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Abstract: The process of allocating rights to resources can be viewed as a contest: parties compete with each other for the right to claim a larger allocation. In some situations, the amount of the resource that is available to allocate may be unknown when parties are competing for shares and perhaps not realized until contestants actually attempt to claim their shares of the resource. For example, fishing quotas may be awarded based on estimated fish populations, but if there are fewer fish than anticipated, those who are last to harvest may not be able to fill their quota. We model contests of this form and test the predictions of the model using a controlled laboratory experiment. The general result is that participants compete less intensively for shares of the resource when uncertainty regarding the size of the prize is resolved later in the process.

Keywords: Contests with Uncertain Prizes, Fisheries, Experimental Economics
JEL Codes: C7, C9, D7, Q2

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Introduction

Recently, there has been considerable theoretical and experimental attention on contests, where parties compete for the right to claim a share of a prize (e.g., Dechenaux et al., 2015; Sheremeta, 2011). Applications vary from election campaigns to patent races and brand advertising to lobbying efforts and political processes for awarding natural resources (Krueger 1974; Tullock 1980; Snyder 1989; Fudenberg et al. 1983; Boyce 1998). The effort and resources dedicated to competing for a share of a prize rather than to productive activities are commonly referred to as rent-seeking behavior (Tullock 1967; Krueger 1974; Posner 1975; Bhagwati 1982). Such behavior has been shown to occur in many institutional settings and to have large social losses (e.g., Angelopoulos et al., 2009; Cowling and Mueller, 1978; Torvik, 2002).

In the literature, it is typically assumed that the contestants know the value of the prize, or at least that the sum of the potential entitlements equals the available prize (see Sheremeta, 2019). However, there are settings in which this assumption may not hold because the amount of the prize is unobserved and shares to the prize are rewarded sequentially. For example, farmers secure rights to sequentially extract from an irrigation canal (Ostrom and Gardner 1993; Janssen et al. 2011). If water flow is less than expected when entitlements were determined, those farmers who extract last may not be able to claim any water. A similar phenomenon can occur in bankruptcy filings, where creditors are prioritized and some may be left unable to recoup losses if the assets turn out to be worth less than anticipated.

In this paper, we study a generalized version of a contest in which players compete for the right to a share of a prize when the size of the prize is uncertain and claims to the prize are filled sequentially. We develop a theoretical model that extends conventional proportional-prize contest models (Tullock 1980; Cason et al. 2010) and generates a set of testable hypotheses under varying assumptions regarding the timing of the prize realization. We test these hypotheses in a laboratory setting with an experimental design that uses the certainty of the prize (known or unknown) and the timing in which the prize is realized as treatments.[1]

[1] The positional asymmetry in a sequential claim setting is distinct from asymmetry in cost or ability that have been studied previously (see Konrad (2009) for an overview of previous theoretical treatments of asymmetry).

Our theory and motivation align with the circumstances of fishermen, who compete for harvest from a stock of unknown size (Laukkanen 2003; McKelvey and Golubtsov 2006). Indeed, intense user group competition and a highly variable prize are common features of many fisheries around the world (Hilborn et al. 2005; Huang and Smith 2014). This is illustrated, perhaps, nowhere better than the salmon fisheries of the Kenai Peninsula in Alaska. There are varied user groups: commercial, sport, and personal-use fishermen. Each group invests significant time and money to compete for fish before and during the season. Pre-season lobbying is important for each user group, particularly sport and commercial, for establishing their share of the total allowable catch. The catch, or the prize, can be significant, but shares of the catch are regulated and depend on nature and the degree of competition with other users. Salmon abundance, particularly Sockeye salmon (a.k.a. Red salmon), is highly variable and difficult to predict (Schoen et al. 2017).

A particular feature of a salmon fishery is that harvesting is sequential due to the spawning habits of the species. Salmon spend their adult lives in the ocean. But on their way to spawn, salmon swim up-river in pulses over a short time period during the summer and early fall; salmon spawn in smaller tributaries and so all fishing is regulated to occur downstream of spawning areas. Different types of users operate in distinct areas, which the fish pass through in a single direction. Competition begins in the salt-water commercial fishery, as salmon converge at the mouth of river systems, and extends upriver where sport and subsistence/personal-use fishing occurs. Downstream and saltwater harvesters typically have a distinct advantage over upstream users, particularly in low-abundance years. In high-abundance years, regulators adjust up allowable catch during the season to avoid "over-escapement" —i.e., too many fish escaping up-river to spawn—and mid-season adjustments often provide heterogeneous benefits.[2] As in other lobbying settings, Kenai River watershed users spend a considerable amount of resources trying to influence the State's Board of Fish and other agencies for favorable treatment. Ongoing declines in the important Chinook salmon (a.k.a. King salmon) fishery has also led to intense lobbying efforts by sport fisherman who generally attribute the decline to a "by-catch" (i.e.,

[2] Too many fish spawning results in too many fry competing for limited resources in the river system. As a result, smolt (who go to the ocean) are less healthy or less abundant compared to smolt in seasons with more sustainable spawning levels.

incidental catch of Chinook salmon by groundfish fishermen) problem with the commercial fishery.

While our theory is motivated by the salmon fishery, the experiments are neutrally framed so the implication of our results are more general and can be directly compared with other contest experiments. Similar to other studies, we find that subjects over-spend relative to predicted amounts in all treatments. In symmetric treatments, when subjects invest prior to the prize amount being determined, we find that player order doesn't matter as lobbying effort doesn't depend on bidding position. In asymmetric treatments, when the sequential nature of the claims is such that prize collection order should impact behavior, we find that those whose claims are filled later invest less than those whose claims are filled earlier, consistent with theoretical predictions. Further, uncertainty is found to reduce overall effort, and when potential resources are capped (e.g., a limit on harvests that is less than the available resource), subjects invest less effort on average. Finally, when resources aren't capped and allocations are awarded before subjects know the amount of the available resource, the total amount of lobbying decreases. Our findings therefore suggest that when allocations are rewarded sequentially, rent-seeking behavior could be partially subdued by constraining lobbying effort to occur before the size of the prize is determined or announced.

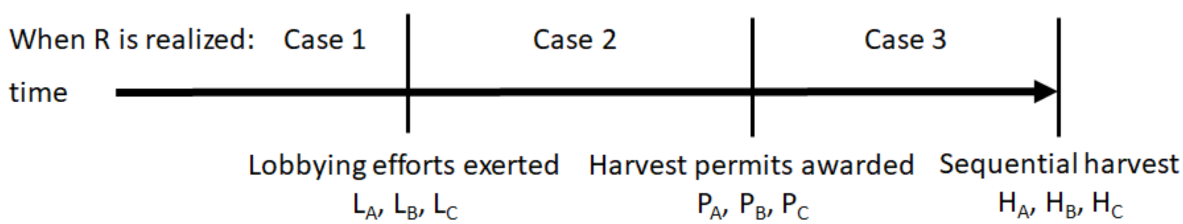
Theoretical Model

Consider the following stylized setting in which three players A, B, and C desire to harvest a resource, R, which is a random variable. For simplicity, we assume R ~U[0,M], where M is the natural maximum of the resource. The nature of harvesting the resource is such that A harvests before B who in turn harvests before C. For simplicity, we assume that harvesting is costless to each player and that the marginal value of each unit harvested is constant and normalized to one. Without some intervention, player A would harvest the entire resource leaving none for B or C to harvest. In such a situation, a benevolent government could choose to allocate the resource through a political process. Specifically, we assume that the players engage in costly Tullock-style lobbying in order to be awarded a permit to harvest a specified amount (Tullock 1980). Let L_i denote the lobbying effort of player *i* where i $\in I$ = {A, B, C} and let P_i denote player i's permitted amount.[3] The sequential nature of the harvest means that player A's actual harvest will be $H_A = \min(P_A, R)$. Player B's actual harvest will be $H_B = \min(P_B, R - H_A)$ and player C's actual harvest will be $H_C = \min(P_C, R - H_A - H_B)$. Player i's profit function is given by $\pi_i = H_i - L_i$.

For reasons that will become apparent, we assume that the government sets a target $T \leq M$ specifying the maximum amount of the resource that can be allocated through the lobbying process. That is, the actual amount of the resource that is permitted to be harvested, $\sum_i P_i$, has two constraints, one natural and one political, and thus equals the min (R, T).

Optimal lobbying efforts and equilibrium outcomes depend on when the resource R is realized. If R is known when the government acts, then permits can be based on both R and T. But, if R is unknown, then permits are based only on the target T, which could exceed the available resource, R. There are three separate cases to consider as depicted in Figure 1. In all cases, it is assumed that players know the government's policy with regards to T.

Figure 1. Sequence of Events



Case 1: R Known Prior to Lobbying and Permit Awards

If the government is willing for the entire realized resource to be allocated (i.e. T = R) then the situation becomes a standard symmetric Tullock contest. Player i's profit function becomes $\pi_i = s_i R - L_i$ where $s_i = L_i / \sum_{j \in I} L_j$. It follows that the equilibrium lobbying effort is $L_i^* = 2R/9$, and as a result, $P_i = R/3$. In this case, the sequential nature of the harvest does not matter because the sum of the permits equals R and thus each player can harvest the permitted amount, P_i, with certainty.

[3] Lobbying efforts, for instance, could be directed toward influencing the government or on influencing public opinion with the intent of influencing the policy maker.

If the government set a target $T = \bar{T} < R$ then there would be some resource left over after the permitted harvests were collected.[4] A government might want to do this for a variety of reasons (e.g. sustainability of the resource, strategic reserves, etc.). Alternatively, the government could allow the final player to simply keep the residual $R - \bar{T}$. Whether the final player is a residual claimant or not would not impact the optimal lobbying effort. If player C is not a residual claimant then player C's profit would be $\pi_C = s_C\bar{T} - L_C$. If player C is a residual claimant then player C's profit would become $\pi_C = s_C\bar{T} - L_C + R - \bar{T}$. The two first order conditions would be identical and thus the equilibrium lobbying effort would be $L_i^* = 2\bar{T}/9$ and each player is guaranteed to receive his permitted harvest.

Notice that the case of $\bar{T} < R$ differs from the previous result where T = R only in that the size of the known prize for which the players are lobbying has changed from R to $\bar{T}$. Treating the last player as a residual claimant would be reasonable if it was not practical for earlier players to harvest again (such as salmon that move systematically) or if the final player valued the unused resource (such as an environmental group wanting to maximize the remaining amount of the resource).

Case 2: R Known After Lobbying but Before Permit Awards

Again, assuming the government will fully allocate the resource to the players (i.e., the government will set T = M), this problem is again a symmetric Tullock contest, but with an uncertain prize.[5] Player i would maximize the expected profit function of the form $E(\pi_i) = s_iE(R) - L_i$ and the optimal lobbying effort would be M/9 for each player given the assumption of a uniform distribution for R so that E(R)=M/2. In equilibrium, each player will harvest one third of the realized resource. As in case 1, the sequential nature of the harvest does not impact equilibrium lobbying efforts as $\sum_i P_i = R$.

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[4] We assume that the government is benevolent and would not knowingly allocate more of the resource than what is available and thus we do not consider the case where T > R.

[5] This policy is effectively the same as the government promising to set T=R once R is realized. A similar construction could be done for case 1 where the government sets T = M to use the full resource or sets $T = \bar{T} < M$ which could result in either the full resource being used or not, but in case 1 players would know this outcome prior to lobbying.

If the government sets T = $\bar{T}$ < M then the government target may or may not bind when permits are awarded. In this case, Player i's expected profit would be E(π_i)= $s_i \left[\frac{\bar{T}^2}{2M} + \frac{\bar{T}(M-\bar{T})}{M}\right] - L_i$ and the resulting optimal lobbying effort would be L_i* = 2 $\left[\frac{\bar{T}^2}{2M} + \frac{\bar{T}(M-\bar{T})}{M}\right]$/9, where the term in brackets is the expected total amount of the resource to be awarded through lobbying efforts. As in case 1, if T = $\bar{T}$ < M then there may be some of the resource left over. If the last player were a residual claimant on this portion of the resource, it would not change the equilibrium outcome and would only represent a (random) transfer to the final player just as it did in case 1. Here too, the sequential nature of the harvest does not impact behavior as $\sum_i P_i = \min(R, T)$, the amount available to be harvested.

Case 3: R Known After Permit Awards

In this case, permits are awarded based on the target T (i.e., $P_i = s_i T$). Because T is set before R is realized, T could exceed R. Thus, it is possible that $\sum_i P_i > R$ and not every player is able to harvest the permitted amount. The profits to the three players are

$$\pi_A = \int_0^{s_A T} r \frac{1}{M} dr + s_A T \int_{s_A T}^{M} \frac{1}{M} dr - L_A$$

$$\pi_B = 0 \int_0^{s_A T} \frac{1}{M} dr + \int_{s_A T}^{s_A T + s_B T} (r - s_A T) \frac{1}{M} dr + s_B T \int_{s_A T + s_B T}^{M} \frac{1}{M} dr - L_B$$

$$\pi_C = 0 \int_0^{s_A T + s_B T} \frac{1}{M} dr + \int_{s_A T + s_B T}^{T} (r - s_A T - s_B T) \frac{1}{M} dr + s_C T \int_T^M \frac{1}{M} dr - L_C .$$

For player A, the first term in the profit function reflects the possibility that the realized resource may be below his permitted amount, in which case he would only be able to harvest the realized amount. The second term in the profit function reflects the outcome when the available resource exceeds his permitted amount. For player B, the first term reflects the possibility that there may be an insufficient amount of the resource for player A to harvest his permitted amount, thus leaving nothing for player B. The second and third terms reflect the possibilities that player B's permitted harvest can be partially and fully fulfilled, respectively. The three terms for player C are similar to those for player B. Notice that if player C is a residual claimant then player C's profit would have an additional term of $\int_T^M (r - \mathrm{T}) \frac{1}{M} dr$, but this term would not depend on the lobbying effort of any player and would therefore not impact the equilibrium lobbying efforts or the permitted harvest amount of any player.

The resulting first order conditions for A, B, and C, respectively are

$$\frac{L_B + L_C}{(L_A + L_B + L_C)^2} T \left[1 - s_A \frac{T}{M}\right] - 1 = 0$$

$$\frac{({L_A}^2 + L_A L_C + L_B L_C)}{(L_A + L_B + L_C)^3} \frac{T^2}{M} - \frac{L_A + L_C}{(L_A + L_B + L_C)^2} T + 1 = 0$$

$$\frac{L_A + L_B}{(L_A + L_B + L_C)^2} T - \frac{(L_A + L_B)^2}{(L_A + L_B + L_C)^3} \frac{T^2}{M} - 1 = 0$$

These equations do not lead to nice closed-form solutions for the equilibrium lobbying efforts; however, it is possible to solve them numerically, as is done below.

Experimental Design

Experimental Treatments

To explore the behavioral impact of sequential harvesting, we conducted a laboratory experiment with 6 treatments, summarized in Table 1. The experiment used neutral language and did not refer to lobbying or the harvesting of resources. Instead, subjects bid for prizes. The treatments included one in which the prize was known prior to the players bidding for their shares of it (case 1). Specifically, we set R = T = 120 and refer to this treatment as *Fixed Prize* (Treatment 1). In this treatment, the equilibrium bid is **26.67** for all three players. The *Fixed Prize* treatment is similar to a standard Tullock contest experiment and thus serves as a means for comparing our subject pool and procedures to previous studies.

In Treatments 2 and 3, subjects bid prior to the prize amount being determined, but the amount of prize that each player is permitted to claim is determined after the size of the prize is realized (case 2). These two treatments differ in terms of T, the maximum amount of the random prize that can be claimed. In Treatment 2, *Full Uncertain Prize*, T = M = 240 so that the full amount of the realized prize can be claimed. The expected value of the claimable prize is 120 in this treatment, just as in *Fixed Prize*, and the only difference between *Full Uncertain Prize* and *Fixed Prize* is uncertainty of the prize amount. This comparison allows us to directly investigate the impact of having prize uncertainty separate from the impact of sequential harvesting. As discussed previously, this uncertainty should not impact behavior if players are risk neutral. Thus, the equilibrium bid is **26.67** in *Full Uncertain Prize* for each of the players. In Treatment 3, the *Partial Uncertain Prize*, we set T=120 (with M=240) and explain to subjects that any portion of the realized prize R > 120 is "unavailable" and only amounts less than or equal 120 are "available." For risk neutral players, this should lead to a decrease in bids as the expected value of the claimable prize is reduced to 90 and thus the equilibrium bid is **20** for all three players.

As demonstrated in our theoretical model, the sequential nature of the claims does not impact behavior or outcomes in cases 1 or 2 so that all three players are strategically symmetric. Thus, we refer to *Fixed Prize*, *Full Uncertain Prize*, and *Partial Uncertain Prize* as the symmetric treatments.[6] In case 3, which includes Treatments 4-6, the sequential nature of the claims is such that prize collection order should impact behavior and hence we refer to those treatments as the *asymmetric treatments*. Specifically, we consider three treatments in which the claimable prize is not known until players attempt to collect their awarded amounts (i.e., after permits are awarded).[7]

Asymmetric Full Uncertain Prize (Treatment 4) is similar to *Full Uncertain Prize* in that T = M = 240, but differs from it in that the available prize is not known when the maximum amount each person can claim is determined. After the variable prize is realized, the prize is allocated sequentially to player A, then player B, and then to player C, up until the point that R is fully allocated. Consequently, all players may not always receive their full permitted allocation. For this treatment, the equilibrium bids for players A, B, and C are **30**, **30**, and **0**, respectively, because

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[6] These treatments are symmetric because the structure makes them equivalent to simultaneous harvest games. As such these treatments were presented as having simultaneous prize claims.

[7] Depictions of the numerical best-response functions and equilibrium lobbying efforts for Treatments 4, 5, and 6 can be found in Appendix 1.

player C finds it optimal to drop out of the lobbying competition. The intuition for this result is that there is a sizeable chance there is an insufficient amount of the resource available to satisfy the permits of A and B, and thus, C is likely to receive nothing. This result is distinct from standard simultaneous Tullock contests where a player should always invest a strictly positive amount.

Asymmetric Partial Uncertain Prize (Treatment 5) is similar to *Partial Uncertain Prize (Treatment 3)* in that T = 120, but differs in that the available prize is not known when the maximum amount each person can claim is determined. Like Treatment 4, in Treatment 5 the prize is allocated sequentially to player A, then player B, and then to player C up until the prize R is fully allocated or until the threshold T is reached. In this treatment, the equilibrium bids for players A, B, and C are **23.07**, **20.07**, and **13.46**, respectively. Capping the maximum amount of the resource that can be harvested in total increases the chance that enough of the resource is available after A and B harvest that player C is willing to compete.

The final treatment is *Residual Claimant (Treatment 6)*. This treatment is identical to *Asymmetric Partial Uncertain Prize* (Treatment 5) except that if R > T = 120 then player C is awarded the additional R – 120. The residual claim should not have any bearing on equilibrium behavior, and thus, the equilibrium bids for players A, B, and C are 23.07, 20.07, and 13.46, respectively.

Given that the main research focus of this paper is the impact of the sequential nature of claiming the resource, the primary comparisons of interest are between *Full Uncertain Prize* (Treatment 2) and *Asymmetric Full Uncertain Prize* (Treatment 4), as well as between *Partial Uncertain Prize* (Treatment 3) and *Asymmetric Partial Uncertain Prize* (Treatment 5). While we could have included a treatment with a residual claimant when the prize is known prior to maximum claims being awarded, we did not do so to balance the number of asymmetric treatments with the number of symmetric treatments, since subjects experienced either symmetric or asymmetric contests in an attempt to reduce subject confusion and experimenter demand effects.

Table 1. Details for Each Treatment

Treatment Name	#	R is Realized (Case)	Harvest Order Matters	Parameters	If R > T	Equilibrium Effort L_A	L_B	L_C	Total Effort
Fixed Prize	1	Before Lobbying (Case 1)	No (Symmetric)	R = T = 120	NA	26.7	26.7	26.7	80.0
Full Uncertain Prize	2	After Lobbying Before Permits (Case 2)	No (Symmetric)	R~U[0,M] T = M = 240	NA	26.7	26.7	26.7	80.0
Partial Uncertain Prize	3	After Lobbying Before Permits (Case 2)	No (Symmetric)	R~U[0,M] M = 240 T = 120	R-T Forgone	20.0	20.0	20.0	60.0
Asymmetric Full Uncertain Prize	4	After Permits (Case 3)	Yes (Asymmetric)	R~U[0,M] T = M = 240	NA	30.0	30.0	0.0	60.0
Asymmetric Partial Uncertain Prize	5	After Permits (Case 3)	Yes (Asymmetric)	R~U[0,M] M = 240 T = 120	R-T Forgone	23.1	20.1	13.5	56.6
Residual Claimant	6	After Permits (Case 3)	Yes (Asymmetric)	R~U[0,M] M = 240 T = 120	R-T Awarded to C	23.1	20.1	13.5	56.6

Behavioral Hypotheses

Previous contest experiments have consistently reported subjects overbidding relative to the theoretical predictions (see Sheremeta (2019) for a review). Thus, we do not expect behavior to match the equilibrium predictions in Table 1. However, the equilibria also provide comparative static predictions regarding treatment and role effects, and it is those predictions that we seek to test. Here were summarize these behavioral predictions.

The first two hypotheses examine behavior between players in a given treatment.

Symmetry Hypothesis: For Treatments 1, 2, and 3, a Player's role should not matter; thus, the effort exerted by A should equal the effort exerted by B, which in turn should equal the effort of C.

Asymmetry Hypothesis: For Treatments 4, 5, and 6, a Player's role should matter, such that the effort exerted by A should be greater than or equal to the effort exerted by B, which in turn should be greater than or equal to the effort exerted by C with strict inequalities holding as indicated in Table 1.

The next two hypotheses test whether features of the task influence behavior, even when those task features should not influence behavior.

Uncertainty Hypothesis: When harvest order does not matter, eliminating uncertainty while maintaining the expected prize does not impact effort (Treatments 1 and 2 yield the same behavior).

Residual Claimant Hypothesis: Making the third player a residual claimant does not impact the effort of any player (Treatments 5 and 6 yield the same behavior).

The next hypothesis examines the effect of setting a cap on the maximum amount of the resource that can be harvested.

Partial Prize Hypothesis: When the harvestable amount of the resource is restricted to less than the realized amount - regardless of whether or not harvest order matters - total effort decreases. That is, Treatment 2 leads to more total effort than Treatment 3, and Treatment 4 leads to more total effort than Treatments 5 and 6.

The final hypothesis is the main focus of the paper and explores how the timing of assigning allowable harvests and the realization of the available resource impact behavior.

Timing Hypothesis: When players may not be able to claim their permitted share of the prize because permits are allocated prior to the available amount of the resource being realized, total effort decreases, regardless of whether the full resource is made available for harvest or not. Consequently, Treatment 2 leads to more effort than Treatment 4, and Treatment 3 leads to more effort than Treatments 5 and 6.

Experimental Procedures

In each laboratory session, there were at least 9 subjects, each of which competed in three of the possible contest treatments: the three symmetric contests (Treatments 1-3) or the three asymmetric contests (Treatments 4-6).[8] In each session, 20 contests were completed in each of the treatments, for a total of 60 rounds. A total of 24 sessions were conducted, 12 for the symmetric treatments and 12 for the asymmetric treatments. As a result, we observe 720 and 760 separate (although not independent) contests for asymmetric and symmetric treatments, respectively. The order of the three treatments within a session was varied across sessions to control for order effects. Specifically, we conducted two sessions in each of the 6 possible orders for each set. Before every contest, subjects were randomly and anonymously placed in groups of size three. Further, the A, B, and C roles were randomly assigned for each contest. Instructions for each treatment were provided immediately prior to the start of the twenty contests for that treatment.[9] Subjects were not informed of how many treatments they would complete during a session.

Subjects were undergraduates at the University of _______________ who were only allowed to participate in a single session and had no prior experience with any related studies. The experiments were conducted at the ____________________________ Laboratory at the university and each subject received $5 plus their salient earnings, which averaged $27.06, for the 120 minute session.[10] Earnings in the contest experiment were determined by selecting two

[8] In one session of the symmetric treatment there were 15 subjects. Every other session included exactly 9 subjects. We find no substantive differences in the results with or without this larger session.

[9] Copies of the instructions are included in Appendix 2.

[10] Experiments were programmed and implemented using oTree (Chen et al. 2016).

rounds at random from each treatment (thus six rounds were used in determining payoffs). All amounts in the contest experiment were denoted in lab dollars, which the subjects were told in advance would be converted into US$ at the rate 16 Lab$ = US$ 1. To absorb potential losses, subjects were given an endowment of 60 Lab$. All contest experiments were preceded by a standard Holt-Laury multiple price list risk elicitation task (Holt and Laury 2002). Earnings from the risk elicitation exercise were added to earnings from the contest experiment and are included in the average salient payment calculation.

Behavioral Results

Table 2 summarizes the observed behavior. The first thing that is apparent from the table is that subjects overbid in comparison to the theoretical predictions: the average investment significantly exceeds the predicted amount in 17 of the 18 combinations of role and treatment. Such overbidding in contests is common in laboratory experiments. In fact, our *Fixed Prize* treatment is directly comparable to previous contest experiments since the prize is know with certainty to the bidders prior to bidding. On average, subjects bid 36 in *Fixed Prize* or 35% above the equilibrium level. For comparison, Lim, Matros, and Turocy (2014) report that bids were 32% and 60% above the predicted level with N=2 and N=4 bidders respectively. (Sheremeta 2011) reported overbidding of 33% with N=2 bidders. This suggests that the subject pool and graphical interface used in our experiment are not impacting observed behavior.

We now turn to testing each of the six behavioral hypotheses. The *Symmetry Hypothesis* holds that lobbying effort does not depend on role in Treatments 1, 2 or 3. Table 3 reports regression results to test this hypothesis. In these specifications, the *Constant* term captures the bid of A while *Second* capture the difference between bids by Player A and Player B and thus Player B's bid is given by *Constant* + *Second*. *Third* captures the difference between the bid of Player C and Player B and thus, Player C's bid is given by *Constant* + *Second* + *Third*. Formally, the hypothesis is that *Second* = *Third* = 0 for each of the three treatments. The regressions include subject fixed effects and standard errors clustered at the session level. As evidence in Table 3, there are no significant differences between players in Treatments 1-3, with two exceptions. In Treatment 3, Player C outbids Players A and B by a statistically significant, although economically small, amount: a difference of 1.21 and 0.96 respectively. Overall, the results support the *Symmetry Hypothesis*.

Table 2. Equilibrium Predictions and Observed Behavior

Treatment		Equilibrium Predictions				Observed Behavior			
Name	#	L_A	L_B	L_C	Total	L_A	L_B	L_C	Total
Fixed Prize	1	26.7	26.7	26.7	80.0	35.5***	37.4***	35.1***	108.0
Full Uncertain Prize	2	26.7	26.7	26.7	80.0	31.7***	32.4***	31.7***	95.8
Partial Uncertain Prize	3	20.0	20.0	20.0	60.0	27.4***	28.6***	28.1***	84.1
Asymmetric Full Uncertain Prize	4	30.0	30.0	0.0	60.0	37.8***	27.1**	20.4***	85.3
Asymmetric Partial Uncertain Prize	5	23.1	20.1	13.5	56.6	34.2***	25.8***	18.8**	78.8
Residual Claimant	6	23.1	20.1	13.5	56.6	33.1***	25.2***	21.5***	79.8

*p<0.1; **p<0.05; ***p<0.01 denote an observed mean that is statistically different than the predicted mean. The tests were conducted by regressing the observed behavior on a constant, allowing for standard errors clustered at the session level. Differences are significant with and without subject fixed effects, except for player B in Treatment 4.

The *Asymmetry Hypothesis* holds that in Treatments 4, 5, and 6 those who claim their prizes later should not bid more than those who claim their prizes earlier. To test this hypothesis, we rely upon regression analysis similar to that done for the Symmetry Hypotheses. However, the prediction is now that Second < 0 and Third < 0 (except for Treatment 4 where the prediction is that Second = 0). These results are presented in Table 3 as well. As indicated, Second and Third bid significantly less than the First player in each treatment. In addition, the Third player always bids significantly less than the Second player in each Asymmetric treatment. These results generally match the comparative statics of the model and support the Asymmetry Hypothesis: in every case where order matters those whose claims are filled later bid less than those whose claims are filled earlier. The one exception is that the Player B is expected to invest as much as Player A in Treatment 4, but actually invests less.

Table 3. Symmetry and Asymmetry Hypothesis Tests: Lobbying Effort by Player and Treatment

	(1) Fixed Prize (Treatment 1)	(2) Full Uncertain Prize (Treatment 2)	(3) Partial Uncertain Prize (Treatment 3)	(4) Asymmetric Full Uncertain Prize (Treatment 4)	(5) Asymmetric Partial Uncertain Prize (Treatment 5)	(6) Residual Claimant (Treatment 6)
First	omitted	omitted	omitted	omitted	omitted	omitted
Second	1.016	-0.220	0.241	-10.794***	-8.267***	-6.701***
	(0.63)	(0.62)	(0.62)	(0.70)	(1.00)	(1.47)
Third	0.010	-0.723	1.206**	-18.499***	-14.838***	-11.573***
	(0.52)	(0.48)	(0.44)	(1.44)	(1.49)	(1.98)
Constant	35.663***	32.228***	27.518***	38.230***	33.945***	32.708***
	(0.29)	(0.30)	(0.33)	(0.66)	(0.79)	(1.10)
N	2280	2280	2280	2160	2160	2160

*p<0.1; **p<0.05; ***p<0.01. Includes subject fixed effects. Robust standard errors are clustered at the group-level.

To test the *Uncertainty Hypothesis*, which predicts that behavior in Treatments 1 and 2 is the same, we again rely upon regression analysis allowing for subject fixed effects and standard errors clustered at the session level. Because the *Symmetry Hypothesis* has been shown to hold, we combine data across roles to test if behavior changes when the prize is uncertain (but each player will receive its permitted amount). The results, shown in Table 4, indicate that this type of uncertainty reduces lobbying effort.[11] Effort in the Fixed Prize Treatment (T1) is significantly greater than in the Full Prize Treatment (T2).

Table 4. Uncertainty Hypothesis Test: Lobbying Effort for Treatment 1 and 2

	All players
Fixed Prize (T1)	4.091**
	(2.08)
Full Prize (T2)	omitted
Constant	31.914***
	(1.14)
N	4,560

*p<0.1; **p<0.05; ***p<0.01.

[11] This reduction may be consistent with risk aversion, but depends on how risk attitudes are modeled since lowering one's lobbying effort also reduces on share of the prize.

We test the *Residual Claimant Hypothesis*—i.e., that behavior is the same in treatments 5 and 6 using specifications (1) – (4) in Table 5. Because behavior depends on role in these treatments, we test the treatment effect overall (specification 1) and separately for each position (specifications 2-4). Regression results indicate that Players A, B and C do not change their behavior in response to the immaterial fact of Player C being a residual claimant. Player C, who is the residual claimant in Treatment 6, allocates slightly more effort, but the difference is not statistically significant (p=0.148).

Table 5. Residual Claimant Hypothesis Test: Lobbying Effort Between Asymmetric Treatments

	(1) All Players	(2) Player A	(3) Player B	(4) Player C
Partial Prize (T5)	omitted	omitted	omitted	omitted
Residual Claimant (T6)	0.373	-1.192	-0.032	2.408
	(0.99)	(1.43)	(0.68)	(1.66)
Constant	26.244***	34.061***	25.836***	18.638***
	(1.44)	(1.65)	(1.31)	(1.87)
N	4320	1440	1440	1440

*p<0.1; **p<0.05; ***p<0.01. Robust standard errors are clustered at the group-level.

The *Partial Prize Hypothesis* states that the total amount invested is reduced when there is a cap on the amount of the resource that can be claimed. This pattern is intuitive because the distribution of the available resource with the cap is first order stochastically dominated by the distribution without the cap and thus is a complex variation of the incentive effect discussed by Sheremeta (2019). To test this hypothesis, we compare total lobbying investment in Treatment 2 and 3 (top panel in Table 6) as well as Treatments 4 and 5 (bottom panel in Table 6) as these are the only treatment pairs that vary only by the presence of a cap. Once again, we rely on regression analysis with standard errors clustered at the session level. In specification (1) of Table 6, we use total group effort, which is not subject specific, so we include session fixed effects. In specifications (2)-(4), we regress subject-level effort for all player positions combined and separately for individual player positions. For both pairs of treatments, the unrestricted case is captured by the constant term while the effect of placing a cap on the amount of the resource that can be harvested is captured by the variable *Cap*. For specifications (1) and (2), the prediction is that total effort will decrease with the cap (*Cap* < 0), which is consistent with both sets of treatments shown in Table 6. For the symmetric case, all players are predicted to decrease their effort uniformly; in contrast, only Players A and B are predicted to reduce effort for the asymmetric case, while Player C is predicted to increase effort. As indicated, the predicted change in effort is largely supported by the empirical results: the reduction in effort is statistically significant (and similar in magnitude) for each player in the symmetric case, whereas in the asymmetric case, the difference between the Cap and No Cap treatment diminishes from Player 1 to Player 2 and is equal to zero for Player 3.

Table 6. Partial Prize Hypothesis Test: Lobbying Effort in Full versus Partial Prize Treatments

		(1) Group Total	(2) Individual	(3) Player A	(4) Player B	(5) Player C
Symmetric	Cap	-11.525**	-3.914**	-5.240**	-4.215**	-2.845
		(4.58)	(1.53)	(1.82)	(1.47)	(1.79)
	Constant	84.591***	31.914***	32.165***	32.564***	31.293***
		(2.27)	(0.76)	(0.91)	(0.74)	(0.89)
	N	1520	4560	1520	1520	1520
Asymmetric	Cap	-6.681**	-2.222*	-4.205**	-1.666	-0.487
		(3.07)	(1.02)	(1.44)	(0.96)	(1.77)
	Constant	85.725***	28.465***	38.102***	27.277***	19.863***
		(1.54)	(0.51)	(0.72)	(0.48)	(0.88)
	N	1440	4320	1440	1440	1440
Fixed Effects		*Session*	*Individual*	*Individual*	*Individual*	*Individual*

Robust standard errors are clustered at the session-level.

Finally, the *Timing Hypothesis* posits that when allocations are awarded prior to the realization of the amount of the resource that is actually available, the total amount of lobbying decreases, despite the heterogeneous responses of the individual players—Player A is predicted to increase effort, Player B is predicted to increase (no cap) or not change (with cap) their effort, and Player C is predicted to decrease their effort. The regression analysis associated with testing this hypothesis is shown in Table 7, with the bottom panel presenting the results with the existence of a cap on the available resource (Treatments 3 and 5) and the top panel presenting results with no cap.[12] Once again, we rely upon regression analysis with standard errors clustered at the session level. The constant term captures total lobbying when the realization occurs before allocations are determined while the variable *Asymmetric* captures the effect of the realization occurring after allocations are awarded relative to the symmetric prize treatment. Note that since participants in a session did not compete under both Treatments 2 and 4 (or Treatments 3 and 5), individual or session fixed effects cannot be included in our specifications. *Asymmetric* is negative and significant for total effort (specification 1) for the full uncertain prize case (i.e., No Cap), but is not statistically significant from zero in the partial uncertain prize (specification 1). This is largely consistent with the *Timing Hypothesis*, since the decrease in total effort is predicted to be large with a full uncertain prize and economically small for the full uncertain prize. Interestingly, the player-specific effects are largely consistent with our theoretical predictions (specifications 3-5): Player A increases effort in both treatments, Player C decreases effort in both cases, and Player B does not change their effort under the partial prize. The only inconsistency with our predictions is that Player B appears to decrease their effort under the full prize, despite being predicted to increase their effort.

Table 7. Timing Hypothesis Test: Lobbying Effort in Asymmetric versus Symmetric Prize Treatments

		(1) Group Total	(2) Individual	(3) Player A	(4) Player B	(5) Player C
No Cap	Asymmetric	-10.559**	-3.449**	5.805***	-4.668***	-11.878***
		(4.75)	(1.59)	(2.19)	(1.57)	(1.53)
	Constant	96.038***	31.914***	32.345***	32.098***	31.618***
		(3.32)	(1.11)	(1.29)	(0.98)	(1.18)
	N	1480	4440	1480	1480	1480
Cap	Asymmetric	-4.972	-1.757	6.837***	-1.988	-9.264***
		(5.86)	(1.97)	(2.12)	(2.00)	(2.21)
	Constant	83.738***	28.000***	27.241***	27.785***	28.379***
		(4.10)	(1.37)	(1.43)	(1.54)	(1.29)
	N	1480	4440	1480	1480	1480

Robust standard errors are clustered at the session-level.

[12] Since behavior varies between Treatments 5 and 6 due to residual claimants increasing their bids when they should not (as shown in testing the *Residual Claimant Hypothesis*), Treatment 6 is not used to test the *Timing Hypothesis*.

Discussion

Many natural resource allocation problems, such as the right to harvest fish or pump water from a river, can be viewed as contests where the prize is uncertain. In these situations, the contestants are awarded shares of the resource which are claimed in a sequential fashion. Upstream farmers can siphon water before it reaches downstream farmers. Ocean based commercial fishers can harvest salmon before river based sport fishers. If the uncertainty regarding the amount of the available resource is not resolved prior to claims being made, the sequential nature of the allocation process creates an asymmetry among otherwise symmetric players. A similar phenomenon can occur in other settings, such as bankruptcy claims where some creditors are given priority.

This paper models sequential-award contests with an uncertain prize and tests the predictions using controlled laboratory experiments. Specially, we develop and test six behavioral hypotheses. The main finding is that when the amount of the available prize is not known at the time shares of the resource are claimed, players invest less in competitive effort, relative to when the available price is known before sequential claims are made (support for the *Timing Hypothesis*). We also find evidence that when uncertainty is resolved before prize shares are claimed, the sequential aspect of the allocation does not impact behavior, which is consistent with our theoretical predictions (support for the *Symmetry Hypothesis*). Furthermore, when uncertainty is not resolved prior to prizes being claimed, then players who are further back in the queue invest less, which is also consistent with our theoretical predictions (support for the *Asymmetry Hypothesis*). We also find evidence that behavior responds to features of the contest that are not predicted to matter: people bid more when prize uncertainty is resolved prior to investment (evidence against the *Uncertainty Hypothesis*) and awarding a residual claimant an additional prize leads that player to invest more (evidence against the *Residual Claimant Hypothesis*). Finally, we also find evidence that players invest less when the expected value of an uncertain prize decreases (support for the *Partial Prize Hypothesis*).

While there is a large literature on behavior in contests, there has been relatively little attention paid to the effects of uncertainty regarding the prize or the chance that the contestants will receive their awarded share, despite the existence of such possibilities in many settings. Our

Fixed Prize treatment is comparable to previous contest experiments and the behavior that we observe is typical; people over invest relative to the equilibrium level and as a result much of the expected surplus is dissipated. Our results are also consistent with previous work showing an incentive effect that leads people to invest less when the prize is reduced (the *Partial Prize Hypothesis*). But our work also offers new insights. For example, increasing uncertainty about the prize while holding the expected value constant led to lower investment and thus reduced rent dissipation, suggesting that contest designers who are motivated by contestant welfare concerns rather than investment maximization may want to add uncertainty. Our work also suggests that dissipation can be further reduced by awarding shares sequentially. This works because the sequential process discourages the last claimant from investing by more than it encourages the first claimant to invest. Of course, this asymmetric process introduces inequality into the distributions of investment and payoffs. We hope this paper will spur investigation into other features of practical significance for contest implementation.

References

Angelopoulos, Konstantinos, Apostolis Philippopoulos, and Vanghelis Vassilatos. 2009. The social cost of rent seeking in Europe. *European Journal of Political Economy* 25 (3): 280–99.

Bhagwati, Jagdish N. 1982. Directly Unproductive , Profit-Seeking (DUP) Activities. *Journal of Political Economy* 90 (5): 988–1002.

Boyce, John R. 1998. Rent-Seeking in Natural Resource Quota Allocations. *Public Choice* 96 (3): 271–94.

Cason, Timothy N, William A Masters, and Roman M Sheremeta. 2010. Entry into winner-take-all and proportional-prize contests: An experimental study. *Journal of Public Economics*.

Chen, Daniel L, Martin Schonger, and Chris Wickens. 2016. oTree-An open-source platform for laboratory, online, and field experiments. *Journal of Behavioral and Experimental Finance* 9: 88–97.

Cowling, Keith, and Dennis C Mueller. 1978. The Social Costs of Monopoly Power. *The Economic Journal* 88 (352): 727.

Dechenaux, Emmanuel, Dan Kovenock, and Roman M Sheremeta. 2015. A survey of experimental research on contests, all- pay auctions and tournaments. *Experimental Economics* 18 (4): 609–69.

Fudenberg, Drew, Richard Gilbert, Joseph Stiglitz, and Jean Tirole. 1983. Preemption, leapfrogging and competition in patent races. *European Economic Review* 22 (1): 3–31.

Hilborn, Ray, JM Orensanz, and Ana M Parma. 2005. Institutions, incentives and the future of fisheries. *Philosophical Transactions of the Royal Society B: Biological Sciences* 360 (1453): 47–57.

Holt, Charles A, and Susan K Laury. 2002. Risk Aversion and Incentive Effects. *American Economic Review* 92 (5): 1644–55.

Huang, By Ling, and Martin D Smith. 2014. The Dynamic Efficiency Costs of Common-Pool Resource Exploitation. *American Economic Review* 104 (12): 4071–4103.

Janssen, Marco A, John M Anderies, and Juan-Camilo Cardenas. 2011. Head-enders as stationary bandits in asymmetric commons: Comparing irrigation experiments in the laboratory and the field. *Ecological Economics* 70 (9): 1590–98.

Konrad, Kai A. 2009. *Strategy and Dynamics in Contests*. Oxford University Press.

Krueger, Anne O. 1974. The Political Economy of the Rent- Seeking Society. *American Economic Review* 64 (3): 291–303.

Laukkanen, Marita. 2003. Cooperative and non-cooperative harvesting in a stochastic sequential fishery. *Journal of Environmental Economics and Management* 45 (2): 454–73.

Lim, Wooyoung, Alexander Matros, and Theodore L Turocy. 2014. Bounded rationality and group size in Tullock contests: Experimental evidence. *Journal of Economic Behavior and Organization* 99: 155–67.

McKelvey, Robert, and Peter V. Golubtsov. 2006. The Effects of Incomplete Information in Stochastic Common-Stock Harvesting Games. In *Advances in Dynamic Games*, 253–92. Boston, MA: Birkhäuser Boston.

Ostrom, Elinor, and Roy Gardner. 1993. Coping with Asymmetries in the Commons: Self-Governing Irrigation Systems Can Work. *Journal of Economic Perspectives* 7 (4): 93–112.

Posner, Richard A. 1975. The Social Costs of Monopoly and Regulation. *Journal of Political Economy* 83 (4): 807–28.

Schoen, Erik R, Mark S Wipfli, E Jamie Trammell, Daniel J Rinella, Angelica L Floyd, Jess Grunblatt, Molly D McCarthy, Benjamin E Meyer, John M Morton, James E Powell, Anupma Prakash, Matthew N Reimer, Svetlana L Stuefer, Horacio Toniolo, Brett M Wells, and Frank DW Witmer. 2017. Future of Pacific Salmon in the Face of Environmental Change: Lessons from One of the World's Remaining Productive Salmon Regions. *Fisheries* 42 (10): 538–53.

Sheremeta, Roman M. 2011. Contest Design: An Experimental Investigation. *Economic Inquiry* 49 (2): 573–90.

------. 2019. Experimental Research on Contests. In *The New Palgrave Dictionary of Economics*, 1–8. London: Palgrave Macmillan UK.

Snyder, James M. 1989. Election Goals and the Allocation of Campaign Resources. *Econometrica* 57 (3): 637–60.

Torvik, Ragnar. 2002. Natural resources, rent seeking and welfare. *Journal of Development Economics* 67: 455–70.

Tullock, Gordon. 1967. The Welfare Costs of Tariffs, Monopolies, and Theft. *Western Economic Journal* 5 (3): 224–32.

------. 1980. Efficient Rent Seeking. In *Toward a theory of the rent-seeking society*, ed. D. Buchanan, R Tollison, and G. Tullock, 97–112.

Appendix 1. Best Response Function and Nash Equilibria for Treatments 4, 5 and 6

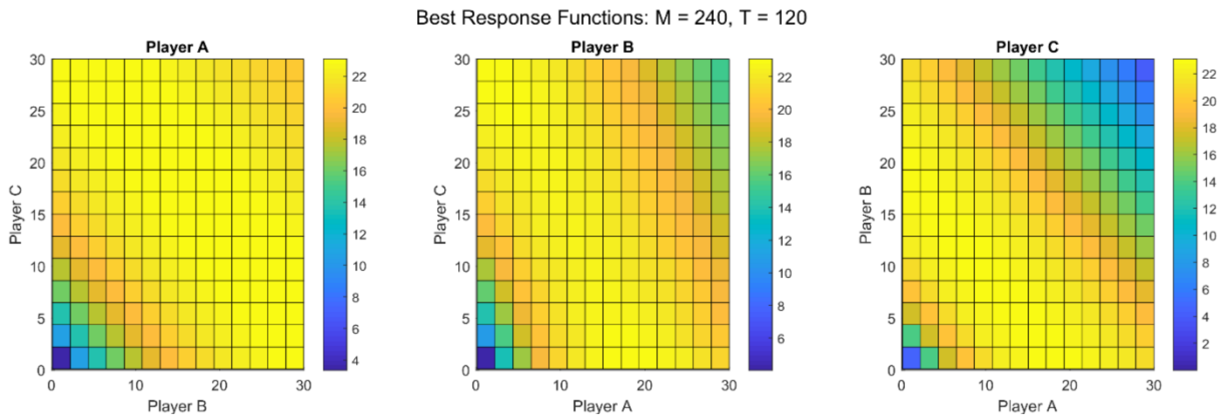

Figure A.1: Best response functions of Players A, B, and C for Treatments 4, 5 and 6.

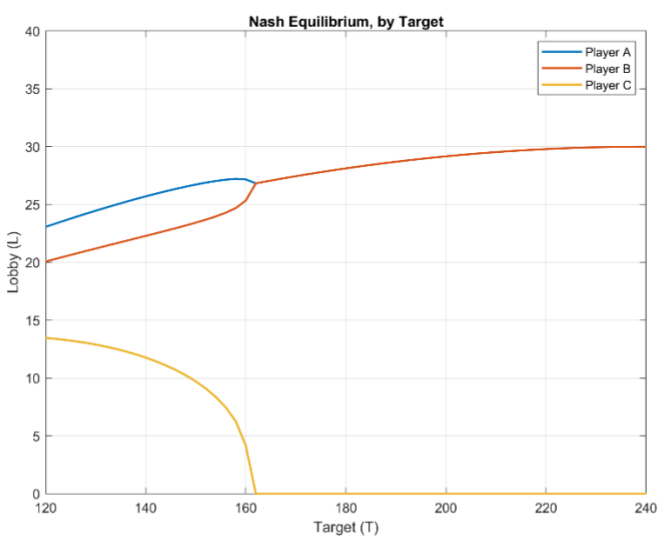

Figure A.2: Nash equilibrium lobbying efforts for Treatments 4, 5 and 6, as a function of target (*T*).

Appendix 2. Subject Instructions

The contest experiment was developed using oTree and instructions were displayed on a web browser. Below, we have pasted the experiment script that was read to subjects during the first part of each experiment. As discussed in the manuscript, all subjects completed part 1, a Holt-Laury multiple price list risk elicitation task, before moving to the contest experiment in Part 2. Screenshots of the instructions in Part 2. are pasted below just as they appeared to subjects for Treatment 5. Other treatments were similar and thus are not presented. However, copies of instructions for all treatments are available upon request.

Before experiment:

Take a seat at any computer with an active screen and a set of instructions. Please put your phones away for the remainder of the session. For this experiment, no one can move on until *everyone* has completed each part, so it is important that you focus on promptly completing each task. If everyone focuses, the experiment will be done relatively quickly.

Part 1:

In front of you is a pencil and a set of instructions for completing Part 1 of the experiment. The first page contains written instructions and the last two pages contain a series of tables. On your computer screen you should see an identifier code made up of letters and numbers. Take a moment to write your ID code at the top of each page for Part 1, and please write legibly.

Wait for everyone to write their ID on their sheets.

Now I will read the instructions for Part 1 out loud. Please follow along on your instructions sheet, and raise your hand if you have any questions.

Read instructions.

Are there any questions?

Please take a few minutes to make your decisions.

Wait about five minutes for everyone to finish.

Part 2:

Now we will begin Part 2 of the experiment. Your earnings from Part 2 will be in addition to your earnings from Part 1 of the experiment. At the end of the experiment, we will revisit Part 1 to calculate your earnings for that part.

This portion of the experiment will be done on the computer, so you can set your pencil and Part 1 pages aside for now.

Please read all of the instructions carefully, and raise your hand if you have any questions. At the end of the instructions, there are two learning comprehension questions that will not count toward your earnings.

Thank you for not using your cell phones during the experiment. You may begin reading the instructions. Feel free to make notes on the back of your decision sheets.

Instructions for Part 2

This part of the experiment consists of 20 decision-making periods. At the beginning of each period, you placed into a group with 2 other participants. The members of your group will be selected at random each period and so the composition of your group will change each period.

The identities of the participants in your group will not be disclosed, that is, participants will be anonymous.

Each period, everyone in your group will be given an initial endowment of 60 ECUs. In addition, there will be a variable prize amount each round that will be distributed as described below.

The *variable prize* can range in value from 0 to 240 ECUs, and the precise amount will be selected at random by the computer in each round. Each value from 0 to 240 is equally likely to be chosen, and thus the average or expected value of the variable prize is 120 ECUs.

The actual amount of the prize selected at random in a specific round is independent of the amounts selected in any other round.

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How the award is distributed

Variable prize amounts can be of two types; either available or unavailable. Available variable prize amounts are added to participants' payoffs according to the rules discussed below. Unavailable variable prize amounts are not added to participants' payoffs. All of the variable prize less than or equal to 120 ECUs is available to the participants. Variable prize amounts above 120 ECUs are unavailable.

Your decision in the game, and the decisions of others, affects how the available amount of the variable prize is distributed among the 3 participants in your group.

At the start of the session you will be randomly assigned a Prize Order which determines the order in which shares of the available variable prize amount will be distributed. You may be Participant 1, 2, or 3, with the number indicating your Prize Order. If you are participant 1 you receive your payoff first, participant 2 receives second, and participant 3 receives last.

In each round you have the opportunity to submit or "bid" some, none or all of your initial endowment of 60 ECUs.

The more you bid, the larger your share of the available variable prize. The more other participants in your group bid, the smaller your share of the available variable prize.

Thus, your share of the available variable prize is given by the number of ECUs you bid divided by the total number of ECUs all three participants in your group bid.

$$Your\ Share\ of\ the\ Available\ Variable\ Prize = \frac{your\ bid}{sum\ of\ all\ 3\ bids\ in\ your\ group}$$

If all participants bid zero, the Prize is shared equally among all three participants in the group.

The amount of the prize you receive is based partly on the order in which the prize is distributed. Participants will receive their shares in order of priority associated with Prize Order; that is priority is given first to Participant 1, then to Participant 2, and finally to Participant 3.

The Prize Order is important because the variable prize changes each period and can be as low as 0 and as high as 240. The computer will make allocation decisions based on 50% of 240, or 120 ECUs, which is also equal to the average or expected value.

The variable prize selected by the computer each round can be less than or more than 120 ECUs. Let's consider when the variable prize is less than or equal to 120 and when the variable prize is more than 120.

Case 1: Variable prize is less than or equal to 120

If the variable prize is equal to 120 ECUs, then shares will be distributed to all participants in light of a 120 prize.

If all participants bid the same, then each participant will receive 1/3 of 120 or 40 ECUs each.

If participants bid different amounts, each participant will be paid based upon their bid share. Suppose that the bid share of participant 1 is 50%, participant 2, 20% and participant 3, 30%. Participant 1 would receive 50% of 120 or 60 ECUs, participant 2 would receive 20% of 120 or 24 ECUs, and participant 3 would receive 30% of 120 or 36 ECUs.

Suppose the variable prize is equal to 80 ECUs. The 80 units will be distributed to participants based on their bid shares of the expected value of 120, up to the point that the prize of 80 is fully allocated.

If all participants bid the same, the maximum each participant would receive is 120/3 = 40 ECUs. With a prize of only 80, participant 1 would receive 40 ECUs, participant 2, 40 ECUs and participant 3, 0 ECUs.

If participants bid different amounts, participants still receive a share of 120 ECUs until the prize of 80 is exhausted. Suppose, that the bid share of participant 1 is 50%, participant 2, 20% and participant 3, 30%. Participant 1 would receive up to 50% of 120 or 60. After the allocation to Participant 1 there is only 20 remaining of the 80 ECU prize (80-60). Participant 2 could receive up to 20% of 120, or 0.2 x 120 = 24. However, since 24 ECUs would exceed the maximum prize (60 + 24 = 84), participant 2 will only receive 20 ECUs. Although participant 3 has a positive bid share, they would receive 0 ECUs because the prize of 80 has been fully allocated.

With a prize less than 120, in most cases Participant 1 will receive their full bid share. Participants 2 and 3 will often receive less than their full bid share, as in the example provided. The prize will be allocated up to the point that the variable prize is exhausted.

Case 2: Variable prize more than 120

When the variable prize is greater than 120, shares will be distributed to participants based on their bid shares of the expected value of 120. Any variable prize beyond 120 ECUs will not be allocated to any participant, it is unavailable.

Suppose the variable prize is equal to 150. In this case, 120 ECUs will be distributed to participants based on their bid shares and 30 ECUs will be unavailable.

If participants bid the same amount, the maximum each participant would receive is 120/3 = 40 ECUs. With a prize of 150, participant 1 would receive 40, participant 2, 40 and participant 3, 40. The difference between 150-120, 30 ECUs, would not be allocated to any participant.

If participants bid different amounts, participants still receive a share until the 120 ECUs are exhausted. For a variable prize of 150, suppose that the bid share of participant 1 is 50%, participant 2, 20% and participant 3, 30%. Participant 1 would receive up to 50% of 120 or 60, participant 2 would receive 20% of 120 or 24, and participant 3 would receive 30% of 120 or 36 ECUs. Again, only 120 ECUs are allocated, the residual of 30 (150-120) is not allocated to any participant.

In summary, with a realization more than 120, all participants will receive their full bid share. Only 120 units will be allocated to participants and any residual is unavailable and is not awarded to any participant.

Please raise your hand if you have any questions.

The remainder of the instructions include:

- An example of the decision screen.
- A complete discussion of the process through which your earnings are determined.
- An example of the share calculations.

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Instructions for Part 2

Round 1 of 60

Total available prize this round: 240

Your harvest position this round: P1

You can bid up to 60 ECUs.

Your bid :

Next

History

Round	Prize Order	Your Bid	Total Bids	Maximum Prize	Prize Amount	P1's Share	P2's Share	P3's Share	Earnings (in ECUs)

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Instructions for Part 2

Your earnings for

After the amount of the variable prize is determined and the shares are calculated, potential earnings for the period are calculated.

Potential Earnings = Endowment + Share of Prize–Your Bid = 60 + Share of Prize–Your Bid

The results from 2 of these 20 periods will be chosen at random at the end of the experiment. To select the rounds that count toward your final earnings, the experimenter will roll a die 2 times in front of everyone. The die rolls will determine which rounds count toward your final earnings.

The earnings from these 2 rounds will be converted to dollars and paid to you in cash at the end of the experiment. In addition, you will also receive your earnings from all other parts of the experiment.

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Instructions for Part 2

Example of the Share Calculation

After each participant bids, the computer will make a random draw which will determine the value of the variable prize and calculate the shares. The random draw will be a number between 0 and 240 as discussed earlier. Finally, the computer will calculate your period earnings based on your bid and your share of the variable prize.

This is a hypothetical example used to illustrate how the computer calculates shares. Suppose Participant 1 bids 15 ECUs, Participant 2 bids 10 ECUs, and Participant 3 bids 0 ECUs. In total, participants bid 25 ECUs (10+15+0). The share of the variable prize is 10/25 = 40% for Participant 1; 15/25 = 60% for Participant 2; and 0/25 = 0% for Participant 3.

Suppose the variable prize selected by the computer is 120.

Participant 1 would earn [60 + .4(120) – 15] = [60 + 48 - 15] = 95 ECUs.

Participant 2 would earn [60 +.6(120) – 10] = [60 + 72 - 10] = 122 ECUs.

Participant 3 would earn [60 +0(120) – 0] = [60 + 0 - 0] = 60 ECUs.

At the end of each period, your bid, the sum of other bids in your group, the value of the variable prize, your share of the variable prize and the potential earnings for the period are reported on the outcome screen. Once the outcome screen is displayed, you may record your results for the period on your Personal Record Sheet under the appropriate heading if you wish.

Are there any questions? If so, please raise your hand.

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Instructions for Part 2

Suppose that Participant 1 bids 5, Participant 2 bids 5 and Participant 3 bids 10. Suppose the award selected at random by the computer is 200 ECUs. What does each person earn, including any unused portion of the endowment of 60?

Participant 1

Participant 2

Participant 3

Submit Answers

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Instructions for Part 2

Suppose that Participant 1 bids 5, Participant 2 bids 5 and Participant 3 bids 10. Suppose the award selected at random by the computer is 200 ECUs. What does each person earn, including any unused portion of the endowment of 60?

Participant 1	85
Participant 2	85
Participant 3	110

Submit Answers

Correct Response: The total bid is equal to 5+5+10 = 20. Participant 1's share is 5/20 = 1/4, Participant 2's share is 5/20 = 1/4, and Participant 3's share is 10/20 = 1/2.

The maximum available prize is 120, any prize above the maximum prize is unavailable. In this example, 80 ECU are unavailable (200-120).

The maximum possible payoff from a Prize for each participant is

- 1/4 x 120 = 30 ECUs for Participant 1
- 1/4 x 120 = 30 ECUs for Participant 2
- 1/2 x 120 = 60 ECUs for Participant 3

Earnings from the Prize is limited to 120, and earnings per Participant is equal to

- 30 for Participant 1
- 30 for Participant 2
- 60 for Participant 3

Given that each Participant starts with an endowment of 60 ECUs, total earnings for

- Participant 1 are 60 - 5 + 30 = 85 ECUs
- Participant 2 are 60 - 5 + 30 = 85 ECUs
- Participant 3 are 60 - 10 + 60 = 110 ECUs

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Instructions for Part 2

Suppose that Participant 1 bids 5, Participant 2 bids 5 and Participant 3 bids 10. Suppose the award selected at random by the computer is 80 ECUs. What does each person earn, including any unused portion of the endowment of 60?

Participant 1

Participant 2

Participant 3

Submit Answers

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Instructions for Part 2

Suppose that Participant 1 bids 5, Participant 2 bids 5 and Participant 3 bids 10. Suppose the award selected at random by the computer is 80 ECUs. What does each person earn, including any unused portion of the endowment of 60?

Participant 1	85
Participant 2	85
Participant 3	70

Submit Answers

Correct Response: The total bid is equal to 5+5+10 = 20. Participant 1's share is 5/20 = 1/4, Participant 2's share is 5/20 = 1/4, and Participant 3's share is 10/20 = 1/2.

The maximum available prize is 120, any prize above the maximum prize is unavailable.

The maximum possible payoff from a Prize for each participant is

- 1/4 x 120 = 30 ECUs for Participant 1
- 1/4 x 120 = 30 ECUs for Participant 2
- 1/2 x 120 = 60 ECUs for Participant 3

Because the award is only equal to 80, earnings from the Prize will be

- 30 for Participant 1
- 30 for Participant 2
- 20 for Participant 3 because only 20 ECU are available after Participant 1 and Participant 2 have received their share of the prize [80 – 30 – 30].

Given that each Participant starts with an endowment of 60 ECUs, total earnings for

- Participant 1 are 60 - 5 + 30 = 85 ECUs
- Participant 2 are 60 - 5 + 30 = 85 ECUs
- Participant 3 are 60 - 10 + 20 = 70 ECUs

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Round 1

Maximum available prize this round: 120

Your Prize Order this round: P2

You can bid up to 60 ECUs.

Your bid :

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History

Round	Prize Order	Your Bid	Total Bids	Maximum Prize	Prize Amount	P1's Share	P2's Share	P3's Share	Earnings (in ECUs)