretic models of political phenomena or processes.

- Keith Kreibehl, *Information & Legislative Organization*, 1991, University of Michigan Press, ISBN # 0-472-09460-2. This book provides a great example of applying games of incomplete information to analyze how and why legislatures in general and Congress in particular have been organized. In addition to innovative use of asymmetric information game theory, the book contains historical evidence and empirical tests in support of an informational (as opposed to distributional) theory of legislative organization. It is written in a nonmathematical style by a leading scholar in this area.
- Paul R. Milgrom & D. John Roberts, *Economics, Organization, and Management*, 1992, Prentice Hall, ISBN # 0-13-224650-3. This book is not about game theory per se, but is part text and part research monograph covering the theory and practice of the modern firm. It is written by two of the leading scholars in organizational economics or comparative institutional analysis. It provides a wealth of interesting real-world examples as well as rigorous theory in a jargon-free, user-friendly way. Topics covered include reputations as contract enforcers, signalling, moral hazard, ownership, property rights, labor contracts, and corporate control contests. Applications include performance incentives, executive compensation, human-resources management, corporate finance, economic restructuring, vertical relations, horizontal expansion, and business alliances. Chapters 5 and 6 cover asymmetric information economics, while chapter 7 is the most technical.
- Karen Schweers Cook & Margaret Levi, editors, *The Limits of Rationality*, 1990, University of Chicago Press, ISBN # 0-226-74239-3. This paperback is an interdisciplinary collection of essays and comments, both by leading researchers. Although the book covers the more general area of rational choice theory, including framing effects, expected utility theory, experimental markets, and preference formation, it also illustrates the application of game theory to the study of norms and institutions. It indicates limitations, explains areas of controversies, and suggests ways to improve the existing methodology.
- Robert J. Aumann & Segiu Hart, editors, *The Handbook of Game Theory with Economic Applications*, Volume I, 1992, North-Holland, ISBN # 0-444-88098-4, and Volume II, 1994, ISBN # 0-444-89427-6. Edited by two seminal figures in game theory, these two hardcover volumes contain chapters by many of the leading researchers in game theory. They are definitely written in a mathematical style (although the first chapter is about Zermelo's theorem and chess). They are not a text per se, but instead a reference source.
- John Eatwell, et al., editors, *New Palgrave: Game Theory*, 1989, Norton, ISBN # 0-393-95858-2. This paperback consists of those entries from the four volume hardcover, *The New Palgrave: A Dictionary of Economics*, that are related to game theory. This collection is written by many prominent figures in the field. The style tends towards the mathematical. There is unevenness in presentation of the key concepts in the area. The intended audience is that of economics graduate students (and the small number of economists who are still ignorant of game theory!).
- Shaun P. Hargreaves Heap & Yanis Varoufakis, *Game Theory: A Critical Introduction*, 1995, Routledge, ISBN # 0-415-09403-8. This paperback offers a very readable survey of the major analytical results of game theory, its application in the social sciences (including bargaining, social contract theory, and theories of the State), the limits as well as philosophical and political implications of its underlying assumptions, evolutionary approaches, and evidence from laboratory experiments. No more technical mathematics is used than arithmetic. A series of "boxes" contain interesting real-world examples, historical notes, and philosophical excursions.
- Shaun P. Hargreaves Heap, Martin Hollis, Bruce Lyons, Robert Sugden, & Albert Weale, *The Theory of Choice: A Critical Guide*, 1992, Blackwell, ISBN # 0-631-18322-1. This very accessible paperback consists of three parts: individual choice, interactive choice, and collective choice. Although only the second part deals with game theory per se, the other two parts are clearly related. This book was coauthored by three economists, a philosopher, and a political scientist. It also contains a series of "boxes" contain interesting

real-world examples, historical notes, and philosophical excursions. Finally, a section provides definitions, conceptual notes, and technicalities relating to Keywords.

Kenneth J. Arrow, Robert H. Mnookin, Lee Ross, Amos Tversky, and Robert Wilson, *Barriers to Conflict Resolution*, 1995, W. W. Norton, ISBN # 0-393-03737-1. This hardcover book is a project of the Stanford Center on Conflict and Negotiation (SCCN). It is the result of a conference at Stanford University in February 1991. The SCCN provides a focal point for the interdisciplinary study of barriers that impede dispute resolution. The scope of the book is far-reaching and goes beyond game-theoretic models, but chapters by Robert Wilson, Ariel Rubinstein, Howard Raiffa, James K. Sebenius, Ronald J. Gilson & Robert H. Mnookin, Jon Elster, Kenneth J. Arrow, Robyn M. Dawes & John M. Orbell, and Max H. Bazerman & Margaret A. Neale deal with strategic and psychological concerns both in theory and practice. The applications include civil litigation, family law, arms control, labor-management bargaining, and environmental disputes, both across and within national borders. This is an excellent glimpse at the current state of the art of conceptual analysis and theory building about resolving disputes. There is a nice blend of theory and practice. The book also points to new directions in game theory, in particular, incorporating social and psychological factors into neoclassical game theory.

Jörgen W. Weibull, *Evolutionary Game Theory*, 1995, MIT Press, ISBN #0-262-23181-6. This textbook for second-year economics graduate students explains the core theoretical concepts and results about (deterministic models of) evolutionary games (in strategic form). The book includes motivating examples, a review on systems of ordinary differential equations, and chapter summaries. Static and dynamic models of single- and multi-population interactions are covered. Alternative processes of social evolution, including replication by imitation are considered.