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Abstract
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Two-Stage Team Rent-Seeking: Experimental Analysis

John Cadigan*

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JEL Classification: D72, C91

1. Introduction

In his seminal contribution on rent-seeking activity, Tullock (1967, 1980) develops a model in which players choose effort levels to influence the chance they are awarded a prize. If player effort does not contribute to the value of the prize, rent-seeking effort results in a social welfare loss and can be viewed as inefficient (see also Krueger 1974; Posner 1975). Most research stemming from Tullock's model focuses on contests with simultaneously chosen effort levels and in which the contest prize is awarded to only one contestant or group (see, e.g., Hillman and Katz 1984; Appelbaum and Katz 1987; Snyder 1989; Nitzan 1991; Gradstein 1993; Fullerton and McAffee 1999).

Many real-world contests are more complicated. For example, congressional elections in the United States typically involve two candidates that receive support from the two major political parties. Both candidates and their parties benefit from a successful bid to capture a seat, and there could be important connections between their effort decisions. A high-quality challenger exerting effort early in an election cycle might receive greater party support by demonstrating an ability to fare competitively in the election. Alternatively, an incumbent's effort might discourage a competitive challenge, freeing party resources for other purposes. In

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this case, the timing of effort is important, and the contest "prize" is awarded to both the candidate and the candidate's party.

As another example, many public policy issues are characterized by interest group lobbying from multiple groups on either side of an issue. Successful lobbying by the National Rifle Association, for example, benefits other groups sharing their policy preferences. In a sense, public policy issues motivating lobbying effort can generate public prizes that affect multiple constituencies in different ways. An important aspect of these environments is their team-oriented nature, typically placing groups in one of two camps (for or against free trade, gun control, choice, etc.).

This paper contributes to the literature on rent-seeking by developing and experimentally testing a two-stage team rent-seeking model in which the contest prize is awarded to each member of the winning team. In one variant of the model, aggregate team effort determines the probabilities associated with the contest outcome. In this case, an individual team member's effort serves as a perfect substitute for the effort of other team members. When effort decisions are sequenced, early movers have the potential to free ride on the effort choices of their later moving teammates. This suggests that lobbying for public policy favors could be subject to the same collective action problems associated with public goods provision. In a second variant of the model, the timing of effort matters. In particular, early effort choices shape the competitive structure of the contest, and in this case early movers cannot free ride on their teammates. The theoretical results also show that effort levels are highest in "competitive contests," with any asymmetries in early effort choices leading to reductions in effort by late-moving teammates.

The theory is tested by laboratory experimental methods. A few authors have used experimental methods to study rent-seeking (Milner and Pratt 1989, 1991; Shogren and Baik 1991; Davis and Reilly 1998; Önçüler and Croson 1998; Potters, de Vries, and Van Winden 1998). Typically, subjects are given an endowment that can be used to invest in a chance to win a prize, with much of the research focusing on symmetric contests with simultaneous effort choices. Generally, subjects tend to overinvest relative to equilibrium predictions, although this tendency diminishes with experience and opportunities for repeated play within a subject group. The paper is also connected to a small but growing literature that examines rent-seeking in more complicated frameworks. Motivated by models of research and development expenditures, Isaac and Reynolds (1988) examine the effects of group size and the degree to which the contest prize is shared on individual investment decisions. They find that a shared prize leads to less investment at the individual level. Anderson and Stafford (2003) examine the effects of cost heterogeneity, group size, and an entry fee on subject participation and expenditures. They find that increases in group size, heterogeneity in costs, and the presence of an entry fee (which makes the decision-making exercise a two-stage game) decrease the number of subjects choosing to participate in the contest. Consistent with theory, increases in group size decrease individual expenditures but increase group expenditures. The use of an entry fee typically reduced individual expenditures, but the results with respect to individual expenditures under cost heterogeneity were mixed. Davis and Reilly (1998) add a "rent-defending buyer" who has a higher value for the contest prize than a group of rent-seeking sellers. In some cases, the buyer bids against one seller who is the winner of a first-stage seller auction, which creates a two-stage game with heterogeneity in the contest prize. Generally, a rent-defending buyer is able to reduce aggregate rent-seeking. In a later paper, Davis and Reilly (2000) examine the effects of experience and adding additional rent-defending buyers, finding that the presence of additional buyers limits efficiency gains. They also find that that experience has limited ability to reduce social costs or the variability of bids.

Below, I examine rent-seeking in a team environment with a sequential structure and a contest prize that is not excludable among teammates. Consistent with existing research, in all treatments, the experimental results show significant overinvestment relative to the Nash equilibrium prediction. Regarding the qualitative predictions of the model, the results are mixed. Early-moving subjects chose higher effort levels when their late-moving teammate's effort served as a complement rather than a substitute. Effort choices of late movers were not best responses in a game theoretic sense but did display patterns consistent with the shape of the best response functions. Generally, late-moving subjects appear to have responded to the effort levels of their early-moving opponents in the case of substitutable effort levels and to the effort levels of their teammates when effort levels were complements. In contrast to the theoretical predictions, however, early movers did not exploit opportunities to free ride in either single-shot or repeated play treatments, perhaps reflecting some concern for their teammate's payoff.

The remainder of the paper is organized as follows: Section 2 presents the model and theoretical results; section 3 details the experimental design, procedures, and results; and section 4 concludes.

2. The Model

Building on the basic structure in Tullock (1980), consider the following two-stage rent-seeking game. In the first stage, two players simultaneously choose effort levels (x and y). These choices are revealed to two second-stage players, who then simultaneously choose effort levels (X and Y). All players are assumed to be risk neutral, and have identical and constant marginal cost of effort (C). The contest prize (B) is awarded to each member of the winning team, with each team consisting of one first-stage and one second-stage player. Effort levels are restricted to be nonnegative.[1] The probability that team X wins the contest (the "contest success function") is

$$Px = \frac{x+X}{x+X+y+Y}.$$

Assuming all players act to maximize expected payoffs, the objective functions for the second-stage players (given the first-stage choices of x and y) are

$$U_x(x,X,y,Y) = \frac{x+X}{x+X+y+Y}B - CX$$

and

$$U_y(x,X,y,Y) = \frac{y+Y}{x+X+y+Y}B - CY.$$

[1] This restriction is consistent with many real-world policy environments. For example, if multiple groups lobby a policy maker, a group acting later cannot reduce lobbying effort exerted previously.

This leads to the following formulas for Nash equilibrium spending in the second stage:

$$X^* = \frac{B}{4C} - x,$$

$$Y^* = \frac{B}{4C} - y.$$

Substituting the second-stage equilibrium expenditure formulas into the objective functions of the stage 1 players and simplifying yields:

$$U_x = \frac{B}{2} - Cx$$

and

$$U_y = \frac{B}{2} - Cy.$$

This implies the subgame perfect Nash equilibrium to this game has $x^* = y^* = 0$, and $X^* = Y^* = B/4C$. Essentially, when the contest prize goes to both members of the winning team, irrespective of their relative effort levels, first-stage players are able to shift the burden of effort completely on their teammates. In anticipation of some of the experimental results to follow, note also that the nonnegativity restriction would be binding for stage 2 players if the stage 1 players chose effort greater than $B/4C$. In this case, although stage 2 players would like to reduce their team's effort, the best they can do is not add to it.

The results demonstrate that stage 1 players can free ride on the effort of their stage 2 counterparts. In equilibrium, each player equates the marginal benefit and marginal cost of effort. When the contest prize is not excludable between teammates, stage 2 effort levels influence the probability that both members of a team win the prize. Thus, an increase in stage 2 effort reduces the marginal benefit of further effort for both team members. With constant marginal costs, and anticipating the effort level chosen in stage 2, the stage 1 player can free ride, relying on the stage 2 teammate to bring the marginal benefit of effort for both team members into equality with their marginal costs. In a sense, the shared nature of the prize induces a collective action problem similar to those associated with the provision of public goods. Whereas in the public goods case this is typically viewed as inefficient, free riding in the rent-seeking case could be beneficial because it limits wasteful spending.

One limitation of the previous model is that the timing of effort does not matter—effort exerted in stage 2 is a perfect substitute for stage 1 effort in the sense that both enter the contest success function in exactly the same way. In many environments, however, early effort shapes the structural characteristics of the contest. For example, in elections for the U.S. Congress, early spending by a high-quality challenger can draw the attention of the major political parties, leading to significant party support as the election cycle closes. Alternatively, heavy spending by an incumbent early in an election cycle may dissuade a high-quality challenger, leading to a lopsided race that draws little party support. Although many contest success functions could capture this feature, I chose to consider a modified version of the "natural advantage" approach used by Snyder (1989). Snyder's paper considers the allocation of party spending across several congressional districts that vary according to competitiveness or natural advantage for one of the parties. Similar to the second-stage effort choice results below, he finds that party spending levels should be high in competitive contests and low in contests in which additional effort has little effect on electoral probabilities. His approach, however, ignores the effect of candidate spending and, as such, the interdependence of candidate and party spending. In the present framework, stage 1 expenditures can be interpreted as candidate spending that influences the natural advantage in a district.[2] Specifically, let the probability that team X wins the contest be

$$P_x = \frac{\alpha X}{\alpha X + (1-\alpha) Y},$$

with

$$\alpha = \frac{x}{x+y}.$$

In this case, α determines the competitiveness of the contest, with values closer to 1 indicating a greater advantage for team X. If stage 1 participants choose identical effort levels, $\alpha = ½$ and drops out of the expression for P_x. However, when $x > y$, $\alpha > ½$, and the stage 2 effort of the player on team X is given a higher weight than the stage 2 effort of the player on team Y.[3] Given the stage 1 effort levels, which determine α, the objective functions of the stage 2 players can be expressed as

$$U_x(x,X,y,Y) = \frac{\alpha X}{\alpha X + (1-\alpha) Y} B - CX$$

and

$$U_y(x,X,y,Y) = \frac{(1-\alpha) Y}{\alpha X + (1-\alpha) Y} B - CY.$$

The expressions for equilibrium second-stage expenditures are

$$X^* = \frac{(1-\alpha)\alpha B}{C}$$

and

$$Y^* = \frac{(1-\alpha)\alpha B}{C}.$$

Substituting the values for X^*_i and Y^*_i into the stage 1 objective functions yields (because $X^* = Y^*$, $P_x = \alpha$)

$$U_x(x,y) = \frac{x}{x+y} B - Cx$$

and

$$U_y(x,y) = \frac{y}{x+y} B - Cy.$$

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[2] For more on this issue, see Cadigan (2006).

[3] Alternatively, the contest is a "weighted raffle," whereby stage 1 players determine the weights for the raffle. This is described in the section containing the experimental results.

Solving for the equilibrium first-stage effort levels yields

$$x^* = \frac{B}{4C}$$

and

$$y^* = \frac{B}{4C}.$$

Thus, the subgame perfect equilibrium has $x^* = X^* = y^* = Y^* = B/4C$. In comparison with equilibrium effort levels for the previous contest success function, stage 2 effort is unchanged, but stage 1 effort is higher. In contrast to the previous results, when early effort influences the competitiveness of the contest, stage 1 players cannot free ride: for stage 2 spending to be effective, the stage 1 participant must exert effort. In equilibrium, stage 1 players match effort levels, $\alpha = \frac{1}{2}$, and the stage 2 decisions remain unchanged from the previous model in which stage 1 players free ride.

As in Snyder (1989), the formulas for X^* and Y^* demonstrate that aggregate stage 2 effort is highest when $\alpha = \frac{1}{2}$. Values of α far from $\frac{1}{2}$ (which occur off the equilibrium path) create an uncompetitive contest and generate reductions in effort by both advantaged and disadvantaged stage 2 players. When stage 1 spending generates a clear advantage, the disadvantaged stage 2 player reduces effort because it is not as productive in affecting the contest outcome. This allows the advantaged player to reduce effort too, while maintaining a high expected value from the prize. Thus, the equilibrium results are consistent with the long-standing observation in U.S. politics that the major parties invest only in competitive races. Asymmetries in terms of the contest success function (perhaps imparted by name recognition or other perquisites of incumbency) might reduce aggregate rent-seeking effort by limiting the number of competitive contests.

In the next section, the models are put to an experimental test. With the use of inexperienced subjects with a one-shot design, separate treatments were conducted to analyze effort choices for each contest success function. Because early movers did not free ride in the case of substitutable effort levels and because this result could have been influenced by the one-shot nature of the design, I also conducted a multiperiod treatment to examine the effects of experience on subject decision making.

3. Experimental Design, Procedures, and Results

All subjects were paid volunteers recruited from the undergraduate population at American University. Before volunteering, subjects received an e-mail invitation to participate in a decision-making exercise. The invitation indicated that participants would be paid a \$5 "show up" fee in addition to an amount that would depend on their decisions and the decisions of others in the experiment. All payments were made in cash, privately, at the end of the experimental session. On arrival at the experiment site, subjects were seated and given the experiment instructions (reproduced in the Appendix), which can be summarized as follows.

One-Shot Treatments: Team Rent-Seeking 1

All participants were endowed with \$6 that could be used to purchase raffle tickets for a monetary prize of \$4. Tickets for the raffle cost \$0.25. Subjects were informed they would be making decisions in a "team raffle" environment wherein each team consisted of two participants. One member of each team was referred to as a stage 1 participant and the other as a stage 2 participant. Each team was matched against one other team, so that each stage 1 participant had a stage 1 opponent, a stage 2 teammate, and a stage 2 opponent. All pairing of participants was random and anonymous in the sense that subjects were never informed of the identity of their teammate or either of their opponents.

Separate \$4 prizes were awarded to each member of the winning team. Before making decisions, subjects were told that the probability associated with their team winning the prize was

$$\text{Probability your team wins the prize} = \frac{\text{(Number of tickets your team buys)}}{\begin{array}{c}\text{(Total number of tickets bought by}\\ \text{your team and your opponent's team)}\end{array}}.$$

In addition, subjects were given access to payoff tables that indicated the expected prize amount associated with different combinations of team ticket purchases.

Stage 1 participants made their ticket purchase decisions first, indicating the desired amount on a decision sheet included with the instructions. After making their choices, the stage 1 decision sheets were collected, and the decision sheets of each stage 2 participant were updated to include the number of tickets purchased by their stage 1 teammate and stage 1 opponent. Next, stage 2 participants indicated the number of tickets they wished to purchase by filling in the desired amount on their decision sheet, and the stage 2 decision sheets were collected. Each subject's decision sheet was updated to include all decisions made by a subject's teammate or opponents. After entering the decisions in a computer, the raffles were conducted using a computerized random number generator that made the draws using the probabilities associated with subject ticket purchases, and the results were recorded on subject decision sheets. Subjects were then individually called out of the room, shown their decision sheet, and paid in cash their experimental earnings. Earnings consisted of the \$5 show up fee, the portion of the \$6 endowment not spent on tickets, and the \$4 prize if applicable.

To put the experimental results in context, it is important to emphasize the one-shot nature of team rent-seeking 1 (TRS1). Subjects were inexperienced with the design, and were not given the opportunity to engage in repeated play. This issue is addressed in the multiperiod experiments described in a later section. Although the one-shot design puts the theory to a difficult test, it has the advantage of being short, generating statistically independent observations, and eliminating the potential for strategic spillovers across periods.

Results for TRS1

A total of 68 subjects participated in the TRS1 treatment in four sessions with about 16 subjects per session.[4] The 34 stage 1 and 34 stage 2 subjects made ticket purchase decisions for a total of 17 separate contests. Each session lasted approximately 35 minutes, and average

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[4] One session had 20 subjects.

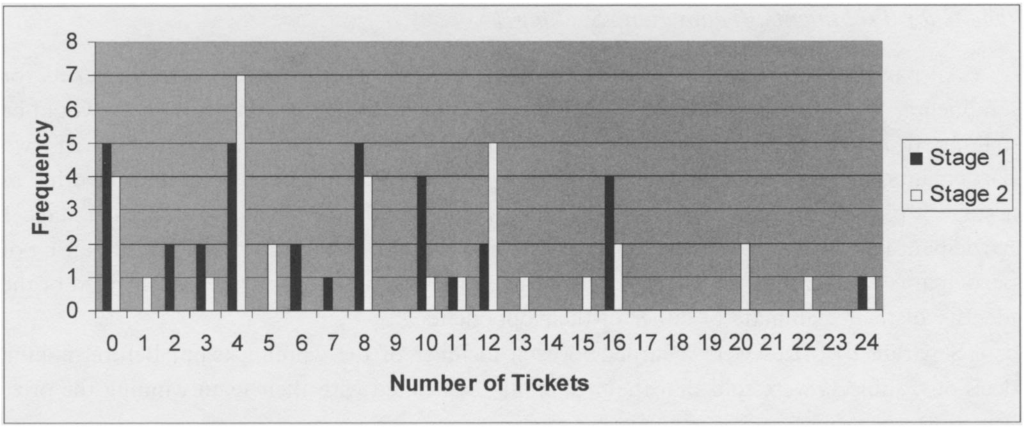

Figure 1. TRS1 Ticket Purchases

earnings (inclusive of the \$5 participation fee) for the stage 1 and stage 2 participants were \$11.15 and \$10.77, respectively. For this treatment, the subgame perfect Nash equilibrium has all stage 1 participants purchase zero tickets and all stage 2 participants purchase four tickets. Figure 1 displays the frequency distribution for ticket purchases for the TRS1 treatment.

As the distribution shows, the data do not support the equilibrium point predictions. The average and mode of stage 1 ticket purchases (7.41 and 4, respectively) were much higher than the equilibrium prediction of zero. The average and mode of stage 2 purchases (8.85 and 4) were also high. Although positive expenditures in the first stage make it inappropriate to compare second-stage expenditures to the equilibrium prediction, comparison of second-stage ticket purchases relative to "best responses" is informative. For the parameters of this treatment, it is never a best response for total team ticket purchases to exceed four. Thus, if a stage 1 teammate buys four or more tickets, the best response (given nonnegativity of purchases) for their stage 2 teammate is to purchase zero tickets. Also, for the parameters of this treatment, the best response to a stage 1 opponent's purchase of 15 or more tickets is to purchase zero tickets (irrespective of stage 1 teammate's ticket purchase). Of the 27 stage 2 subjects whose best response was 0, only four actually purchased zero tickets. The results clearly indicate that first- and second-stage participants overinvest relative to the Nash prediction. This result is consistent with the experimental results of the majority of previous two-person rent-seeking contests, and the literature on "bubbles" and false equilibria (see Sunder [1995] or Smith, Suchanek, and Williams [1988] for examples).

Interestingly, although the average stage 2 ticket purchase was higher, differences in stage 1 and 2 ticket purchases are not statistically significant (Wilcoxon $p = 0.432$). This suggests that the stage 1 players did not exploit their strategic opportunity to free ride. Failure to do so is consistent with the results of several experiments on public goods (Isaac and Walker 1988) and could illustrate concerns for other participant's payoffs as in Levine (1998). In particular, the team-oriented aspect of the game might have led subjects to increase purchases so that their teammate had a greater chance to receive the prize. Alternatively, and as stated above, the one-shot nature of design might not have given subjects the opportunity to learn to free ride because there was no repeated play.

Furthermore, although the data indicate that stage 2 ticket purchases were not best responses, insight into the behavior of the stage 2 subjects can be gained by breaking ticket

Table 1. OLS Regression Output; Dependent Variable: S2 Ticket Purchase

Variable	Coefficient Estimate	p-Value	VIF
S1TEAM	−0.08	0.739	1.39
S1OPP	−1.66	0.087	21.48
OPPZERO	−28.26	0.106	27.69
OPPMOD	−33.46	0.058	45.91
S1OPP × *OPPMOD*	1.98	0.065	13.68
Constant	39.94	0.025	
R^2	0.16		

purchases into the following categories: zero, moderate (defined as 1–14), and high (defined as 15–24). Although the choice of 15 tickets as the cutoff point between the moderate and high categories is somewhat arbitrary, note that the best response for a stage 1 player to an opponent's purchase of 15–24 is 0. In other words, ticket purchases are classified as "high" if they are sufficient to keep a rational stage 2 opponent from participating in the contest.[5] Table 1 displays the results of an ordinary least squares (OLS) regression of stage 2 ticket purchases on stage 1 teammate purchases (*S1TEAM*), stage 1 opponent purchases (*S1OPP*), intercept dummies for whether the stage 1 opponent purchase was 0 (*OPPZERO*) or in a moderate range (*OPPMOD*), and an interaction term (*S1OPP* × *OPPMOD*). Note that the baseline case for this specification is a subject whose stage 1 opponent made high purchases.[6]

The coefficient estimates indicate that in the case of high participation, an increase in a stage 1 opponent's purchase led to a decrease in the stage 2 subject's purchase. Relative to the case of high participation, the *OPPZERO* coefficient indicates stage 2 purchases were lower when the stage 1 opponent purchased zero tickets, and the estimated coefficient on the interaction term indicates that in cases of moderate participation (1–14 tickets purchased), increases in a stage 1 opponent's purchases led to increases in stage 2 ticket purchases. A limitation of this specification is the collinearity between the stage 1 opponent's ticket purchase variables (as indicated by the high variance inflation factors [VIFs] reported in Table 1). The severe collinearity might help explain why the coefficient estimates achieve only marginal statistical significance (with a range of $p = 0.05$–0.11).

Although the data clearly indicate overinvestment by stage 2 participants relative to their best responses, the regression results suggest the pattern of purchases (increasing in opponent's purchases over one range and decreasing over a second, higher range of opponent's purchases) is consistent with the shape of the theoretical best response functions. This is also reflected in the regression estimates of the specification presented in Table 2, which includes the squared value of a stage 1 opponent's purchases ($S1OPP^2$) in addition to *S1TEAM, OPPZERO*, and *S1OPP*.

Note, in particular, the positive estimated coefficient for *S1OPP* and negative coefficient on $S1OPP^2$. The magnitude of the estimated coefficients suggests that the turning point is

[5] Also, subjects buying more than 15 tickets spent as much or more on tickets as the value of the prize, which is irrational if subjects only care about their own earnings.

[6] Alternative specifications using a stage 1 teammate's purchases (zero, moderate, and high) or both stage 1 teammate's and stage 1 opponent's purchases generate coefficient estimates that are qualitatively similar but are not statistically significant. Although the coefficient estimate is not significant, the *S1TEAM* variable is included to avoid an omitted variable bias.

Table 2. OLS Regression Output; Dependent Variable: S2 Ticket Purchase

Variable	Coefficient Estimate	p-Value	VIF
S1TEAM	−0.01	0.959	1.36
OPPZERO	9.71	0.085	2.88
S1OPP	1.54	0.085	18.46
S1OPP^2	−0.06	0.089	13.19
Constant	1.56	0.775	
R^2	0.13		

around 14 tickets.[7] Taken as a whole, the results offer limited support for the model predictions.

One-Shot Treatments: Team Rent-Seeking 2

The same procedures were used for the team rent-seeking 2 (TRS2) treatment, but the contest success function was changed to

$$\text{Probability your team wins the prize} = \frac{\text{(Weighted ticket purchases of your team)}}{\text{(Total weighted ticket purchases of your team and your opponent's team)}}.$$

Weighted ticket purchases for a team was defined as the number of tickets purchased by the stage 1 participant multiplied by the stage 2 purchases of their teammate (which is functionally equivalent to the second contest success function used in the theory section). The value of the endowment, prize, cost of ticket purchases, and sequencing of decisions remained as in TRS1.

Results for TRS2

A total of 76 subjects participated in the TRS2 treatment in four sessions with about 20 subjects per session.[8] The 38 stage 1 and 38 stage 2 subjects made ticket purchase decisions for a total of 19 separate contests. Each session lasted approximately 35 minutes, and average earnings (inclusive of the \$5 participation fee) for the stage 1 and stage 2 participants were \$10.30 and \$10.86, respectively. For this treatment, the Nash equilibrium has all participants purchase four tickets. Figure 2 displays the frequency distribution for ticket purchases for the TRS2 treatment.

Similar to the results from TRS1, the data display significant overinvestment relative to the equilibrium prediction.[9] For stage 1 participants, the mean and mode of ticket purchases were 10.79 and 8, respectively, and for stage 2 participants the mean and mode were 8.57 and 4.

Importantly, although the point predictions from both TRS1 and TRS2 are not supported, average stage 1 ticket purchases did rise from 7.41 in TRS1 to 10.79 in TRS2, and

[7] Note also that no stage 1 subject purchased 13, 14, or 15 tickets. Thus, altering the specification presented in Table 1 so that high purchases are defined as 14–24 (which would be consistent with the turning point estimated in Table 2) does not influence the regression results.

[8] One session had 16 subjects.

[9] Given the parameters for this treatment, the maximum ticket purchase consistent with the best response functions in stage 2 is four (this occurs when both stage 1 players buy the same number of tickets). Comparing actual stage 2 purchases with the best responses shows that 30 of the 38 stage 2 participants overinvested relative to the best response.

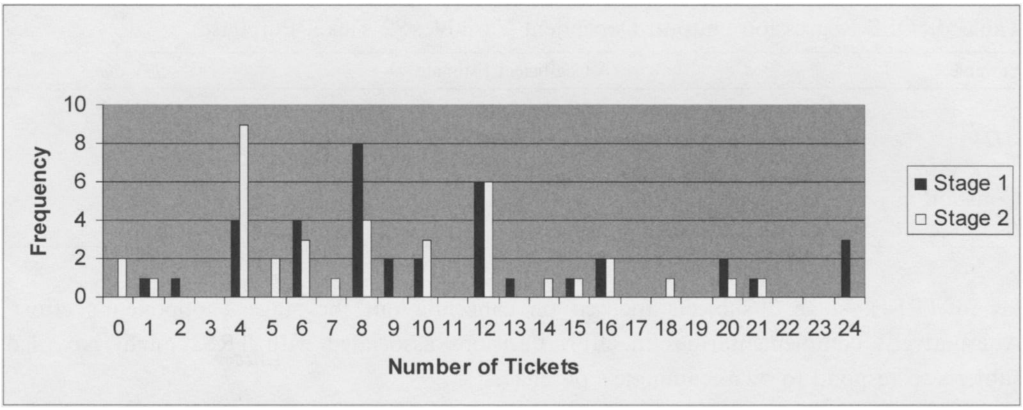

Figure 2. TRS2 Ticket Purchases

the difference is statistically significant (Mann–Whitney $p = 0.019$). Thus, although overinvestment relative to the Nash prediction was significant in both treatments, the qualitative theoretical prediction regarding an increase in stage 1 purchases is supported by the data. Intuitively, subjects exerted more effort when a teammate's effort was a complement to rather than a substitute for own effort.

As with the TRS1 treatment, stage 2 ticket purchases, although not best responses, displayed consistent patterns. Table 3 reports the results of a regression of stage 2 ticket purchases on the stage 1 purchases of opponent (*S1OPP*) and teammate (*S1TEAM*), as well as a dummy variable for whether the stage 1 teammate's purchases were moderate (*TMMOD* = 1 if stage 1 ticket purchase is between 1 and 14) and an interaction term (*S1TM* × *TMMOD*).[10]

The coefficient estimates and significance results suggest stage 2 purchases were responsive to a stage 1 teammate's purchase. Holding constant the effect of a stage 1 opponent's purchase, an increase in stage 1 teammate's purchases led to a decrease in ticket purchases by stage 2 participants. The coefficient on the interaction term suggests the effect of an increase in stage 1 purchases was less severe in the moderate range, but still negative (the sum of coefficients on *S1TEAM* and the interaction term is negative). It is interesting that stage 2 purchases varied in a statistically significant way with the stage 1 opponent's purchase for TRS1 and the stage 1 teammate's purchase for TRS2. It could be that when team member effort is a perfect substitute

[10] Alternative specifications, with a stage 1 opponent's purchases in categories (moderate and high) or with the use of the difference or ratio of stage 1 opponent and teammate purchases, generate coefficient estimates that are not statistically significant. Although the coefficient estimate is not significant, the *S1OPP* variable is included to avoid an omitted variable bias.

Table 3. OLS Regression Output; Dependent Variable: S2 Ticket Purchase

Variable	Coefficient Estimate	*p*-Value	VIF
S1OPP	0.06	0.680	1.04
S1TEAM	−1.24	0.020	13.52
TMMOD	−23.68	0.033	28.67
S1TM × *TMMOD*	1.17	0.056	9.35
Constant	32.36	0.005	
R^2	0.169		

Table 4. OLS Regression Output; Dependent Variable: S2 Ticket Purchase

Variable	Coefficient Estimate	p-Value
α	2.967	0.812
ADV	3.74	0.696
$ADV \times \alpha$	−8.91	0.613
Constant	8.27	0.053
R^2	0.02	

(as in TRS1), stage 2 subjects focused on canceling out the stage 1 opponent's effort. Alternatively, complementarities in effort decisions associated with TRS2 might have led subjects to respond to own teammate's purchases.

An alternative econometric specification for stage 2 purchases can be tied directly to the theoretical model. The model suggests stage 2 ticket purchases should reach their peak when $\alpha = ½$ (with α defined as a stage 1 teammate's purchase divided by total stage 1 purchases). If a stage 2 participant is at a disadvantage ($\alpha < ½$), increases in α should lead to greater expenditures because they make the contest more competitive. Alternatively, for an advantaged stage 2 participant, increases in α above ½ make the contest less competitive and allow for a reduction in purchases. Table 4 presents the results of a regression of stage 2 purchases on α, a dummy variable for whether the stage 2 subject was advantaged ($ADV = 1$ if $\alpha > ½$), and an interaction term ($ADV \times \alpha$).

Although the signs of the estimated coefficients are consistent with the theory, none of the estimated coefficients are statistically significant. Unfortunately, although there was significant variation in stage 1 ticket purchases (and as such in α), in no contest did stage 1 participants purchase an identical number of tickets. This makes it difficult to assess whether first-stage asymmetries reduce rent-seeking effort in the second stage (as predicted by the model). Several other aspects of the TRS2 treatment could explain the lack of statistically significant results. In particular, the two-stage nature of the game, which introduces a "team"-oriented component, could lead stage 2 participants to respond directly to a teammate's or opponent's action rather than consider how these actions influence the marginal benefit and cost of ticket purchases. As suggested earlier, the presence of teammates might also highlight concerns for other participants' payoffs. Finally, the lack of repeated play or subjects who were experienced with the institution might have increased the variance associated with subject decision making, leading to coefficient estimates that are not statistically significant.

Discussion of One-Shot Results

Several aspects of the experimental results from the one-shot treatments support theoretical predictions. Stage 1 ticket purchases were higher when team member effort served as a complement, and the differences in stage 1 ticket purchases between TRS1 and TRS2 are statistically significant. Stage 2 ticket purchases, although high relative to best responses, were broadly consistent with the shape of the best response functions. However, the lack of free riding associated with stage 1 ticket purchases in TRS1 is surprising and not consistent with theoretical predictions. As noted earlier, this could have been related to the one-shot nature of TRS1 and the reliance on inexperienced subjects. To investigate whether experience with the institution and opportunities for repeated play would influence the free riding result, I conducted the following multiperiod treatment.

Multiperiod Treatment for TRS1

For the multiperiod treatment, the stage game described in TRS1 (which used the contest success function for which team member efforts were perfect substitutes) was repeated for a total of eight periods. The following modifications were made to the parameter values. In each period, participants were endowed with \$2.00 that could be used to purchase \$0.10 raffle tickets for a monetary prize of \$1.60. The periods were independent in the sense that subjects could not use earnings from prior rounds to purchase tickets in any subsequent round. To give subjects experience with a particular role, they were assigned to be a stage 1 or stage 2 participant for the duration of the experiment. However, subjects were randomly and anonymously repaired at the beginning of each period to determine teammates and opponents and were never informed of the identity of any of their teammates or opponents. At the beginning of each period, stage 1 participants indicated the number of tickets they wanted to purchase on their decision sheets, the sheets were collected and the information was recorded on the stage 2 decision sheets, which were then distributed. Stage 2 participants indicated their ticket purchase decision, their decision sheets were collected, and the raffles were conducted with a computerized random number generator. Subject decision sheets were updated to include all information regarding teammate and opponent ticket purchases, whether their team won the raffle, and their earnings from the period. The stage 1 decision sheets were returned, and the second period began (with a random and anonymous rematching of subjects). At the conclusion of the eighth period, subjects were individually called out of the room and paid in cash their experimental earnings, which were the sum of earnings in the eight periods, plus a \$5 show-up fee.

Results from the Multiperiod Treatment

A total of 48 subjects participated in the TRS1 treatment, in three sessions with 16 subjects per session. The 24 stage 1 and 24 stage 2 subjects made ticket purchase decisions for a total of 96 separate contests. Each session lasted approximately 1 hour and 30 minutes, and average earnings (inclusive of the \$5 participation fee) for the stage 1 and stage 2 participants were \$22.50 and \$23.58, respectively. In each period, the subgame perfect Nash equilibrium for this treatment has all stage 1 participants purchase zero tickets and all stage 2 participants purchase four tickets. Figure 3 displays the frequency distribution for ticket purchases for the multiperiod treatment.

Similar to previous results, the data display significant overinvestment relative to the Nash equilibrium prediction. Average ticket purchases for stage 1 and stage 2 participants were 6.13 and 4.77, respectively. However, of the 192 separate decisions for stage 1 participants, 33 (approximately 17%) were 0, and for stage 2 participants, 49 of 192 (approximately 26%) were best responses. Because these percentages are higher than those for the TRS1 and TRS2 treatments, it seems that experience with the institution might have influenced play for some subjects. Given the experience generated by repeated play, it is useful to analyze ticket purchases by round. Figure 4 displays the average ticket purchase for stage 1 and stage 2 participants by round.

The data clearly demonstrate that stage 1 participants did not exploit their free riding opportunity, even with the experience generated by repeated play. Although average ticket purchases for stage 1 participants declined over the course of the experiment (a result consistent

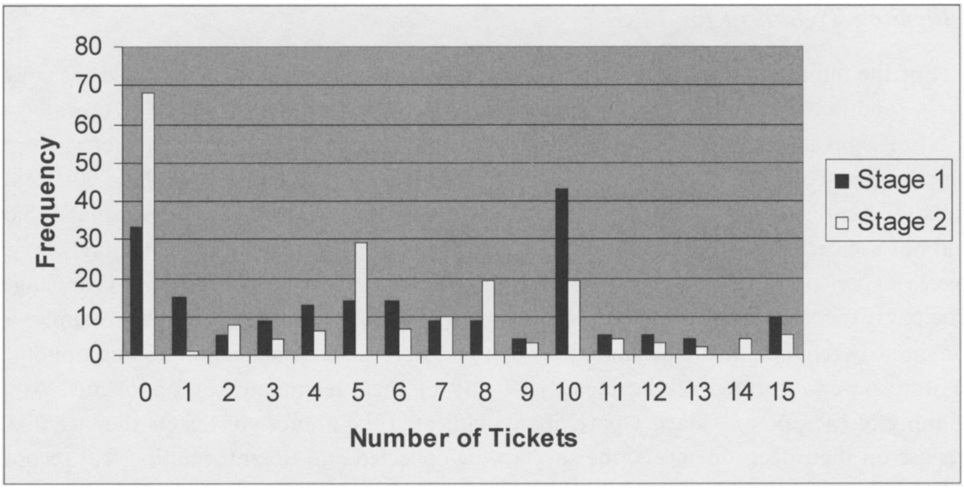

Figure 3. Multiperiod Ticket Purchases

with several rent-seeking experiments using simultaneous decision making over multiple periods), average ticket purchases for stage 1 participants were higher than average ticket purchases for stage 2 participants in each round. Over the final four rounds of the experiment, differences in stage 1 and stage 2 ticket purchases were not statistically significant (Mann–Whitney $p = 0.317$). This reinforces the results obtained in TRS1; significant levels of free riding occur even when subjects are experienced with the institution.

As was the case with TRS1, although stage 2 participants did not "best respond" in a game theoretic sense, their purchases were broadly consistent with the shape of best response functions. Table 5 displays the results of a regression of stage 2 ticket purchases in a period on

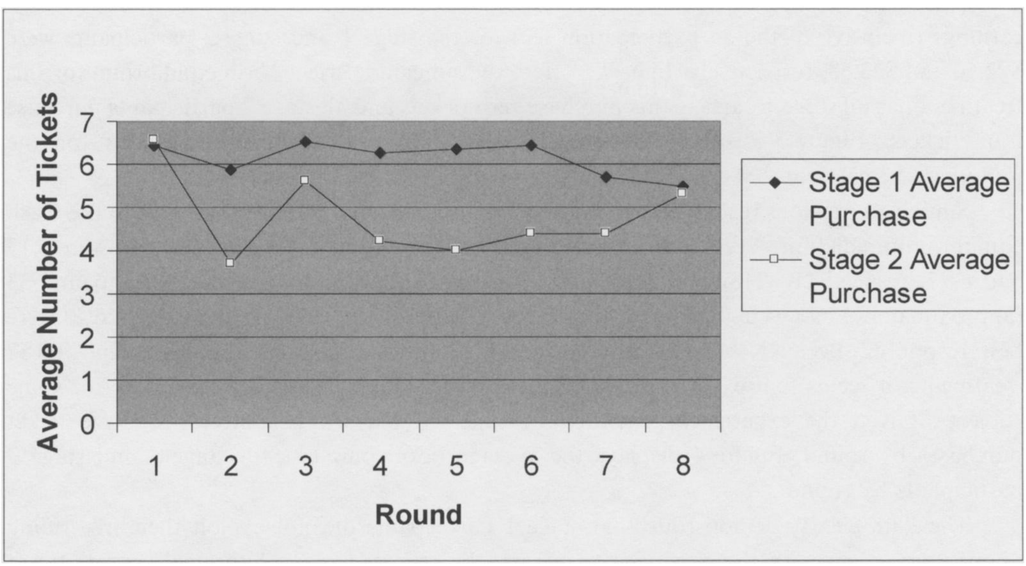

Figure 4. Average Ticket Purchases by Round

Table 5. OLS Regression Output; Dependent Variable: S2 Ticket Purchase

Variable	Coefficient Estimate	p-Value
OWN-1	0.22	0.010
PROBWIN	0.663	0.109
PROBWIN^2	−0.07	0.043
RD	0.14	0.434
SESSION1	1.18	0.187
SESSION2	0.50	0.571
Constant	1.78	0.146
R^2	0.11	

lagged ticket purchases (*OWN-1*),[11] the probability a player would win the contest if both stage 2 players bought zero tickets (*PROBWIN* = stage 1 teammate purchase/total purchase of stage 1 teammate and opponent) and this value squared (*PROBWIN*^{2}), and round (*RD*) and dummy variables for the experimental session the subject participated in (*SESSION 1, SESSION 2*).

The coefficient estimates and significance results for the *PROBWIN* and *PROBWIN*^{2} terms suggest stage 2 ticket purchases and *PROBWIN* varied according to an inverted U shape, which is consistent with the intuition that subjects exert greater effort in close contests. Note also that the coefficient estimates on session are not significant, nor is the round coefficient.[12] Taken as a whole, the results from the multiperiod treatment reinforce those from TRS1. The lack of free riding associated with stage 1 ticket purchases does not appear to be an artifact of subject experience, and might be related to the team-oriented nature of the contests. Although stage 2 purchases were high relative to best responses, stage 2 subjects appear to have responded to the competitiveness of the contest.

4. Conclusion

This research extends the basic approach in Tullock (1980) by developing and experimentally testing a team-oriented two-stage rent-seeking model. Separate variants of the contest success function are used to model cases wherein team member effort serves as a perfect substitute or complement. The model is motivated by the observation that rent-seeking for public policy favors might affect multiple constituencies simultaneously, and for many issues, multiple groups share a preference on either side of an issue. Moreover, when various groups exert effort independently and at different times, the sequencing of effort choices might have important effects on contest outcomes. Congressional races in the United States provide one example in which a contest prize goes to multiple groups (a candidate and that candidate's party), and the sequencing of effort decisions plays an important role in shaping the contest outcome.

[11] This variable helps to control for subject-specific effects. An alternative specification that uses dummy variables to induce subject-specific fixed effects results in parameter estimates and significance results that are consistent with those in Table 5.

[12] Note, however, that the effects of learning are captured in the *OWN-1* coefficient. The point estimate for this coefficient (0.22) suggests that, controlling for the other included variables, subjects reduced their ticket purchases over the course of the experiment.

The theory suggests that when effort levels serve as perfect substitutes, early actors can free ride on the efforts of those moving later, introducing collective action problems similar to those affecting public goods provision. Incentives to free ride are mitigated when early effort serves as a complement to later effort. This is particularly relevant when asymmetries in early effort create an advantage for a later moving competitor. In these cases, the model predicts asymmetries in early effort that generate reductions in late effort.

Experimental methods are used to test the theory, and data from the experiments provide limited support for the theory. Stage 1 participants in the TRS1 treatment (in which team member efforts are substitutes) purchased fewer tickets than those in the TRS2 treatment (which models complementarities), and differences in ticket purchases are statistically significant. However, the free riding prediction associated with the contest success function, for which team member effort serves as a perfect substitute, is not supported by the data. In both the one-shot and multiperiod treatments, stage 1 participants purchased a significant number of tickets, and differences in ticket purchases between stage 1 and stage 2 participants were not statistically significant. The lack of free riding in late rounds of the multiperiod treatment suggests that experience is not an explanation for this result. Although this finding merits further research, the team-oriented nature of the contests may be an important element in subject decision making. One possibility for future research would be to investigate whether subjects learned to free ride in an environment in which they were matched with the same teammate and opponents over the course of the experiment. In addition, providing subjects with more experience by extending the multiperiod treatment past eight rounds might, eventually, lead to subject play that is consistent with theoretical predictions. Nonetheless, results from the current set of experiments provide interesting insights into subject play in team-oriented contests.

In terms of stage 2 effort choices, the data suggest subjects responded to decisions made in the first stage. For the TRS1 treatment, stage 2 purchases tended to be lower when a stage 1 opponent purchased either zero tickets or a high number of tickets. In the TRS2 treatment, ticket purchases of stage 2 subjects declined as those of their teammate increased, and this effect was particularly strong when a stage 1 teammate purchased a high number of tickets. Finally, in the multiperiod treatment, stage 2 participants appear to have responded to the competitiveness of the contest. Consistent with the results from many other rent-seeking experiments, subjects made significant overinvestments relative to the Nash equilibrium prediction in all treatments.

Appendix

Instructions for TRS1

This is an experimental study of decision making. All of the money you earn from the experiment is yours to keep. Your earnings will be paid to you in cash, privately and confidentially, immediately after the experiment. Now that the experiment has begun, please do not talk.

Introduction

The experiment will be conducted in two stages. You are a "STAGE 1" participant. For the purposes of the experiment, you will be randomly and anonymously paired with one other STAGE 1 participant, who will be referred to as your "opponent." You will also be randomly and anonymously paired with two separate "STAGE 2" participants, one who is on "your team" and one who is on your "opponent's team." Importantly, you will not be told who you are paired with or against, and decisions will be made anonymously in the sense that no participant will be able to identify the decision of any other participant.

Conducting the Experiment

All participants begin the experiment with \$6.00, and will decide how many "raffle" tickets to purchase. Each ticket will cost 25¢. Because each participant begins with \$6.00 and each ticket costs 25¢, each participant can purchase 0–24 tickets. The raffle prize is \$4.00, and will be awarded to each member of the winning team. This means that if your team wins the raffle, you will be awarded \$4.00. You will indicate how many tickets you wish to purchase by writing the desired amount on the attached decision sheet. The raffle will be conducted as follows:

After all "STAGE 1" participants make their ticket purchase decisions, the experimenter will collect the decision sheets. The decision sheets will be randomly and anonymously paired (this will determine your opponent). The experimenter will record the number of tickets you and your opponent chose to purchase on the decision sheets of two randomly selected STAGE 2 players, under the headings "*tickets purchased by the STAGE 1 participant on your team*" and "*tickets purchased by the STAGE 1 participant on your opponent's team.*"

Next the experimenter will distribute the STAGE 2 decision sheets. After viewing the number of tickets purchased by the STAGE 1 players on their team and on their opponent's team, the STAGE 2 participants will decide how many tickets to purchase. After all STAGE 2 participants have indicated the number of tickets they wish to purchase, the experimenter will collect the STAGE 2 decision sheets. The STAGE 1 decision sheets will then be updated to reflect the number of tickets purchased by team members and opponents.

Next, the experimenter will conduct the raffle. A computer-generated random drawing will determine which team wins the raffle. The probability that your team wins is

$$\text{Probability your team wins the prize} = \frac{\text{(Number of tickets your team buys)}}{\text{(Total number of tickets bought by your team and your opponent's team)}}.$$

BOTH members of the winning team will receive separate \$4.00 prizes. If neither team buys any tickets, the prize will be awarded randomly, with each team having an equal chance of winning the prize.

Expected Earnings

Your expected earnings (in dollars) are equal to the \$6.00 endowment *minus* the amount you spend buying tickets *plus* the probability your team wins the prize *times* \$4.00 (the amount of the prize).

$$\text{Expected Earnings} = \$6.00 - \text{(amount you spend buying tickets)} + \text{(probability your team wins the prize} \times \$4.00)$$

Included with these instructions is a table that lists the "expected prize" for your group associated with different combinations of group ticket purchases. Note that this table does not list your expected earnings because it does not include the \$6 endowment or the amount you spend on tickets.

It is important to remember that the expected prize is based on the *probability* your team wins the prize. Your actual earnings are dependent on whether you win the prize or not. You can think of the expected prize as an average prize amount awarded if we repeated the raffle many times using the same probability that your team wins the prize each time.

The table is provided to help you make your decision. Feel free to take time to study the sheet before you make a decision.

Actual Earnings

Your earnings will be the part of your \$6.00 endowment that is not spent on tickets, plus the \$4.00 prize if your team wins.

PLEASE INDICATE THE NUMBER OF TICKETS YOU WISH TO PURCHASE BY FILLING IN THE DESIRED AMOUNT ON YOUR DECISION SHEET.

Instructions for TRS2

This is an experimental study of decision making. All of the money you earn from the experiment is yours to keep. Your earnings will be paid to you in cash, privately and confidentially, immediately after the experiment. Now that the experiment has begun, please do not talk.

Introduction

The experiment will be conducted in two stages. You are a "STAGE 1" participant. For the purposes of the experiment, you will be randomly and anonymously paired with one other STAGE 1 participant, who will be referred to as your "opponent." You will also be randomly and anonymously paired with two separate "STAGE 2" participants, one who is on "your team" and one who is on your "opponent's team." Importantly, you will not be told who you are paired with or against, and decisions will be made anonymously in the sense that no participant will be able to identify the decision of any other participant.

The experiment is a "weighted" raffle for a prize of \$4.00. Separate raffle prizes will be awarded to each member of the winning team. This means that if your team wins the raffle, you will be awarded \$4.00. The probability your team wins the prize is:

$$\text{Probability your team wins the prize} = \frac{\text{(Weighted ticket purchases of your team)}}{\text{(Total weighted ticket purchases of your team and your opponent's team)}}.$$

Weighted ticket purchases for each team will be determined according to a process described below. They are the product of a weight and an amount of tickets purchased. For example, if TEAM 1 has a weight of w and ticket purchases of x, weighted ticket purchases for TEAM 1 equal w^*x . If TEAM 2 has a weight of y and ticket purchases of z, their weighted ticket purchases would be y^*z . This means the probability TEAM 1 wins the raffle is $w^*x/(w^*x + y^*z)$, and the probability TEAM 2 wins is $y^*z/(w^*x + y^*z)$.

If the weights for both teams are zero or ticket purchases for both teams are zero, the raffle prize will be awarded randomly, with both teams having an equal chance of winning the prize.

Conducting the Experiment

All participants begin the experiment with \$6.00. In Stage 1 of the experiment, the weights for the raffle will be determined. In Stage 2 of the experiment, ticket purchases will be determined.

Stage 1 participants will indicate the weight they choose for their team's ticket purchases on their decision sheet. Each 1 unit increase in the weight will cost 25¢. Because each participant begins with \$6.00 and each unit costs 25¢, Stage 1 participants can choose a weight of 0–24.

After all Stage 1 participants make their decisions, the experimenter will collect the decision sheets. The decision sheets will be randomly and anonymously paired. The experimenter will record the weights chosen on the decision sheets of two randomly selected Stage 2 players, under the headings "*weight for your ticket purchases chosen by the STAGE 1 participant on your team*" and "*weight for your opponent's tickets purchases chosen by the STAGE 1 participant on your opponent's team.*"

Next the experimenter will distribute the Stage 2 decision sheets. After viewing the weights, the Stage 2 participants will decide how many tickets to purchase, each of which costs the Stage 2 participant 25¢. Because each participant begins with \$6.00 and each ticket costs 25¢, Stage 2 participants can purchase 0–24 tickets. After all Stage 2 participants have indicated the number of tickets they wish to purchase, the experimenter will collect the Stage 2 decision sheets. The Stage 1 decision sheets will then be updated to reflect the number of tickets purchased by team members and opponents.

Once the weights and ticket purchases have been determined, the experimenter will conduct the raffle. A computer-generated random drawing will determine which team wins the raffle.

Expected Earnings

Because you are a STAGE 1 participant, your decisions will determine the weight for your team's ticket purchases. Your expected earnings (in dollars) are equal to the \$6.00 endowment *minus* the amount you spend on the weight *plus* the probability your team wins the prize *times* \$4.00 (the amount of the prize).

$$\text{Expected Earnings} = \$6.00 - \text{(amount you spend on the weight)} + \text{(probability your team wins the prize} \times \$4.00)$$

Included with these instructions is a table that lists the "expected prize" for your group associated with different combinations of weighted group ticket purchases. Note that this table does not list your expected earnings because it does not include the \$6 endowment or the amount you spend on the weight.

It is important to remember that the expected prize is based on the *probability* your team wins the prize. Your actual earnings are dependent on whether you win the prize or not. You can think of the expected prize as an average prize amount awarded if we repeated the raffle many times using the same probability that your team wins the prize each time.

The table is provided to help you make your decision. Feel free to take time to study the sheet before you make a decision.

Actual Earnings

Your earnings will be the part of your \$6.00 endowment that is not spent on weight, plus the \$4.00 prize if your team wins.

PLEASE INDICATE THE WEIGHT YOU CHOOSE FOR YOUR TEAMMATE'S TICKET PURCHASES BY FILLING IN THE DESIRED AMOUNT ON YOUR DECISION SHEET.

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