CLASSROOM GAMES
STRATEGIC INTERACTION ON THE INTERNET

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Journal of Economic Perspectives, Spring 1999

I. Introduction

Game theoretic concepts arise in many economics courses: for example, the prisoner's dilemma in the principles course; Nash equilibrium in industrial organization; bargaining games in labor economics, strategic interactions in managerial economics, free-riding and common-pool resources in public economics, and so on. Learning about game theory can be enhanced by having students play the games themselves, so that they can directly experience the incentives and difficulties. Such games can be played in person, of course, but an intriguing alternative is for students to play the games with each other on the Internet. This allows students to interact after class, thereby conserving valuable lecture and discussion time. When a game is played over the Internet, a dedicated classroom laboratory is not necessary, since players can connect from many outside locations, and the games can include players from different universities, or even different countries.

This paper describes a flexible program for running 2-person strategic form games. The program is freely available at the internet address:[1] **http://www.cmu.edu/comlabgames**. The program, developed by Marko Grobelnik, Peter Kese, Robert Miller, and Vesna Prasnikar, can handle large numbers of participants and strategies, with a variety of options for matching players and for stopping the game. The "moderator" program that controls the interaction must be run

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1 The web site also includes a program for running extensive- form games. In this module the instructor uses a mouse-driven game tree editor to design the game, by specifying information sets, choices at each decision node, payoffs for each outcome, and exogenous probabilities for moves by "nature."

from a PC with Windows 95, Windows 98 or Windows NT and a standard Internet connection.[2] The student players can connect to the program from any platform using Netscape or Internet Explorer (i.e. PC, Machintosh, HP-s, or Sun-s).

The moderator program can be downloaded from the Comlabgames web page mentioned above. This program allows the instructor to design the specific game to be played, by specifying such features as the numbers of decisions for each player role (row or column), the payoff matrix, the protocol for matching players (random or fixed pairings from the pool of participants), and the protocol for stopping the game (random or fixed number of rounds). Since this is a two-person game, there must be at least two players who log on, but you can specify a target number of players that must be logged on before the program begins. These features are saved on the instructor's computer, and can be accessed or modified any time. When the instructor starts the game, the moderator program automatically displays the internet address of the moderator computer. Players have to know this address in order to connect and play the game. Players open any browser (i.e. Internet Explorer 4.01 or later, or Netscape 4.06, or later), type the moderator address that the instructor gave them, and connect to the game by providing their name and organization, as shown in Figure 1.

Each game consists of a series of rounds in which players are prompted to make independent decisions. At the start of a round, a payoff matrix appears on the screen, and each player is assigned randomly to a role: row or column. Players indicate a decision by clicking on the desired row or column. Once a decision is made, all payoffs in the row or column selected are highlighted, and the player then either makes a different choice or confirms the decision by clicking on the "Execute" button. After both players have confirmed, the decisions and/or payoffs for each player are displayed on their respective screens. The data are also stored in an output file on the moderator computer, along with some summary statistics. This feature enables the instructor to monitor the data patterns on line for use in subsequent classroom discussions.

Detailed instructions for downloading and setting up a game are available at the

[2] More specifically, the communications are controlled via the TCP/IP protocol that is used for FTP, Telnet, and Netscape, so if your Windows 95, 98, or NT computer has any one of these applications, then the moderator game program can be run without additional adjustments.

Comlabgames website. Here, we wish to give a broad perspective for how to proceed, and to review a particular example that can be interpreted either as a Cournot quantity competition game or as a common-pool resource problem.

II. Steps for the Instructor

The first step for the instructor is to download the necessary files from the website **http://www.cmu.edu/comlabgames**. The loading is automatic and begins when you click on the instructor's program: MtxGmMd.exe, following the instructions on the website. This installation process will create a moderator icon on the screen display of the computer that monitors the interactions -- for example, on the instructor's PC that is used for downloading. Then the instructor can set up the experiment by clicking this icon, which brings up the screen window for designing strategic-form games. The File menu at the top allows one to create new game files, open existing files, save files, run games, and exit from the matrix game editor. The options in the file menu are listed: "New," "Open," "Save," "Save as," "Run Server" and "Exit."

The "New" option in the File menu allows you to create a new customized payoff matrix, with the number of rows and columns that you specify. Then a payoff matrix appears, and you must go to each cell and type in the payoffs, with the row player's payoff to the left of the comma and the column player's payoff to the right of the comma. If you choose the symmetric-payoffs option, however, then you need to type only one number in each cell. These payoffs are saved by choosing "File" and then "Save as." This produces a box for the file name, and you should type a name (with a maximum of eight characters), which will automatically be given ".mtx" extension when you click "Save." The "Open" option allows you to retrieve a previously used payoff matrix, and edit it if you desire.

Once you have specified the payoffs and have saved them in a file with an ".mtx" extension, you are ready to specify game parameters by going to "File" and selecting "Run Server". The display will ask you to type a name for the game to be run in the Session identification box. By default the file name of the game in the strategic form will be the name given to the payoff matrix. The next box is the "Rounds" box that lets you choose between "Fixed" and "Random". A fixed ending for a game is determined by typing the total number of rounds that the game should be repeated in the "Fixed" box, and typing zero in the "Random" box. For a random ending, the probability of continuation to the next round should be typed in the "Random" box. For example, with Fixed set to 10 and Random set to .5, the game will go for at least ten rounds, with a .5 probability of being stopped after the tenth and each successive round. If the random stopping process should start from the beginning of the game, then the "Fixed" number should be set to one.

After finishing the Rounds box, go to the "Games" box, which is also divided into "Fixed" and "Random" parts, which allows you replay the whole game a fixed or random number of times. For example, if you could run a fixed number of one-round games, which allows you to reassign row and column roles between each game. A fixed ending is determined by typing the total number of games in a box name "Fixed", and typing zero in the "Random" box. The "Minimum Number of Players" box is then used to specify the number of participants that must logon before the game starts. This number has to be an even number since participants will be matched in two-person games. By default the minimum number is set to two, but the instructor should normally set this to the number of participants in the class who will be playing this game. When the game is run at a preannounced time after class, the minimum number of participants should be low enough to reduce the risk of not having enough students sign on to get the game started. The "Fixed Pairs" box is used to indicate how players are to be matched with each other. A check mark in the box determines fixed pairings for all periods, so clicking on the box and leaving it blank will result in random re-matching of players after each round. The "Show Info Options" boxes control the information available to players: that is, whether or not they see the *other* player's identification number, payoff, history of play, or cumulative payoffs. It is even possible to hide the payoff matrix itself, if payoff information is to be presented in words or formulas.[3] There is also a "Log File box" that allow you to enter the name of the file that will be created for data storage.

Once you have entered all information needed to set up the game, select "OK," which brings up a window with the instructor's computer address. This address has to be provided to students in order for them to connect to the experiment. (If the instructor runs several

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[3] You may wish to hide the payoff matrix if it is large and payoffs are explained in a different manner. For example, the demand and cost information that determine payoffs in a market game may be given to students in a separate handout.

experiments from the same computer at the same time, the number at the end of the address changes. This flexibility allows the instructor to use one game for part of the class and another game for the others.) The "Matrix Game Server" box allows you to monitor the play as it occurs. You will be able to see the names or identification numbers of the players, and their moves in each round. The results are saved in an ASCII file that can be imported into other programs for data summary, analysis, and to serve as a basis of subsequent classroom discussion.

IV. Steps for the Student/Players

We have found it useful to pass out the following list of instructions to student/players, especially if they are going to log on after class at a specified time from another location.

1) Equipment Needed: In order to play the game, you will need to access Internet Explorer (version 4.01 or later) or Netscape (4.06 or later) from a computer with just about any operating system (i.e. Windows 95/98, Windows NT, Machintosh, Unix, etc.).

2) Logging On: To enter the game, open Internet explorer or Netscape, type in the address that the instructor provided, and press "Enter." The box that appears on the screen requests three pieces of information: Server, Name, and Organization. The server name is, by default, the address that you used to login. If the instructor gave you several addresses that differ only in the final four digits, you can connect to a different game just by changing the last four numbers in the server name box. The instructor will tell you what to enter in the Name and Organization boxes (normally your name and university). Unless this information is entered correctly, you will not be able to play. Finally, click on "Launch the Game."

3) Making Your Decision: After you connect and enough other participants have logged on, a matrix will appear on your screen. The numbers that are colored in red are your payoffs; the numbers that are colored in black are the other player's payoffs. There will be a message that tells you the round of the game, and if the instructor chooses, the identification number or name of the player with whom you are matched. At the top of the payoff matrix there is the message to "Select Row" or "Select Column" depending on whether you are a row or column player. That is, you will either choose which row you prefer, out of all the rows, or which column you prefer, out of all the columns. When you click on one of the rows or columns that contains your desired

decision, the whole row or column of possible payoffs will be highlighted. At this point you may either change your mind by clicking on another decision, or you may confirm by clicking on "Execute."

4) Payoffs: Your payoff depends on your decision and on the other person's decision. You will not know the other player's decision until after you have made and confirmed your own decision. For example, if you are a Row player and highlight a row of payoffs by clicking that row, you will not find out which of these payoff numbers is your actual payoff until you confirm your decision and then are told what the column player chose. You may need to play several rounds of the game; the instructor will decide how many. When you see the "Game is Finished" message, you should click on "OK" to close the window.

V. An Example: Procedures for a Common-Pool/Cournot Game

In this section, we describe a two-person game that can be interpreted as either a Cournot market or a common-pool resource dilemma. We focus on the latter interpretation since this is less familiar to most instructors. The main difference in interpretation is that in a common-pool problem, the joint maximum for two players is also a social optimum; but in the case of a Cournot market, the collusive joint profit maximum for sellers is harmful to consumers.

If the common-pool resource is presented as being a fishery, then the quantity choices for each player correspond to effort levels. Assume that each of the two players is equally skilled, in the sense that an individual's fraction of total catch is equal to the individual's fraction of the total effort. Let the level of effort for player i be denoted by x_i, and let total effort be X, so that player i will obtain a share x_i/X of the catch. The second assumption used in constructing the payoff matrix is that the total value of the catch is a quadratic function of total effort: that is, $AX - BX^2$. If the cost of effort is linear in the level of effort, Cx_i, then the payoff for player i is the share, times the total catch, minus the cost: $(x_i/X)(AX - BX^2) - Cx_i$, or equivalently, $x_i(A - BX) - Cx_i$. This payoff structure corresponds to that of a Cournot market with constant marginal cost and a linear inverse demand. In addition, we add a constant to all payoffs to reduce the prevalence of negative payoffs.

One set of parameter values that we have used successfully in classroom situations is taken from Holt (1985): $A = 30$, $B = 1$, $C = 6$, and a constant amount, 45, that is added to all payoffs. These parameters yield the payoff matrix shown in Figure 2. The payoff for the each player is determined by the intersection of the row and column decisions of the two players, and the row player's payoff is listed first. Notice that if the column player chooses an effort of 8, then the best response of the row player is also 8, which is the only symmetric Nash/Cournot equilibrium.[4] However, if the players could make a binding agreement, they would both choose a common effort level of 6, which has a higher payoff of 81 for each.

The common-pool resource dilemma is that each person has a private incentive to increase effort above this joint-maximizing level, since the increase in their own share more than offsets the decline in the total catch. That is, if a player unilaterally increases work effort from 6 to 7, while the other player remains at 6, the individual who works more will gain 2, even though the joint output is reduced by 1. This externality can lead to "over-dissipation" of the value of the resource.[5] Total dissipation occurs when the total catch for all is equal to the sum of all costs, i.e. the sum over i of $(x_i/X)(AX - BX^2)$ equals sum over i of Cx_i. This dissipation condition is: $X(A - BX) = CX$. Dividing both sides by total effort, one obtains an average-value-equals-average-cost condition. For the parameters being used, this rent dissipation condition is: $30 - X = 6$, that is, when the sum of the two players' efforts is 24. (Total dissipation, which corresponds to a price-equals-average-cost condition, yields a payoff of 45 to each player since this amount was added to all payoffs.)

Although the computer program provides payoff information and prompts to make decisions, the economic context of any particular application may be provided, on a separate instruction sheet. The common-pool resource game can be explained by distributing the following paragraph:

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[4] There are asymmetric equilibria that arise due to round-off errors in the payoffs (Holt, 1985).

[5] Bergstrom and Miller (1997) offer an interesting classroom market experiment with externalities.

Common Pool Resource Instructions: This exercise involves a situation in which you are matched with another person, and each of you will decide how many hours to spend fishing in a common fishery. Higher efforts are more costly to you, but an increase in your own effort will increase your share of the total catch, which depends on both of your effort levels. The net effects of these cost and catch factors will be summarized by the payoff matrix shown on your screen. Your effort is a number between 4 and 22, and the payoff matrix tells you how much you earn, given the efforts chosen by you and by the other person with whom you share the resource. When you log on to begin the exercise, you will be designated as a "row player" or a "column player," which determines whether you choose a row and the other player chooses a column, or vice versa. Your payoff is the number at the intersection of this row and column, and is colored in red, and the other player's payoff is shown in black color. For example, if both players choose effort levels of 14, then both would earn 17; or if you choose an effort level of 10 while the other person chooses 4, you would earn 95 while the other person would earn 65. You will each be prompted by the computer to make your decisions without knowing what the other person is going to do, so you must give some thought to anticipating what the other player is likely to do. After both of you have made your decision, the program will use the table to determine your earnings and those of the other person, and your earnings will be shown to you. The program will keep track of your decisions and earnings. Your instructor will tell you how many periods will be conducted in this manner, and whether you will be matched with the same person in all periods or whether you will be randomly matched with a different person in each successive period. All choices are automatically stored so that they can be discussed later in class.

When students are paired together in repeated matchings for, say, 10 periods, the average efforts tend to vary considerably across matched pairs. Some pairs will manage to reach the joint maximum payoff that is obtained with efforts of 6, and it is useful in the classroom discussion to ask these people what they were trying to do and how they managed to achieve low efforts.

You can identify these people as being those who made the highest earnings, which usually induces them to talk more freely. One interesting pattern of adjustment that is sometimes observed is for people to find themselves with identical decisions in one period and then to lower efforts by one unit at a time in each following period until they reach a common effort level of 6 (Holt, 1985). Others may to signal cooperation by going straight to a lower effort. By looking at the data, the instructor can also spot jumps to very high effort levels and then ask the person about the purpose of this action, and in particular, whether it was a punishment or (at least in retrospect) just a mistake. People who do not manage to reduce their efforts to 6 should be asked about whether they tried and if so, why this effort failed. This leads naturally to a discussion of the unilateral incentive that each person has to increase efforts if the other is using an effort of 6.

Some pairs will end up at the Nash equilibrium, where each makes an effort of 8, and asking people in those pairs to explain their decisions will lead naturally to a discussion of why efforts of 8 constitute an equilibrium -- that is, a mutual best responses. Success at reducing efforts below 8 is a lot less common when students are matched randomly after each round, and the effort decisions often rise above the Nash level of 8. If you ask students with higher efforts to explain, they often offer rivalistic comments, like: "When the other chooses 8 and I choose 9, I make more than the other person." Students in one M.B.A. class were so rivalistic that they ended up with average efforts 10.5 in the 10th period of random matchings, a level that is quite close to the level (12) that results in full dissipation of the resource value.[6]

For the common-pool resource application, the most important pedagogical point is to tie the decisions to the idea of a negative externality. Ask students what happens to their own payoffs when the other person’s effort increases. Then mention the fishery example that is used in the instructions, and ask how one person’s fishing effort can damage another’s payoffs. This leads naturally to a discussion of how people may end up in a situation in which everybody would be better off if they could jointly reduce their efforts. Ask what kind of laws and practices are used to solve the problem created by these externalities. Some students may point out that

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[6] These were students at the University of Ljubljana in Slovenia. The game was presented as a quantity-choice market game, not as a common-pool resource game.

the fishery example has important dynamic elements that are missing from the static repetition of the same game with a payoff table that is unaffected by the size of the total catch in the previous period. The discussion can move on to other examples of negative externalities.

VI. Further Reading

For discussion of linear-quadratic Cournot and common pool resource games, a useful starting point is Davis and Holt (1993, chapter 6). Some of the earliest Cournot market experiments were reported in Fouraker and Siegel (1963), and more recent contributions are surveyed in Holt (1995). Ostrom, Gardner, and Walker (1994) contains a collection of papers on theoretical, applied, and experimental work on common-pool resources.

The Matrix Game program can be used for a wide variety of games. Perhaps the most commonly discussed game in a principals microeconomics course is the a prisoners' dilemma. Holt and Capra (1997) contains some suggestions for how to structure a prisoner's dilemma game and the associated classroom discussion. For introductory macroeconomics classes, a simple classroom coordination game described in Capra and Holt (1999) illustrates how complementarities in production can produce a situation with multiple, Pareto-ranked equilibria.[7] For a wide array of experimental games, many of which could be programmed for classroom use with the Matrix Game software, the interested reader might begin with three books: Davis and Holt (1993) on experimental economics in broad terms, Delemeester and Neral (1995) for a set of experiments meant to accompany a principles course, and Bergstrom and Miller (1997) for a principles course based primarily on experiments. Goeree and Holt (1999) present a number of paired variations of simple games, where the "treasure" variation produces choices close to the Nash prediction, and the "contradiction" variation yields choices that are quite different. In addition to the strategic form games discussed here, the Comlabgames site also contains a program for running extensive-form games, which allows the incorporation of exogenous randomness, dynamics, and information asymmetries.

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[7] These and other related papers are available from Charles Holt's web site: *http://www.people.virginia.edu/~cah2k*.

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Figure 1. The Logon Screen

(not in the pdf file)

Figure 2. A Payoff Matrix for the Common-Pool Resource Game

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