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It's not how you play the game, it's winning that matters: an experimental investigation of asymmetric contests.

Miguel A. Fonseca

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El Dr. Miguel Fonseca es doctor en economía de la Universidad de Londres, Royal Holloway College. Actualmente es investigador de post-doctorado en el Center for Research in Environmental Decisions (CRED) de la Universidad de Columbia. Se especializa en la investigación microeconómica utilizando métodos experimentales. Su trabajo está dividido en dos áreas de investigación: en economía Industrial estudia las condiciones para el surgimiento del liderazgo en mercados y el impacto de fusiones en el rendimiento de los mercados; y en economía pública, donde investiga el impacto de las asimetrías en modelos de contiendas. Recientemente, su investigación en teoría de contiendas se ha extendido a contiendas dinámicas y sus aplicaciones al análisis de conflictos.

Dr. Miguel Fonseca has recently completed his PhD in Economics from the University of London, Royal Holloway College. He is currently a Post-Doctoral researcher at the Center for Research in Environmental Decisions (CRED) at Columbia University. He specialises in the empirical research applied to microeconomics using experimental methods. His work is divided into two main areas of research. Industrial Economics, where he studies the conditions for the emergence of market leadership and the impact of mergers on market performance; and Public Economics where he researches the impact of asymmetries in contests. Recently, his interests in contest theory have extended to dynamic contests and applications to conflict theory.

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CERAC - Centro de Recursos para el Análisis de Conflictos
Carrera 10 N° 65-35 Of. 603
Tels.: +(571) 3458572 / 3
Bogotá, Colombia
www.cerac.org.co
Cover Design: Adela Martínez Camacho

It's not how you play the game, it's winning that matters: an experimental investigation of asymmetric contests*

Miguel A. Fonseca†

February 3, 2006

Abstract

This paper reports an experimental test of asymmetric Tullock contests. Both the simultaneous-move and sequential-move frameworks are considered. The introduction of asymmetries in the contest function generates experimental behavior qualitatively consistent with the theoretical predictions. However, especially in the simultaneous-move framework, average bidding levels are in excess of the risk-neutral predictions. We conjecture that the reason behind this behavior lies in subjects attaching positive utility to victory in the contest.

JEL – classification numbers: C72, C92, D72

Keywords: Laboratory experiments, contests, asymmetries.

1 Introduction

The problem of a set of agents spending effort in order to increase the likelihood of obtaining a prize was first put forth by Tullock (1967) and later formalized by the same author in 1980.

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†CRED - Columbia University, 419D Schermerhorn MC 5501, 1190 Amsterdam Avenue, New York, NY 10027, USA; Tel: +1 212 8548384; Fax: +1 212 854 3609; Email: *mf2318@columbia.edu.*

In the latter paper, the main result was that depending on parameters of the contest, the total amount of effort spent by the agents competing for a rent (which we will define as rent dissipation) could be smaller than, equal to or larger than the value of the rent (implying under-, full or over-dissipation of the rent.) This spawned a strand of theoretical literature so large it merited its own historical recollection[1]. In addition, it also gave economists a tool by which several economic phenomena could be modelled. Applications of this encompass sports competitions, job promotion tournaments, warfare, litigation, in fact any activity that involves rent-seeking behavior of some type.

Despite the prolific theoretical literature on contest theory either in abstract or applied settings, it has not received much attention by experimentalists. In fact, the experimental approach seems to be particularly well suited to test the predictions of theory, given the great difficulty in successfully collecting the relevant data from the field. Empirical studies of rent-seeking behavior based on real-world data would be faced with difficulties in attaining data that successfully proxies the effort level variable in the standard Tullock contest model. Additionally, the question would arise of what parameter specification would be the most appropriate for the specific contest under study, or should there be one set of parameters that should fit all contests? Experimental methods allow for the controlled study of this model, and for the collection of the relevant data without any noise spawning from external sources to the data generation process.

Most of the experimental studies on contests have focused their attention on whether the predicted under-dissipation of rents predicted by Tullock was in fact verified. The existing evidence is mixed; Millner and Pratt (1989), (1991) as well as Davis and Reilly (1998) conducted studies that present evidence towards over-dissipation of rents, while Baik and Shogren (1991) present a different design that yields results consistent with the theory.

Surprisingly, most theoretical and experimental studies on contests have assumed symmetric players as well as simultaneous-moves. The exception in the experimental literature on Tullock contests is Davis and Reilly (1998) who test for the effect of asymmetries in the value of the prize in standard Tullock contests, as well as purely discriminating contests. The authors find that having players with asymmetric valuations of the prize of the contest reduces the amount of overbidding but does not completely erradicate it. They also find that experience tends to reduce the overbidding by subjects. Weimann, Yang and Vogt (2000) is to our knowledge the only other experimental study of sequential-move Tullock contests with fixed order and finite number of moves[2].

In reality, examples which are consistent with the assumption of symmetry may be difficult to find. If one considers rent-seeking activities, it is likely that one agent may have a competitive advantage that makes her efforts more likely to result in the attainment of the rent in question. If one considers the example of legal conflict, one side may be better represented in court, which makes each dollar invested in the legal battle more effective than the other side's. Similarly, in a job promotion tournament, one individual may have a better set of skills, allowing him or her to be more productive for each hour spent, which in turn makes his or her promotion more likely.

Additionally, when considering real-world contests, the simultaneous-move framework does not always capture the essence of the process. While in some situations, one could find a level playing field wherein all rent-seekers have an equal start, (an easy example is the allocation of grants by a government body or a foundation, where the announcement to all applicants is made simultaneously) there are cases where a sequential framework may be more appropriate, especially when one of the rent-seekers has an intrinsic advantage over the others. When lobbying in Congress, an experienced lobbyist may have preferential access to the Congressman due to the number of years spent in Washington getting acquainted with the system; when renewing a consulting contract, a company may want to listen to the incumbent firm's offer before listening to any other firms. Finally, in lawsuits, the plaintiff must first incur effort in order to hire legal counselling and in collecting evidence before launching the suit. The defendant can obviously only spend effort in the legal battle once it knows it is being sued.

This experimental study seeks to investigate the role of asymmetries in contests. For this purpose, we consider two different timing assumptions, a game where players move simultaneously and one where players move sequentially. The research question underlying this study is whether the introduction of asymmetries in the contest success function would lead to bidding behavior consistent with the risk-neutral Nash equilibrium in the simultaneous-move case and to behavior consistent with the subgame perfect Nash equilibrium in the sequential-move case.

The main findings are that in simultaneous-move contests, subjects bid over the risk-neutral Nash equilibrium, even with the introduction of asymmetries. In the sequential-move contests, the introduction of asymmetries helps subjects coordinate on the subgame perfect Nash equilibrium more often than in the symmetric case and more often than in previous studies. However, when second-movers participate in the contest, they seem to choose actions that ensure a high probability of victory, as opposed to actions that maximize their expected payoffs.

Section 2 deals with the model to be implemented. Section 3 outlines the experimental design to be used. Section 4 contains the data analysis. A discussion of the results in Section 5 concludes.

2 The Model

The experiment will consider a two-player game, where each player selects her level of effort, E_i in order to obtain a prize (J_i). The value of the contest,V_i, is given by the following equation:

$$V_i = p_i J_i - C_i, \tag{1}$$

where

$$p_1 = \frac{aE_1}{aE_1 + E_2} \tag{2}$$

$$p_2 = \frac{E_2}{aE_1 + E_2}. \tag{3}$$

The timing of the decisions and the a parameter are the treatment variables. In one variant of the experiment, both players make their decisions simultaneously. In the other variant, one of the players (player 1) makes his choice in the first period, and the other (player 2) makes her decision in the second period. In the experiment J_i will be equal to 200 and the cost function will be defined as $C_i = E_i$.

2.1 Simultaneous Play

In the simultaneous-move game, the Nash equilibrium is found when either player is selecting a strategy which is a best reply to the other player's strategy. This implies that when both parties maximize their expected value of the contest, we have a pair of reaction functions:

$$E_1 = \frac{(JaE_2)^{\frac{1}{2}} - E_2}{a}$$

$$E_2 = (JaE_1)^{\frac{1}{2}} - aE_1$$

Solving them simultaneously, gives us the unique Nash equilibrium where

$$E_1 = E_2 = E = \frac{a}{(a+1)^2} J, \forall a \neq 0 \tag{4}$$

Note that both players submit the same effort in equilibrium for all values of a. To see the intuition behind this, let us consider the simple symmetric case, where a is equal to 1. There, both players have the same marginal "benefit" of bidding, in that the same bid by both players implies the same probability of victory. Without loss of generality, as the a parameter increases, the only thing that changes is the marginal probability of winning, since costs remain unaltered. Therefore, the benefitted player obtains the same probability of victory by bidding a smaller amount, whilst the reverse applies for player 2. This means that player 2 will therefore bid a lower amount in order to maximize its expected value of the contest, which is the always the same for both players. This also means the Nash equilibrium bid function has its highest level of E when $a = 1$. Also, given that in equilibrium both players' bids are equal, total rent dissipation will vary in a similar way to changes in a.

2.2 Sequential Play

When calculating the Subgame-Perfect Nash Equilibrium of the sequential-move game, we work by backward induction. Thus we have the second-mover, player 2, maximize his expected value of the contest, given the effort level submitted by the first-mover, player 1, yielding the following reaction function:

$$E_2 = max\{(aJE_1)^{\frac{1}{2}} - aE_1, 0\}$$

Player 1 realizes this and incorporates player 2's reaction function into his expected value function:

$$V_1 = \frac{aE_1}{aE_1 + (aJE_1)^{\frac{1}{2}} - aE_1} J - E_1 = (JaE_1)^{\frac{1}{2}} - E_1$$

The best-reply of the function above is given by:

$$E_2 = max\{(aJ)\frac{1}{2}(aJE_1)^{-\frac{1}{2}} - 1, 0\}$$

The optimal E level for player 1 is therefore

$$E_1 = \frac{aJ}{4} \tag{5}$$

Substituting this expression back into Player 2's reaction function gives:

$$E_2 = max\{\frac{aJ}{2} - \frac{a^2 J}{4}, 0\} \tag{6}$$

However, the second-mover will only participate if $E_2 > 0$. If his reaction function dictates a non-positive value for E_2, then he will submit zero effort. We can then calculate for which values of a will the second-mover not find it profitable to enter the contest. It is easy to show that $E_2 \geq 0$ if and only if $0 < a \leq 2$

For values of a greater than 2, Player 2 should always submit zero effort (provided $E_i = aJ/4$.) Player 1 anticipates this and thus we can calculate the effort level that deters Player 2 from entering the contest for values of a great than or equal to 2: $(aJE_1)^{\frac{1}{2}} - aE_1 = 0 \Rightarrow E_1 = \frac{J}{a}$.

We can now define the Subgame Perfect Equilibria as a function of a:

$$E_1 = \begin{cases} \frac{aJ}{4} \text{ if } a \in [0, 2] \\ \frac{J}{a} \text{ if } a \in (2, \infty) \end{cases}$$

and

$$E_2 = \begin{cases} \frac{aJ}{2} - \frac{a^2 J}{4} \text{ if } a \in [0, 2] \\ 0 \text{ if } a \in (2, \infty) \end{cases}$$

It is evident that predicted behavior in the sequential game is radically different from the simultaneous game. Here, we see the equilibrium level of effort of the follower is higher than the one of the leader for values of a smaller than 1. At $a = 1$, the effort levels of both players are equal. From that point on, we see the level of effort of the follower in equilibrium decline until reaching zero at $a = 2$, while the equilibrium level of effort of the leader continues to increase until the critical point of a is also reached. At this point, the leader deters the follower from entering the contest, and as the value of a approaches infinity, the equilibrium level of E_1 approaches zero. Rent dissipation rises monotonically until $a \simeq 1.5$, when aggregate effort reaches a maximum. This is due to the fact that the rate of increase in the effort level of the leader is faster than the rate of decrease of the follower's effort level, until the critical level of a is reached. Thereon, aggregate effort declines until reaching zero when a approaches infinity. This implies that the contests which are fought the hardest are not the symmetric ones. Rather, the cases where aggregate effort is highest are when the first-mover has an edge over the second-mover.

3 Experimental Design and Procedures

The experiments will investigate the impact of the introduction of asymmetries on the effectiveness of individual bids in two separate environments: simultaneous-move and sequential-move contests. For each timing environment, we will consider two treatments. In one, which will be denominated symmetric, player 1 will have the a coefficient set to 1, which corresponds to the standard games. In the other treatment, player 1 (first-mover in the sequential-move treatment) will have a coefficient[3] of $a = \frac{7}{3}$. Table 1 outlines the different treatments as well as the predictions for each one.

[Table 1 about here.]

The symmetric experiments test the standard simultaneous-move Tullock contests, thus they are the control treatments. This will also contextualize the experimental results with the existing literature. The asymmetric treatments will be the focus of the analysis. The chosen parameters imply that in the simultaneous play environment, both players submit the same bid, but smaller than in the symmetric case. In the sequential-move case, the parameter asymmetry induces a corner solution where the first-mover commits to a level of effort that forces the other player to drop out of the contest.

The working hypotheses are that in the simultaneous-move case, the average symmetric bid will be higher than the average asymmetric bid, as predicted by the theory. In addition, it will be relevant to investigate whether both types of players will submit similar levels of effort in the asymmetric case. In the sequential-move case, the hypothesis is that theory will be vindicated in that in the asymmetric case, the first-mover will be able to commit to an effort level such that the second-mover will not find it profitable to enter the contest.

As for the experimental design itself, it consisted of the following. For all treatments, three computerized sessions[4] were run. In each session, ten subjects were invited to take part in an experiment. They were undergraduate and post-graduate students from a variety of subjects from Royal Holloway College, University of London. Individuals were recruited via e-mail and fliers posted around the university campus. Upon arrival to the lab, they were told to select one of ten available booths. Once everybody was seated, a set of written instructions was handed to them, and absolute silence was requested. The instructions[5] were read aloud by the experimenter and the five subsequent minutes were allocated for a detailed study of the instruction sets and possible questions. Once the experimenters had ensured that no subject had any queries, the experiment was initiated.

In both symmetric and asymmetric experiments, each subject was told he was taking part in an experiment that would last 30 rounds. There would be two types of persons, A and B. In each round all subjects were given 300 Experimental Currency Units (ECU) and a type-A person would be randomly matched with a type-B person. They were told they could use any part of their endowment to bid for a prize valued at 200 ECU. The more they bid, the more likely they were to win the prize; the more the other person bid, the less likely they were to win. They were also informed that they would forfeit their bids regardless of winning or not. To aid them in the computations, the software enabled subjects to calculate the probability of winning the prize, given a pair of hypothetical bids. They were informed of the timing structure of the experiment, and were given on-screen information about the value of the prize and their endowment in every period. In the sequential experiments, the second-movers were also informed of the bid of the first-movers they were matched with in that period. Each ECU was worth one pence. Each session lasted about an hour and subjects' average payment was £11.40. All sessions were conducted between September and November 2003 in the Experimental Economics Laboratory in the Economics Department at Royal Holloway University of London.

4 Experimental Results

4.1 Simultaneous-move Games

We begin by analyzing the simultaneous-move treatments. Table 2 gives average bids for subjects in both the symmetric and asymmetric treatments. It is evident that average bids decline steadily over the course of the experiments. It is also noticeable that the average bid for the symmetrical players is always above the average bids for the two types of asymmetric players.

[Table 2 about here.]

Average bids in the initial stages of the experiments were much higher than the predictions for both treatments. However, a sharp decline not only in average bids but also in their standard deviations are also noticeable for all types of subjects over the course of the sessions. Therefore for most of the analysis we will focus on the last third of observations[6].

Additionally, in order to conduct significance test for the mean values, we will run OLS regressions of the form $E = \beta_0 + \beta_1 D_i + \epsilon_i$. The dependent variable, E is individual subjects' average effort level across the last ten periods and D_i is a dummy variable accounting for the type of bidder (e.g. "weak" vs "strong" or "symmetric" vs "asymmetric" bidders). The estimate of β_1 can therefore be interpreted as the difference in means. To avoid the problem of non-independence of observations within sessions, we use White-adjusted standard errors (White, 1980)[7]. Also, for presentational reasons, we will only refer to the statistical significance of the regression coefficient. The complete breakdown of each regression is available upon request.

Closer observation shows that average bids on the last third of the experiments are still higher than predictions for both treatments. In addition, average bids for both types of bidders in the asymmetric case are remarkably close (61.35 for the "weak" bidders and 62.08 for the "strong" bidders) and indeed they are not statistically different. Average bids in the *simsym* treatment are also higher than predicted; when compared with the asymmetric bidders, the average bids in *simsym* appear to be much higher than the average bids in the *simasym*[8]. This is our first result.

Finding 1: *Average effort levels are above predictions in both symmetric and asymmetric treatments.*

In order to understand subjects' behavior, we now look at the distribution of bids in the last ten periods.

[Figure 1 about here.]

For the weak bidders the modal bid was 50 with 16% of observations. Other bid levels with high frequencies are 10 and 1 with 10% and 7.33% of observations respectively. For the strong bidders the modal bid was 30 with 12.67% of observations. Other common bid levels were 50 and 100 with 11.33% and 10% of observations.

The bid distribution for the weak bidders has the majority of observations (66%) between 0 and 60 and the mode is between 0 and 20 with just under a third of all observations. Note that eleven observations recorded bids of 1, while bids of 2 and 10 were recorded 9 and 15 times respectively. This appears to demonstrate that disfavored bidders were aware of their position in the game and therefore attempted to minimize their losses from bidding whilst giving themselves a minuscule chance of winning. Finally, the strong bidders' distribution has the mode in the interval $[0, 20]$ and another interval of bids with a high frequency is $[81, 100]$. However, the distribution for the strong bidders seems to be flatter than for the other types of subjects.

While some “strong” subjects in the *simasym* treatment seem to realize that their advantage allows them to bid a smaller amount and still give them a very good chance of winning, others seem to want to practically guarantee their success in the contest by bidding much higher. Likewise, a large proportion of observations shows weak bidders bidding very small levels, almost conceding the fact that they will not have a good chance of winning but also a non-negligible fraction of observations showing weak bidders bidding very high values, thus demonstrating a clear willingness to obtain the prize. This is inconsistent with Nash equilibrium behavior, where both types of players should bid equal amounts, despite the fact that on average one type will win more often.

Finding 2: *Effort levels are less dispersed in the asymmetric treatment.*

Perhaps a clearer picture will emerge once the individual behavior of subjects is analyzed more closely. The following figure displays a histogram of subjects' average effort levels. For both treatments, the Nash equilibrium is in the $[41, 60]$ interval, even though if one allows for a degree of error in subjects' choices (i.e. plus or minus ten bid units) one can also consider the $[21, 40]$ interval as admissible as Nash equilibrium for the *simasym* treatment.

[Figure 2 about here.]

The individual level figures seem to confirm our initial conjecture. Behavior in the *simsym* treatment is very dispersed, although over a quarter of subjects' average bid is in the Nash equilibrium category. However, a substantial amount of subjects (40%) is bidding in excess of the Nash equilibrium prediction. In the *simasym* treatment, we do observe that most “strong” subjects either bid below the Nash equilibrium predicion, or subtantially above. The “weak” subjects in the *simasym* treatment seem to behave more according to Nash predictions, with just under 50% of subjects bidding close to Nash. A small group of subjects bids on average very little, while another group (33%) bid very high values. Clearly these subjects are not maximizing the expected value of the contest. Rather, it would appear that they either wish to have a good probability of victory, or that they wish to punish the "strong" subjects for their seemingly unfair competitive advantage. In order to ascertain what drives subjects behavior, one would require information regarding individual first-order beliefs on the bidding levels of opponent players. Unfortunately, this data is not available to us. We conclude the analysis of simultaneous-move treatments with the final result.

Finding 3: *Average effort levels are higher in the symmetric treatment than in the asymmetric treatment.*

4.2 Sequential-move Games

Before beginning to analyze the sequential data, it is worth recapitulating the predictions of the model. In the symmetric case, both players are to submit equal expenditure levels (50 units) and in the asymmetric case where the first-mover has the advantage ($a = \frac{7}{3}$) the predictions are that the first-mover should spend 86 units and the second-mover should not put forward any effort at all.

4.2.1 Symmetric Case

Table 3 depicts the average effort levels and their standard deviations by players throughout the course of the experiments.

[Table 3 about here.]

The first observation is that unlike the simultaneous-move treatment, there is no sharp decline of bidding values over the course of the experiment. First-movers' average bids decline over the second third of the experiments, but rise again in the last third. Second-movers' average bids on the contrary rise in the second third of the experiment only to fall toward the end. One should note, however that the standard deviations do fall sharply after the first ten periods of the experiments.

In the last ten periods of the experiments, the average expenditure by first-movers is equal to 92.6, while the average second-mover expenditure is 76.45 units[9]. An additional fact that can be easily drawn from table 3 is the high values of the standard deviations, especially for the second-movers. It is therefore interesting to investigate further the bidding behavior of leaders and followers in the last third of the experiment. Table 4 depicts the average reply by followers to a range of values by first-movers. It also outlines in the last column what would the best-reply to each observation be, averaged out across observations.

[Table 4 about here.]

The distribution of first-mover bids shows that the modal choice range is between 81 and 100, well above the prediction of 50. However the second most chosen effort range is $[41, 60]$. Also, it is worth noting that only 26.67% of observations show first-movers choosing effort levels above 100. Second-movers seem to overbid first-movers when the latter choose effort levels under 60, and they choose effort levels similar to those chosen by first-movers when the latter set their efforts between 60 and 100. Additionally, their bidding levels are much higher than what would be predicted by a risk neutral best-reply function for any range of first-mover bids, which is quite clear upon inspection of the values of the second column (the actual average bidding level) and the values of the last column (average best-reply). For first-movers' effort levels higher than 100, follower behavior is difficult to characterize using the information available in this table, so we will continue this in the additional analysis of the data. To have a better idea of what follower behavior was, we present a figure displaying the distribution of bid pairs. The x-axis measures first-mover bids and the y-axis measures second-mover bids.

[Figure 3 about here.]

When first-movers choose effort levels under 60, the majority of second-movers bids are between 41 and 100. Note that about three quarters of second-movers submitted bids that would give them at least an equal chance of winning the contest, just under 50% chose bids that gave them at least 66.6% probability of winning and 12% bid such that they would have no less than a 83.33% probability of victory. When first-movers' effort level are between 60 and 100, we see that the vast majority of observations (72%) are recording second-movers' effort levels below 100, being that the modal range (28%) was the one with effort levels between 81-100. It should be noted that only 2.83% of subjects chose a bid of zero, as opposed to 40% of second-movers who chose a level of effort that would give them at least a 50% chance of winning, whilst only 3.77% of followers bid at least twice as much as the first-movers with whom they were matched. As for the distribution of second-movers' bids when first-movers' efforts are in excess of 100, we see that the modal choice is between 0 and 20. In fact, 17.39% of all second-movers chose not to participate in the contest. Here the percentage of second-movers who bid at least as much as the first-movers declines even further to 20.29%. However, about 30% of observations still record bid choices between 121 and 200.

Finding 4: *Average effort levels in the* SeqSym *treatment are above predicted levels.*

We should also note that subjects are not maximizing their expected value of the contest. The average absolute difference from observed bid and the risk-neutral best-reply is 49.10 for the first sub-group, 44.50 for the second sub-group and 69.99 for the last group. If we express this in terms of average foregone expected value these are -33.24, -17.24 and -25.47. This means that we can divide follower behavior in this (small) subset of observations into those who choose not to enter the contest and ensure they get the guaranteed 300 units of profit for the round, or spending a small amount of effort just to have a marginal probability of success and those who behave in a far more aggressive manner and demonstrate a far greater eagerness to win the contest.

Finding 5: *Second-movers overbid relative to best-reply predictions.*

Finding 5a: *A substantial proportion of bids seem to be geared towards achieving a high probability of victory in the contest rather that expected utility maximization.*

4.2.2 Asymmetric Case

Let us turn our attention to the asymmetric case. Recall that the prediction is that the first-mover should submit a bid of 86 and the second-mover should not bid at all. This was observed 28 times out of 450 observations[10]. The outcome where the first-mover bids a positive amount and the second-mover bids zero occurred 104 times out of 450, whereas if you consider the case where the second-mover only bids a very small amount, smaller than 5, then this is observed 200 times out of 450 observations.

In our experiment, a significant proportion of first-mover bids are close to SPNE and in those cases, the majority of second-movers also plays according to the SPNE. Additionally, only one observation is consistent with cooperative behavior by first-movers (where by cooperative behavior, we mean very low bidding level, in the same spirit of collusive behavior in a Cournot market), and extreme bidding above the predictions is only observed in 5% of all observations. This is unlike Weimann et al. (2000) who report that the most observed outcomes were when first-movers bid close to zero, followed by a best-reply by second-movers or when first-movers bid extreme amounts, and second-movers bid zero.

Therefore, it would appear that the introduction of the asymmetry helps subjects to coordinate on the SPNE, since punishments by second-movers become more "expensive", in that to get an equal chance of winning, second-movers must bid 2.33 times more than first-movers.

Finding 6: *A larger proportion of observations are consistent with predictions vis-'a-vis the* SeqSym *treatment.*

Table 5 gives us a first look at the behavior by outlining the average bids by both types of subjects over time.

[Table 5 about here.]

This time, we observe a steady decline in average bids by both types of players as the experiment goes on. Also, it is noticeable that average first-mover behavior is always higher than second-mover behavior, including the last third of the experiment[11]. This decline in average bids is also accompanied by a sharp decline in standard deviations, especially in the first-movers' case. However, it is readily noticeable that the standard deviations of the average second-mover bid are always higher than the mean, implying a huge dispersion of values, something that is not parallelled in the first-mover case. It is therefore important to extend the analysis of second-mover behavior, in particular relatively to how first-movers played. Table 6 shows the relative frequency of bids of first-mover in the last 10 periods of the experiments, as well as average bids by second-movers, conditional on the range of bids chosen by the first-movers.

[Table 6 about here.]

The majority of bids (78.73%) are between 41 and 100 and its distribution has two peaks, one is the interval of bids between 81 and 100, which includes the Nash equilibrium bid of this game (86). The other encompasses bids between 41 and 60. So we can say that leaders can be divided into 2 different types: those who assume that the asymmetry in the game will enable them to win the contest without exerting too much effort, and those who prefer to assert their advantage by bidding much higher and ensuring a high probability of winning the contest. As for followers, their average bid is higher than leaders bids if the latter bid below 60, but soon becomes much smaller than leaders' bids for when the latter go over 60. Still, it is still much in excess of what the average best reply data would suggest as the optimal response. However, one should proceed with caution when drawing any inferences from these figures, because of the unusually high values of standard deviations, which imply a very large dispersion of bids by followers. It is then important to look at the distribution of followers' bids conditional on the choices by the first-movers.

[Figure 4 about here.]

Figure 4 gives an interesting view of subjects' behavior. As first-movers' bids increase, the proportion of second-movers who choose a very small (or zero) level of effort increases from one quarter to almost two thirds of observations. However, the range of second-movers' bids also increases as leaders bids rise. When first-movers choose relatively low values of effort, a quarter of the second-movers seems to settle for a relatively small bid (of which only 6.25% chose a bid of zero). The majority choose higher effort levels than leaders; nevertheless, 86.66% of observations show second-movers choosing bids which are at least 2.5 times as large as the first-mover bid[12].

When first-movers bid between 21 and 60, the dispersion of second-mover bids is much higher here, with just under 60% of second-movers choosing effort levels higher than 60. Also, the proportion of second-movers who chose effort levels at least twice as high as the first-mover effort level was 52.73%. Finally, for the range of first-mover bids higher than 60, the proportion of second-movers who chose not to participate in the contest was 26.58% and the share of subjects who chose to bid at most 20 units was 66.21%.

In addition, just under 23% submit bids that at least matched those of the first-movers and 6.33% of second-mover bids were such that the probability of victory was at least 50%, which shows that there were subjects who had a firm interest in winning the contest. The most interesting reading of these figures is that second-movers are again definitely not maximizing their expected value of the contest. In fact the average difference between the risk-neutral best-reply and the observed reply was 50.03 units for the first sub-group, 38.61 in the intermediate sub-group and 40.20 for the last sub-group. This had an associated loss in expected value terms of -20.36, -14.01 and -23.03, respectively.

Finding 7: *In the sequential-move treatments, overbidding seems to be mainly driven by the objective of obtaining a high probability of victory.*

5 Discussion

The research question underlying this study was whether the introduction of asymmetries in the contest success function would lead to lower bidding behavior in the simultaneous-move case and to behavior consistent with the subgame perfect Nash equilibrium in the sequential-move case. The reasoning behind the first conjecture was that on one hand, the benefitted subjects would realize that they did not have to bid very highly to have a good chance of success in the contest, and similarly the jeopardized bidders would also see this and therefore also bid lower levels in order to maximize their earnings in the experiments. In the sequential-move case, the conjecture would be that the asymmetry would dampen the potential threat that second-movers could pose of punishing first-movers who made high bids by making equally high bids, as Weimann et al. (2000) had observed.

In the simultaneous play treatments, much like previous research, average bids are much higher than the risk-neutral Nash equilibrium predictions. There is a high dispersion of average bids at the individual level, especially when considering the symmetric case. The introduction of asymmetries reduces both the average bid as well as the variance of bids.

One is left with the task of finding suitable explanations for the experimental behavior thus far reported in this paper. The first avenue of explanation could be subjects' attitudes towards risk. Is the assumption of risk-neutrality appropriate for this type of model? Surely the analysis of contests would be richer if one would allow for subjects to exhibit aversion to risk. There is however, a stumbling block concerning modelling this type of preferences into contests. Millner and Pratt (1991) show that the Nash equilibrium of such a contest assuming risk aversion will depend on the type of risk aversion one assumes on the players in the game, and that different types of risk aversion may lead to higher or lower equilibrium bids than the risk-neutral prediction.

An alternative explanation for the simultaneous-play data is that subjects attach some utility to the act of winning the contest itself, which overrides the foregone gains which were associated with the expected value maximizing bid. In fact, this argument can be encountered in most of the real world situations we can model as contests. Consider the following examples: a court case where each agent is a parent, and where the "object" of the contest is the custody of the couple's children. It is very unlikely that either parent will attempt to maximize his or her expected value from taking part in the contest. Alternatively, one could consider the case of a sports competition of any type, say the U.S. Open. Again, each athlete is unlikely to carefully calculate the expected utility of participating in the contest. Rather, each athlete may instead over-exert effort in order to guarantee his or her success in the competition, and probably will assume her counterpart will do so too. Finally, when competing for a promotion, a driven employee may view the promotion not only in terms of the additional salary, but also in the increased social status associated with the position. In all these examples there is certainly a high emotional weight on whether one wins or loses, which may lead players in the game to behave in a different way than the risk-neutrality postulate.

In the sequential-move games, we observe that in the symmetric case, first mover behavior is on average similar to second mover behavior. Closer inspection reveals that second movers bid above what the risk neutral best reply function would postulate. Instead, subjects seem to choose bidding levels which give them a good probability of victory. When the asymmetry is introduced in the Tullock function, behavior conforms more often to predictions, with first movers bidding enough to induce second movers not to play a part in the contest. When this is not the case, we again observe second movers seeking to attain a “fair” probability of victory in the contest, rather than expected value maximization.

What can we draw from these results? It would seem that the definition of the “prize” of the contest cannot completely capture the essence of the model under study. Subjects appear to attach a positive utility to the event of defeating their counterpart in the contest, and therefore successfully attaining the prize. However, the introduction of asymmetries lead to a reduction in effort levels in both simultaneous-move and sequential-move treatments. This can empirically be interpreted as some type of competitive advantage in that one player can be better at rent-seeking. This can be due to, for instance the fact that the individual has already gone through the process of lobbying and has already mustered the connections which are necessary to more efficiently influence the decision-makers. If one is to extrapolate these results with a view to use them to analyze real-world rent-seeking processes, then the practical implications create an interesting trade-off. If a government is intending to attribute a rent of some type, like a large research grant and is interested in minimizing the amount of wasteful expenditures, it should make sure (or it would prefer that) one of the competitors for that rent is benefitted (or is better than) with regards to the remainder of the field. This obviously raises issues of equity; on one hand, a government would like to ensure a level playing field for all entities which are competing for a public grant. On the other hand, the socially wasteful rents implicit to the contest would ideally be kept to a minimum.

If we consider the application of this model to legal conflict, then these findings may be good evidence in support of the claim that there is significant over-spending in the American legal system[13]. A justification for this behavior could be the emotional attachment behind winning or losing especially in the cases that approximate symmetry, where it would not be very discernible to the court which side is righteous. This sentiment may be even stronger than what was observed in the lab due to the moral and ethical implications which are intrinsic to a legal battle.

Notes

[1]Lockhard and Tullock (2001)

[2]Vogt, Weimann and Yang (2002) test an open ended sequential Tullock game.

[3]In the experiment, this is equivalent to player 1's bid variable being given a weight of 7 and player 2's bid variable having a weight of 3.

[4]We are grateful to Urs Fischbacher for letting us use his software toolbox "z-Tree" (Fischbacher, 1999).

[5]The instruction sets are available from the author upon request.

[6]This is common to all treatments. Therefore in the data analysis, unless noted, all the data will refer to the last 10 periods of the experiment.

[7]Due to the random matching of subjects across rounds, error terms resulting from an OLS regression using individual average data cannot be assumed independent within sessions. The robust estimation of the covariance matrix then takes the form $(\frac{N-1}{N-k})(\frac{M}{M-1})(X'X)^{-1}(\sum_{m=1}^{M} u'_m u_m)(X'X)^{-1}$, where X is a $k \times 1$ vector of regressors and M is the number of clusters.

[8]Average bids in the *simsym* treatment are statistically different (higher) at the 10% level from the average bids in *simasym* both when pooling the observations from the two types of asymmetric

bidders and when taking each of them separately.

[9]However, this difference is not statistically significant.

[10]The case where the follower replied to an effort level of 86 with a bid of either 1 or 0 was recorded 36 times out of 450 observations. If one considers the case where the first-mover bids within 4 units of the Nash equilibrium and the second-mover bids either 0 or 1, this is observed 63 times (14% of all observations).

[11]This difference is significant at the 10% level regarding the data from the last ten periods.

[12]Remember that in order for a follower to have an equal probability of winning the contest she would have to bid 2.33 times more than the leader.

[13]Note that the all-pay rule is in accordance with the American legal system, as opposed to the British system, where in general the losing party has to incur the full amount of the legal costs by the two conflicting parties.

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A Sample Instruction Sets

Simultaneous Asymmetric Treatment Instructions

Welcome to our experiment! Please read these instructions very carefully! Do not talk to your neighbours and keep quiet during the entire experiment. If you have any questions, please raise your hand, and we will answer your question privately.

In this experiment you will be given an endowment of 300 Experimental Currency Units (ECU) in every period. You will use any part of your endowment to bid for a prize. There will be another person bidding for the same prize. This prize is worth 200 ECU to you and the other person. Importantly, **regardless of who wins, both persons will have to pay their bids**.

So if you win the prize, your payoff is equal to your endowment plus the prize minus your bid. If you lose, your payoff will be equal to your endowment minus your bid. Note that in the event that both persons bid zero, neither of them will win the prize.

If you win: Payoff = Endowment + Prize - Bid

If you lose: Payoff = Endowment - Bid

The experiment will work as follows: there will be two types of persons, type A and type B persons. There are as many type-A persons as there are type-B persons in the room. To find out what type of person you are, please check the top right-hand corner of this instruction set.

In every round, a type-A person is randomly matched with a type-B person, and both persons will decide how many ECU's to bid.

The more you bid, the more likely you are to win. The more the other person bids the less likely you are to win.

Specifically, each ECU a type-A person bids counts as 3 blue balls and each ECU a type-B person bids counts as 7 red balls. All red and blue balls are put into an opaque bag, and one is taken at random. If the chosen ball is blue, the type A person wins the prize, if the chosen ball is red, the type B person wins the prize.

To help you compute how likely you are to win the prize, we provide you with a probability calculator. It tells you the probability of winning the prize given the bids made by you and the other person. You can compute this as many times as you wish.

After both persons have made their decisions, the winner will be decided and you will receive information about your payoffs on a separate screen.

There will be 30 periods in this experiment. At the end of the experiment, we will calculate the sum of your earnings and pay them to you in cash. 1000 ECU are worth £1.20.

Sequential Symmetric Treatment Instructions

Welcome to our experiment! Please read these instructions very carefully! Do not talk to your neighbours and keep quiet during the entire experiment. If you have any questions, please raise your hand, and we will answer your question privately.

In this experiment you will be given an endowment of 300 Experimental Currency Units (ECU) in every period. You will use any part of your endowment to bid for a prize. There will be another person bidding for the same prize. This prize is worth 200 ECU to you and the other person. Importantly, **regardless of who wins, both persons will have to pay their bids**.

So if you win the prize, your payoff is equal to your endowment plus the prize minus your bid. If you lose, your payoff will be equal to your endowment minus your bid. Note that in the event that both persons bid zero, neither of them will win the prize.

If you win: Payoff = Endowment + Prize - Bid

If you lose: Payoff = Endowment - Bid

The experiment will work as follows: there will be two types of persons, type A and type B persons. There are as many type-A persons as there are type-B persons in the room. To find out what type of person you are, please check the top right-hand corner of this instruction set.

In every round, a type-A person is randomly matched with a type-B person. Then in the first part of the round, the type-A persons will decide how much they should bid. After the type-A person have submitted their bid, it will be the turn of the type-B persons to make their decision after knowing the bid of the type-A their are matched with.

The more you bid, the more likely you are to win. The more the other person bids the less likely you are to win.

Specifically, each ECU a type-A person bids counts as 1 blue ball and each ECU a type-B person bids counts as 1 red ball. All red and blue balls are put into an opaque bag, and one is taken at random. If the chosen ball is blue, the type A person wins the prize, if the chosen ball is red, the type B person wins the prize.

To help you compute how likely you are to win the prize, we provide you with a probability calculator. It tells you the probability of winning the prize given the bids made by you and the other person. You can compute this as many times as you wish.

After type-B persons have made their decisions, the winner will be decided and you will receive information about your payoffs on a separate screen.

There will be 30 periods in this experiment. At the end of the experiment, we will calculate the sum of your earnings and pay them to you in cash. 1000 ECU are worth £1.20.

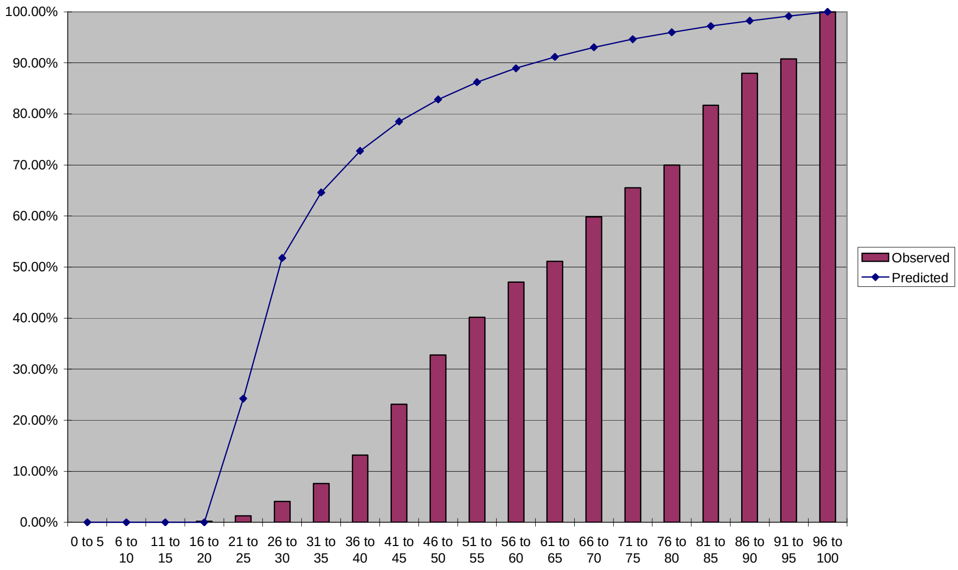

Figure 1: Distribution of bids in simultaneous play treatments in the last 10 periods

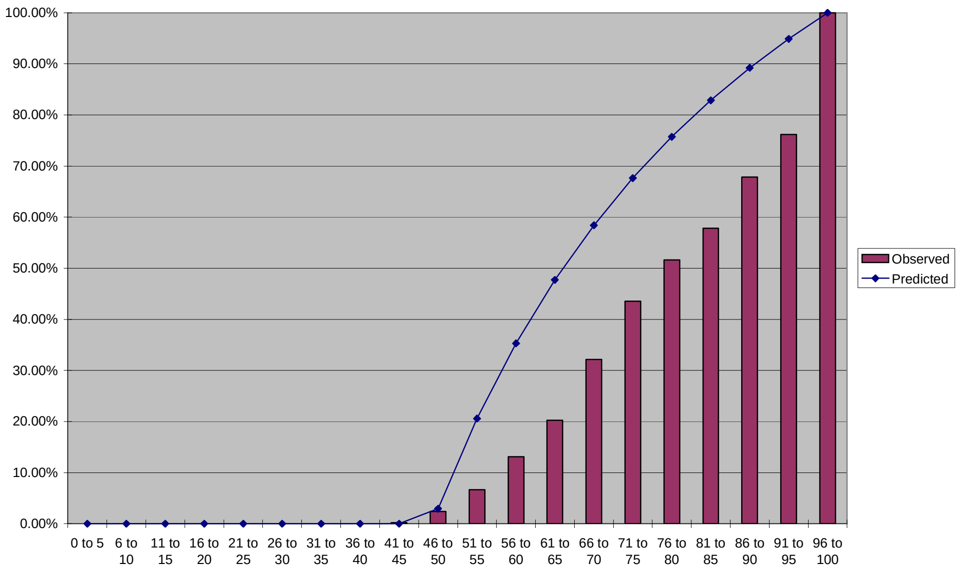

Figure 2: Individual bidding behavior

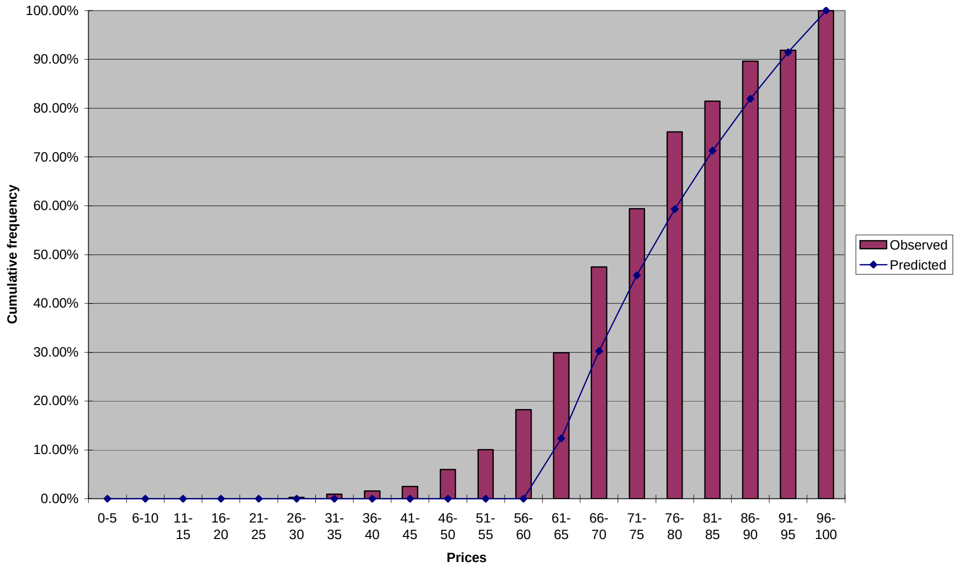

Figure 3: Plot of the distribution of followers' bids conditional on leaders' bids - *seqsym treatment*

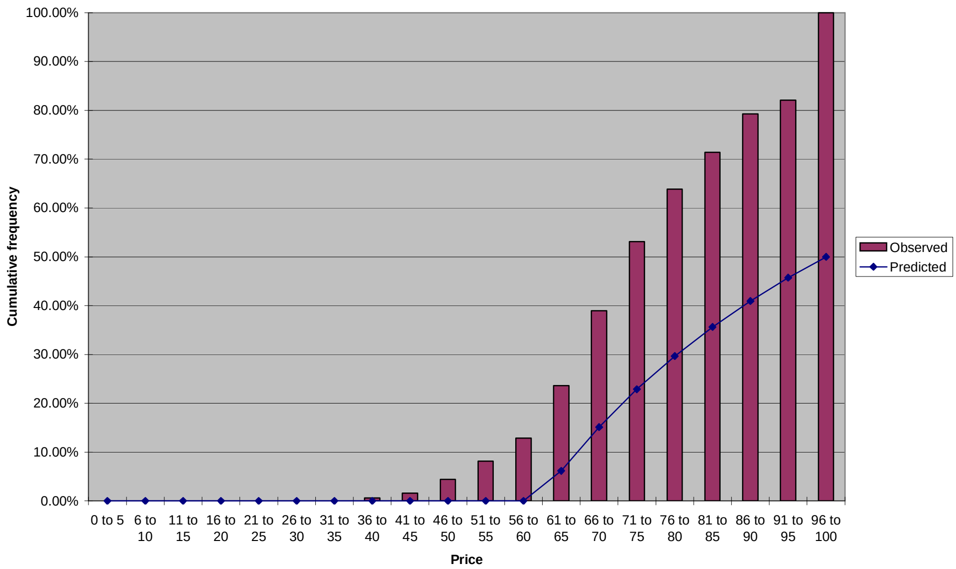

Figure 4: Plot of the distribution of followers' bids conditional on leaders' bids - *seqasym* treatment

Treatment Name	Move Order	Symmetry	Prediction (Player 1, Player 2)	Rent Diss.
simsym	Simultaneous	Symmetric	(50,50)	100
simasym	Simultaneous	Asymmetric	(42,42)	84
seqsym	Sequential	Symmetric	(50,50)	100
seqasym	Sequential	Asymmetric	(86,0)	86

Table 1: Theoretical predictions for the different treatments

Periods	1-10	11-20	21-30	All
E (Symmetric bidders)	119.5	95.36	85.4	100.08
	(75.96)	(63.45)	(52.54)	(66.19)
E ("Weak" bidders)	100.93	69.12	61.35	77.13
	(95.42)	(76.70)	(57.00)	(79.66)
E ("Strong" bidders)	115.51	81.19	62.08	86.26
	(85.56)	(69.68)	(39.87)	(71.12)

(Standard deviations in parenthesis)

Table 2: Average effort levels over time — *simsym* and *simasym* treatments

Periods	1-10	11-20	21-30	All
(1st mover)	100.08	81.84	92.60	91.51
	(84.30)	(56.38)	(56.30)	(67.24)
(2nd mover)	75.55	82.31	76.45	78.10
	(72.98)	(53.20)	(55.58)	(61.16)

(Standard deviations in parenthesis)

Table 3: Average effort levels by subject type — *seqsym* treatment

1st mover E	avg 2nd mover E	st dev	# of obs	%	Statistical BR
0-20	46	17.92	10	6.67	37.13
21-40	63.24	13.22	17	11.33	48.36
41-60	86.24	36.7	33	22	49.78
61-80	75.6	25.66	10	6.67	48.19
81-100	83	53.84	40	26.67	41.88
101-120	162.25	43.44	4	2.67	37.31
121-140	45	62.25	5	3.33	32.21
141-160	35.73	52.48	11	7.33	24.01
161-180	170	.	1	0.67	13.47
181-200	96.5	98.27	16	10.67	2.36
201-220	.	.	0	0	.
221-240	14.5	20.51	2	1.33	0.00
241-260	.	.	0	0	.
261-280	0	.	1	0.67	0.00
281-300	.	.	0	0	.

Table 4: Average second-mover bids conditional of first-mover's bid — *seqsym* treatment

Periods	1-10	11-20	21-30	All
First Mover E	99.01	71.45	64.13	78.2
	(71.12)	(42.85)	(30.03)	(53.04)
Second Mover E	71.65	56.59	53.46	60.57
	(91.74)	(72.21)	(61.78)	(76.5)

(Standard deviations in parenthesis)

Table 5: Average bid levels — *seqasym* treatment

First-mover E	Second-mover E	st dev	# of obs	%	Statistical BR
0-20	44.69	29.74	16	10.69	42.20
21-40	87.45	58.1	11	7.33	46.00
41-60	77.55	66.06	44	29.36	35.56
61-80	38.2	62.72	25	16.69	14.01
81-100	36.2	57.79	49	32.68	0.07
101-120	15	21.21	2	1.34	0.00
121-140	10	.	1	0.67	0.00
141-160	80.5	112.43	2	1.34	0.00
161-180	.	.	.	0	0.00
181-200	.	.	.	0	0.00
201-300	.	.	.	0	0.00

Table 6: Average second-mover bids conditional on first-mover's bid — *seqasym* treatment