1 Introduction

This chapter is an introduction to experimental design. It outlines our approach to strategic play. We discuss the how to model a real life situation rife with strategic issues, as a game that subjects can play in an experimental session. We informally introduce the study of games, called noncooperative game theory, describing the common components essential to all games, demonstrating the central role of strategic play in game theory, and arguing that noncooperative game theory provides a natural framework for studying strategic behavior. This leads into a discussion of the solution concepts used in game theory, which provide the basis for how rational players wil behave. Then we show how experimental methods can be used in understanding strategic behavior. We describe the issues that must be confronted for conducting experimental sessions, and then finally, an approach to data analysis.

The next section describes how an experiment is motivated by focusing on the key features of a strategic issue, the players, their choices and their information, and the payoffs the choices induce. These elements are formalized within a game. There are many ways to represent a game, including the strategic and extensive form favored by game theorists, briefly introduced in Section 3, and discussed along with several other representations. An attractive feature of posing a strategic situation as a game is that games are sufficiently well defined objects to have solutions, and hence yield predictions. Section 4 outlines the main solution concepts in game theory. Three stand out, backwards induction, dominance, and forming a best reply to a conjecture about how others will behave. Sections 2 through 4 describe the theoretical portion of experimental design, while Section 5 and 6 focus on the empirical side. The conduct of experimental sessions are described in Section 5. Experimental subjects are selected and assigned to player roles within the game. The payoffs in the games are linked to the rewards the subjects receive from participating in the experiment. Other critiera might be imposed such as time limits on moves by players, or having subjects play the game more than once (perhaps to test whether their behavior changes with experience palying the game). The last step, described in Section 6, is to analyze the data from the experiment by evaluating the predictions of the embedded game and extrapolating to the strategic situation which motivated the whole exercise.

The sections which follow describe each phase of experimental design. To summarize, there are five: paring the strategic issue down to something simple enough to analyze, designing a specific game to model the the essential issues, solving the game, conducting an experiment in which subjects play the game, and analysing the results of the experiment. The first phase is exploratory, the next two belong to the province of game theory, while the last two are empirical. But what is strategic play, and why should anybody think this approach is useful?

1.1 What is strategic play?

Saying a person played strategically conjures up several images. Other people are involved. They have different goals from the person. The person acts or decides with deliberation using all relevant information available. Viewed in retrospect the choices made by the person follow a behavioral pattern that exhibits a stable set of preferences. We now briefly elaborate upon these four points.

First, "playing strategically" suggests the person was taking decisions or actions that directly affect others, implying more than one person is involved. Few people since Jonah have seriously tried to play strategically with nature or with God; people play strategically with other people, and perhaps with their canine pets, in other words living mortal organisms about as intelligent as they are. There are several ways the other people could be affected. What they know, and/or what their own opportunities are, might be affected by the strategist's actions. Another way the person could have affected them is directly through damages or the benefits he caused them. Another way of defining this interdependence is to characterize its complement, namely those situations where the actions of people and their consequences occur independently. There are essentially two types of environments where players act independently of each other. First when they are alone, and second where there are so many people that the actions of any one individual do not make an appreciable difference to the outcomes of the others, environments that we shall analyze at the beginning and at the end of this text.

Second, the objectives of everybody are not aligned. When strategic play is observed we may infer that the people involved do not have exactly the same goals in mind. If everyone had the same goals, actions might not be directed towards those common goals because of poor coordination, possibly stemming from problems information sharing or a mismatch of skills, but certainly not attributable strategic concerns. Team play is an example of interdependence where interests of players are (more or less) aligned. The problem is to aggregate information and coordinate actions across the team. Thus conflicting interests are a necessary condition for strategic play. Saying that two people are in conflict is more than an acknowledgement that they place different values on two outcome. In a choice settings where there is no uncertainty about the ensuing outcomes, and everyone ranks the outcomes the same way, a unanimous consensus can be reached about what to do, even if players put different values on the outcomes. Strategic play could only be observed in this case if the people involved had different rankings over what was at stake.

A third image conjured up by the phrase "strategic play" is that the person chooses on the basis of what she knows; perhaps she has private intelligence, or maybe not. Before moving she consciously weighs the alternatives and anticipates how the others involved might react. In addition we would tend to discount the notion that a strategic player is guided by astrology or mysticism. Animal cunning, however, should not be ruled out, because it encapsulates the idea of being able to size up a situation and move decisively.

Last, a person who acts strategically is typically regarded as rational, acting out of self interest. Rational choice and self interest are themsleves loaded terms, which mean different things to different people. Our axiomatic approach is based on the notion that rational actions follow patterns that reflect a definition of stable preferences, and are likely to recur in similarly reconstructed situations. This definition of rationality does not preclude altruism by the dedicated faithful, nor for that matter, some forms of dementure commonly associated with lunitics and madmen. But as we shall see, rational decisions are unlikely to emerge from nonprofit organizations that represent several stakeholder groups with conflicting interests, even if the individual stakeholder groups are playing strategically.

So the four elements of "strategic play" are interdependence, conflicting goals, information processing, and actions based on self interest. Defined this way, strategic play is evident in card games, sports, business, politics, religious institutions, social life, the family, in short: all walks of life. Here we depart from more some conventional definitions, which place more emphasis on the application of strategic play in business, and less emphasis on the conceptual basis for thinking strategically. There is a simple but surpisingly powerful rationale for our approach. We believe that strategic thinking learned in one type of environment is deftly applied in others. Consequently it is useful to build up strategic capability in professional life by leveraging knowledge about strategic play that has already been acquired elsewhere, such as in the home, on the sports field, and during parlour games.

1.2 Why this book?

This book is based on the premise that combining game theory with empirical methods in experimental settings helps in teaching and learning social science and business strategy. We believe that problems encountered in social science and business can be illuminated by designing simple games that model these problems, playing the games in experimental settings such as a classroom laboratory that try to mimic them, and analyzing the results of the experiments using basic statistical methods. Hence the purpose of this textbook: to help develop these skills. We seek to characterize situations where strategic play might occur, develop a theory that predicts the affects of strategic play, explain how to design experiments that investigate strategic play, provide instruction on designing and conducting experimental sessions that encourage practicing strategic play, and review statistical methods for analyzing data from such experiments.

Starting with the axioms that define rationality and a review of statistical tools for analyzing experimental evidence, ending with applications of competitive equilibrium in markets for financial assets, the core of this book is about devising and analyzing models for people who collectively resolve all manner of interpersonal and organizational conflicts with whatever means are available to them, whether violent or benign, cooperative or vindictive. This book places roughly equal emphasis on inventing games, solving them, playing them, and comparing the predictions from the theoretical solutions with the outcomes of experimental practice. Acquring these skills, we assert, will help budding strategists and policy makers to more accuratley predict the decisions that made in the real world, evaluate the usefulness of their own models, and hence better formulate policies that serve their own ends.

The purpose of this book is to help students and practitioners become stronger strategic players, but it comes with a disclaimer. The book is not meant to be read in isolation. That would be a little like learning mathematics by attending lectures but never working through the homework exercises, or hoping to become a better skier to by watching experts instead of actually skiing. This book should be used as a manual and guide in conjunction with experiments devised, conducted, played and analyzed by groups of people seeking to develop their strategic skills and increase their understanding of human nature.

2 Primitives

Distilling the situation to its essentials is the next step. Model them as games that your business partners can understand. A Language for recognition and recall. Distil commonality from specifics that is comprehensible to those not familiar with further detail. Reconstruct situations so that they can be compared with each other. build up a data base of comparison points, corporate or organizational history. Since there is not model that exactly captures all the detail, several models might yield parts

The problem or issue under consideration is modeled as a noncooperative game. The game must include those factors which the scientist believes is central to understanding the issue, and should exclude those factors that are peripheral. If there is some uncertainty about which game best represents the issue, several distinct variations of the game might be presented. Having determined which games the experimental subjects will play, the scientist should also decide how the game should be presented, since as we shall see, there are many ways of defining the same game.

Models cannot replicate reality. Real life is a myriad of interconnected matter that no report of finite size can exhaustively detail. Fully describing a situation within a model is therefore infeasible. Consequently every abstraction we draw upon in our experiments is an incomplete description of reality, ignoring many aspects that might relevant to the particular problem we are studying. This is an important limitation for those who use models to answer questions about reality. Offsetting this serious disadvantage, models have one potential advantage. In contrast to reality which, defying complete description, is unmanageably complicated, internally consistent models are objects that we can understand, analyze, and hence learn from. Whether the lessons that models can teach us are applicable to reality is ultimately an act of faith.

These remarks directly lead to the first challenge we must confront upon embarking an experimental project. We must decide what aspects of reality to include within our model, and what to exclude. In this way we form a manageable game from a complex real world situation in order to focus on the critical feaures of the strategic conflict. To accomplish this challenging task, we can categorize the main assumptions made within the game. Our taxonomy is based on identifying the main decision makers, their choice sets, how much they know, the role of other factors in determining the outcomes, and the net benefits accruing to each decision maker.

2.1 Players

Typically more people are involved in a real world strategic scenario than is practical to include there are players in the game seeking to reflect it. consider for example an oligopolistic industry where are there several firms, each of which employs thousands of workers, selling a product to millions of customers each year, and supplied by other firms. There are literally millions of people involved. It would be impractical to design a game for as many players as there are people connected with the automobile industry.

How groups of people are designated as individual players depends on the strategic issue. for example if the the union representing the auto workers, management and takeover group.

In a game of pricing, the players might be a manager of each automobile manufacturer.

In both examples consumers are treated as a demand curve and the preferences of shareholders aggreagte to wealth maximiation of the firm. In the first case managment might find its interests algined with shareholers. In the second case managers are concerned about their own tenure if there is a hostile takeover, so part of teh strategic confilct would be hidden if we ame that assumption.

What we mean as a player differs by application

the role of nature

2.2 Moves

The other place where the game greatly simplifies reality is in the rules that determine what the palyers can do during the game. A game should only include those moves that are essential to the strategic aspects of the situation being considered. In addition the choices should not fully reflect everything available in reality

2.3 Information

Having modeled the players and their choice sets, all that reamins is to specify the information avilalbe to the players about what has happened in the game at the time they make their move. For example if plant capacity takes time to install, but companies undertake the first stages of adding capaicity without the knowledge of their rivals, then in a game where players compete for market share, this feature should be preserved.

One assumption that we typically make in game theory is that players are not forgetful, and have perfect recall. In reality the succession of leadership is often accompanied by the loss of organizational memory, even in organizations that single midnedly pursue a common goal, such as value maximizing corporations. It is, however, possible to capture this in a game, providing we speartate the functions of ownership from control. This information should reflect what is Games with , no such thing as forgetting or memeory loss. what teh choices can depend on

2.4 Payoffs

The payoffs in the game provide the incentives for players to strategize amongst themselves. Ideally the payoffs should not only reflect the real life situation that the game models, but should also translate to a system of rewards and punishments for subjects participating in the experimental sessions. We return to this second point when we discuss how to conduct an experiment. we have several remarks pertaining to the first issue.

When there is no uncertainty in the game, that is uncertainty that is embedded in the structure of the game, as well as uncertainty that arises endogenously through players making random moves, then the ranking of the outcomes by each player suffices to determine the outomce of teh game. This result implies that the only time the value of teh payoffs as opposed to their preference ordering makes a difference to the outcome of the game when the solution outcome is uncertain.

The payoffs from real life in strategic situations are sometimes monetary, sometimes nonpecuniary, depending upon the situation. By monetary payment, we mean generalized purchasing power. When the payoffs are not monetary, then it is natural to express their value in monetary equivalents as well. If the the person or entity being modeled maximizes expected wealth (or its monetary equivalent), translating the payoffs to the play the game is straightforward scaling them to the outcomes in the game. However if the person is not risk neutral, as implied by expected wealth maximization, then his attitude towards risk helps determine his behavior. Since the real wealth of experimental subjects changes changes only a little during the course of a game, we should allow for the fact that during a game experimental subjects are exposed to a trivial amount of risk relative to that faced by the groups being modeled.

3 Representing the Game

Game theory provides a way of modeling and analyzing the outcomes of strategic play.

The scope for strategic play can be indicated with examples of situations where strategic play might arise, showing why there is interdependence, self interest in the sense we have described above,

We now provide a sense of what games are available to play over the internet as a way of illustrating the range of games that are covered of this book.

We describe, heuristically, the basic elements of a game. Then we demonstrate, by way of example, the scope for analyzing strategic play with game theoretic tools, and show how the close relationship between noncooperative game theory and strategic play can be investigated within experimental sessions. This leads us to ask how a person becomes a good strategist. One method is get practice by playing games within experimental sessions. More generally it is useful to learn how to recognize strategic situations, model them, work through the implications of the models, verify the behavior with experiments, and bring together the evidence. In the final parts of the chapter we discuss what learning each of these steps entails.

Games have probably been studied as long as they have been played. The academic discipline of game theory is, however, relatively new. Since its inception 50 years ago, game theory has been used to explain all kinds of social and business interactions. There are three main elements to any game. First of all, no game can be played without participants or players. A game is described by the rules or protocol that defines how play starts, progresses, and ends. The rules also define how much information about previous play is available to players making moves or taking decisions. In this book we summarize the rules by the set of strategies available to the various players. The third element is the rewards or the payoffs players receive at the end of the game, which depend on how the game was played. There are many ways of representing games, but in this book we focus on a handful of generic representations that later chapters develop in detail.

3.1 Extensive form

Game theorists invented two abstract forms to represent games, which are designed to subsume descriptive paraphernalia that cloaks any conflicting interests between the players, so that easier to compare different games along those dimensions. The extensive form, defined in the next chapter, focuses on the moves of the players, their timing in relation to each other, and the information available to players when they move.A game drawn in extensive form looks like a multiple player decision tree.

In principle any game that has a finite number of moves can be represented in extensive form. Games with many moves are, however, cumbersome to represent in this fashion. The discrete form is a more parsimonious way of representing games that have elements of repetition, while preserving an abstract depiction that facilitates comparisons between the strategic elements of games. It is analyzed in Part VI, Chapters 10 through 12.

The two main features distinguishing the discrete from the extensive form is there existence of multiple game trees and transition probabilities that determine how play proceeds from tree to tree.

3.2 Strategic form

In everyday parlance, the meaning of strategy differs from its meaning in game theory. the study of economics, strategies are instructions that fully dictate a person’s behavior, and equilibrium is a strategy for everyone involved, which has the special self -enforcing property that no individual prefers another strategy to his equilibrium strategy if everybody else obeys their equilibrium strategy. It is therefore very difficult to discuss the notion of a strategy or equilibrium in economic analysis without specifying very precisely the issues that confront all the relevant parties.

In business and society at large, more often than not, a strategy are not maps to deal with every conceivable contingency, but something much less complete. For example business strategies are more detailed than a mission but typically less detailed than a cookbook's instructions. They convey more than they dictate by calling upon imagery and benchmarks to communicate and guide.

Rather than sequentially playing a game, we might imagine a player picking a strategy at the very beginning of the game that determines what he would at any given point in the game. The other abstract representation developed by theorists, is based on this idea. Called the strategic form of a game, and defined in Chapter 5, it presents games in a more consolidated fashion than the extensive form. In Chapter 5 we also explain how to derive the strategic form of a game from its extensive form.

When there are only two players in the game, the strategic form can be depicted as a matrix with two elements in each cell.

3.3 Other representations

In principle any game that has a finite number of moves can be represented in extensive form. Games with many moves are, however, cumbersome to represent in this fashion. The discrete form is a more parsimonious way of representing games that have elements of repetition, while preserving an abstract depiction that facilitates comparisons between the strategic elements of games. It is analyzed in Part VI, Chapters 10 through 12.

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Market Form

The extensive, strategic and discrete form representations of games are ideal for highlighting the strategic elements of games, and for defining and analyzing solution concepts. They are less compelling descriptors of games that occur in real time, where the number of possible choices confronting players is typically infinite. For example, if an air ticket is purchased over the internet at any instant within a five minute interval, then the price paid might depend on exactly when the order was placed, and this in turn affects the terms of trade between the passenger and the airline. By way of contrast, the three example games depicted above at most depend on the order in which players move, not how long they take to move. In this important respect the extensive, strategic and discrete form representations of games are not well suited to modeling markets and many other trading institutions, where the speed at which traders process new information is critical in determining how successful they are.

Perhaps a more satisfactory way of presenting trading games played in real time is to mimic the institutions they model. For example Figure 1.4 displays the state of play in an English auction game seconds into the bidding.

Sealed bid auction (Market)

Supply and Demand

Auctions only model one side of teh market

Customized form

Aside from the fact that many games are played in real time, rather than as a discrete sequence of choices players make subject to what they know about play up to that point. Another drawback of the three abstract forms is the very limited way in which moral suasion, rhetoric and imagery can be deployed by a player in order to persuade others to acquiesce to his viewpoint. There is nothing to prevent the designer of a game from allowing parties to send text messages, graphics and other images as part of the game. Since digital imagery is based on binary code, one could in principle translate all language and art into binary code and thus incorporate it within the extensive form, but this is not feasible in practice. Moreover, viewing a glossy photograph of scantily clad tanned bodies sunbathing on a beach of fine white sand in Australia creates a very different impression than reviewing the code contained in the packets used to send that photograph over the internet. In the language of economists, translating the contents of a computer packet to a visual image is a costly capital intensive process.

4 Solving the Game

Having defined the game, the next step is to solve it. This means using principles and algorithms that rational players would accept to deduce the moves that they would make. The tools of noncooperative game theory to accomplish this task. A solution to a game might take the form of a move made by the designated player at any node, or decision point, in the game; this would generate a deterministic outcomes to the game, unless chance plays some role. Alternatively a probability distribution might characterize a player's move at some nodes; in this case rational play generates a probability distributrion over the possible outcomes. There is always one solutions to each game, but it may not be unique.

We begin with a discussion of strategic play, briefly outlining its main premises. This leads us to a definition of rational behavior, a topic Chapter 3 explores in greater depth. Then we describe ways of modeling how groups of strategic players interact with each other are amenable to analysis from a strategic perspective. The concept of a game and its various incarnations is introduced at this point, and we introduce different game forms with several examples as a way of previewing material that is extensively treated later on in the text. Specifically, Chapter 4 defines the extensive form of a game, Chapter 6 the strategic form, in Chapter 11 we discuss the discrete form, in Chapter 13 the free form, and in Chapter 18 we discuss limit order markets.

Having defined a game, we can characterize strategic play within it. Three concepts are emphasized throughout the text. The first is backwards induction, the idea that players should anticipate how strategic players will react to This concept is extensively discussed in chapter 3 in the context of decision analysis, in Chapter 5 where we show how to solve for perfect information games, and also Chapter 9, on games with complete information. The second concept that is emphasized throughout the book is dominance, situations where assessing the merits of a strategy do not depend on what other rational players do. We analyze different types of dominance in Chapter 7, and apply it throughout the applications whcih follow. The other concept widely accepted accepted in noncooperative game theory to predict rational behavior is the notion of a best reply. This expression captures the notion that given the strategies that all the other players pick, a player's best reply serves is his own interests at least as well as any other choice. Within economics more generally, competitive equilibrium is often used to characterize how markets mediate between suppliers and demanders. In a competitive equilibrium, all players take the price as given The last two chapters of this text seek to reconcile how markets in which players are strategic might yield outcomes that are well approximiated by amodel of competitive equilibrium.

When all the players in a game behave strategically, its outcome is predictable.Games are defined to conform with strategic players in the sense that they are defined in sufficient detail so that players behaving strategically face know ambiguity in forming to in a precise way that This leads into an introduction to the main solution concepts for games and the outcomes that are induced when players behave strategically.

solution leads to data generation process: what if there is more than one solution? what if teh solution is hard to fully characterize?

Having designed a game, the research scientist might draw upon a human subject pool, run an experiment in which subjects are are assigned roles in the game

The third is the ability to solve the models using game theory. This skill is developed with practice at playing games, and also by studying the structure of games. Having built a model we solve it to predict the outcome of rational players Is it unique. do people play deterministically or randomly? Another reason for building models is that the situation can be analyzed. Predict how the games you have modeled will be played

The scientist should then propose one or more solutions to the game, which generates a complete description of how she predicts play will progress from its very beginning through to the end. The description might be deterministic, in which case the solution describes exactly how players will move when they join the game. Alternatively the solution might be a stochastic process, assigning probabilities to what happens at each point in the game.

This text extensively uses three concepts to define solutions of games, backwards induction, dominance and best responses to conjectures about other players

4.1 Backwards induction

The use of backwards induction in solving games is the topic of Chapter 3, and then used repeatedly throughout the text. It is motivated by the idea that forward thinking players anticipate the future consequences of their own actions, and therefore make choices that account for those consequences. The principle of backwards induction applies to moves within the extensive form of a game. Figure1.6 illustrates the extensive form of a two player game where backwards induction should be used by

Note that if the first player believes that the second player is equally likely to choose left or right, then teh first player should move left. But why should the first player believe that the second player is equally likely to make either choice when the right choice yields more than . . .

4.2 Dominance

The second solution concept repeatedly drawn upon throughout the text, dominance, applies to strategies, not moves. A player has a dominant strategy if the payoff he obtains from selecting it strctly exceeds the payoff from playing any other strategy regardless of what the other players do. Although the other strategies may affect his payoff, they do not affect his strategic choice in this case: he plays his dominant strategy. Figure 1.7 illustrates the strategic from of a game fro two players, where the first player chooses between three strategies labelled and the second player picks either his first or second strategy.

After defining the strategic form in Chapter 5, we analyze the concept of dominance in Chapter 6. Actually the concept of dominance goes beyond identifying dominant strategies when they exist. Accordingly, Chapter 6 also defines and explains the use of weakly dominant strategies, dominated strategies and iteratively dominated strategies in solving stategic form games.

4.3 Best response to a conjecture

Many games can be solved by applying only the principles of backwards induction and dominance. When that is not the case, however, the researcher must appeal to other solution concepts to predict the game outcome. Suppose each player conjectures the strategies that every other player in the game willl choose, and then maximizes his objective function by choosing a strategy that gives him the highest payoff when the other players follow his conjecture about their strategies. If every player thinks and acts in this fashion, and none of them are surprised by the outcome because all the conjectures are confirmed, then the strategies they had picked are called a Nash equilibrium.

This approach is illustrated in Figure 1.8

The fragility of Nash equilibrium is also shown there. It is not clear which of the three equilibrium will be played.

4.4 Competitive equilibrium

The equilibrium concepts we have introduced above are applied to games. The backwards induction principle to the extensive form of a game, and the dominance and best reply concepts to the strategic forms. All three concepts can be applied to market games, as our discussions of market microstructure in Chapters 18 and 19 establish. When discussing market outocmes in which many traders participate, economists often eshew institutional descriptions that describe the trading rules, and subsume all detail about the trading process by predicting the outcome of trading on the basis of the the preferences of the consumer demanders and the production technology of the firm suppliers. they assume that all units of the goods are traded at the same price, and at that the price consumes demand exactly the quantity that firms are willing to supply in aggregate. This is called a competitive equilibrium.

5 Conducting an Experiment

Experiments can be run in various ways over the internet. A firm's strategic focus group meets on company premises to conduct an experiment inside the firewall perimeters. A course instructor conducts an experiment within a classroom that has computer facilities with internet connectivity for the students. Project team members located at several remote sites log in to the project leader's machine at a prearranged time to participate in experimental trials. A researcher schedules his experiments in a specially designed computer laboratory. In all of these examples the session organizer, or moderator, is balancing the convenience of arranging an experiment against against the value of the experience to subjects, and the usefulness of the results to others.

Leaving aside administrative barriers that regulate internet communication between and within organizations, a message sent from a computer arrives almost as quickly to a recipient within the same room as a recipient located on a different continent. Thus the integrity of the experiment is less related to the physical layout of the physical or virtual computer laboratory, than with the arrangments for organizing the session, the selection of the subjects, how their incentives are tied to the outcomes of the game, and whether the session organizer prevents players from communicating with each other outside of the rules permitted within the game. This section discusses some of the issues that arise from these considerations.

5.1 Selecting the subjects

In survey analyses of human behavior compiled by researchers in universities, government agencies and marketing firms, socioeconomic and demographic characteristics of the sample population often figure prominently as explanitory predictors. Such variables are less influential in experimental outcomes, because the incentives for subjects are determined by the player roles to which they are assigned, not by their personal backgrounds. For this reason, we believe that how subjects are selected is less important for data analyses based upon experiments than those based on surveys.

This is fortuitous because, depending on the circumstances, a moderator might not excercise much control over his subject pool. For example instructors teaching courses and strategic consulting groups conducting in class and within group experiments do not have much say in how their subject pool is assembled. Course enrollment process usually have scientist should now be ready to conduct the experimental session. Advertising billboards on campus and past experience

Nevertheless the selection process for subjects may have a bearing on the game outcomes. To the extent that players deviate from behavior predicted by the game solution, we conjecture that the background of the subjects sometimes systematically affects the course of play. There are two noteworthy factors, the background of the subjects as it relates to their ability to solve games, and the social interactions between subjects after the experiment session ends.

First is whether subjects have had the opportunity to see the game ahead of time, and how familiar they are with solution techniques for non cooperative disccussed in this text and elswhere. When subjects have general knoweldge about game theory and specific knowlgdge about the game, they tend to play more predictably thatn otherwise for a given experimental design. On a related point is whether the subjects some familiarity with similar problems in real life. In an experimetnal setting that faithfully reflects the real life situation we expect those with related real life experience would capitalize on their knowledge.

Second is how well do the subjects know each other, if at all. Supposing the game is part of some larger social interaction and the payoffs are not anonymous, then teh experiemtn is compomised by becoming embedded with a In this case the incentives to the palyers within the experiment are modified by hos teh subjjects. If the player roles are disclosed, then a subject might play poorly to graciously lose to an opponent, or punish ano in the hope of currying favor withiafter teh game session is complete. In this way the outcomes of the experimental session become embedded within a larger game of life, contaminating the experimental outcomes in the process. Extensivley using remaote sites can mitigate this effect.

5.2 Assigning roles

When the subjects join the experimental session they are assigned to a game and a player role.

We argued above that sample selection into the subject pool does not affect the solution to the games played but may affect the incidence of deviations from the pedicted path as well as the type of deviations observed. Similar arguments can be made about assigning subject to player roles. Assigning players who know each other to the same game might induce deviations from the solution to the game. Also if subjects are more familiar with some types of games and player roles than others, there are less likely to be deviations from the solution. These two issues

if subjects believe that their decisions during the experimental session affect the way they are treated over and above the payoffs they received.Assigning players anonymously to games prevents players from size of subject pool with software that guarantees the anonymity of players in order to control communication between subjects matched with each other in the same game, during and after the session.

because of prior training or familiarity with the real life situations they represent. Drawing players from different remote sites to participate in teh same game

by subject chacteristics

5.3 Incentives for subjects

One reason why experimental subjects would not necessarily be guided by the theory in playing a game is that they might not actually receive the payoffs in the game are not reflected in the consequences of their play. Researchers often provide monetary payoffs that exactly match the payoffs earned by subjects who have participated in an experiment. Thus it is possible in principle for a strategy group testing its theory about a game outcome to require the participants to pay an entry fee, which is then redistributed after the game has been played in proportion to the payoffs implied by the oucome. Similarly a professor might allocate a portion of the grade to participation in the games, where the payoffs received by the subjects accurately reflect their performance.

Whatever incentive mechanism used, the comments we have made above about our easily experimental results can be generalized, seem pertinant. One should think that if the payoffs to a game were all changed by several orders of magnitude, leaving all the solution proposed in this book unchanged, subjects would concentrate more closely on the progress of the game. This remark highlights another problem that

Are grades used? If so how are they assigned?

rewarding by prediction versus rewarding proportionately

and thus compromise the results from teh experimental session through illegal collusion.

Project team all throw in money to create incentives, but winner is expected to pay of drins at hte end

5.4 The experimental session

Typically many games can be played during an experimental session lasting an hour or so. Conduct experiments with your games with different payoffs different variations on the same game different subjects, lots of time to think about the situation, little time role switching, no role switching, For example when a subject pool of between twenty and fifty meet to participate in the session, each of six games for a handful of players might be run about fourty times, a typical subject playing each game at least twice with different players. Software for conducting the experiments automatically identifies the subjects as they log on as clients, records self reported background data that the moderator has programmed prior to the session, follows the sequence of subjects to whom they are partnered throughout the course of the experimental session, tracks their every move, and at the discretion of the moderator provides them with summary feedback on their performance in the various games.

Most of this process can be automated, including the instructions given to the subjects at the beginning of the session, how many repetitions subjects should play each game, how they are anonymously matched with each other in different games, their roles, and the calculations for the payouts to the subjects at the end. The main advantage of automating the process is that it lends credibility to the subjects, easier to draw inferences, more credibilty to researchers reading teh results and also to being methodical reuces error and unanticipated effects into what is sometimes described as a controlled environment.

We have already addressed many of the issues concering the format and conduct of the games, but there are three which deserve noting here, because they concern the timing of moes by subjects particiapting in the session and the backup material at their disposal for helping their decision making.

Many of the games are silent on the amount of time the palyer has to move, and those that are not silent assume that players react instantaneously. In experimental sessions the moderator should determine whether a time limit will be imposed on moving, and if so, wht atht elimit should be and how the game should proceed if the limit is violated. How long does each player have to move?This issue is assumes most relevance when the payoffs are significant, because giving players more time to move imporves their performance, but also slows the pace of play.

A related issue is the penalties subjects face when they diconnect from a game that seems to be going badly for them. Naturally reliable software will record these disconnections, along siht eh plays that led to it, but unless players are heavily penalized for disconnecting, it would seem that the option to bow out shouldb eincorporated into the theorietical solution of the game.

A third issue related to is what resources should be available to subjects druing the course of play to assist them with decision making, such as calculators, interent internet resources such as online textnotes, and so forth. We are not arguing that should be banned, simply that the experiemtnal outcomes might be affected by whether subjects have such assistance or not.

6 Data Analysis

In principle the solution to a game predicts how players will choose, so if players conform to the theory, then the process by which the game are played is perfectly anticipated. In this way game theory provides a benchmark for scientists, strategists and students evaluating the outcomes of game. Deviations from those outcomes then become the object of attention because they may indicate ways in which players are not confomring to the theoretical predictions and/or ways in which the data generation process is supported by a different game from the one being assumed.

The data generated by the outcomes from subjects playing the games serve two purposes. They are the record of account for settling with the subjects in accord with contract, whether the medium is cash or grade points. and they also that hold to

Collect the data from the experiment, analyze the data, and present the findings in a report which describes also describes the previous phases.

6.1 Summarizing the data

The solution to the model provides a benchmark for how experimental subjects might behave in a computer laboratory. For example in the prisoner's dilemma game, both players should always choose to confess. In this case the model predicts that all outcomes will fall in the bottom left cell of the matrix depicted in Figure 1. As we demonstrated, some of the solutions are stated as deterministic predictions, while other solutions are stated in terms of probability distributions that govern strategic decision making. For example in the matching pennies game depicted in Figure 1, both players should randomize between heads and tails putting an equal probability on both outcomes. Consequently the model predicts that the sample of game outcomes will be dispersed evenly over the four matrix cells in Figure 1.

When the solution to the model is a probability distribution that covers all possible outcomes, such as the matching pennies game, the relative frequencies observed in the data typically differ from the predicted theoretical counterparts because of sampling error. For example if there are less than four trials in the matching pennies game, then at least one cell is left vacant, and the relative frequency for that cell is zero, not one quarter as predicted by the theory. Statistics provides a way of anwering the question whether the deviations between the cell probabilities predcted by teh solution to the model and the relative frequencies computed from the game outcomes are too large to be explained by the size of the experimental sample. The law of large numbers implies that If the predictions are correct, then the relative frequencies should converge to one quarter as the sample size increases without bound. Furthermore the central limit limit theorem . . .

Evidence from an experiment in the matching pennies game can be used to illustrate these points. In this sample . . .

Interpreting samples of experimental outcomes on games that have a deterministic solution is a little more problematic. Suppose that out of one hundred trials in the prisoner's dilemma game, all but one outcome falls in the bottom left cell as predicted by the theory. Should we conclude that the theory fails? Fearing consumer backlash, few managers would tolerate a manufacturing plant with quality controls that accepts a one percent failure rate. They would instigate measures that reduces the rate to a small fraction of that rate, depending on the part, where it fits within the system assembly and the cost of instituting a production line that reduces the the output of malfunctioning parts. For simlar reasons harsh critics might wish to discard the dominance principle used rto derive the solution to the prisoner's dilemma game upon observing this evidence. But a more satisfactory solution is feasible, as in the case of the manufacturing example, such criticism rings hollow.

In this book we take a less rigid view, which readily . The argument for rejecting the dominance pricinciple in teh prisoner's dilemma should not hinge on observing a single violation outside the bottom left cell, but rather whether there is a systematic tendency away from that cell, that is whethe the probability of reaching that cell is some proper fraction. Thus under the null hypothesis that there is no systematic tendency, the relative frequency observed in the experimental sample should converge to unity as the sample becomes larger, and that deviations about its sample mean cannot reject the hypothesis that the treu mean is less than one. This approach to testing the theory uses the same statistical analysis to models that have random outcomes as ahve deterministic outcomes.

Table 1 depicts one hundred experimental outcomes from running the prisoners dilemma game to randomly matched subjects.

6.2 The data generation process

There is little reason to expect that even well trained subjects will slavishly follow the precepts dictated by strategic play. The rules of the games might not be clear, subjects might reason poorly and make mistakes, they might process information in mystical ways that a natural scientist would find hard to fathom, and perhaps the goals of subjects are not so easy to discerrn. Even if the subjects played strategically, we shall discover in Chapter 8 that rationality alone does not suffice to predict the outcomes of all games. Experimental methods can thus be used to evaluate how closely human behavior conforms to the predictions of game theory, and gauge the extent to which deviations from the theory are systematic, and consequently amenable to further analysis. Accordingly the latter sections of this chapter turn to relationship between these theoretical concepts and behavior by experimental subjects.

First we establish the umbilical cord joining a particular solution to a game with the data generating process it produces. Then we mention several reasons why our reliance on this connection must be tempered by how the game relates to the problem that motivated it, the potential for multiple solutions, and the fact that experimental subjects do not always play strategically. These mitigating factors suggest that outcomes from experimental sessions are partly determined by fine details that characterize the design of the games, the population from which the subjects are selected, how the experiment is presented to the subjects and the conduct of the session. Because the details matter, our approach on this issue has been to embed critical discussion of this topic within the application that are developed throughout the text, rather than provide a comprehensive discussion of this topic in isolation. Careful analysis of data from experimental sessions take all these factors into consideration in order to provide a compelling interpretation of how experimental subjects play games, and what can be inferred about human behavior in non-experimental settings. In the last section of this chapter we lay out some focal points for analyzing the data before taking up the topic of analyzing experimental data in greater detail in the next chapter.

There are essentially two reasons why the data generation process might be rejected by teh experimental outcomes. First, the game is misspecified. Conduct of experiment follows rules of game?

Second, the solution does not apply because players do not behave as the solution predicts.Although some people may be innately better strategists than others, much about strategic play may be learned. Learning about strategic play should be undertaken when the stakes are low: learning how to play strategic by experience might be a one time opportunity. This motivation provides the rationale to acquire three skills in social science through study and practice.

ultimatley new theories of behavior

where is the old one most realiable

where is it least informative or downright misleading

6.3 Testing for deviations from the solution

We shall argue in the text that some of the solution concepts are more robust than others. For example solutions that can be derived relying only on dominance and backwards induction algorithms are arguably more Rather than treat the theory as a unified object which must accepted or rejected as an all or nothing proposition, it is reasonable to test the various components of the solution separately where possible.

Conseider for example the following game in which

consider an experiment with a four by four matrix where the top diagonal elements are high adn equla for both players and the bottom stuff is low

In a backwards induction game one player might play properly, another poorly. We can tell the difference

Characterzing the solution fully or partially

Not all the features of the solution are equally interesting and relevant to the scientist undertaking this research. Consider a game in which nature plays a role at the end. are we interested in testing whether the random number generator performs properly. If not we should group the outcomes to remaove that source of uncertainty.

When there are multiple solutions to the model, the process of testing them is complicated by teh fact that the experimental subjects playing in a game together might not coordinate their behavior around the same solution. This reduces the power of the solution technique to distill from all possible outcomes those that are more likely to occur

Subjects

An important is to Integrity of the experiment depends on sticking to the rules yourself, so that the

First of all, your report will provide the basis for determining how the other students performed on your project for the purposes of grading Part B. Thus the report should include tables that show which role or roles each of the class subjects played in your experiment, and the number of points the person received in the games he or she played. It should also show the number of points the person would have received if they had played according to their part of the equilibrium strategy profile, and their opponent had played according to (one or more of the equilibrium profiles as well.

Learning through experiment

Are subjects rational. Playing against a nonrational oponent

Another question of interest is whether subjects improve their play over a longer period. One could compare class performance on similarly rated problems at the beginning and end of the term

Players

The second part of the report should explain the main features of the sample population of subjects, using statistics and econometrics to help summarize the data from your experiment. You should use bar charts, pie diagrams and other relevant graphical devices to illustrate your points. When arguing how well the theory works you should know how to adjust for sampling error with t statistics, confidence intervals and so on. By all means, estimate some parameters of interest to your research questions, provide some confidence intervals, and test some hypotheses of interest to your project. Be sure to focus on the extent of deviations in the experimental outcomes from the theory, seeking to explain why. (Did some subjects fail to optimize in all the rounds, or did people learn? Do subjects individually mix or does the population simply divide into proportions that give the appearance of mixing to any individual player facing an anonymous opponent?)

6.4 Extrapolating beyond the experiment

The last part of the project should speak to the economics of the behavior you have just analyzed. A discussion of individual rationality (drawing on material we covered in the first part of this course), as well as the non-cooperative equilibrium concepts we have learned should be included in this section if relevant. Analyze the data from your experiments when people in the simulation differ from the predicted outcome, did they play a solution you identified. If so this lends credbility to your prediction. If not several further questions should be answered: did they play another solution, or is it simply that you picked one of several possible solutions. supposing they did not play a solution, was it simply that the stakes were not high enough, complexity, would people in real life sort that through better. Act on the basis of your conclusions. If you do not take the analysis seriously enough to follow through with it, the question remains Exploit such situations for the benefit of your business

Then the data from the experiment are collated and summarized. The scientist evaluates the test statistics defined in the third stage, derives the parameter estimates and their standard errors, and prepares a report that describes all the steps in detail, including the findings.

Learning going on?

Can we generalize the experiment to situations beyond the specific classroom experience?

In the previous section we argued that one way of becomes a better strategic player is to acquire experience playing lots of different kinds of noncooperative games. Another way is to study them, forming theories about how people play strategically, and then deduce from that how best to respond. Social scientists test their theories by applying them in three different ways. The first method is to collect, compile and analyze field data. A second method is to actively participate in the formulation of public policy, and in business strategy, and update policy based on experience. The third is to conduct experiments in artificial settings that seek to simulate the essentials for testing the theory.

Each of these three methods has its benefits and drawbacks. With the advence of electronic record keeping, field data has become more prolific, and its retrieval for scientific analysis is cheap. However data generated outside a controlled laboratory setting is susceptible to many factors that may distort their analysis, particularly if the econometrician is not fully cognizant of them. Furthermore the data available might not contain the variables that the scientist is most interested in.

Using human populations as subjects in pilot projects and trial programs is limited in scope, and typically very expensive. This does not deter firms from conducting product tests in trial markets, nor researchers in pharmaceutical companies from testing drug by research doctors on selected patients willing to participate. Nevertheless there are many questions in business that cannot be answered by a repeated trail and error process without jeopodize the futures of the main participants, such as the firm itself.

The main benefits of using experimental methods within laboratories is that data can be cheaply and quickly obtained from a study framed by the investigators. The main limitation of this approach is that the artificial environment in which experiments are undertaken cannot easily be generalized to more realistic settings. Nevertheless a growing literature in experimental economics attests to the credibility within the profession that this methodology has acquired over the last 20 years.

This advantage is particularly useful to students undertaking empirical research, who have neither the resources of professional social scientists, nor the time to undertake field studies which might otherwise last several years, and also strategic consultants seeking to literally play out a variety of scenarios that depict possible courses of action for the industry or some other collection of parties with conflicting goals.

What can we conclude?

Increasing levels of generality but at cost of less robustness

Running a similar experiment on teh other groups

Theory extends more than deviations from it

7 Summary

A strategic situation exists when the actions of one person directly affects the well being of some else. Game theory is the study of such interactions. A premise of game theory is that each player pursues his or her respective objectives taking that interdependence into account. That focus also explains why game theory is helpful to you. Solving games encourages you to put yourself into the shoes of the other players, rather than viewing games solely from your own perspective, and in this way better anticipating the actions of your friends, and also your rivals. Be alert to recognizing strategic situations, seizing opportunities and deciphering from others how their opportunities are linked to yours. Know how to model real world problems as games that reflect constrained choices facing businessmen, high ranking bureaucrats and elected officials. This book emphasizes two ways of acquiring this skill, Rational play . . empirical methods namely presenting models designed others as cases, and designing games oneself for experimental purposes in the classroom.

This chapter introduced the main themes of this book. We began by explaining the four ingredients for strategic play, interdependence of actions between people, conflicting interests and goals, informed intelligence that guides their thinking and decision making, as well as self interest. Then we stated the central thesis of our book, that a better understanding of strategic play can be achieved by integrating noncooperative game theory with experimental methods and statistical analysis.

The rest of the chapter then intoduced the approach that we shall develop in this book to analyze strategic play. From a complex world with a myriad of details we distil a game, defined by its players, along with their information, choices and payoffs. This constitutes the first phase, game design. Finite games can be defined in their extensive or strategic form, depending on whether we wish to be explicit about the roles of information and precedence or not. The next phase is to solve the game analytically or numerically using game theoretic solution concepts. The solution to a game amounts to a prediction about how the game will be played. It yelds the data generating process for experimental subjects who play the game according to the precepts of game theory. We mentioned the three main concepts that game theorists apply to predict rational behavior, backwards induction, dominance, and Nash equilibrium.

The third phase is the conduct of the experiment itself, with experimental subjects participaping in classes and/or strategic focus groups. The last phase is to analyze the results from an experiment to assess how closely the subjects conformed to the theoretical predictions and test for deviations from the theory that might be consequential in the original situation. In our discussion of empirical methods, we briefly compared the main advantages and limitations of conducting and analyzing experiments with the alternative of analyzing field data. It seems hard to sustain the argument that everyone should specialize in the same approach, and this, we believe, is the only textbook on strategy that concentrates on the former.

When designing and performing your experiment think about:

. Explanation of the experiment and why it will be able to answer the question

- What are we changing or what is different from the original state (independant variables)
- what are we recording
- anything that may affect the information we want to record (controlled variables).

To prevent the things to have an effect.

- What are we comparing the changes against, the baseline (control).
- the starting point along with specific changes to be made (treatments).
- how many times we think this experiment need to be performed
- procedures we will use
- the answers we will find after performing the procedures (results)