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Timing theory in contests with experimental evidence

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1. INTRODUCTION

Baik and Shogren (1992b) examine the efficiency characteristics of a contest between two unequally matched players competing over a fixed reward. By allowing irreversible and observable strategic commitment of effort, Baik and Shogren find that both players undercommit effort in equilibrium relative to the traditional simultaneous move Nash game. The player with the lesser influence over the probability of winning, or the underdog, finds it advantageous to take the first punch and move first. The player with the greater influence over the probability of winning, or the favorite, finds it advantageous to move second. An important implication of this equilibrium order of play is lower social costs. The underdog leader subgame entails the lowest rate of rent dissipation in any of the three possible subgames, decreasing the cost to society from the conflict.

The objective of this thesis is to test the predictive power of Baik and Shogren's (1992b) endogenous timing theory in an experimental setting. We will analyze actual verses predicted effort levels, rent dissipation, and timing choices. Few experiments have researched the interaction between unequally matched opponents, subsequently results will dictate directions for future research.

Actual findings do not support the predictions of Baik and Shogren's model of endogenous timing. Instead, results support the theory that underdogs place more value on the potential gain than do the favorites. Experimental results suggest that the underdogs may value the gain more than two times as much as the favorites. The higher valuation of the gain by the underdogs leads to greater rent dissipation than predicted by symmetric valuation and a greater social cost.

The thesis proceeds as follows. Section 2 develops the analytical framework for strategic behavior between favorites and underdogs. Section 3 discusses the basis for experimental economics, develops the experimental design used to test endogenous timing theory, and summarizes the results. Section 4 examines three possible explanations for the observed behavior. Finally, section 5 contains concluding remarks and directions for future research.

2. THEORETICAL BASIS

2.1 General Background

Contest theory is the study of the competition between agents to gain a prize. Dixit (1987) explains that many economic and social games are contests where agents exert effort in order to increase their probability of winning a prize. Dixit includes examples such as (i) research and development rivalry for an innovation; (ii) bribery competition to secure a contract from the government; and (iii) sporting contests such as the Wimbledon final or the Superbowl.

Contest theory has been studied in terms of research and development rivalry (Dasgupta and Stiglitz 1980), monopoly rent seeking (Tullock 1980), and from the viewpoint of incentive design (Nalebuff and Stiglitz 1983). In the case of rent seeking, as studied in industrial organization, the prize is associated with monopoly profit due to market power. The agents in this case are potential monopolists spending money in hopes of securing a monopoly position and capturing the monopoly profit or rent. An important aspect of the study of rent seeking is the concept of rent dissipation. Rent dissipation is the total expenditure by agents to obtain the rent. The theory is that the monopoly profit may only be part of the welfare loss associated with rent-seeking. The effort or expenditure exerted in attempting to gain the rent may be an additional deadweight loss to society (Tullock 1980).

Traditionally, monopoly pricing has been considered inefficient for society because marginal cost is equated with marginal revenue in equilibrium instead of with the market price as in the case of perfect competition. Rent seeking and rent dissipation address the additional loss to society created by the competition for the monopoly rent. Competition such as bribing government officials in the hopes of capturing a government contract or retaining attorneys in the hopes of getting a patent to ensure monopoly rent is considered a directly unproductive activity. This competition does not directly benefit society. The idea of "efficient rent seeking" as forwarded by Tullock (1980) considers the cost to society created by the rent seeking activity. As Tullock points out, many theoretical studies of rent seeking activity find that agents seeking to capture monopoly rent will collectively spend more money to capture the rent than the actual value of the rent[1]. The rent dissipation percentage is a yardstick that measures the inefficiency of the rent seeking activity. If the total effort exerted to capture the rent is equal to the total value of the rent, rent dissipation is 100 percent.

Experimental studies of contest theory have researched the extent to which agents in an experimental market follow theoretical predictions in terms of observed behavior and rent dissipation. Millner and Pratt (1989) tested two versions of Tullock's (1980) model of efficient rent seeking. In both versions of Tullock's model, agents simultaneously selected effort levels to influence the probability of winning a reward. Millner and Pratt (1989) found that experimental participants dissipated more than predicted with both versions of the model. Further study of the Millner and Pratt experiment by Shogren and Baik revealed that one of the versions of Tullock's model tested by Millner and Pratt (1989) did not have a Nash equilibrium. Shogren and Baik (1991) redesigned the experiment and found participant behavior consistent with predicted rent seeking and dissipation. The experiment examined simultaneous move Nash behavior between two players in a symmetric game. Shogren and Baik (1992) later tested Dixit's (1987) model of strategic behavior in experimental contests between unequally matched opponents involving Stackelberg leadership. Shogren and Baik (1992) found only partial support for theoretical predictions of Dixit's model.

In these experiments and throughout experimental economics, researchers must select specific versions of general models to test theoretical predictions. The belief is that for a theory to be applicable to the very complicated economies found in nature, it must hold for specific cases. To quote Plott (1991) "Models that do not apply to the simple special cases are not general and thus cannot be viewed as such."[2] In this thesis, we will test a specific version of Baik and Shogren's (1992b) endogenous timing model.

2.2 Endogenous Timing

To test endogenous timing requires choosing a specific parameterization of the general theoretical model. The general model proposed by Baik and Shogren (1992b) consist of two unequally matched players competing for a fixed prize. Each player can increase his or her probability of winning the prize by expending more effort. Define the favorite as the player with greater than a one-half chance of winning at the Nash equilibrium and the underdog as the player with less than a one-half chance. Dixit (1987) found that if the favorite moves first, he or she will overcommit effort relative to the Nash equilibrium, leading to greater social costs. If the underdog moves first, he or she undercommits relative to the Nash equilibrium leading to smaller social cost. Baik and Shogren (1992b) demonstrate that, given endogenous order of moves, the favorite will never overcommit. The underdog will move first, the favorite will move second, and the rent dissipation will be smaller relative to the Nash equilibrium, leading to smaller social cost. Allowing agents to choose timing we can decrease the inefficiency caused by competition over a prize.

The theory of endogenous timing can be applied to institutions that incorporate rent seeking. Tullock (1980) explained that the legal system was one institution that closely paralleled rent seeking models. Plaintiff and defendant choice between attorneys of differing skill levels would be comparable to the selection of effort level. A decision by the court in the favor of a particular party would be equivalent to that party winning the prize or capturing the monopoly rent. Publicly announcing counsel would correspond to precommiting effort. Following the argument by Baik and Shogren (1992b) the underdog in the contest would publicly announce counsel first, the favorite second, and the total expenditures on attorney's fees would be reduced relative to the simultaneous move case[3].

To illustrate the findings of Baik and Shogren (1992b) and to set up specific model parameters, consider a contest between two risk neutral players, a favorite and an underdog. Players are competing to win a fixed reward, G, representing the monopoly rent. Players choose effort levels which influence the probability of winning the reward. The larger the effort level selected by player i, the greater the probability that player i wins the reward and the smaller the probability that player j wins the reward. Let player 1 represent the favorite and player 2 represent the underdog. The probability that player 1 wins is represented by the following logit function

$$p_1(x_1, x_2) = \alpha x_1 / (\alpha x_1 + x_2) \tag{1}$$

where $\alpha > 1$ and x_i is the observable and irreversible effort level of player i. The probability that player 2 wins the reward is represented by

$$p_2(x_1, x_2) = \left(1 - \frac{\alpha x_1}{\alpha x_1 + x_2}\right) = \frac{x_2}{\alpha x_1 + x_2}. \tag{2}$$

The probability of winning function reflects the technology of the conflict. Baik and Shogren (1992b) employ a more general functional form to demonstrate the theory. Using a specific functional form allows for parameterization of the conflict. A specific functional form also allows researchers to quantitatively test the predictive power of a theory in an experimental market. Tullock (1975) introduced the logit function as a probability function in modelling conflict. The logit function has been used by Millner and Pratt (1989), and Shogren and Baik (1991, 1992) to experimentally test contest theories. The logit function is especially suited for experimental research because it generally produces manageable equilibrium solutions and it can easily be modified to represent conflicts with different technologies. This version of the logit function assumes player 1 is more powerful in influencing the probability of winning. The greater ability to influence the probability of winning for a monopolist could be equated with an incumbent advantage or better access to resources. If $\alpha = 1$ the model collapses to Tullock's (1980) traditional model of a rent seeking contest where players have symmetric ability.

In the contest, players 1 and 2 unilaterally select observable and irreversible effort levels x_1 and x_2 to maximize expected returns, π_1 and π_2

$$\underset{x_1}{Max}\ \pi_1 = \frac{\alpha x_1}{\alpha x_1 + x_2} G - x_1 \tag{3}$$

$$\underset{x_2}{Max}\ \pi_2 = \frac{x_2}{\alpha x_1 + x_2} G - x_2 \tag{4}$$

yielding the following first-order conditions

$$\frac{\partial \pi_1}{\partial x_1} = \frac{\alpha x_2}{(\alpha x_1 + x_2)^2} G - 1 = 0 \tag{5}$$

$$\frac{\partial \pi_2}{\partial x_2} = \frac{\alpha x_1}{(\alpha x_1 + x_2)^2} G - 1 = 0 \tag{6}$$

and the following second-order sufficient conditions

$$\frac{\partial^2 \pi_1}{\partial x_1^2} = -\frac{2\alpha G}{(\alpha x_1 + x_2)^3} < 0 \qquad for\ x_2 > 0 \tag{7}$$

$$\frac{\partial^2 \pi_2}{\partial x_2^2} = -\frac{2G}{(\alpha x_1 + x_2)^3} < 0 \qquad for\ x_1 > 0. \tag{8}$$

Second-order conditions are satisfied since expected returns π_i are strictly concave in x_i for $i = 1,2$. Reaction functions define the optimal reaction or best response of one player to a choice by the other player (see Kreps 1990). Let $R_i(x_j)$ be the best response of player i to a choice by player j. The reaction functions, $R_1(x_2)$ and $R_2(x_1)$, derived from the first-order conditions for player 1 and 2 are

$$R_1(x_2) = \frac{1}{\alpha}\left[(\alpha G x_2)^{\frac{1}{2}} - x_2\right] \qquad for\ 0 < x_2 \leq \alpha G \tag{9}$$

$$R_2(x_1) = (\alpha G x_1)^{\frac{1}{2}} - \alpha x_1 \qquad for\ 0 < x_1 \leq \frac{G}{\alpha}. \tag{10}$$

The simultaneous move Nash equilibrium derived from the first order conditions is given by

$$(x_1^N, x_2^N) = \left[\frac{\alpha G}{(1+\alpha)^2}, \frac{\alpha G}{(1+\alpha)^2}\right]. \tag{11}$$

Player 1 is the favorite since he or she has a greater chance of winning at the simultaneous move Nash equilibrium. By definition, Nash equilibrium implies that neither player wants to change effort level given how he or she believes the other player will react to the change (Kreps 1990).

To determine the equilibrium order of play, players decide and announce publicly the periods in which they will reveal their effort level. The announcement is simultaneous and perfectly enforced. Effort levels are observable and irreversible. Since the game consists of two periods, indicating the preference to reveal an effort level in the first period is synonymous to choosing to lead. Indicating the preference to reveal an effort level in the second period is synonymous to choosing to follow. The order of play is determined as follows: if player i chooses to lead and player j chooses to follow, player i announces his or her effort level and player j chooses an effort level with the knowledge of player i's choice. If both players choose to lead or both players choose to follow, they play the simultaneous move Nash game. For example, if player 1 chooses to lead and player 2 chooses to follow, they will play a Stackelberg leader/follower subgame in which player 1 leads and player 2 follows. If player 1 chooses to lead and player 2 chooses to lead the simultaneous move Nash subgame will be played.

To determine player's preferences to lead or follow, we compare the expected returns in each of the three possible subgames: the simultaneous move Nash subgame, the Stackelberg favorite leader subgame, and the Stackelberg underdog leads subgame. In the favorite leader subgame, player 1 chooses x_1 to maximize expected returns subject to the player 2's reaction function, $R_2(x_1)$

$$\underset{x_1}{Max}\ \pi_1 = \frac{\alpha x_1}{\alpha x_1 + x_2} G - x_1$$

$$s.t.\ x_2 = R_2(x_1) = (\alpha G x_1)^{\frac{1}{2}} - \alpha x_1, \tag{12}$$

yielding the following first and second-order conditions

$$\frac{\partial \pi_1^{FL}}{\partial x_1} = \frac{1}{2}\left(\frac{\alpha G}{x_1}\right)^{\frac{1}{2}} - 1 = 0 \tag{13}$$

$$\frac{\partial^2 \pi_1^{FL}}{\partial x_1^2} = -\frac{1}{4}\left(\frac{\alpha G}{x_1^3}\right)^{\frac{1}{2}} < 0. \tag{14}$$

Using the first-order condition, the Stackelberg equilibrium with the favorite leading is given by

$$(x_1^{FL}, x_2^{FL}) = \left[\frac{\alpha G}{4}, \frac{\alpha G(2-\alpha)}{4}\right]. \tag{15}$$

From the Stackelberg favorite leader equilibrium we see that $\alpha > 2$ would compel player 2 (the underdog) to choose a negative effort level. To avoid this outcome we will restrict α to values no greater than two.

The Stackelberg equilibrium in the underdog leader subgame is determined by the underdog selecting x_2 to maximize expected returns subject to the favorite's reaction function, $R_1(x_2)$

$$\max_{x_2} \pi_2 = \frac{x_2}{\alpha x_1 + x_2} G - x_2$$

$$s.t.\ x_1 = R_1(x_2) = \frac{1}{\alpha}\left[(\alpha G x_2)^{\frac{1}{2}} - x_2\right], \tag{16}$$

yielding the following first and second-order conditions

$$\frac{\partial \pi_2^{UL}}{\partial x_2} = \frac{1}{2}\left(\frac{G}{\alpha x_2}\right)^{\frac{1}{2}} - 1 = 0 \tag{17}$$

$$\frac{\partial^2 \pi_2^{UL}}{\partial x_2^2} = -\frac{1}{4}\left(\frac{G}{\alpha x_2^3}\right)^{\frac{1}{2}} < 0. \tag{18}$$

Using the first-order condition, the Stackelberg equilibrium with the underdog leading is given by

$$(x_1^{UL}, x_2^{UL}) = \left[\frac{G(2\alpha - 1)}{4\alpha^2}, \frac{G}{4\alpha}\right]. \tag{19}$$

In Tullock's (1980) traditional model of rent seeking, α was equal to one. With α equal to one, there is no timing preference since each of the three possible subgames yield identical expected returns. Figure 1 and Figure 2 (Appendix A) illustrate favorite and underdog expected returns for values of α from one to two. The favorite's expected returns are monotonically increasing in α and the underdog's expected returns are monotonically decreasing in α in the relevant range. For the favorite and the underdog, larger values of α create incentives to play the underdog leads subgame. The result is a timing equilibrium in the underdog leader subgame that is unique and subgame perfect. It is unique because there is no other timing equilibrium for these parameters. Subgame perfect refers to an overall Nash equilibrium where every subgame also has a Nash equilibrium [see Kreps (1990) for a complete treatment of subgame perfection].

At α equal to one effort level for each player in each subgame is equal to twenty-five percent of the gain (G/4), i.e. $x_i^N = x_i^{FL} = x_i^{UL}$ for $i = 1,2$. In this case there is no favorite and no underdog since both players would have a fifty percent chance of winning the prize at the simultaneous move Nash equilibrium. But, when α is greater than one player 1 becomes the favorite and player 2 becomes the underdog. Figures 3 and 4 (Appendix A) illustrate effort levels for different levels of α for the favorite and underdog. Effort levels for both players decrease in the underdog leader subgame when α is greater than one.

As we can see from the model parameterization, effort level in the conflict between perfectly symmetric players playing a perfectly symmetric game is identical, there is no favorite or underdog and no timing preference. But when one player is more productive at influencing the probability, strategic commitment becomes advantageous. Intuitively, when α is greater than one, player 1's marginal effectiveness is increased and player 2's marginal effectiveness is decreased relative to the symmetric case. This creates a first mover advantage for the underdog and a second mover advantage for the favorite. Both players will have higher expected returns when the underdog leads. The outcome relies on credibility of the underdog's commitment to move first. Endogenous timing follows Dixit's (1987) assumption of perfectly observable effort such as taking the first swing in a fight. Permitting unreliable effort choices would open the door for alternate strategies and equilibria.[4]

To determine the social cost of the conflict we must examine the total amount of effort exerted. This is equivalent to looking at the amount of rent dissipation. Figure 5 (Appendix A) graphically illustrates total rent dissipation for each of the three subgames for $\alpha \in [1,2]$. As discussed, theory predicts that if $\alpha > 1$ the endogenous timing equilibrium is the underdog leads subgame. In the underdog leads subgame, rent dissipation is less than in the simultaneous move Nash subgame and the favorite leads subgame (see Figure 5 in Appendix A). Larger values of α lead to even less rent dissipation. In this case, allowing asymmetric players to choose timing in a contest over a fixed prize decreases the total cost to society of the struggle. Both parties exert less effort and have higher expected profits by choosing the endogenous timing equilibrium over the conventional simultaneous move Nash equilibrium.

Implications are that institutions should be designed to allow for the choice of timing. The legal system is one candidate. Other candidates are: A two party competition over a government contract, firms competing for monopoly rent, political campaigns, duopoly price competition, and labor disputes. The question we will turn to now is how well do agents' actions match the predictions of the theory.

3. HYPOTHESIS TESTING IN EXPERIMENTAL MARKETS

[T]his theory is not speculative in origin; it owes its invention entirely to the desire to make physical theory fit observed fact as well as possible...the justification for a physical concept lies exclusively in its clear and unambiguous relation to facts that can be experienced - Albert Einstein

3.1 Why Experimentation?

The true test of any theory is its ability to predict the environment. Economists often assume that since a theory is logically correct, it will predict agent behavior. The study of experimental economics has shown that this is not always the case. A common theme that V. L. Smith (1989) has seen in experimental economics is that economic agents do not solve decision problems by thinking about them and solving them the same way as economists. This does not mean that every economic model must perfectly represent the agent of study, but that models must be evaluated on the basis of their predictive and descriptive power.

Experiments reveal aspects of behavior not predicted by theory. It can also reveal theoretic shortcomings that are not easily observable in natural environments. One such shortcoming that has been repeated in a number of experiments is the preference reversal phenomenon. One basic assumption of economics is that preferences are independent of the method used to elicit them and a well-defined preference ordering exists. A possible violation of preference ordering assumptions was illustrated by Lichtenstein and Slovic (1971). When questioned over gambles with similar expected values, subjects often placed a higher dollar value on one bet while stating that they would prefer to play another. This finding was replicated by Lichtenstein and Slovic (1973) with real money in a Las Vegas casino and by Grether and Plott (1979).

Experiments can also chart the path to the rejection of existing theories and the adoption of new theories. An example is recent research into the divergence between willingness to pay (WTP) and willingness to accept (WTA) measures of value. A consistent divergence between the measures was observed in field studies and in laboratory markets. Jack Knetsch (1989) explained the divergence by inferring that indifference curves may be nonreversible. Knetsch's explanation violates the assumption that the rate of commodity substitution at a point on an indifference curve is the same for movements in either direction. Through a series of second price auctions, Shogren, Shin, Hayes, and Kliebenstein (1992), provided strong evidence contrary to Knetsch. They showed that the divergence between WTP and WTA can be attributed to the elasticity of substitution between the two goods, a theory promoted by Michael Hanemann (1991).

Laboratory markets are a simplification of markets found in nature. But, the simplification does not make laboratory markets any less real. As summarized by Plott (1991), in laboratory markets "Real people motivated by real money make real decisions, real mistakes and suffer real frustrations and delights because of their real talents and real limitations. Simplicity should not be confused with reality. Since the laboratory economies are real, the general principles and models that exist in the literature should be expected to apply with the same force to these laboratory economies as to those economies found in the field. The laboratories are simple but the simplicity is an advantage because it allows the reasons for a model's failure to be isolated and sometimes even measured."[5]

The usefulness of experiments is derived from this ability to control for extraneous variables that may be present in the environment. Environmental "noise" can be controlled so that the experimenter can clearly determine cause and effect. To quote Alvin E. Roth (1988) "It is precisely this control of environment, and access to the agents (sufficient to observe and measure the attributes that are not controlled) that give laboratory experiments their power."[6] This power to control the environment is the vehicle for testing theories.

3.2 Experimental Design and Economic Hypothesis

3.2.1 General Experimental Design

We designed an experiment to test Baik and Shogren's endogenous timing theory. The experiment was conducted in two treatments. Treatment 1 was designed to test predicted timing choices, equilibrium values, and rent dissipation. Treatment 2 was designed as a test of timing and response choices with different incentives and a simpler game structure.

The experiment was conducted with participants recruited from economics and sociology undergraduate courses. Thirty-eight students participated in treatment 1 and twenty-six students participated in treatment 2. The experiment was carried out in student groups of eight to sixteen. Participants were told that they would receive a minimum of $4.00 for participating in the experiment and possibly more depending on their performance. Each session lasted for approximately one hour and fifteen minutes. Before the start of each experimental session, participants were required to read and sign an experimental consent form approved by the Iowa State University Human Subjects Committee. Copies of the consent form and experimental instructions for both treatments are contained in Appendix B.

Participants were seated in a room one at a time by an experimental monitor. Whether a participant was a favorite or an underdog was determined when they were seated. Favorite or underdog status alternated with each participant that entered the room.[7] Each favorite was seated facing an opposing underdog. As in Millner and Pratt (1989), the experiment consisted of twenty trials, one of which was randomly chosen as the binding trial to control for income effects. The first two trials were practice and not binding. After each trial, either the favorites or the underdogs rotated one seat so that all participants would play against a different opponent. Even though participants played against different opponents every trial, players did not change type, favorites were always favorites and underdogs were underdogs throughout the experiment. There was no time limit for any trial.

There were two stages in each trial. In stage one, participants selected the timing for stage two. In stage two, participants chose effort levels in the order determined in stage one. To determine timing, each participant was given two poker chips with a "L" and a "F" marked on one side to indicate lead or follow. Each participant placed a chip face down on the table to indicate the order in which they preferred to move. When the favorite and the underdog chips were both on the table, they were turned over to reveal the timing order for stage two. If the result was two L's or two F's, both players would move simultaneously in the stage two. If the favorite's chip was an L and the underdog's chip was an F, the favorite would move first (lead) and the underdog would move second (follow) in stage two. If the favorite's chip was an F and the underdog's chip was an L, the favorite would follow and the underdog would lead in the stage two.

Stage two consisted of choosing a row or a column from a payoff table which corresponded with a particular effort level. Treatment 1 used a five-by-five payoff table and treatment 2 used a three-by-three table. Figure 6 of Appendix A is the Payoff Table for treatment 1 and Figure 7 of Appendix A is the Payoff Table for treatment 2.

3.2.2 Design Specifics: Treatment 1

To test timing, equilibrium values, and rent dissipation, we selected specific parameter values for the model presented in section 2.2. The asymmetry index α, was chosen to be 2, the largest value for which the second order conditions would hold in the favorite leader subgame. The reward was chosen to be 1440 to provide whole number equilibrium values in all subgames. With these parameter values, the simultaneous move, underdog leader, and favorite leader subgame equilibria reduce to:

$$(x_1^N, x_2^N) = [320\ ,\ 320] \tag{20}$$

$$(x_1^{UL}, x_2^{UL}) = [180\ ,\ 270] \tag{21}$$

$$(x_1^{FL}, x_2^{FL}) = [720\ ,\ 0] \tag{22}$$

From these five effort levels, we constructed the Payoff Table for treatment 1 (see Figure 6 in Appendix A). Player A was the underdog and chose from rows R1 through R5. The favorite was player B and chose from columns C1 through C5. Rows or columns 1-5 corresponded to effort levels 0, 180, 270, 320, and 720, respectively. A copy of the experimental instructions for the favorite and the underdog in treatment 1 are included in Appendix B.

Each cell in the Payoff Table represented a underdog/favorite payoff combination for the effort levels chosen. The first number in each cell represents the underdog's payoff (player A) and the second number in each cell represents the favorite's payoff (player B) in tokens. For instance, if player A chose row R2 and player B chose column C2, player A would receive 700 tokens and player B would receive 1180 tokens if that trial was chosen as binding at the end of the experiment (see Figure 6 in Appendix A). Players received the value of the token payoff in the binding trial plus \$3.00 for participating in the experiment. Tokens were worth \$0.01, so player A would have received \$10.00 [(700 × \$.01) + \$3.00] and player B would receive \$14.80 [(1180 × \$.01) + \$3.00]. The predicted equilibrium effort levels listed above correspond to three cells in the Payoff table. The predicted underdog leader subgame equilibrium is (R2, C3), corresponding to an underdog effort level of 180 and favorite effort level of 270. The favorite leader equilibrium is cell (R1, C5) corresponding to underdog effort level 0 and favorite effort level 720. The simultaneous move equilibrium is cell (R4, C4) corresponding to favorite and underdog effort levels of 320.

Each payoff in the Payoff Table was derived from the selected parameter values and the specific logit probability function discussed in section 2.2. To induce risk neutral behavior, the Payoff Table values are expected values or certainty equivalents. No actual lottery was conducted to determine the winner of the 1440 tokens. For example, the token value of 700 for player A corresponds to the expected value of a lottery for 1440 tokens if player A chooses effort level 180, player B chooses effort level 180, $\alpha = 2$, and each player has an initial endowment of 400 tokens. The expected value of 700 is a risk neutral player's certainty equivalent. A risk neutral player would be indifferent between receiving 700 tokens with certainty or playing the lottery. The token value of 700 is computed as follows

$$\left(\frac{180}{2(180) + 180}\right)1440 - 180 + 400 = 700 \tag{23}$$

Including an initial endowment amount in the Payoff Table does not change the results. It simply ensures that there are no negative payoffs that participants might avoid.

Using this experimental design we test seven hypotheses. The first two hypotheses concern the timing selected:

Underdog Timing Hypothesis: The underdog will choose to lead.

Favorite Timing Hypothesis: The favorite will choose to follow.

Choosing the predicted timing maximizes expected returns for the favorite and the underdog. We can also test whether participants perform as predicted given their timing choice. To analyze non-timing or effort performance we must look at actual verses predicted leader effort levels, follower effort levels, effort levels when moving simultaneously, and total effort or rent dissipation. The effort hypotheses are:

Underdog Leader Hypothesis: If the underdog leads he or she will select the predicted effort level of 180.

Favorite Leader Hypothesis: If the favorite leads he or she will select the predicted effort level 720.

Best Response Hypothesis: The follower will select the best response. The best response is the effort level that maximized his or her expected returns given the opponent's effort level.

Simultaneous Move Hypothesis: If the simultaneous move Nash subgame is played, favorites and underdogs will select effort level 320.

Rent Dissipation Hypothesis: The total rent dissipation will be 32.5 percent ((180 + 270)/1440).

The Favorite Leader and the Simultaneous Move Hypotheses are constructed for the possibility that participants do not select the theoretically predicted timing. It could be the case that participants select the predicted subgame equilibrium even though they do not select the predicted timing. If this is the case, the Favorite Leader and the Simultaneous Move Hypotheses can reveal whether the subgame equilibrium in question is attained. Endogenous timing is predicted to improve efficiency by dissipating a smaller percentage of rent compared to the simultaneous move Nash equilibrium. The Rent Dissipation Hypothesis will determine if the predicted rent dissipation is observed.

3.2.3 Results: Treatment 1

The average percent each player chose the predicted timing was analyzed to test the timing hypotheses. If the average percent the underdogs chose to lead is statistically different from 100 percent we will reject the Underdog Timing Hypothesis. Similarly, if the average percent the favorites chose to follow is statistically different from 100 percent we will reject Favorite Timing Hypothesis. Figure 8 (Appendix A) shows the frequency underdogs chose to lead in trials 1-20. Figure 9 (Appendix A) shows the frequency underdogs chose to lead in trials 16-20. The frequency distributions were computed by determining the average percent each participant chose the predicted timing and then grouping into intervals. The purpose of a repeated trial design is to allow for repeated market exposure and allow convergence to a equilibrium value. For this reason experimenters often examine the last several trials to look for convergence to an equilibrium. The graphs do not reveal a convergence to the predicted timing for the underdogs. The average percent underdogs chose to lead in trials 1-20 was 35.26 percent while the average percent the underdogs chose to lead in the last five trials was only 27.37 percent. We reject the Underdog Timing Hypothesis.[8]

On average, the favorites selected the predicted timing more than the underdogs. Figure 10 and 11 (Appendix A) show the frequency favorites chose to follow in trials 1-20 and trials 16-20. Favorites chose to follow an average of 55.0 percent in trials 1-20 and 55.79 percent in trials 16-20. Even though favorites did appear to choose the predicted timing on average more frequently than underdogs, we reject the Favorite Timing Hypothesis.

To test the Underdog Leader Hypothesis, we computed the average underdog effort level when leading for each trial. We would like to assume that each of the twenty trials are independent for ease of statistical testing. To support this assumption, we tested for first and second degree serial correlation. We estimated first and second-order autocorrelation models using Cochrane-Orcutt[9] type procedure. The basic model was

$$Y_t = \beta_0 + \beta_1 t + e_t \tag{24}$$

where Y_t is effort level in trial t for t = 1,...,20. First-order autocorrelation models incorporated

$$e_t = \rho_1 e_{t-1} + v_t \tag{25}$$

and second-order autocorrelation models incorporated

$$e_t = \rho_1 e_{t-1} + \rho_2 e_{t-2} + v_t \tag{26}$$

where v_t is independently and identically distributed with a mean of zero. Similar procedures were used in subsequent hypothesis tests involving effort levels. For ensuing tests, t remained the independent variable and the appropriate dependent variable was used for each model. We failed to reject the hypotheses that ρ_1 and ρ_2 are equal to zero at the 95 percent significance level, supporting the assumption of independent trials. The underdog's average effort level when leading was 257.16 compared to a predicted effort level of 180. No significant trend was found in the effort level. With 95 percent confidence we reject the Underdog Leader Hypothesis and conclude that underdogs exerted more effort on average than predicted by endogenous timing theory.

The Favorite Leader Hypothesis was tested in a similar manner to the Underdog Leader Hypothesis. But, we found first degree autocorrelation for favorite average effort level when leading between trials. Rho was found to be significant at the 95 percent significance level using a Cochrane-Orcutt type procedure. Rho was estimated at .47 with a standard error of .197. We did not find a significant trend in the favorite leader effort level. Since autocorrelation was found we used the square root of the mean square error from the first-order autocorrelation model as the sample standard deviation. With 95 percent confidence we reject the Favorite Leader Hypothesis. The favorite average effort level was only 365.29 compared to the predicted level of 720.

The Best Response Hypothesis was tested separately for favorites and underdogs. The average percent each player chose the best response when following was computed for all twenty trials. The favorite selected the best response an average of 67.88 percent of the time while the underdogs chose the best response an average of 68.92 percent of the time. Because of the relatively straight forward task of picking the best response from only five possible responses we looked at all twenty trials rather than only later trials. There were also some players who did not follow in the last five trials, making analysis of only the last five trials with respect to best response impossible. We find that the favorite's average percent of best responses is statistically less than 100 percent. We also find the underdog's average percent of best responses less than 100 percent. We reject the Best Response Hypothesis for the favorite and the underdog. But, we do not find the nearly 70 percent best response rate for all twenty trials entirely unreasonable since early trials and practice trials are included in this statistic.[10]

The Simultaneous Move Hypothesis was tested separately for favorites and underdogs. Average effort per trial was computed for favorites and underdogs. Again we assume that each trial is independent and support this assumption by failing to reject the hypothesis of no first or second order autocorrelation between trials for favorite or underdog effort levels when moving simultaneously.[11] No significant trend in average effort levels was found for favorites or underdogs. We reject the simultaneous move proposition for the favorite and the underdog at the 95 percent significance level. The favorite's average effort when moving simultaneously was 294.88 and the underdog's average effort when moving simultaneously was 281.67. Favorites and underdogs exerted less effort than predicted in the simultaneous move subgame.

To test the Rent Dissipation Hypothesis, average dissipation was computed per trial. We again assume that each of the twenty trials are independent. To support this assumption, we tested for first and second degree serial correlation by constructing first and second-order autocorrelation models with Cochrane-Orcutt type procedures. We failed to reject the hypotheses that ρ_1 and ρ_2 are equal to zero at the 95 percent significance level, supporting the assumption of independent trials. We did find a significant positive trend in the dissipation level over the twenty trials with an estimated coefficient of .396 and a standard error of .101. The Rent Dissipation Hypothesis is rejected at the

95 percent significance level. Participants dissipated more than the predicted level of 31.25 percent and dissipated more each trial.

In terms is social welfare, the result is worse than predicted because players exert more effort to capture a fixed prize than predicted. But relative to the traditional simultaneous move equilibrium, social welfare is improved. The predicted dissipation in the simultaneous move equilibrium is 44.4 percent ([320 + 320] / 1440) which is statistically larger than the actual average dissipation of 39.92 percent. Even though players did not achieve the dissipation predicted by endogenous timing theory, on average, they dissipated less than the simultaneous move Nash subgame improving overall efficiency. Figure 12 (Appendix A) illustrates the average dissipation, predicted underdog leader dissipation, predicted favorite leader dissipation, and predicted simultaneous move Nash dissipation by trial for all twenty trials. Table 1 contains descriptive statistics for the results in treatment 1.

Table 1: Treatment 1 Summary

	MEAN	95% c.i.*		PREDICTED
TIMING HYPOTHESES				
UNDERDOG TIMING^P	35%	28%	42%	100%
FAVORITE TIMING^P	55%	43%	67%	100%
EFFORT HYPOTHESES				
UNDERDOG LEAD^T	257	235	279	180
FAVORITE LEAD^T	365	324	407	720
UNDERDOG BEST RESPONSE	69%	59%	78%	100%
FAVORITE BEST RESPONSE	68%	53%	83%	100%
UNDERDOG SIMULTANEOUS^T	282	261	310	320
FAVORITE SIMULTANEOUS^T	295	272	317	320
RENT DISSIPATION	40%	38%	42%	31%

T - indicates results are in terms of tokens.

P - listed as a percentage of actions predicted by theory.

* - c.i. represent confidence interval.

All data is computed for trials 1-20.

3.2.4 Design Specifics: Treatment 2

Treatment 2 was designed to retest the timing and best response hypotheses with more robust incentives and a simpler game structure. Twenty-six undergraduate economics and sociology students participated in treatment 2. The design is identical to treatment 1 except the Payoff Table for treatment 2 (Figure 7 in Appendix A) is a 3 by 3 and the payoffs were not generated from a specific functional form. The Payoff Table for treatment 2 was designed in order to have a higher opportunity cost for deviations from optimal responses and to make the experiment easier to understand. The 3 by 3 design is more manageable than the 5 by 5 Payoff Table used in treatment 1. Also, cells are in terms of whole dollars, making the payoff differences between competing cells larger. A copy of the experimental instructions for the favorite and the underdog for treatment 2 are contained in Appendix B.

3.2.5 Results: Treatment 2

As in Treatment 1, the average percent each player chose the predicted timing was analyzed to determine if the Underdog Timing and Favorite Timing Hypotheses could be rejected. The average percent the underdogs chose to lead in treatment 2 for all twenty trials was 58.46 percent, an improvement over the 35.26 percent the underdogs chose to lead in treatment 1. Favorites improved in a similar fashion, increasing the percent they chose to follow from 55 percent in treatment 1 to 76.54 percent in treatment 2. The increases in choosing predicted timing is not enough to support the Underdog Timing or the Favorite Timing Hypotheses. The tests were conducted in the same manner as treatment 1. For the Underdog Timing Hypothesis the null hypothesis is that the average percent the underdogs led will not be statistically different from 100 percent. Likewise the null hypothesis for Favorite Timing Hypothesis is that the average percent the favorite follows is not statistically different from 100 percent. The Underdog Timing and the Favorite Timing Hypotheses are rejected at the 95 percent significance level. Figure 13 (Appendix A) shows the frequency underdogs chose to lead in treatment 2 for trials 1-20. Figure 14 (Appendix A) shows the frequency the underdogs chose to lead in trials 16-20. The average percent underdogs chose to lead in trials 16-20 was 53.85 percent, a small decrease relative to the overall average percent of 58.46. Figure 15 and 16 (Appendix A) show the frequency the favorites chose to follow in treatment 2 for trials 1-20 and 16-20. The favorites chose to follow 76.54 percent in trials 1-20 and 83.08 percent in trials 16-20. Both overall underdog and favorite timing averages are higher than treatment 1, but neither is high enough to keep us from rejecting the null hypotheses at the 95 percent confidence level.

As in treatment 1, the average percent each player chose the best response when following was computed for all twenty trials to test the Best Response Hypothesis. Favorite and underdogs selected the best response more frequently in treatment 2. Favorites selected the best response an average of 86.07 percent of the time, while underdogs chose the best response an average of 90.00 percent of the time. At the 95 percent significance level, the favorite's and underdog's average percent of best responses is statistically less than 100 percent. But, the upper bounds on the confidence intervals for the favorite and underdog are close to 100 percent at 96 and 99 percent. Table 2 summarizes the results from treatment 2.

Table 2: Treatment 2 Summary

	MEAN	95% c.i.*		PREDICTED
TIMING HYPOTHESES				
UNDERDOG TIMING	58%	41%	75%	100%
FAVORITE TIMING	77%	66%	87%	100%
EFFORT HYPOTHESES				
UNDERDOG BEST RESPONSE	90%	76%	99%	100%
FAVORITE BEST RESPONSE	86%	76%	96%	100%

All results from treatment 2 are listed as a percentage of actions predicted by theory.

* - c.i. represent confidence interval.

All data is computed from trials 1-20.

4. ANALYSIS

Experimental results do not support Baik and Shogren's endogenous timing theory. The Favorite Timing, Underdog Timing, Favorite Leader, Underdog Leader, Best Response, Simultaneous Move, and Rent Dissipation Hypotheses were all rejected at the 95 percent significance level for treatment 1. In treatment 2 we saw a higher percentage of participants choosing the predicted timing and best responses. There was not enough improvement to keep us from rejecting the Favorite Timing Hypothesis, Underdog Timing Hypothesis, Favorite Best Response, or Underdog Best Response Hypotheses. In treatment 1 we observed underdog choosing to lead less than half of the time and favorite choosing to follow only slightly more than half of the time. When the underdogs led, on average, they exerted more effort than predicted while favorites exerted much less effort than predicted while leading. When moving simultaneously, both player types exerted less effort than predicted. Average dissipation was higher than predicted by endogenous timing but lower than the traditional simultaneous move Nash equilibrium. The best response percentage was around 70 percent for both player types in treatment 1, although it did improve significantly in treatment 2 to around 90 percent.

In an attempt to interpret the observed behavior, consider three possible explanations. First, a possible explanation is provided by Harrison (1989) concerning the opportunity costs of choosing the best response. Second, there is the possibility that equitable split behavior, observed in previous experiments, played a role. Third, if underdogs placed more value on the reward than the favorites, effort levels and timing preferences would change for both player types.

4.1 Harrison's Theory of Misbehavior

In "Theory and Misbehavior of First-Price Auctions" (Harrison 1989) Harrison reconsidered experimental evidence that appeared to reject Nash equilibrium models of bidding behavior in First-Price auctions. Instead of looking at participant divergence from theoretical predictions in terms of bid deviations, Harrison looked at the behavior in terms of expected payoff space. Harrison examined the forgone income for any given bid. When the actual bid and the predicted bid are the same the forgone income is zero. Harrison argues that when the forgone income or opportunity costs for not choosing the optimal bid is very small, participants cannot be expected to choose the optimal bid. The question then becomes how to define a "small" opportunity cost. Harrison concludes that foregone income must be greater than or equal to $0.03 before data can lead to the rejection of a theory.[12]

Although the test of endogenous timing theory differs from the analysis of bidding behavior in first price auctions, we can use Harrison's insight to evaluate possible participant responses in terms of forgone income or opportunity cost. First, we look at the opportunity costs for not choosing the best response in treatment 1. Given a row or column choice by a leader, the follower has five possible responses. For the best response, the opportunity cost is zero. Figure 17 (Appendix A) graphically illustrates the opportunity cost for best response deviations for the underdog in treatment 1. BR1 through BR5 represent the first through fifth best response. For example, if when leading the favorite chose column 4 from the Payoff Table in treatment 1 (Figure 6 in Appendix A), the underdog's first best response would be row R4 and second best response would be row R3. In this case, the opportunity cost of choosing the second best response instead of the first best response is only $0.03. Figure 18 (Appendix A) illustrates the opportunity costs for best response deviations for the favorite in treatment 1 when the underdog leads.

Clearly, given a number of leader effort levels, follower opportunity cost for deviating from the best response is small in treatment 1. Treatment 2 was designed to correct for this potential problem. Figure 19 and 20 (Appendix A) illustrate the opportunity cost for best response deviations in treatment 2. The smallest cost for choosing a bid other than the best response in treatment 2 was $1.00, significantly above the $0.03 threshold established by Harrison.

Timing and best response choices in treatment 2 follow the theoretical predictions more closely than in treatment 1. But, not closely enough to accept Harrison's theory as the exclusive explanation of participant performance. The average percent that favorites and underdogs chose the predicted timing in treatment 2 was not high enough to support the Underdog Timing Hypothesis or the Favorite Timing Hypothesis even with the increased opportunity costs and the simpler Payoff Table. If the lack of proper opportunity costs was the only cause of deviations from theory in treatment 1, we would expect to fail to reject all four hypotheses in treatment 2.

4.2 Equitable Split Behavior

A number of economic experiments have documented individuals acting more equitable than predicted by economic theory. One of the key assumptions of economics is that individuals are rational and self interested rather than fair and altruistic. Experiments on Coasian bargaining [see Shogren (1992)] and on ultimatum games [see Roth (1988) and Thaler (1988)] have found that this is not necessarily the case. Shogren (1992) found that in an experiment on Coasian bargaining with uncertain payoff streams, 85 percent of agreements resulted in splitting the reward equally rather than the mutually advantageous splits predicted by theory. Roth (1988) reviews tests of several versions of the Ultimatum Game where the modal offer was a fifty percent split of the prize.[13]

The fact that when the favorites led they only chose an average effort level of 365.29 in treatment 1 rather than the predicted level of 720 can be considered evidence of equitable split behavior. By choosing less than the payoff maximizing effort level, the favorite forfeited some potential returns and allowed the underdog the opportunity to increase his or her returns. This is illustrated in Figures 21 and 22 (Appendix A). Figure 21 shows the favorite and underdog's average payoff per trial as a percent of the equilibrium predicted by endogenous timing theory in treatment 1. If both the favorite and the underdog were entirely self interested, both would receive 100 percent of their predicted payoff: 1210 for the favorite and 580 for the underdog. Instead, the favorite average payoff was 91 percent and the underdogs average payoff was 103 percent of the predicted payoff for twenty trials in treatment 1. Figure 22 shows the favorite and underdog's average payoff per trial as a percentage of predicted payoff in treatment 2. In treatment 2 neither the favorites or the underdogs captured 100 percent of their predicted returns, but the underdogs did capture a higher percentage of the expected returns than the favorites. Underdogs average 91 percent of predicted returns while favorites averaged 84 percent of predicted returns in treatment 2.

If equitable split behavior is the player objective, we would expect the modal cell choice to minimize the difference between favorite and underdog payoffs. In treatment 1, the five cells with the smallest difference between payoffs (see Figure 6 in Appendix A) in order of increasing difference are: (R1, C1); (R5, C2); (R4, C2); (R5, C3); and (R3, C2). The payoff difference for these five cells are: 0, 60, 224, 244, and 296. None of the five cells are the modal response for treatment 1. The modal response was (R4, C4) which has a payoff difference of 480. The second most frequently observed outcome was cell (R4, C3) which has a payoff difference of 418. In treatment 2, the modal response was cell (R2, C1) which has a payoff difference of $3.00. The second most frequently observed outcome in treatment 2 was cell (R3, C2), which was the cell with the minimum payoff difference of $1.00. These results provide only weak support for equitable splitting behavior. If equitable splitting was the objective, we would expect the frequency of observed equitable splitting to be similar to that in previous experiments [see Shogren (1992), Roth (1988), and Thaler (1988)], which is not the case.[14]

4.3 Asymmetric Gain Valuation

A third explanation of observed behavior lies in the concept of asymmetric gain valuation. It is conceivable that the underdogs place a higher value on the gain than the favorites. Sporting events provide examples of disadvantaged teams or players who try harder than predicted. A team with an injured star player will often raise their effort level to compensate for the loss. Often teams not predicted to excel in playoffs will exceed popular expectations. Placing a team or a player at a disadvantage may inspire increased effort. The theory is epitomized by the Biblical conflict between David and Goliath. The weaker contender places much more value on the victory than the stronger contender, inducing greater effort by the weaker party. This can be modeled by assuming the underdog places more value on the gain than the favorite, which will be referred to as asymmetric gain valuation.

In this model, a player has more influence over the probability function, while the other player places more value on the gain. For simplicity, designate the player with the greatest influence over the probability function as the favorite, even though in this contest the favorite may not have a greater than fifty percent chance of winning at the Nash equilibrium. Designate the underdog as the player with less influence over the probability of winning. In this model, the favorite's objective function is unchanged from Baik and Shogren's (1992b) model of endogenous timing. The favorite maximizes expected returns

$$\underset{x_1}{Max}\ \pi_1 = \frac{\alpha x_1}{\alpha x_1 + x_2} G - x_1 . \tag{27}$$

The underdog maximizes expected returns with greater value placed on the gain denoted by $\delta > 1$. The underdog's objective function is

$$\underset{x_2}{Max}\ \pi_2 = \frac{x_2}{\alpha x_1 + x_2} \delta G - x_2 . \tag{28}$$

Using methods analogous to those used in section 2.2 we derive the simultaneous move Nash equilibrium, the favorite leader equilibrium, and the underdog leader equilibrium:

$$(x_1^N, x_2^N) = \left[\frac{\alpha \delta G}{(\delta + \alpha)^2} , \frac{\alpha G}{\left(1 + \frac{\alpha}{\delta}\right)^2} \right], \tag{29}$$

$$(x_1^{FL}, x_2^{FL}) = \left[\frac{\alpha G}{4\delta} , \frac{\alpha G(2\delta - \alpha)}{4\delta} \right], \tag{30}$$

$$(x_1^{UL}, x_2^{UL}) = \left[\frac{\delta G(2\alpha - \delta)}{4\alpha^2} , \frac{\delta^2 G}{4\alpha} \right]. \tag{31}$$

Appendix C contains a complete derivation of the three subgame equilibria.

Figures 23 and 24 (Appendix A) show the favorite and underdog's expected returns for different gain valuations, δ. The gain and α parameter values are identical to those used in treatment 1. The gain value is 1440 and $\alpha = 2$. Figures 23 and 24 illustrate that the favorite and the underdog prefer the underdog leads subgame for $\delta < 2$. But, when $\delta > 2$ the underdog prefers to play the favorite leads subgame. The favorite also prefers the favorite leads subgame, but the preference for the favorite leads subgame over the simultaneous move subgame is very small. This is because favorite expected returns in the favorite leads subgame are only slightly higher than the simultaneous move subgame. For both players, the critical value for δ is two. At $\delta = 2$, neither player has a timing preference. In this case, the favorite's greater influence over the probability of winning is perfectly offset by the underdog's greater gain valuation.

Figures 25 and 26 (Appendix A) show how player effort level vary with different gain valuations. Figure 25 illustrates that the favorite effort level decreases in the favorite leads subgame with any gain valuation asymmetry. Conversely, Figure 26 shows that the underdog effort level increases in all subgames when the valuation asymmetry is greater than unity. Notice that when $\delta = 2$, the underdog's effort level is twice the favorite's effort level. In this case each player has a fifty percent chance of winning the reward. The favorite is twice as productive at influencing the probability of winning but the underdog tries two times as hard. If $\delta > 2$, the underdog exerts enough effort to make his or her chance of winning more than fifty percent, favorites and underdogs trade roles. Figure 27 (Appendix A) shows how total effort increases with increases in the valuation asymmetry, leading to greater social cost from the larger amount of rent dissipated in all subgames. In this context, valuing a reward at more than its monetary worth if inefficient for society.

From Figures 23-27 (Appendix A) and the subgame equilibrium levels derived in this section, let us examine four propositions which will be fulfilled if asymmetric gain valuation exists

Proposition 1: A significant number of underdogs will chose to follow.

Proposition 2: When leading, the favorite's effort level will be lower than predicted by endogenous timing without asymmetric gain valuation.

Proposition 3: When leading, the underdog's effort level will be higher than predicted by endogenous timing without asymmetric gain valuation.

Proposition 4: Rent dissipation will be higher than predicted by endogenous timing without asymmetric gain valuation.

Proposition 1 assumes that the underdog's gain valuation is at least two times higher than the favorite's valuation. If the gain asymmetry was less than two we would still expect the underdogs to lead rather than follow. Since the difference between favorite expected returns in the favorite leads subgame and the simultaneous move subgame is trivial, a prediction for favorite timing choice will not be tested. Propositions 2, 3, and 4 will be fulfilled even if the gain valuation is less than two, as depicted by Figures 25, 26, and 27 (Appendix A).

To examine the four propositions, we will use the results from all twenty trials of treatment 1. Treatment 2 results will not be used since there are no explicit effort levels associated with them. Using 95 percent confidence intervals associated with the results in section 3.2.3, all four asymmetric gain valuation propositions are supported. For proposition 1, the average percent each underdog chose to lead was 35, with a 95 percent confidence interval of (28, 42). Conversely, the average percent underdogs chose to follow was 65 with a similar confidence interval. The large frequency that the underdogs chose to follow supports proposition 1. With respect to proposition 2, the favorite's average effort level when leading was 365 relative to the predicted level of 720. The 95 percent confidence interval of (324, 407) lead to the strong support of proposition 2, favorites did exert less effort when leading. For proposition 3, the underdog's average effort level when leading was 257 compared to the predicted level of 180. The 95 percent confidence interval for underdog effort level when leading is (235, 279) supporting proposition 3, underdogs did exert more effort when leading. The average rate of dissipation per trial of 40 percent and 95 percent confidence interval of (38, 42) also support proposition 4. The observed dissipation rate of 40 percent was significantly higher than the predicted rate of 31 percent.

Support for asymmetric gain valuation motivates questions concerning the value of δ. The average percent that underdogs chose to follow of 65 percent in treatment 1 indicate that δ may be greater than two. The favorite's average effort level when leading of 365 indicates an estimated δ of 1.97. The underdog's average effort level when leading of 257 points to an estimated δ of only 1.19. Clearly, experimental evidence implies a gain asymmetry larger than one, but whether δ is greater than two remains to be answered.

Results from Shogren and Baik (1992) experimental study of leader/follower behavior also support asymmetric gain valuation. Baik and Shogren tested leader/follower behavior analogous to the favorite leader subgame from section 2.2 of this thesis. Baik and Shogren found that favorite leader effort level was significantly lower than predicted. They also found that underdogs tended to expend more effort than predicted by theory and the dissipation rate was greater than predicted by theory (greater than the predicted Nash). All three of these findings support the predictions of asymmetric gain valuation.

5. CONCLUSION

Baik and Shogren's (1992b) theory of endogenous timing finds little support in this experimental study. Harrison's theory of misbehavior in first price auctions provide some insight into the results from treatment 1. In treatment 2 we saw a dramatic increase in the percentage of best responses. But, the simpler payoff table and opportunity costs designed to incorporate Harrison's theory did not bring results in line with theoretical predictions. The Underdog Timing and Favorite Timing Hypotheses were still rejected in treatment 2, as were the Favorite and Underdog Best Response Hypotheses. The concept of equitable splitting is another possible explanation for observed behavior. We did see underdogs capture a greater percentage of the predicted gains and favorites capture a smaller percentage of the predicted gains in both treatments. But, we did not find choices centering on cells with the most equitable splits. Asymmetric gain valuation does explain much of the deviation from theoretical predictions, and provides testable propositions relative to endogenous timing theory. Common folklore predicts that underdogs try harder in conflicts, asymmetric gain valuation supports this belief. Understanding the dynamics of the conflict between large and small can provide insight into a large number of economic environments. Future experiments should be designed to clearly test between the competing theories. An experiment incorporating robust incentives, testing between equitable splitting and asymmetric gain valuation is the obvious next step. Another important and possibly more difficult question to answer is how risk aversion would change the results.

An important point to remember is that even though results did fail to support the original theory, this should not be interpreted as failure of experimental economics. Results counter to accepted theories illustrate the importance of experimental tests. To paraphrase Einstein, theory should owe its invention entirely to the desire to make physical theory fit observed fact as well as possible [Albert Einstein (from Smith 1989)].

ENDNOTES

1. Tullock (1980), p.97.

2. Plott (1991), p.905.

3. In this example, fees spent on attorneys are considered a directly unproductive activity.

4. Baik and Shogren (1992b) explain that the underdog would prefer to bluff the favorite by stating that he or she will move first, but then waiting until the favorite moves before he or she actually expends effort. Irreversible and observable effort levels prevent this outcome.

5. Plott (1991), p. 905.

6. Roth (1988), p.629.

7. Participants were seated in the order that they arrived at the experimental session. Monitors did attempt to keep participants that knew each other from sitting in close proximity.

8. The Underdog Timing and Favorite Timing Hypotheses were conducted assuming that participant's timing choices are independent and distributed according to a truncated normal distribution, where the truncation points are zero and one. In each case, simulation procedures (with 10,000 random drawings) were used to construct both the truncated distribution and the 95 percent confidence interval, based on the observed sample mean and standard deviation of that mean. Ensuing hypotheses tests involving timing or best responses were conducted in a similar fashion for treatment 1 and treatment 2.

9. See Pindyck and Rubinfeld (1991) for discussion of Cochrane-Orcutt procedures.

10. Shogren and Baik (1992) found that 74 percent of underdogs in one group selected the best response in a Stackelberg favorite leader framework. In another test group, 61 percent of underdog effort levels exceed the best response. Direct comparison to the current experiment is difficult since the Shogren and Baik experiment used a twenty-four by twenty-four "expected" payoff table compared to the current five by five payoff table. Additionally, Shogren and Baik analyzed the degree of over expenditure rather than the percent each individual selected the best response.

11. This was performed with a Cochrane-Orcutt type procedure as in the underdog leader hypothesis.

12. See Harrison (1989), p. 760.

13. See Thaler (1988) for a complete description of the Ultimatum Game.

14. In treatment 2, participants were asked a series of questions (see Appendix B) after completing the practice rounds. Approximately 75 percent of answers indicated that the participant would make

a choice in order to get higher payoffs. No participants indicated that they were attempting to minimize the difference between favorite and underdog payoffs.

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APPENDIX A: FIGURES

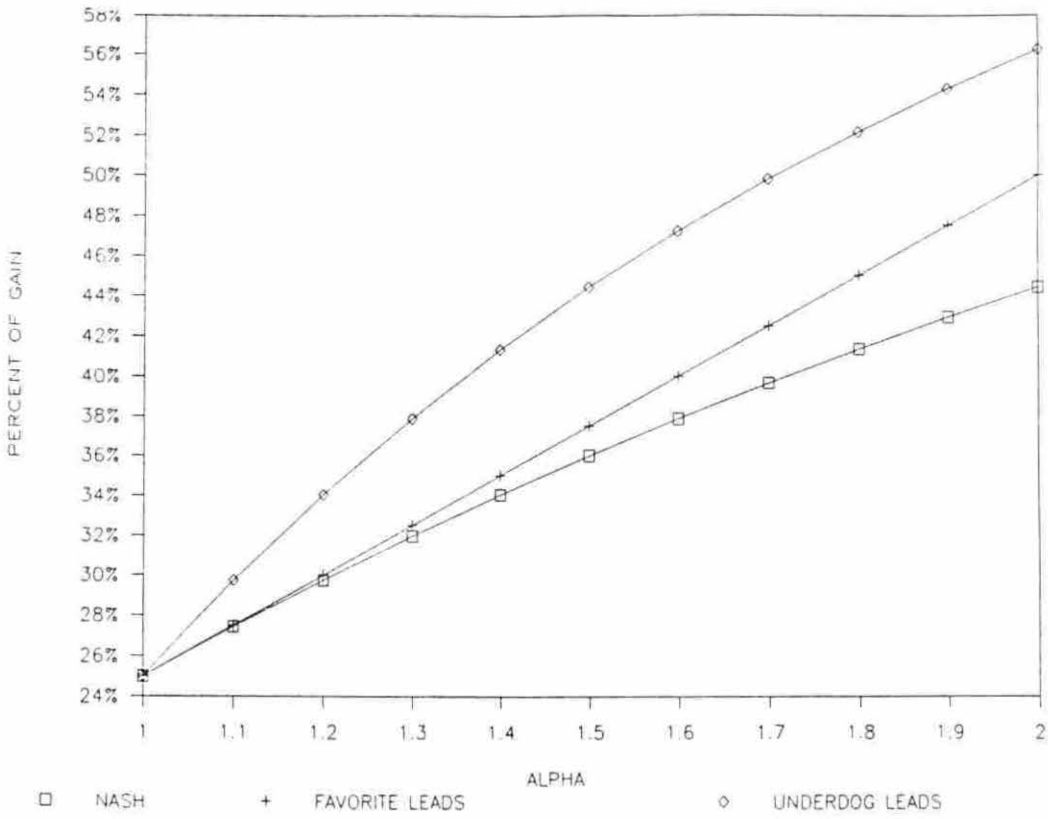

Figure 1. Favorite expected returns for different levels of α.

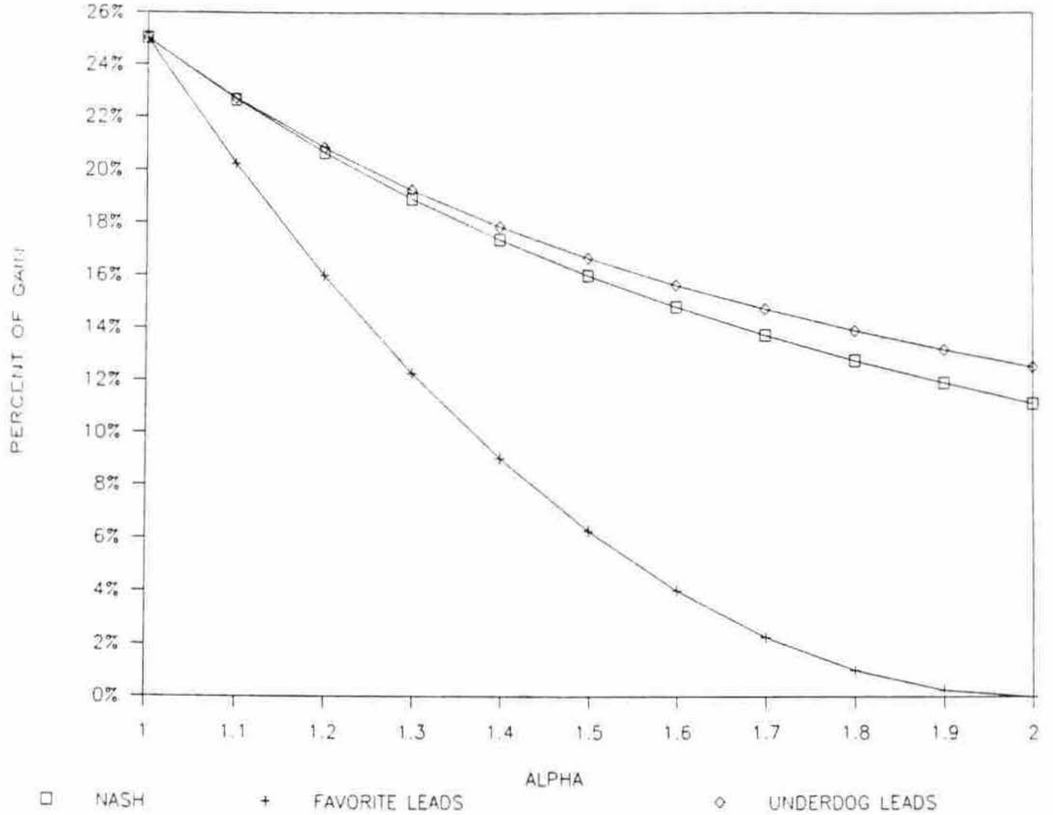

Figure 2. Underdog expected returns for different levels of α.

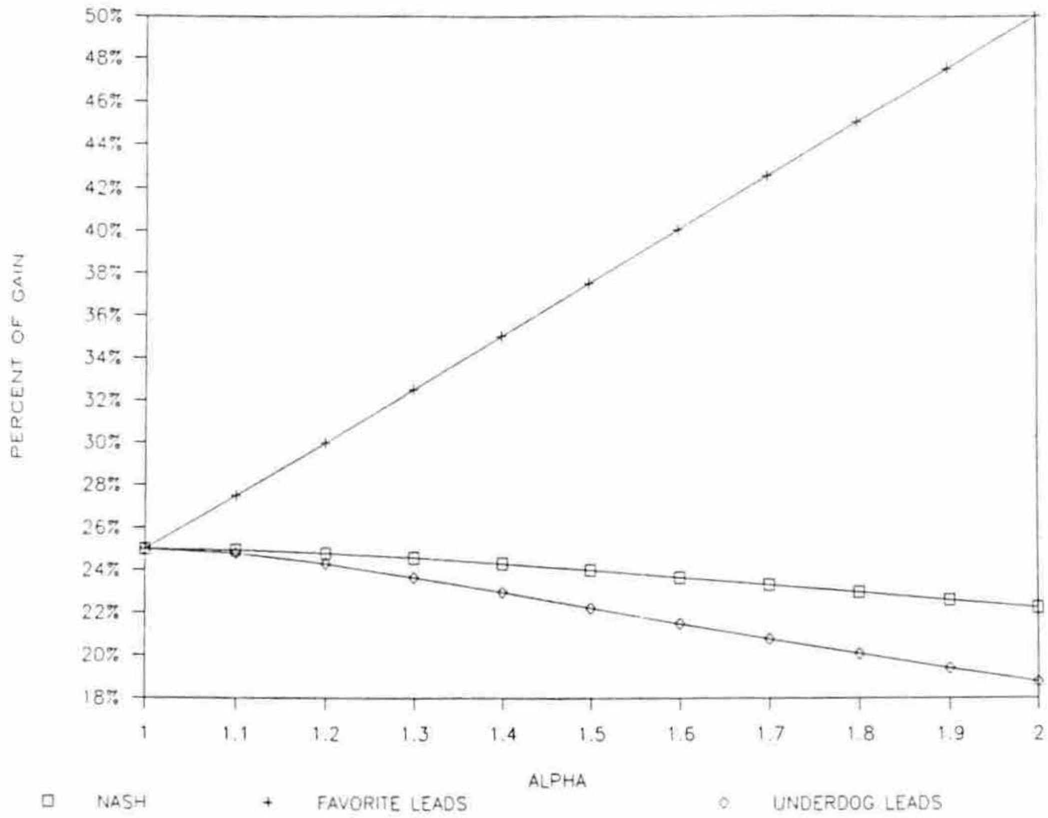

Figure 3. Favorite effort level for different levels of α.

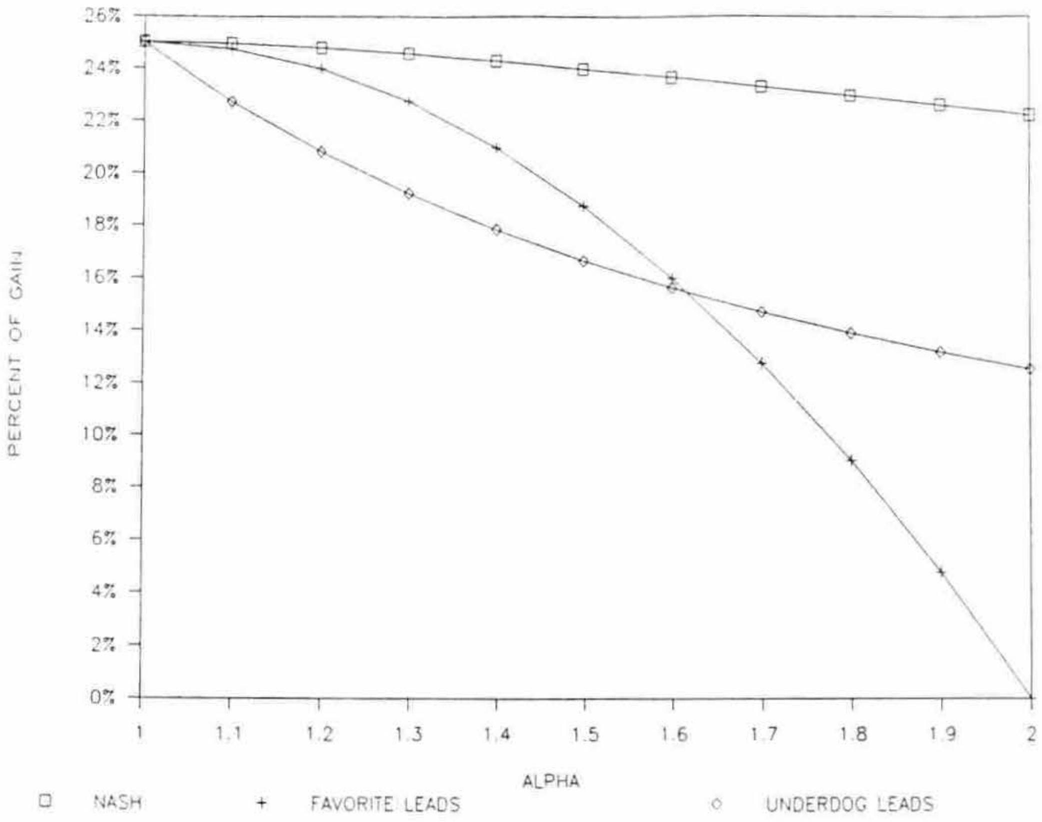

Figure 4. Underdog effort level for different levels of α.

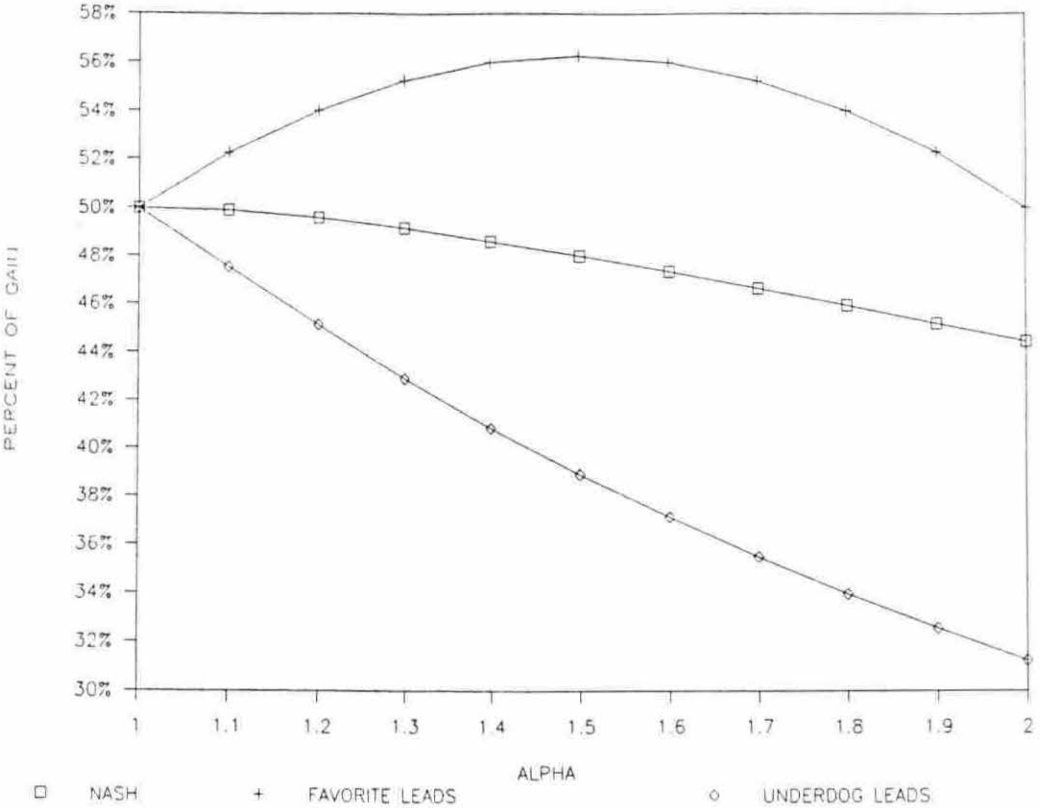

Figure 5. Dissipation by subgame for different levels of α.

PLAYER B

PLAYER A		C1	C2	C3	C4	C5
	R1	400,400	400, 1660	400, 1570	400, 1520	400, 1120
	R2	1660, 400	700, 1180	580, 1210	536, 1204	380, 960
	R3	1570, 400	747, 1043	610, 1090	557, 1093	357, 893
	R4	1520, 400	758, 982	616, 1034	560, 1040	342, 858
	R5	1120, 400	640, 700	503, 747	442, 758	160, 640

Figure 6. Payoff table for treatment 1.

PLAYER A	PLAYER B	C1	C2	C3
	R1	6, 14	6, 13	6, 10
	R2	9, 12	7, 11	5, 7
	R3	10, 8	8, 9	4, 6

Figure 7. Payoff table for treatment 2.

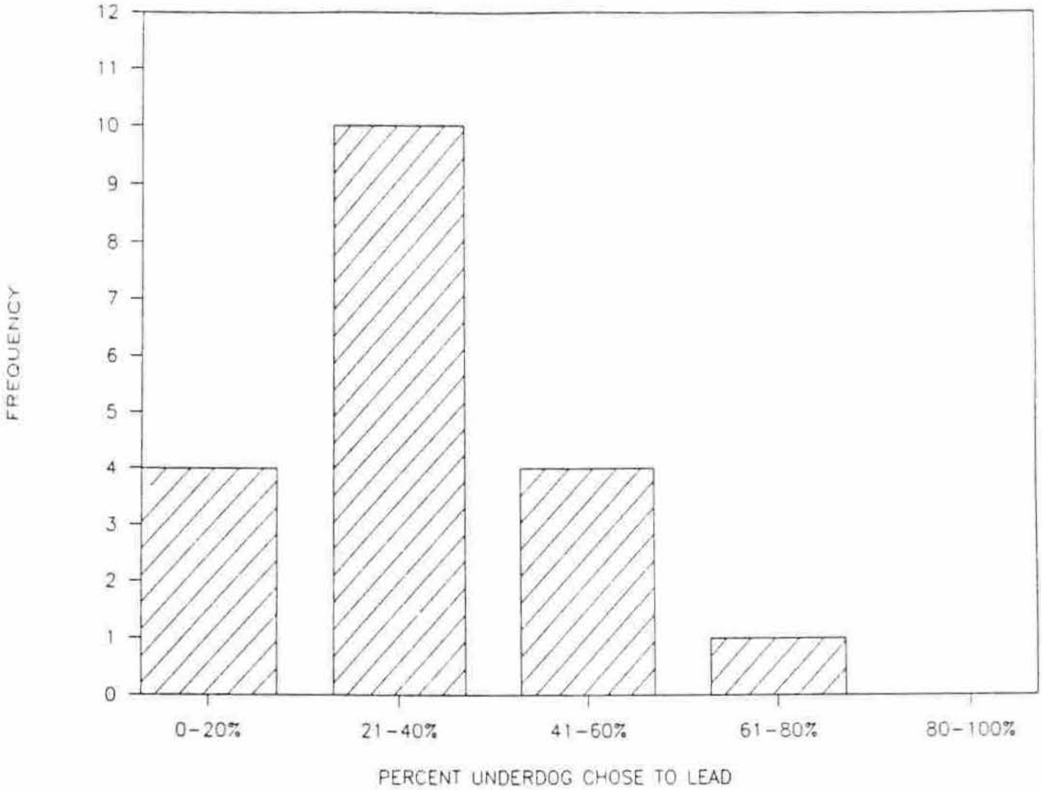

Figure 8. Percent underdog chose to lead in treatment 1 (trials 1-20).

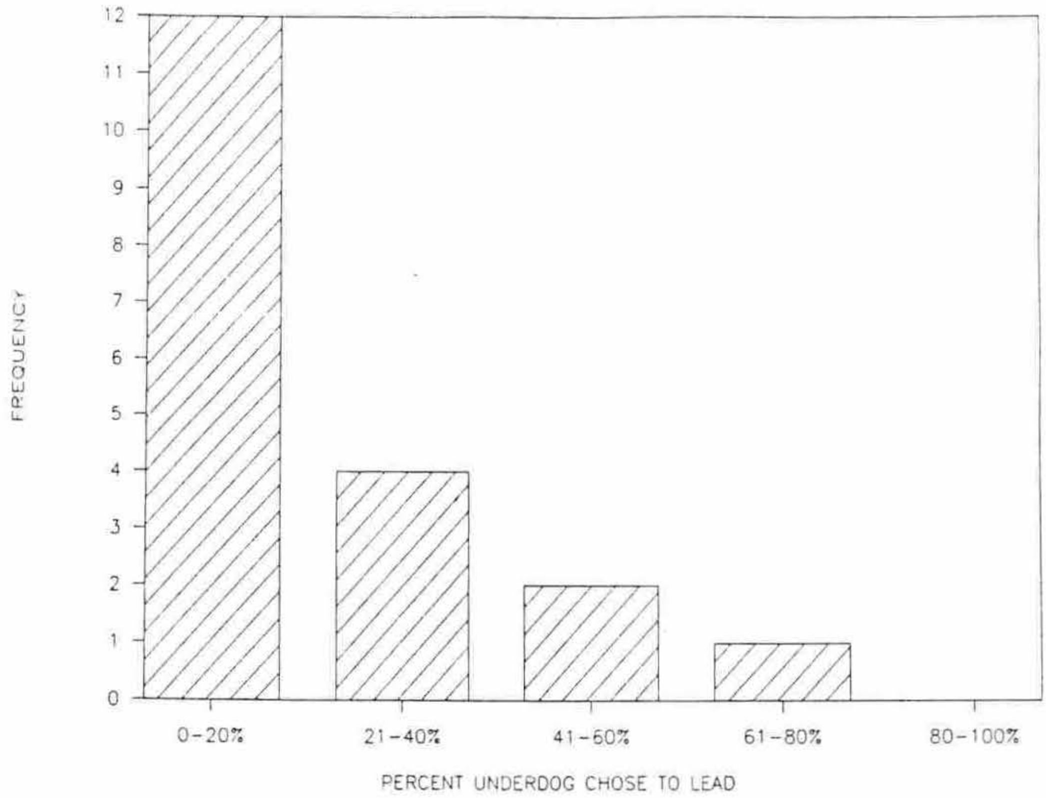

Figure 9. Percent underdogs chose to lead in treatment 1 (trials 16-20).

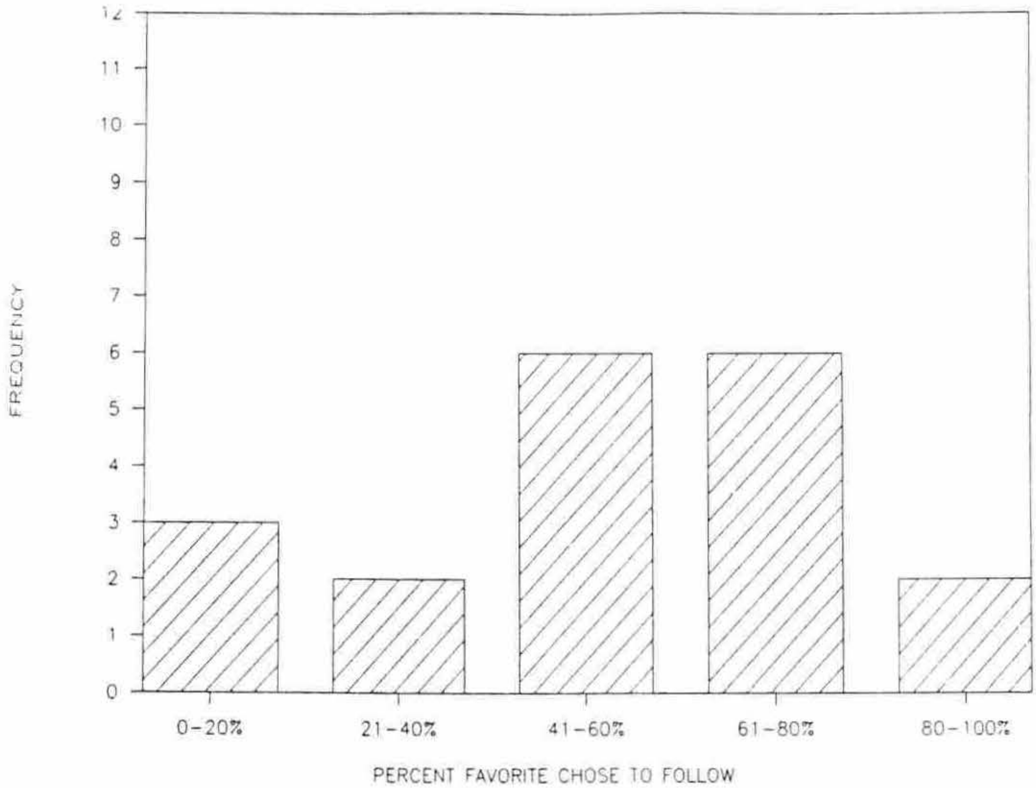

Figure 10. Percent favorite chose to follow in treatment 1 (trials 1-20).

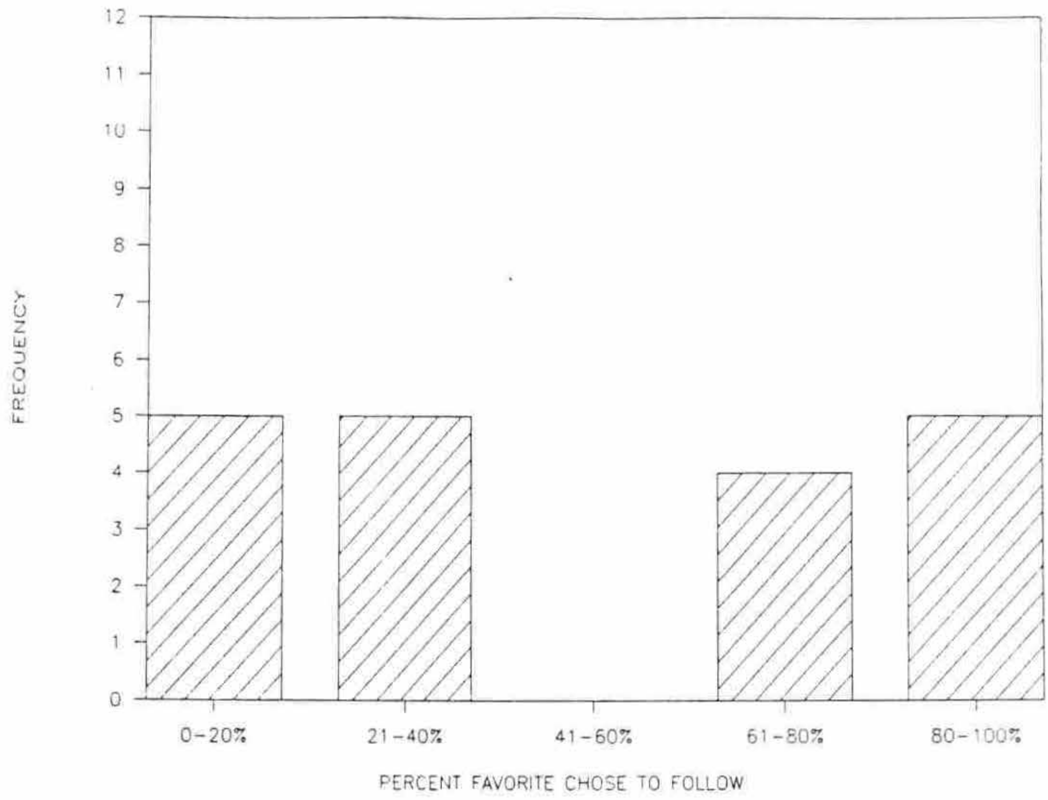

Figure 11. Percent favorites chose to follow in treatment 1 (trials 16-20).

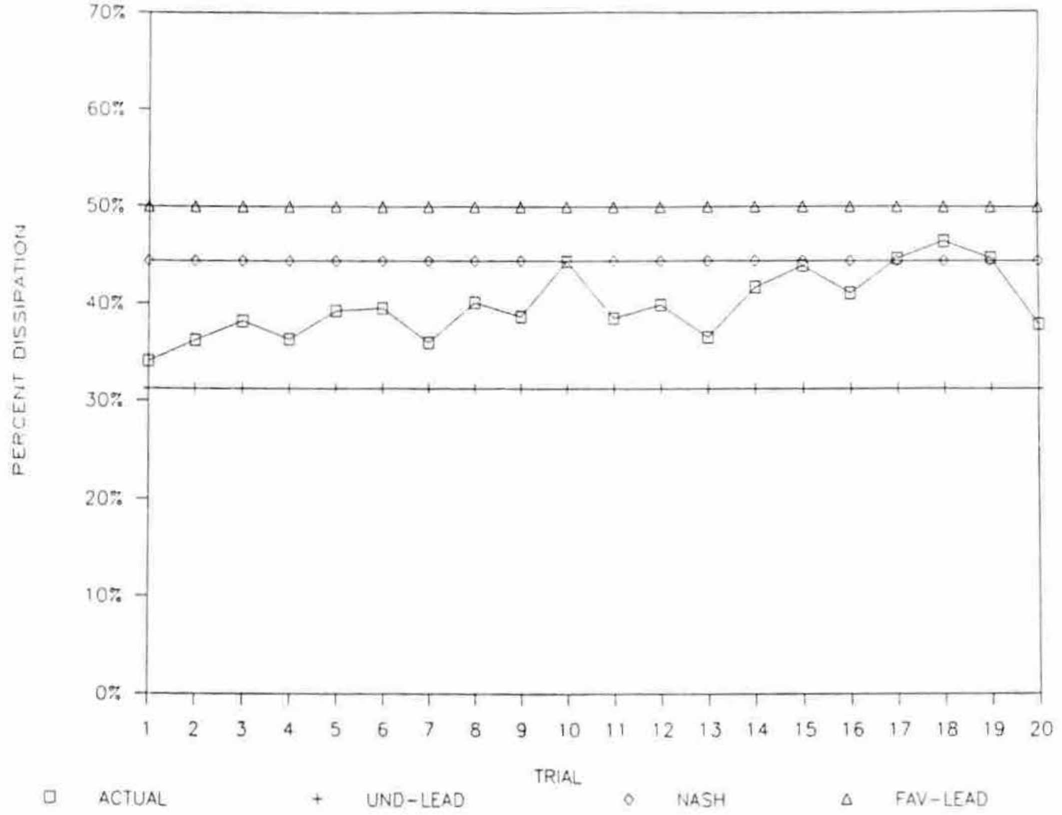

Figure 12. Average dissipation by trial compared to predicted dissipation.

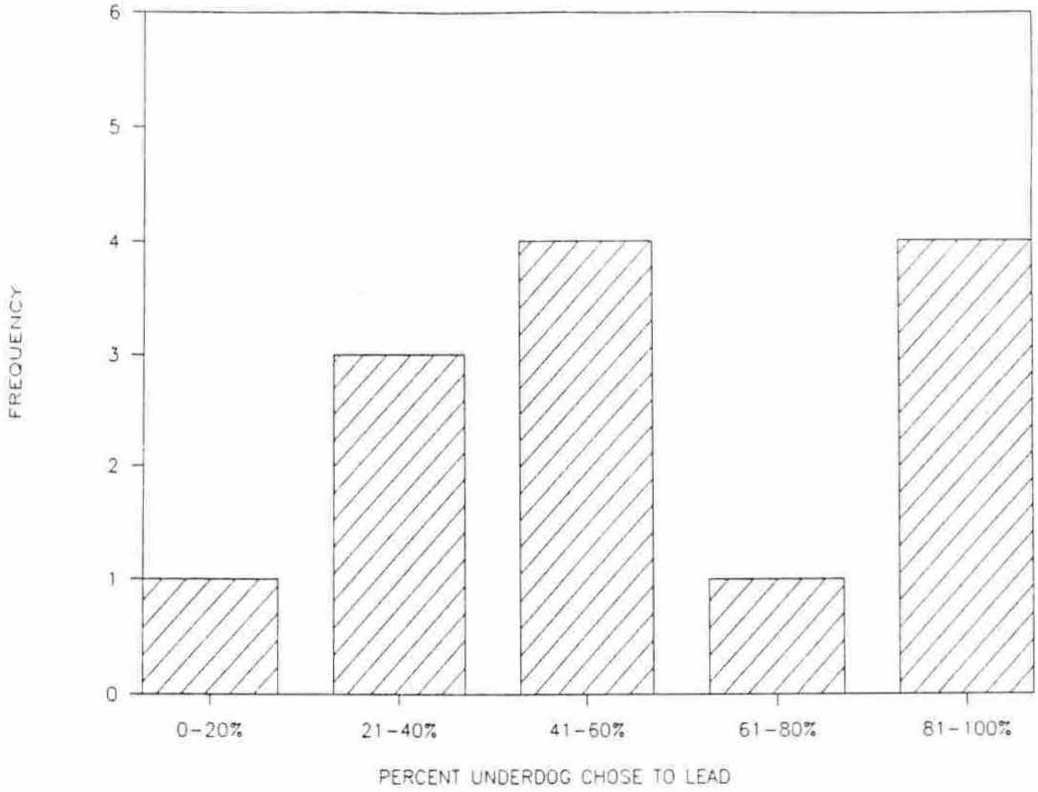

Figure 13. Percent underdog chose to lead in treatment 2 (trials 1-20).

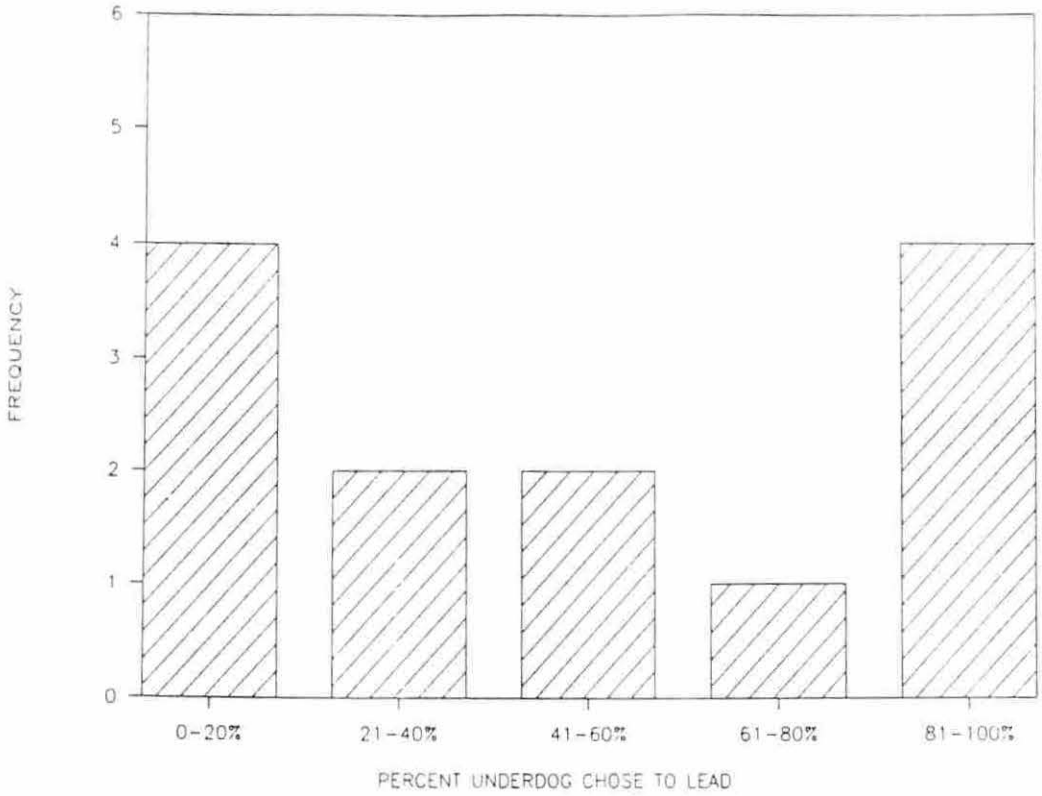

Figure 14. Percent underdogs chose to lead in treatment 2 (trials 16-20).

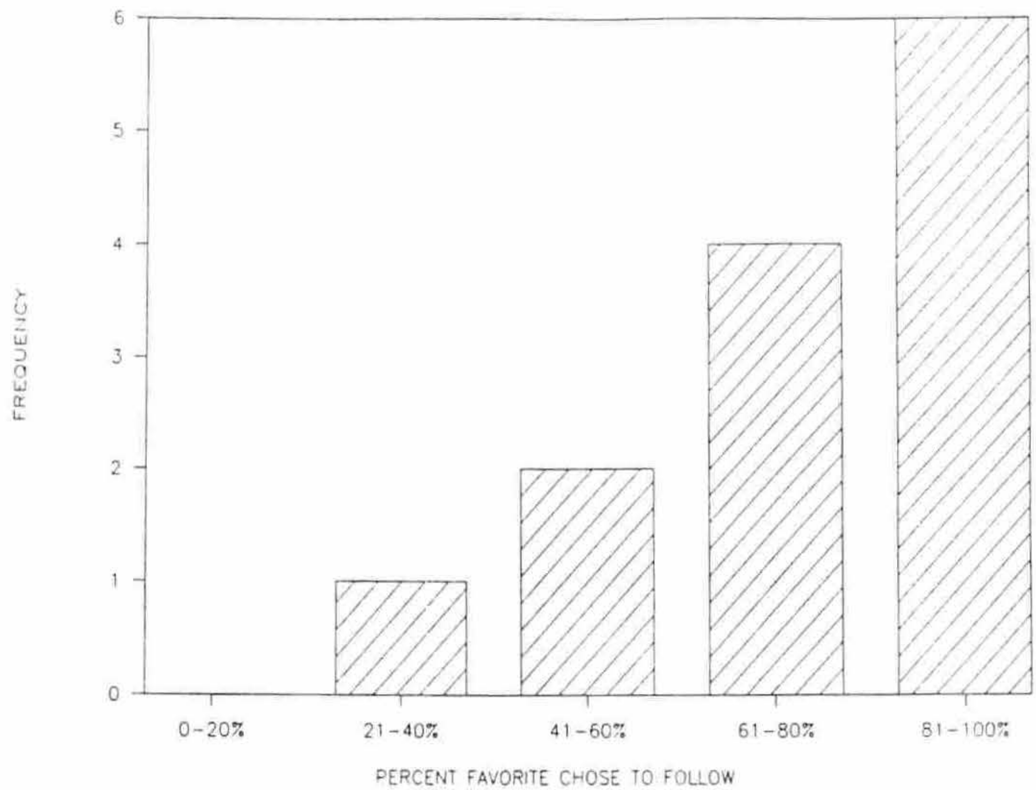

Figure 15. Percent favorites chose to follow in treatment 2 (trials 1-20).

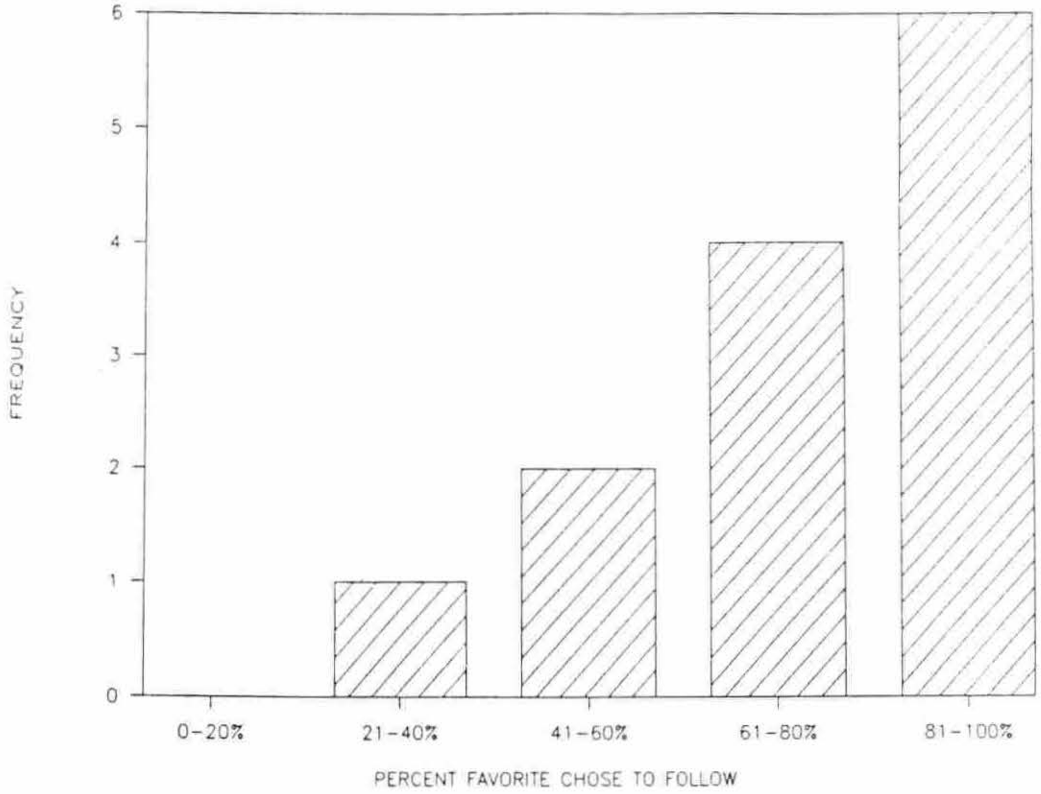

Figure 16. Percent favorites chose to follow in treatment 2 (trials 16-20).

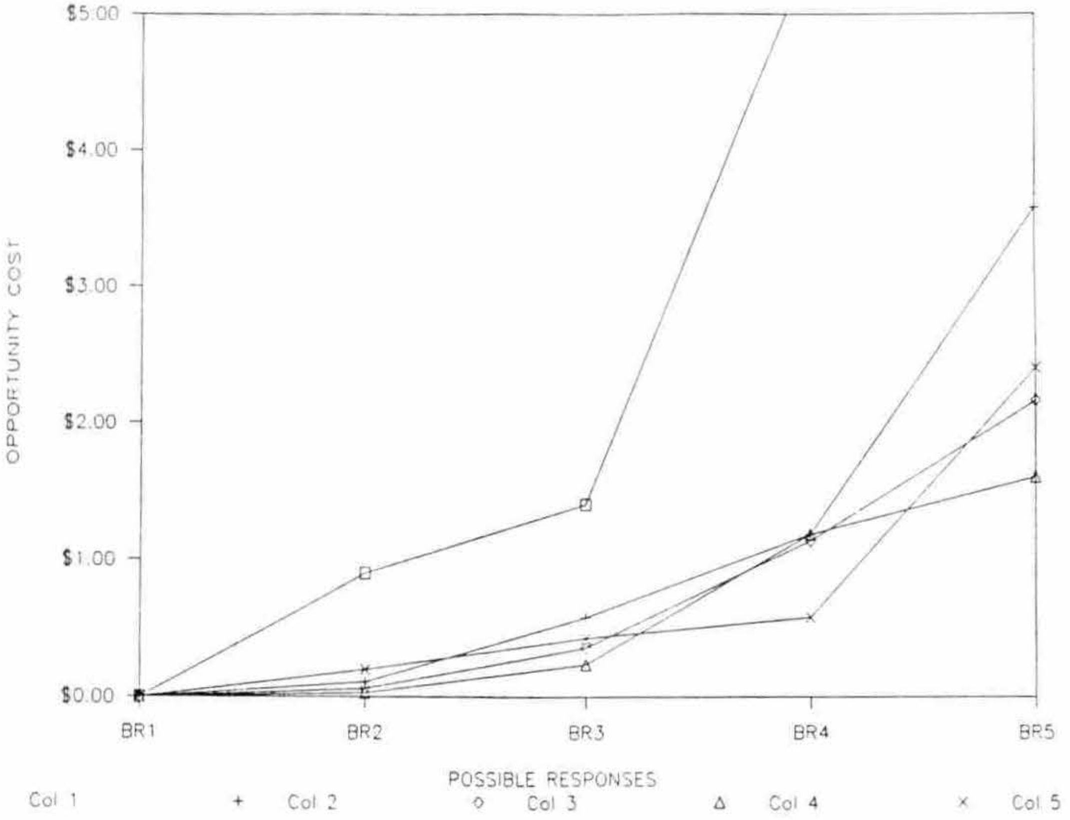

Figure 17. Underdog best response deviations for treatment 1.

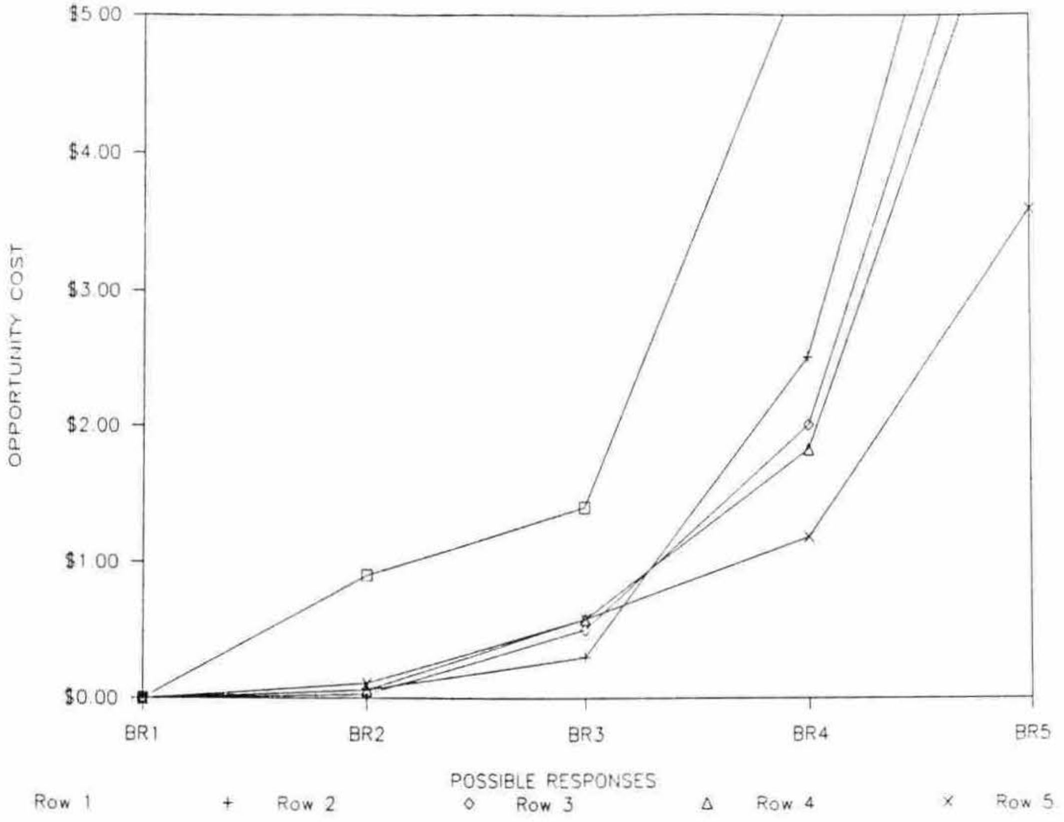

Figure 18. Favorite best response deviations for treatment 1.

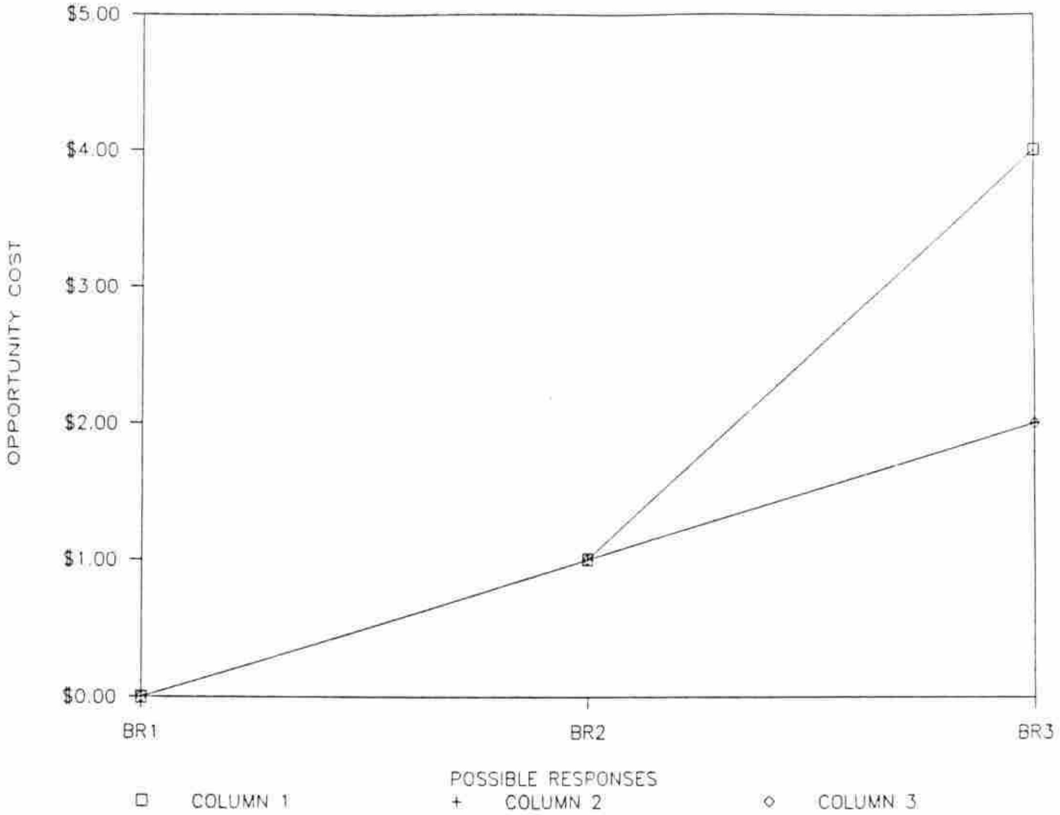

Figure 19. Underdog best response deviations for treatment 2.

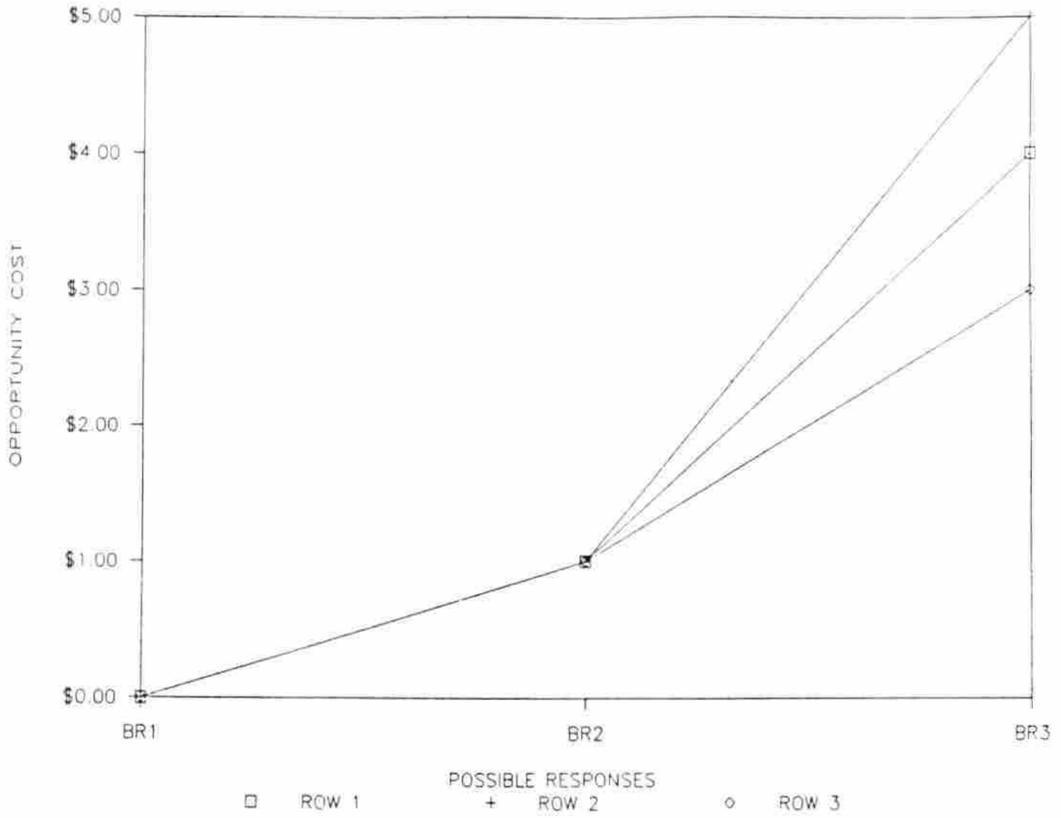

Figure 20. Favorite best response deviations for treatment 2.

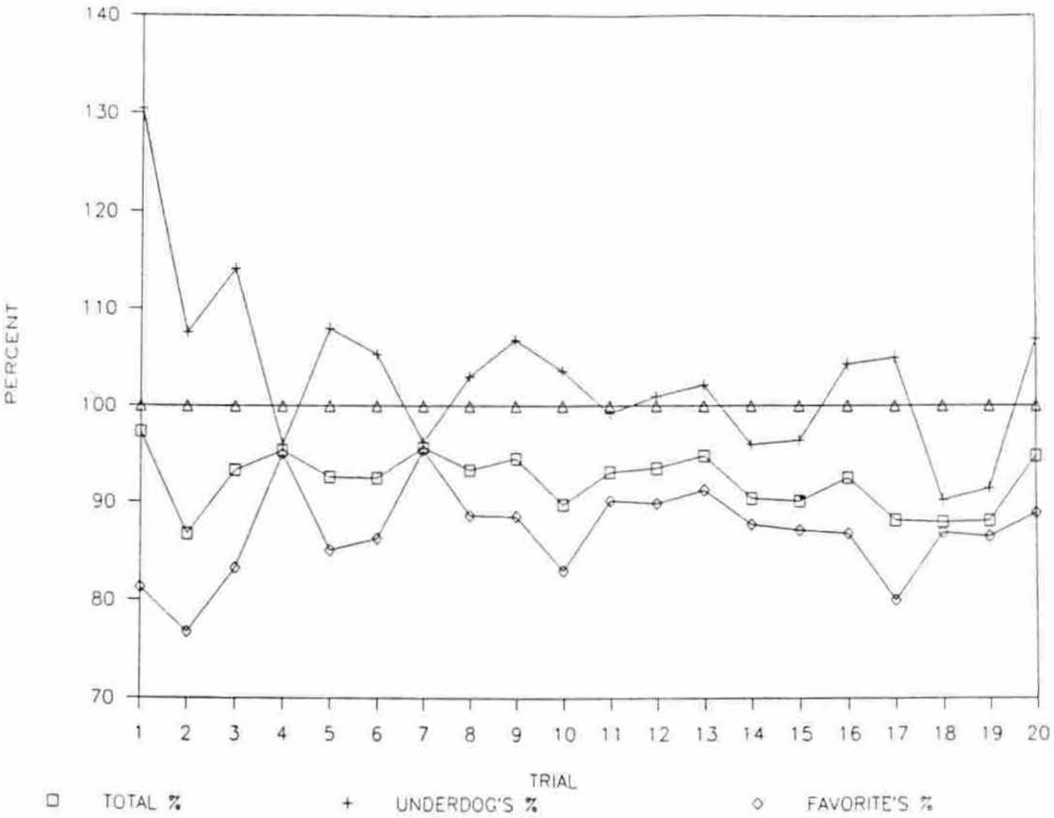

Figure 21. Percent of equilibrium predicted by theory attained in treatment 2.

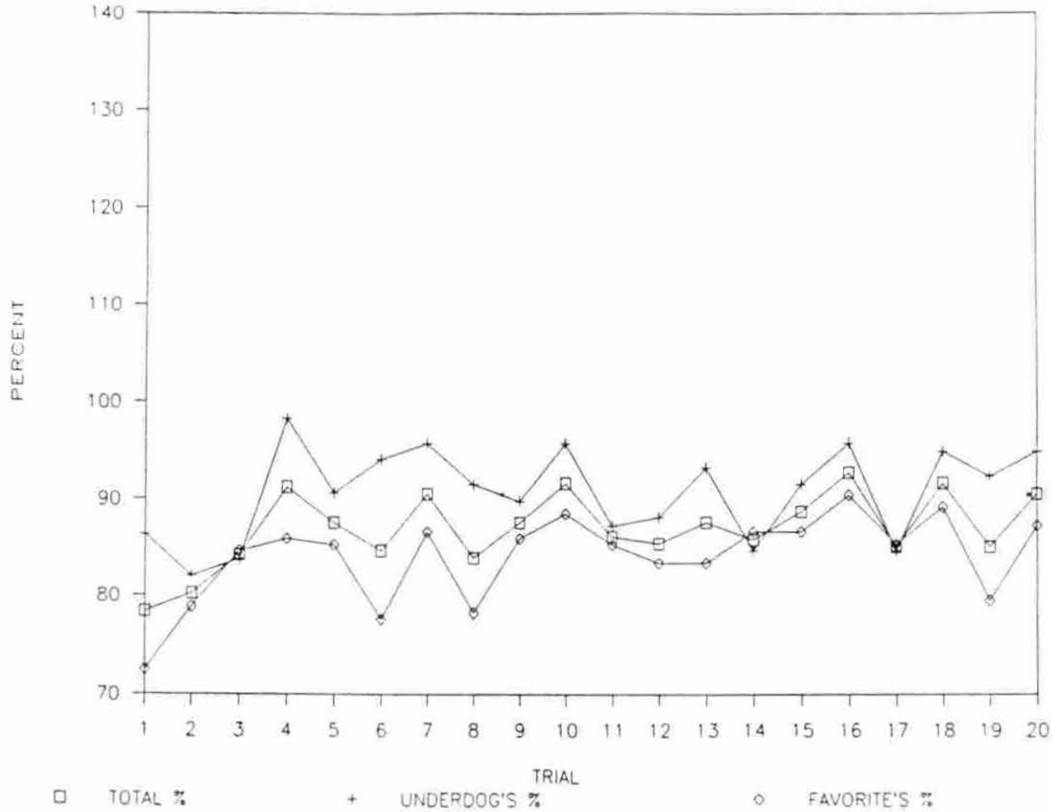

Figure 22. Percent of equilibrium predicted by theory attained in treatment 2.

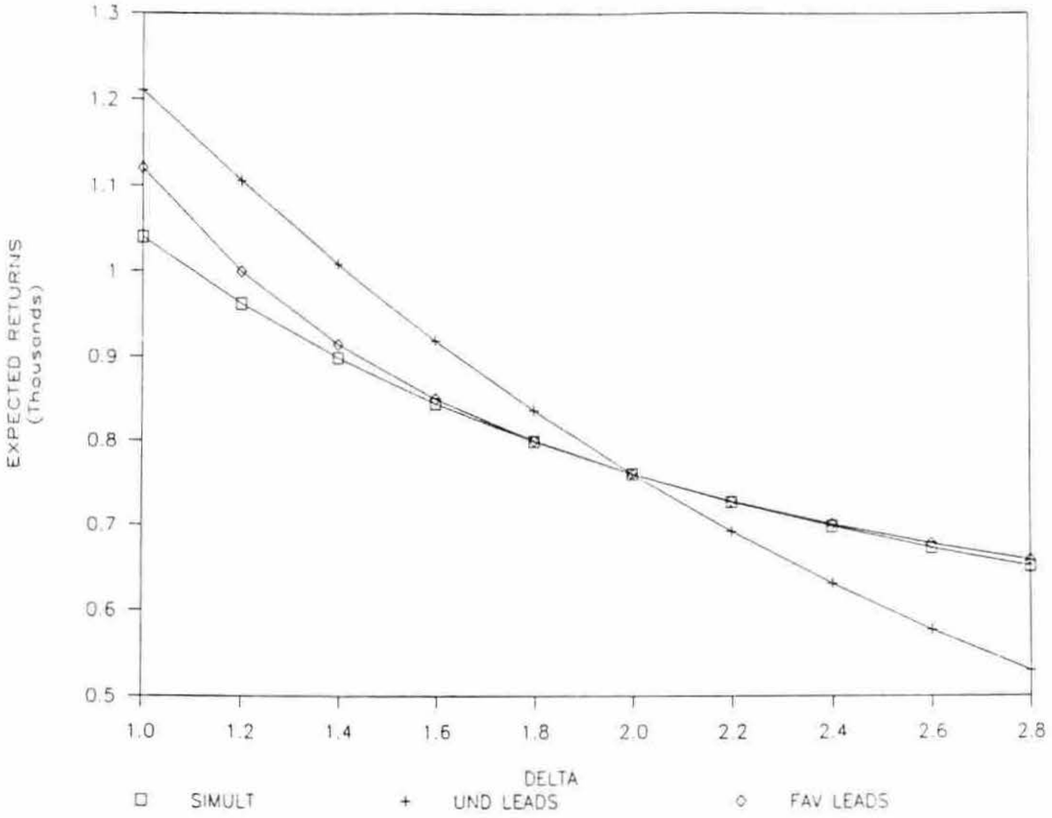

Figure 23. Favorite expected returns for different gain valuations.

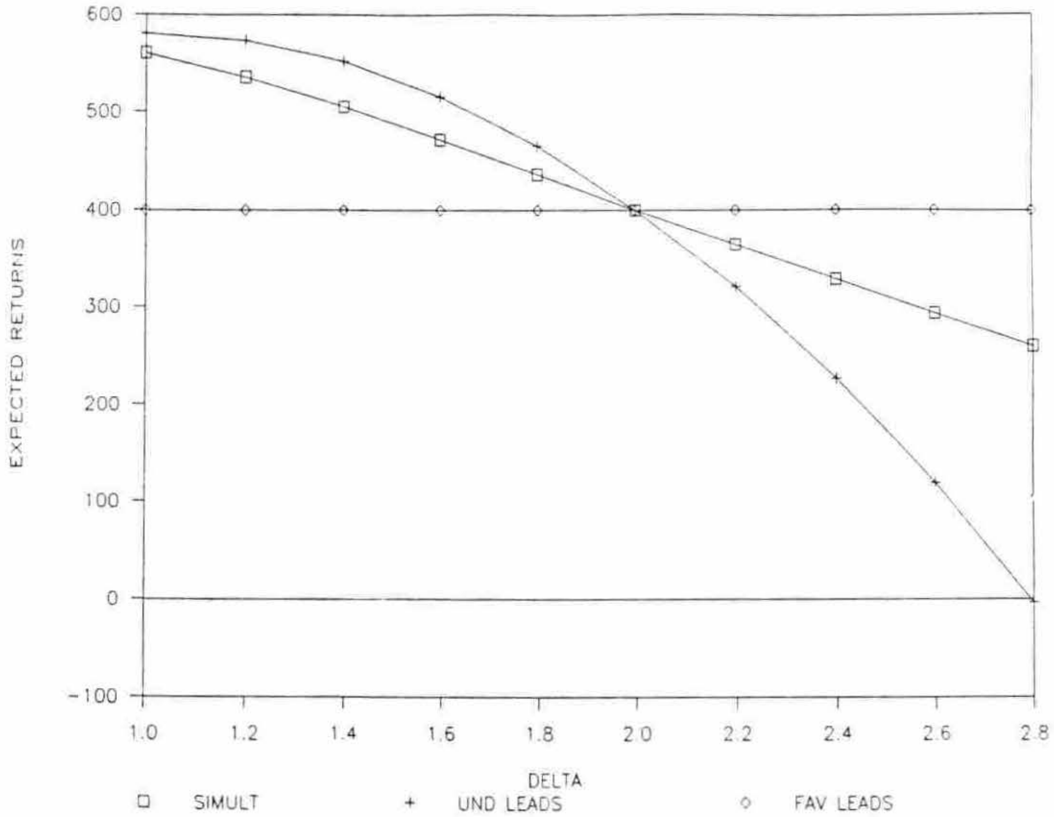

Figure 24. Underdog expected returns for different gain valuations.

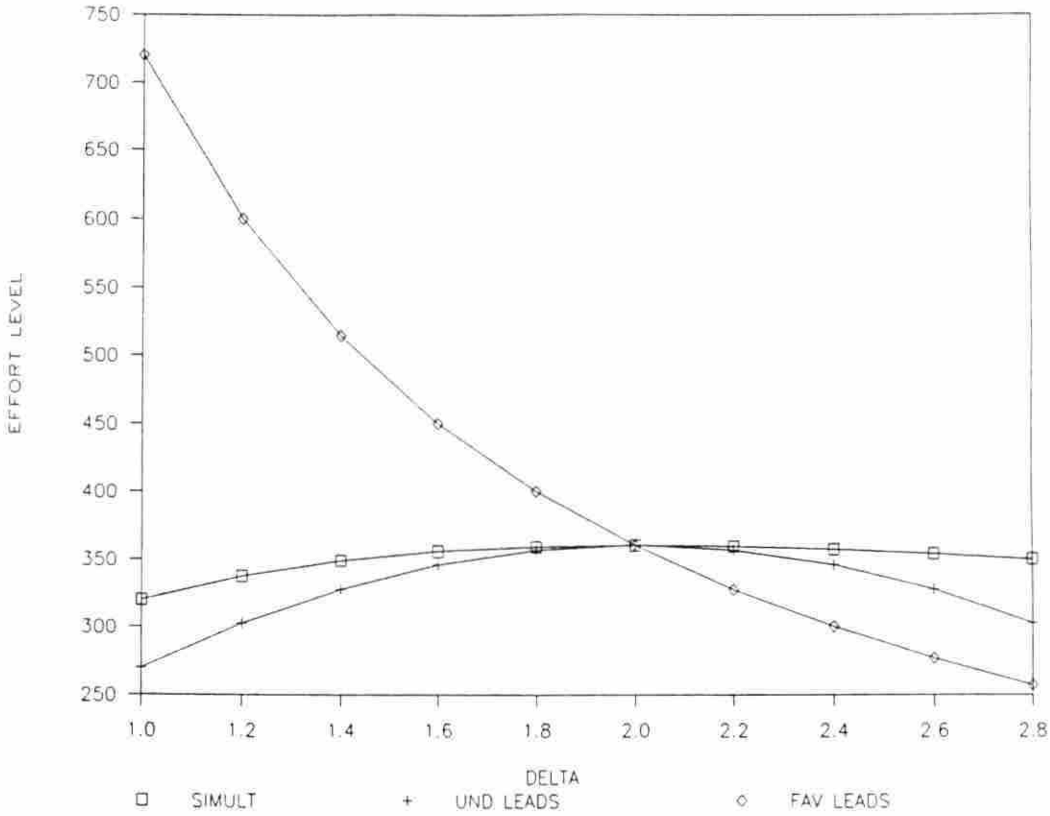

Figure 25. Favorite effort level for different gain valuations.

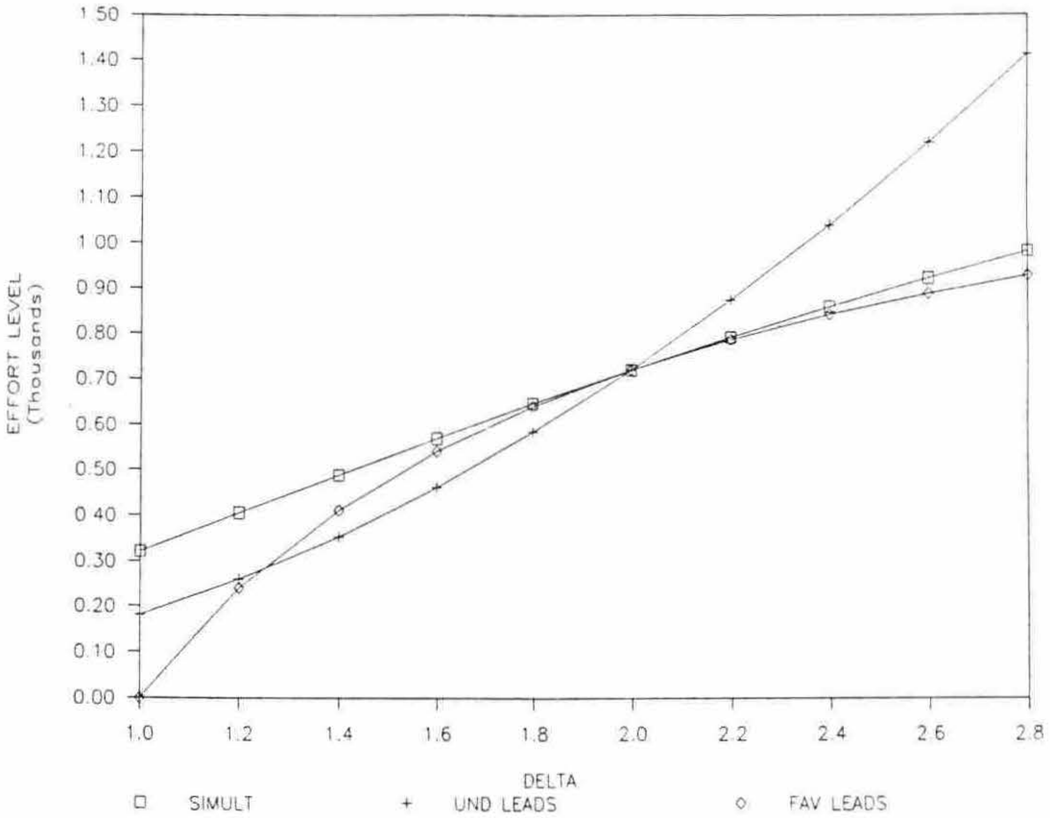

Figure 26. Underdog effort level for different gain valuations.

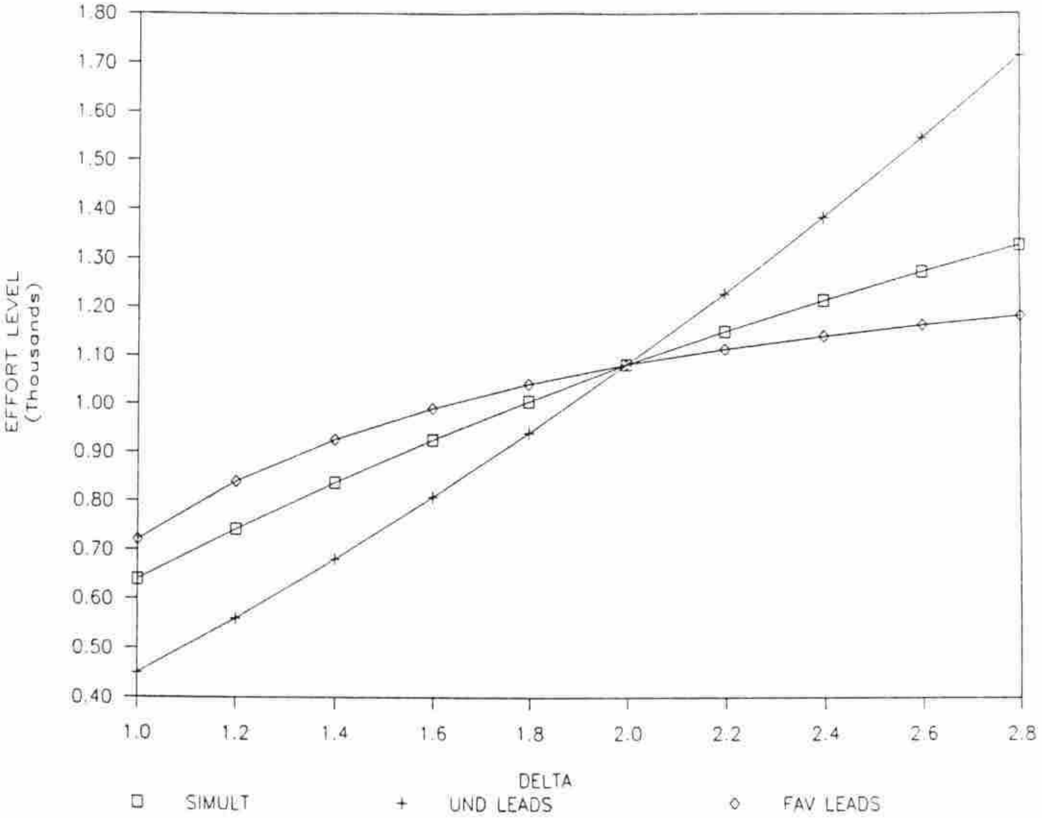

Figure 27. Total effort level for different gain valuations.

APPENDIX B: EXPERIMENTAL INSTRUCTIONS

Consent Form

You are about to participate in an experiment in endogenous timing. The purpose is to gain insight into how you choose timing in an economic setting. The experiment will take roughly one hour and thirty minutes. Results from the experiment will be used in a thesis and/or dissertation.

We need your signed consent if you are to act as a subject. Your participation in the experiment is completely voluntary and you may withdraw from the experiment at any time without prejudice to you. Results from the experiment will be strictly confidential. Any name associated with the experiment will be deleted upon completion of the experiment.

If you consent to participate in the experiment, please sign the consent form below.

I have read the consent form statement and agree to act as a subject in the experiment, with the understanding that I can withdraw from the experiment at any time without prejudice to me.

/ /

Signature Date

Treatment 1 Underdog Instructions

You are about to participate in an experiment about decision making. The purpose of this experiment is to gain insight into certain features of economic processes. If you follow the instructions carefully you can earn money. You will find it helpful to refer to the Payoff Table and Individual Record Sheet on the back of the handout as you read these instructions.

The experiment proceeds as follows:

1. **PLAYER OBJECTIVE:** You and your opponent will independently make decisions that will determine how many tokens you receive at the end of the experiment. Each token is worth one cent (1 token = $0.01).

2. **PAYOFF TABLE:** You (Player A) will choose from rows R1 through R5. Your opponent (Player B) will choose from columns C1 through C5. The Payoff Table shows the amount of tokens you will receive given the row you select and the column your opponent selects. Your payoff is the first number in each cell. For example, if you select R2 and your opponent selects C2, then your payoff is 700 tokens.

3. **TRIALS:** The experiment consist of 20 trials. Trials 1 and 2 are for practice and will not affect your actual take-home-pay. Trials 3-20 are potentially binding (could determine how much money you receive at the end of the experiment). In each trial there are two stages. In the first stage you and your opponent will choose to lead or follow. This determines the order of play in the second stage. In the second stage you will select a row and your opponent will select a column according to order of play

determined in the first stage.

Stage 1: Both you and your opponent will independently and simultaneously choose to lead or follow. If you choose to lead and your opponent chooses to follow, then in stage 2 you lead and your opponent follows. If you choose to follow and your opponent chooses to lead, then in stage 2 your opponent will lead and you will follow. If you both choose to lead or if you both choose to follow, you and your opponent will move simultaneously. The order of play in stage 2 is summarized below.

YOUR CHOICE	**YOUR OPPONENT'S CHOICE**	**ORDER OF PLAY**
Lead	Lead	Simultaneous
Follow	Follow	Simultaneous
Lead	Follow	A Leads, B Follows
Follow	Lead	B Leads, A Follows

Stage 2: If you lead, you select a row and reveal it to your opponent. Your opponent will follow by choosing a column with the knowledge of your choice. If you follow, your opponent will select a column and reveal the choice to you. You will then select a row with the knowledge of your opponent's choice. If you and your opponent move simultaneously, you

select a row, your opponent selects a column, and you both reveal your choice to each other at the same time.

4. **RECORDING TRIALS:** On your Individual Record Sheet you will record your opponent's identification number, Player A and B's choice to lead or follow, the actual leader stage 2, Player A and B's selected row or column, and <u>your</u> corresponding payoff. In the Actual Leader column enter an "S" if both players moved simultaneously.

5. **TAKE-HOME-PAY:** The actual take-home-pay is determined as follows: after all 20 trials are completed, the Monitor will randomly select one of trials 3-20 to determine your take-home-pay. You will receive the value of the token payoff for that trial plus $3.00 for participating in the experiment.

<u>AN EXAMPLE</u>: Assume trial 17 is selected to determine take-home-pay. If in trial 17 you chose R2 and your opponent chose C2, your <u>payoff</u> is 700 tokens. The actual dollar amount you will receive is

$$\$10.00 - 700(tokens) \times \$0.01 + \$3.00$$

6. **OPPONENTS:** You will play against a different opponent every trial. However, you will always be an "A Player" and your opponent will always be a "B Player".

QUESTIONS

Name:___________________________________

Player Identification number:__________

Please circle the correct answer.

1. Your payoff is listed first or second in each cell?

   FIRST SECOND

2. What happens if you and your opponent both choose to follow?

   YOU FOLLOW YOU LEAD

   YOU AND YOUR OPPONENT MOVE SIMULTANEOUSLY

3. If Player A chooses row R3, and Player B chooses column C5, what is your payoff (remember you are Player A)?

   503 700 357 580 893

4. Your <u>take-home-pay</u> will be determined based on each trial or based on one of trials 3-20 chosen at random?

   EACH TRIAL ONE TRIAL

DO YOU HAVE ANY QUESTIONS?

Treatment 1 Favorite Instructions

You are about to participate in an experiment about decision making. The purpose of this experiment is to gain insight into certain features of economic processes. If you follow the instructions carefully you can earn money. You will find it helpful to refer to the Payoff Table and Individual Record Sheet on the back of the handout as you read these instructions.

The experiment proceeds as follows:

1. **PLAYER OBJECTIVE:** You and your opponent will independently make decisions that will determine how many tokens you receive at the end of the experiment. Each token is worth one cent (1 token = $0.01).

2. **PAYOFF TABLE:** You (Player B) will choose from columns C1 through C5. Your opponent (Player A) will choose from rows R1 through R5. The Payoff Table shows the amount of tokens you will receive given the column you select and the row your opponent selects. Your payoff is the second number in each cell. For example, if you select C2 and your opponent selects R2, then your payoff is 1180 tokens.

3. **TRIALS:** The experiment consist of 20 trials. Trials 1 and 2 are for practice and will not affect you actual take-home-pay. Trials 3-20 are potentially binding (could determine how much money you receive at the end of the experiment). In each trial there are two stages. In the first stage you and your opponent will choose to lead or follow. This determines the order of play in the second stage. In the second stage you will select a column and your opponent will select a row according to order of

play determined in the first stage.

Stage 1: Both you and your opponent will independently and simultaneously choose to lead or follow. If you choose to lead and your opponent chooses to follow, then in stage 2 you lead and your opponent follows. If you choose to follow and your opponent chooses to lead, then in stage 2 your opponent will lead and you will follow. If you both choose to lead or if you both choose to follow, you and your opponent will move simultaneously. The order of play in stage 2 is summarized below.

YOUR CHOICE	**YOUR OPPONENT'S CHOICE**	**ORDER OF PLAY**
Lead	Lead	Simultaneous
Follow	Follow	Simultaneous
Follow	Lead	A Leads, B Follows
Lead	Follow	B Leads, A Follows

Stage 2: If you <u>lead,</u> you select a column and reveal it to your opponent. Your opponent will <u>follow</u> by choosing a row with the knowledge of your choice. If you <u>follow</u>, your opponent will select a row and reveal the choice to you. You will then select a column with the knowledge of your opponent's choice. If you and your opponent move <u>simultaneously</u>, you

select a column, your opponent selects a row, and you both reveal your choice to each other at the same time.

4. **RECORDING TRIALS:** On your Individual Record Sheet you will record your opponent's identification number, Player A and B's choice to lead or follow, the actual leader in stage 2, Player A and B's selected row or column, and <u>your</u> corresponding payoff. In the Actual Leader column enter an "S" if both players moved simultaneously.

5. **TAKE-HOME-PAY:** The actual take-home-pay is determined as follows: after all 20 trials are completed, the Monitor will randomly select one of trials 3-20 to determine your take-home-pay. You will receive the value of the token payoff plus $3.00 for participation in the experiment.

   <u>AN EXAMPLE</u>: Assume trial 17 is selected to determine take-home-pay. If in trial 17 you chose C2 and your opponent chose R2, then your <u>payoff</u> is 1180 tokens. The actual dollar amount you will receive is

$$\$14.80 = 1180(\textit{tokens}) \times \$0.01 + \$3.00$$

6. **OPPONENTS:** You will play against a different opponent every trial. However, you will always be a "B Player" and your opponent will always be an "A Player".

QUESTIONS

Name:____________________________________

Player Identification number:__________

Please circle the correct answer.

1. Your payoff is listed first or second in each cell?

   FIRST SECOND

2. What happens if you and your opponent both choose to follow?

   YOU FOLLOW YOU LEAD

   YOU AND YOUR OPPONENT MOVE SIMULTANEOUSLY

3. If Player A chooses row R3, and Player B chooses column C5, what is your payoff (remember you are Player B)?

   1180 747 893 357 1093

4. Your <u>take-home-pay</u> will be determined based on each trial or based on one of trials 3-20 chosen at random?

   EACH TRIAL ONE TRIAL

DO YOU HAVE ANY QUESTIONS?

Treatment 1 Individual Record Sheet

Player Identification number:__________

Name:____________________________________

OPPONENT	TRIAL	Your Choice L or F	Your Opponent's Choice L or F	Actual Leader in Stage 2 (S= Simultaneous)	A's Row	B's Column	Your Payoff
	1	L F	L F				
	2	L F	L F				
	3	L F	L F				
	4	L F	L F				
	5	L F	L F				
	6	L F	L F				
	7	L F	L F				
	8	L F	L F				
	9	L F	L F				
	10	L F	L F				
	11	L F	L F				
	12	L F	L F				
	13	L F	L F				
	14	L F	L F				
	15	L F	L F				
	16	L F	L F				
	17	L F	L F				
	18	L F	L F				
	19	L F	L F				
	20	L F	L F				

Treatment 2 Underdog Instructions

You are about to participate in an experiment about decision making. The purpose of this experiment is to gain insight into certain features of economic processes. If you follow the instructions carefully you can earn money. You will find it helpful to refer to the Payoff Table and Individual Record Sheet on the back of the handout as you read these instructions.

The experiment proceeds as follows:

1. **PLAYER OBJECTIVE:** You and your opponent will independently make decisions that will determine how much money you receive at the end of the experiment.

2. **PAYOFF TABLE:** You (Player A) will choose from rows R1 through R3. Your opponent (Player B) will choose from columns C1 through C3. The Payoff Table shows the amount of money you will receive given the row you select and the column your opponent selects. Your payoff is the first number in each cell. For example, if you select R2 and your opponent selects C2, then your payoff is 7 dollars.

3. **TRIALS:** The experiment consist of 20 trials. Trials 1 and 2 are for practice and will not affect your actual take-home-pay. Trials 3-20 are potentially binding (could determine how much money you receive at the end of the experiment). In each trial there are two stages. In the first stage you and your opponent will choose to lead or follow. This determines the order of play in the second stage. In the second stage you will select a row and your opponent will select a column according to order of play determined in the first stage.

Stage 1: Both you and your opponent will independently and simultaneously choose to lead or follow. If you choose to lead and your opponent chooses to follow, then in stage 2 you lead and your opponent follows. If you choose to follow and your opponent chooses to lead, then in stage 2 your opponent will lead and you will follow. If you both choose to lead or if you both choose to follow, you and your opponent will move simultaneously. The order of play in stage 2 is summarized below.

YOUR CHOICE	**YOUR OPPONENT'S CHOICE**	**ORDER OF PLAY**
Lead	Lead	Simultaneous
Follow	Follow	Simultaneous
Lead	Follow	A Leads, B Follows
Follow	Lead	B Leads, A Follows

Stage 2: If you lead, you select a row and reveal it to your opponent. Your opponent will follow by choosing a column with the knowledge of your choice. If you follow, your opponent will select a column and reveal the choice to you. You will then select a row with the knowledge of your opponent's choice. If you and your opponent move simultaneously, you select a row, your opponent selects a column, and you both reveal your choice to each other at the

same time. The Monitor will demonstrate how to reveal your choices.

4. **RECORDING TRIALS:** On your Individual Record Sheet you will record your opponent's identification number, Player A and B's choice to lead or follow, the actual leader stage 2, Player A and B's selected row or column, and <u>your</u> corresponding payoff. In the Actual Leader column enter an "S" if both players moved simultaneously.

5. **TAKE-HOME-PAY:** The actual take-home-pay is determined as follows: after all 20 trials are completed, the Monitor will randomly select one of trials 3-20 to determine your take-home-pay. You will receive the dollar value for that trial.

   <u>AN EXAMPLE</u>: Assume trial 17 is selected to determine take-home-pay. If in trial 17 you chose R2 and your opponent chose C2, your <u>payoff</u> is 7 dollars.

6. **OPPONENTS:** You will play against a different opponent every trial. However, you will always be an "A Player" and your opponent will always be a "B Player".

QUESTIONS

Name:______________________________

Player Identification number:__________

Please circle the correct answer.

1. Your payoff is listed first or second in each cell?

   FIRST SECOND

2. What happens if you and your opponent both choose to follow?

   YOU FOLLOW YOU LEAD

   YOU AND YOUR OPPONENT MOVE SIMULTANEOUSLY

3. If Player A chooses row R2, and Player B chooses column C3, what is your payoff (remember you are Player A)?

   4 5 6 7 8

4. Your take-home-pay will be determined based on each trial or based on one of trials 3-20 chosen at random?

   EACH TRIAL ONE TRIAL

DO YOU HAVE ANY QUESTIONS?

QUESTIONS

Name:__________________________________

Player Identification number:__________

Please answer the following questions (there are no incorrect answers)

1. If you move simultaneously you would prefer to choose row ________.
   Why?

2. If you lead you would prefer to choose row ________.
   Why?

3. If your opponent leads he/she will prefer to choose column ________.
   Why?

   Your response will be ________.

4. Circle your preference:

   LEAD FOLLOW MOVE SIMULTANEOUSLY

Treatment 2 Favorite Instructions

You are about to participate in an experiment about decision making. The purpose of this experiment is to gain insight into certain features of economic processes. If you follow the instructions carefully you can earn money. You will find it helpful to refer to the Payoff Table and Individual Record Sheet on the back of the handout as you read these instructions.

The experiment proceeds as follows:

1. **PLAYER OBJECTIVE:** You and your opponent will independently make decisions that will determine how much money you receive at the end of the experiment.

2. **PAYOFF TABLE:** You (Player B) will choose from columns C1 through C3. Your opponent (Player A) will choose from rows R1 through R3. The Payoff Table shows the amount of money you will receive given the column you select and the row your opponent selects. Your payoff is the second number in each cell. For example, if you select C2 and your opponent selects R2, then your payoff is 11 dollars.

3. **TRIALS:** The experiment consist of 20 trials. Trials 1 and 2 are for practice and will not affect your actual take-home-pay. Trials 3-20 are potentially binding (could determine how much money you receive at the end of the experiment). In each trial there are two stages. In the first stage you and your opponent will choose to lead or follow. This determines the order of play in the second stage. In the second stage you will select a column and your opponent will select a row according to order of play determined in the first stage.

Stage 1: Both you and your opponent will independently and simultaneously choose to lead or follow. If you choose to lead and your opponent chooses to follow, then in stage 2 you lead and your opponent follows. If you choose to follow and your opponent chooses to lead, then in stage 2 your opponent will lead and you will follow. If you both choose to lead or if you both choose to follow, you and your opponent will move simultaneously. The order of play in stage 2 is summarized below.

YOUR CHOICE	**YOUR OPPONENT'S CHOICE**	**ORDER OF PLAY**
Lead	Lead	Simultaneous
Follow	Follow	Simultaneous
Lead	Follow	B Leads, A Follows
Follow	Lead	A Leads, B Follows

Stage 2: If you <u>lead,</u> you select a column and reveal it to your opponent. Your opponent will <u>follow</u> by choosing a row with the knowledge of your choice. If you <u>follow</u>, your opponent will select a row and reveal the choice to you. You will then select a column with the knowledge of your opponent's choice. If you and your opponent move <u>simultaneously</u>, you select a column, your opponent selects a row, and you both reveal your choice to each other at the

same time. The Monitor will demonstrate how to reveal your choices.

4. **RECORDING TRIALS:** On your Individual Record Sheet you will record your opponent's identification number, Player A and B's choice to lead or follow, the actual leader stage 2, Player A and B's selected row or column, and <u>your</u> corresponding payoff. In the Actual Leader column enter an "S" if both players moved simultaneously.

5. **TAKE-HOME-PAY:** The actual take-home-pay is determined as follows: after all 20 trials are completed, the Monitor will randomly select one of trials 3-20 to determine your take-home-pay. You will receive the dollar value for that trial.

   <u>AN EXAMPLE</u>: Assume trial 17 is selected to determine take-home-pay. If in trial 17 you chose C2 and your opponent chose R2, your <u>payoff</u> is 11 dollars.

6. **OPPONENTS:** You will play against a different opponent every trial. However, you will always be a "B Player" and your opponent will always be an "A Player".

QUESTIONS

Name:__________________________________

Player Identification number:__________

Please circle the correct answer.

1. Your payoff is listed first or second in each cell?

   FIRST SECOND

2. What happens if you and your opponent both choose to follow?

   YOU FOLLOW YOU LEAD

   YOU AND YOUR OPPONENT MOVE SIMULTANEOUSLY

3. If Player A chooses row R2, and Player B chooses column C3, what is your payoff (remember you are Player B)?

   4 5 6 7 8

4. Your <u>take-home-pay</u> will be determined based on each trial or based on one of trials 3-20 chosen at random?

   EACH TRIAL ONE TRIAL

DO YOU HAVE ANY QUESTIONS?

QUESTIONS

Name:______________________________

Player Identification number:__________

Please answer the following questions (there are no incorrect answers)

1. If you move simultaneously you would prefer to choose column ________.
   Why?

2. If you lead you would prefer to choose column ________.
   Why?

3. If your opponent leads he/she will prefer to choose row ________.
   Why?

   Your response will be ________.

4. Circle your preference:

   LEAD FOLLOW MOVE SIMULTANEOUSLY

Treatment 2 Individual Record Sheet

Player Identification number:__________

Name:____________________________________

OPPONENT	TRIAL	Your Choice L or F	Your Opponent's Choice L or F	Actual Leader in Stage 2 (S= Simultaneous)	A's Row	B's Column	Your Payoff
	1	L F	L F				
	2	L F	L F				
	3	L F	L F				
	4	L F	L F				
	5	L F	L F				
	6	L F	L F				
	7	L F	L F				
	8	L F	L F				
	9	L F	L F				
	10	L F	L F				
	11	L F	L F				
	12	L F	L F				
	13	L F	L F				
	14	L F	L F				
	15	L F	L F				
	16	L F	L F				
	17	L F	L F				
	18	L F	L F				
	19	L F	L F				
	20	L F	L F				

APPENDIX C: DERIVATION OF ASYMMETRIC GAIN EQUILIBRIA

As explained in the text, the favorite maximizes expected returns

$$\underset{x_1}{Max}\ \pi_1 = \frac{\alpha x_1}{\alpha x_1 + x_2} G - x_1, \tag{32}$$

and the underdog maximizes expected returns with greater value placed on the gain denoted by $\delta > 1$. The underdog's objective function is

$$\underset{x_2}{Max}\ \pi_2 = \frac{x_2}{\alpha x_1 + x_2} \delta G - x_2. \tag{33}$$

Maximizing the favorite and underdog objective functions yield the following first-order conditions

$$\frac{\partial \pi_1}{\partial x_1} = \frac{\alpha x_2}{(\alpha x_1 + x_2)^2} G - 1 = 0 \tag{34}$$

$$\frac{\partial \pi_2}{\partial x_2} = \frac{\alpha x_1}{(\alpha x_1 + x_2)^2} \delta G - 1 = 0, \tag{35}$$

and the following second-order sufficient conditions

$$\frac{\partial^2 \pi_1}{\partial x_1^2} = -\frac{2\alpha G}{(\alpha x_1 + x_2)^3} < 0 \qquad {}_2 > 0 \tag{36}$$

$$\frac{\partial^2 \pi_2}{\partial x_2^2} = -\frac{2\delta G}{(\alpha x_1 + x_2)^3} < 0 \quad for\ x_1 > 0, \tag{37}$$

which are satisfied since expected returns π_i are strictly concave in x_i for i = 1,2. Define $R_1(x_2)$ and $R_2(x_1)$ favorite and underdog reaction functions derived from the first-order conditions

$$R_1(x_2) = \frac{1}{\alpha}\left[(\alpha G x_2)^{\frac{1}{2}} - x_2\right] \quad for\ 0 < x_2 \le \alpha G \tag{38}$$

$$R_2(x_1) = (\alpha\delta G x_1)^{\frac{1}{2}} - \alpha x_1 \quad for\ 0 < x_1 \le \frac{\delta G}{\alpha}. \tag{39}$$

The simultaneous move Nash equilibrium is given by

$$(x_1^N, x_2^N) = \left[\frac{\alpha\delta G}{(\delta + \alpha)^2}\ ,\ \frac{\alpha G}{\left(1 + \frac{\alpha}{\delta}\right)^2}\right]. \tag{40}$$

In the favorite leads subgame, player 1 (the favorite) chooses x_1 to maximize expected returns subject to the player 2's (the underdog) reaction function, $R_2(x_1)$

$$\underset{x_1}{Max}\ \pi_1 = \frac{\alpha x_1}{\alpha x_1 + x_2} G - x_1$$

$$s.t.\ x_2 = R_2(x_1) = (\alpha\delta G x_1)^{\frac{1}{2}} - \alpha x_1, \tag{41}$$

yielding the following first and second-order conditions

$$\frac{\partial \pi_1^{FL}}{\partial x_1} = \frac{1}{2}\left(\frac{\alpha G}{\delta x_1}\right)^{\frac{1}{2}} - 1 = 0 \tag{42}$$

$$\frac{\partial^2 \pi_1^{FL}}{\partial x_1^2} = -\frac{1}{4}\left(\frac{\alpha G}{\delta x_1^3}\right)^{\frac{1}{2}} < 0. \tag{43}$$

Using the first-order condition, the Stackelberg equilibrium with the favorite leading is given by

$$(x_1^{FL}, x_2^{FL}) = \left[\frac{\alpha G}{4\delta}\ ,\ \frac{\alpha G(2\delta - \alpha)}{4\delta}\right]. \tag{44}$$

To maintain a positive level of effort from the underdog in the favorite leads subgame requires $\alpha/\delta < 2$.

In the underdog leads subgame, the underdog chooses x_2 to maximize expected returns subject to the favorite's reaction function $R_1(x_2)$

$$\max_{x_2} \pi_2 = \frac{x_2}{\alpha x_1 + x_2}\delta G - x_2$$

$$s.t.\ x_1 = R_1(x_2) = \frac{1}{\alpha}\left[(\alpha G x_2)^{\frac{1}{2}} - x_2\right], \tag{45}$$

yielding the following first and second-order conditions

$$\frac{\partial \pi_2^{UL}}{\partial x_2} = \frac{\delta}{2}\left(\frac{G}{\alpha x_2}\right)^{\frac{1}{2}} - 1 = 0 \tag{46}$$

$$\frac{\partial^2 \pi_2^{UL}}{\partial x_2^2} = -\frac{\delta}{4}\left(\frac{G}{\alpha x_2^3}\right)^{\frac{1}{2}} < 0. \tag{47}$$

Using the first-order condition, the Stackelberg equilibrium with the underdog leading is given by

$$(x_1^{UL}, x_2^{UL}) = \left[\frac{\delta G(2\alpha - \delta)}{4\alpha^2}, \frac{\delta^2 G}{4\alpha}\right]. \tag{48}$$

To maintain a positive level of effort from the favorite in the underdog leads subgame requires $\delta/\alpha < 2$. If $\delta = 1$, the result is the original endogenous timing game.