Valuation structure in incomplete information contests: Experimental evidence [1]

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Abstract

We experimentally examine perfectly discriminating contests under three valuation structures: pure common-value, pure private-value and a case with both private and common value components. In line with the results from the previous literature, we find that, regardless of valuation structure, contestants often choose very conservative expenditures, and very aggressive expenditures. Average expenditures exceed Nash equilibrium predictions. In valuation structures with a common value component, contestants often choose expenditures in excess of the expected value of the prize conditional on winning the contest. That is, they often guarantee themselves negative payoffs in expectation.

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1 Introduction

In perfectly discriminating contests, also known as all-pay auctions, contestants compete for a prize by simultaneously choosing irrevocable expenditures, and the contestant with the highest expenditure wins. The canonical example involves firms pursuing monopoly rights (Tullock, 1967). However, such contests are used to model a wide variety of situations involving conflict between players. Examples are numerous, and range from sporting events to warfare. As a result, all-pay auctions are the subject of a large and burgeoning literature.[1]

However, the experimental literature focuses on the case of independent private values wherein no contestant faces uncertainty about his or her value of winning the contest. In practice, such certainty is likely to be the exception rather than the rule. For example, when firms lobby the government for a monopoly right, uncertainly about demand is likely and, thus, there is uncertainty about the value of the monopoly right. How does uncertainty about the value of winning affect behavior? Of particular interest is whether or not contestants choose expenditures in excess of the expected value of the prize conditional on winning the contest. That is, do contestant's fall victim to the winner's curse in incomplete-information contests?

When information is complete, equilibrium behavior is well understood: Baye et al. (1996) characterize the set of all equilibria.[2] However, when information is incomplete, less is known. Krishna and Morgan (1997) identifies a sufficient condition for the existence of a symmetric and monotonically increasing equilibrium when each player's private information (his/her type) is affiliated with the private information of the other players.[3] In a related paper, Siegel (2014) demonstrates existence and uniqueness

[1]See Corchón (2007) and Konrad (2009) for recent surveys of the theoretical literature. Dechenaux et al. (2015) and Sheremeta (2013) survey the experimental literature.

[2]More recently, Siegel (2009) and Siegel (2010) have broadened our understanding of equilibrium behavior in complete information contests.

[3]Affiliation is a notion of positive dependence between random variables, which is often assumed in the auction literature.

of equilibrium in an asymmetric two-player contest with a discrete set of types. However, a monotonicity assumption similar to that of Krishna and Morgan (1997) is required. Hereafter, we refer to this condition as the KMS condition.[4] Rentschler and Turocy (2016) provides an algorithm for computing all symmetric equilibria when the KMS condition does not hold, but restricts attention to a discrete set of values and types.

The KMS condition is restrictive enough that it does not hold in contests that utilize information structures common in the experimental literature on winner-pay auctions. In particular, the typical setup studied in common-value, first-price auctions, in which each bidder privately observes the true value plus some iid noise drawn from a uniform distribution centered around zero. Bidders in such first-price auctions fall victim to the winner's curse, and that phenomenon has attracted considerable attention (Kagel and Levin, 2002). Not only does the KMS condition fail in perfectly discriminating contests with such an information structure, Athey (2001) notes that the single crossing property fails. As a result, to the best of our knowledge, no experimental study of perfectly discriminating contests with common values and incomplete information has been conducted.

We experimentally study behavior in perfectly discriminating contests in three separate valuation structures, all with incomplete information: pure common-values, pure private-values and, lastly, an environment wherein the value of the prize has both private and common value components.[5] Our private value treatment provides a basis for comparison with the existing literature, while our pure common value treatment allows us to compare our results with the winner's curse literature in winner-pay auctions. The motivation for the treatment with both private and common value components is that the valuation struc-

See e.g., Milgrom and Weber (1982).

[4]While we study environments with a continuum of types, so that the relevant version of the condition is found in Krishna and Morgan (1997), we did not want to neglect the contribution of Siegel (2014). As such, we refer to it as the KMS condition, rather than the KM condition.

[5]Winner-pay auctions with both common and private components to the value have been studied in Goeree and Offerman (2003) and Hartnett and Offerman (2002).

ture in real-world contests is not likely to be either pure private or pure common value. In particular, real-world contests are likely to lie between those two extremes.

In our setup, common-value components of the value (when applicable) are the average of iid signals. The fact that such signals are independent ensures that the single crossing property applies and that the KMS condition holds. Indeed, we derive closed form symmetric Bayes Nash equilibria in all valuation structures studied. More importantly, this setup a good approximation of reality. Information about the value of a common-value component of the prize is likely to be dispersed, and different contestants are likely to observe distinct pieces of relevant information.[6] Assuming that each piece of information receives an equal weight in determining a common value component of the prize ensures that our setup is simple and symmetric.[7]

In addition to ensuring the existence of equilibrium, the fact that types are independent in all the environments we study is a significant benefit of our experimental design. In particular, it allows us to study behavior in a common-value contest in as simple an environment as possible. In our setup, a contestant's type provides information only about the value of winning, and nothing about the types of other contestants. To the extent that behavior correlates with type, types do not allow contestants to infer anything about the degree of competitiveness in the contest at hand.

In all of the information structures studied we find that, as is typically observed in private value contests with incomplete information, expenditures at or close to zero, as well as very aggressive expenditures, are common. Average expenditures exceed Nash predictions, and contestants are, on average, earning

[6]Hayek (1945) famously notes: "...the knowledge of the circumstances of which we must make use never exists in concentrated or integrated form but solely as the dispersed bits of incomplete and frequently contradictory knowledge which all the separate individuals possess." While Hayek was speaking about the information that would be required by a social planner, we feel that the argument also applies to how the information regarding the value of a prize is likely to be distributed among contestants.

[7]An interesting avenue for future research would be to experimentally examine environments wherein the weights are not equal, or wherein uncertainty exists about the relative weights.

negative payoffs. Interestingly, prize dissipation is smaller in the two valuation structures that involve a private value component than it is in pure common-value contests.

Our most striking result is the observation that the winner's curse is alive and well in contests where contestants face uncertainty about the value of the prize. That is surprising because contestants know they must pay their chosen expenditure, regardless of whether or not they win. Choosing an expenditure above the expected value of winning the contest is much more drastic than in a winner-pay environment. In addition to guaranteeing a negative expected payoff conditional on winning the contest, contestants risk a large loss if the contest is not won. That observation carries obvious practical implications for the social cost of rent-seeking.

As mentioned above, several experimental papers also study perfectly discriminating contests with incomplete information.[8] However, it is important to note that in all cases, the valuation structure involves independent private values. The first such paper, Noussair and Silver (2006), experimentally examines a simple perfectly discriminating contest with independent private values. Hörisch and Kirchkamp (2010) experimentally examines both a perfectly discriminating contest and a dynamic war of attrition in which marginal costs are independent draws from a common distribution. Müller and Schotter (2010) experimentally tests the model of Moldovanu and Sela (2001) regarding the optimal allocation of a contest's prize budget. Each contestant has an ability parameter that is an independent draw from a common distribution. Hyndman et al. (2012) experimentally tests a model in which ex post regret may influence behavior in a perfectly discriminating contest with independent private values. Schram and Onderstal (2009) experimentally compare three mechanisms that are used to raise money for charities in an independent private values framework. In each of the three mechanisms, each subject received a fraction of the revenue gener-

[8]See the online supplement of this article for a detailed review of the literature regarding contests (both perfectly and imperfectly discriminating) with private information.

ated. The mechanisms that are tested are the first-price sealed bid auction, a lottery contest and a perfectly discriminating contest.

The remainder of the paper is structured as follows. Section 2 presents the equilibrium in all three valuation structures. Section 3 illustrates our experimental design. Section 4 contains our results, and Section 5 concludes.

2 Theoretical predictions

A set of risk neutral contestants $\mathbf{N} \equiv \{1, ..., n\}$ compete for a prize. The value to contestant $i \in \mathbf{N}$ of this prize P_i is the sum of two components, $P_i = v_{1i} + v_2$. Contestant i observes two pieces of information regarding P_i, one for each of the two components of P_i. The first, v_{1i}, is the private-value component, and is indexed by i. The second, v_2, is the common-value component. The form this information takes will determine the valuation structure of the contest. In each of the three valuation structures we consider, the valuation structure is common knowledge. After contestants observe their (potentially private) information, they simultaneously choose nonnegative and unrecoverable expenditures. We denote the expenditure of contestant i as e_i. The contestant who chooses the highest effort level obtains the prize (ties are broken by a fair randomization).

We are interested in comparing behavior against symmetric Nash equilibrium. In the interest of brevity, we relegate equilibrium derivations to the online supplement. We are also interested in comparing behavior to the expected value of the prize conditional on winning the contest. Choosing expenditures above that threshold is analogous to falling victim to the winner's curse, a well known concept from the common value winner-pay auction literature (Kagel and Levin, 2002).

2.1 Independent private value

In an independent private value (PV) environment, v_{1i} is an independently drawn realization of the random variable V_1. The distribution function of V_1, F (with corresponding density function f), is continuously differentiable and has support on $[v_L, v_H]$, where $v_L \geq 0$. Each v_{1i} is privately observed prior to contestant i's choice of e_i. Furthermore, $v_2 = a > 0$. Note that a simply shifts up the distribution of the private values.

The symmetric equilibrium expenditure function is given by

$$\beta\left(v_{1i}\right) = F\left(v_{1i}\right)^{n-1}\left(E\left(Y_1|Y_1 \leq v_{1i}\right) + a\right), \tag{1}$$

where Y_1 is the highest order statistic of the $n-1$ independent draws of V_1 observed by contestants $j \in \mathbf{N}/i$. To understand the intuition underlying the equilibrium bid function, it is instructive to compare it to the analogous function for a first-price sealed bid auction. In such a first-price auction, bidder's account for the fact that no bidder will bid above his or her own value, and that the bidder with the highest valuation will win the auction, by bidding $E\left(Y_1|Y_1 \leq v_{1i}\right) + a$. That is, players bid at the expected second highest valuation, conditional on having the highest valuation themselves. As such, in expectation, players shade their bids below their valuations as much as possible, without giving the bidder with the second highest valuation an incentive to out-bid them. The same logic induces contestants in the all-pay auction to shade their expenditures below their valuations. However, contestants also account for the fact that expenditures are paid, regardless of whether or not they win, by scaling expenditures down (relative to the first-price auction) by the probability that they win, which is also the probability that they have the highest valuation.

Note that in this valuation structure each contestant knows that the expected value of winning the contest is $v_{1i} + a$; no uncertainty exists. Given the lack of uncertainty, the fact that expenditures in excess of $v_{1i} + a$ result in a negative payoff is likely to be salient to contestants.

2.2 Common value

In a common value (CV) environment $v_{1i} = v_{1j} = c \, \forall i, j \in \mathbf{N}$, and $c > 0$. The second component of the value is $v_2 = \sum_{i \in \mathbf{N}} \frac{v_{2i}}{n}$, where each v_{2i} is an independent draw of the random variable V_2. The distribution function of V_2, G (with corresponding density function g), is continuously differentiable and has support on $[v_L, v_H]$, where $v_L \geq 0$. This valuation structure is a pure common value with c shifting the distribution of the common value up.

Since the private information of contestants is independent, the results of Krishna and Morgan (1997) apply. That is in contrast to the way in which a pure common value environment typically is studied in the experimental analysis of winner-pay auctions. In that canonical setup, each player's private information is the true value of the prize plus iid noise, so that signals are conditionally independent. As discussed in Athey (2001), the single crossing property fails in such an environment, and the degree of affiliation between signals is strong enough that the results of Krishna and Morgan (1997) do not apply.

Our setup has two distinct advantages. First, we are able to derive equilibrium predictions. Second, the environment we study is relatively simple for experimental subjects to understand. Since information is independent, each contestant's private information is only about the expected value of winning the contest. There is no way of inferring anything about the distribution of opponents' expenditures. Do contestants choose expenditures that guarantee themselves negative payoffs in such and environment?

The symmetric equilibrium is given by

$$\gamma\left(v_{2i}\right)=G\left(v_{2i}\right)^{n-1}\left(\frac{1}{n}E\left(Y_2|Y_2\leq v_{2i}\right)+\left(\frac{n-1}{n}\right)E\left(V_2|V_2\leq v_{2i}\right)+c\right), \tag{2}$$

where Y_2 is the highest order statistic of the $n-1$ independent draws of V_2 observed by other contestants. The interpretation of the equilibrium bid function here is similar to the PV case. The CV analogue of the expected valuation of the second highest type, conditional on contestant i being the highest type, is the belief that the contestant with the second highest type is expected to hold about the common value, conditional on contestant i being the highest type. The analog is given by: $\frac{1}{n}E\left(Y_2|Y_2\leq v_{2i}\right)+\left(\frac{n-1}{n}\right)E\left(V_2|V_2\leq v_{2i}\right)+c$. Expenditures continue to be scaled down by the probability of contestant i having the highest type, which in the CV case is given by $G\left(v_{2i}\right)^{n-1}$.

With a common value, no contestant observes the value of the prize. The resulting uncertainty about the value of winning leaves room for the possibility that a rational player wins the contest and ends up with a negative payoff. We are interested in whether or not contestants choose expenditures that are aggressive enough to guarantee negative payoffs on average. That is, do contestants choose expenditures in excess of the expected value of the the prize conditional on winning the contest? This expected value is simply

$$\frac{v_{2i}}{n}+\left(\frac{n-1}{n}\right)E\left(V_2|V_2\leq v_{2i}\right)+c.$$

2.3 Private and common value

In a private and common value (PC) environment, each of the two pieces of information that a contestant observes is private. The first (second) piece of information, v_{1i} (v_{2i}), is an independently drawn realization of the random variable V_1 (V_2). As in the common value environment, $v_2=\sum_{i\in\mathbf{N}}\frac{v_{2i}}{n}$. That valuation structure has been studied in the context of winner-pay auctions by Goeree and Offerman (2003) and Hartnett and Offerman (2002).

In equilibrium, contestants aggregate the two pieces of private information into a single statistic: $s_i = v_{1i} + \frac{1}{n}v_{2i}$. We denote that random variable by S, and its distribution function by H. Notice that each contestant observes an independent draw of S.

The symmetric, risk-neutral equilibrium expenditure function is given by

$$\rho\left(s_i\right) = H\left(s_i\right)^{n-1}\left(E\left(Y_S|Y_S \leq s_i\right) + \left(\frac{n-1}{n}\right)E\left(V_2|S \leq s_i\right)\right), \tag{3}$$

where Y_S is the highest order statistic of the $n-1$ independent draws of S observed by other contestants. Once again, the intuition underlying the equilibrium bid function is similar to the PV case. In the PC case, the expected valuation of the contestant with the second highest type, conditional on contestant i being the highest type, is given by $E\left(Y_S|Y_S \leq s_i\right) + \left(\frac{n-1}{n}\right)E\left(V_2|S \leq s_i\right)$, and the probability that contestant i is the highest type is $H\left(s_i\right)^{n-1}$.

In the PC valuation structure, the same degree of uncertainty exists regarding the value of the common value component of the prize as in the CV structure. In addition, more uncertainty arises regarding the values of the other contestants, because of the private component in valuations. Contestants must form beliefs regarding the value of winning the contest that account for both components. This expected value is given by

$$s_i + \left(\frac{n-1}{n}\right)E\left(V_2 \mid S < s_i\right).$$

Recalling that $s_i = v_{1i} + \frac{1}{n}v_{2i}$, this is simply contestant i's realized private component of the value (v_{1i}) plus i's observed share of the common-value, $\frac{1}{n}v_{2i}$, plus the expected value of the remaining components of the common value, conditional on contestant i being the highest type.

3 Experimental design

In each session, a group of 12 participants are anonymously and randomly matched into three groups of four. In every round, each group of four participates in a perfectly discriminating contest to obtain a prize whose value is the sum of two components. Each contestant observes a piece of information for each of these two components. Each piece of information is an independent draw from a uniform distribution on $[0, 50]$.

After observing the two pieces of information, each contestant chooses an unrecoverable expenditure. The contestant with the highest expenditure obtains the prize (ties are broken by a fair randomization).

After contestants have chosen their expenditures, they observe the expenditures of all contestants in their group (ordered from highest to lowest), both components of the value of the prize, their own payoff, and the payoff of the contestant who obtained the prize. Participants are then again anonymously and randomly re-matched until 40 rounds have been completed.

We considered three valuation structures (and varied them on a between-subject basis): independent private values (PV), common values (CV) and a setting with both private and common (PC) components of the value.

1. In PV contests, the first component of the value is a separate iid draw for each contestant. The second component of the value is the same draw for all four contestants in the group and that is common knowledge. The second component of the value simply shifts the distribution of private values up.

2. In CV contests, the first component of the value is the same draw for all four contestants and is

common knowledge. Each contestant privately observes a separate iid draw corresponding to the second component, and the value of the second component is the average of those draws. Notice that the first component of the value is a constant that simply shifts the common value up for all contestants.

3. In PC contests, the first component of the value is a separate iid draw for each contestant. Each contestant also observes a second iid draw corresponding to the second component, and the value of the second component is the average of those four draws. Thus, the first component of the value is private, while the second component is common.

Within a given valuation structure, the same iid draws were used in each session to ensure maximal comparability. Additionally, to the extent possible, the same iid draws were used across valuation structures. Specifically, in PC sessions, each participant observed two iid draws in each round. In PV sessions, the draws corresponding to the private values were the same as those used for the private component of the value in PC sessions. Furthermore, one of the draws corresponding to the common value component of value in PC sessions (within each group of four contestants in a given round) was used as the (constant and common knowledge) second component of the value in PV auctions. Similarly, in CV sessions the (constant and common knowledge) first component of the value in a given contest was one of the draws corresponding to the private component of value in PC sessions (within each group of four contestants in a given round), while the draws corresponding to the common value component in PC sessions also were used as the common value signals in CV sessions.

In each valuation structure four sessions were held, so that each valuation structure had 48 participants. All sessions were run at the Centro Vernon Smith de Economa Experimental at the Universidad Francisco Marroqun, and participants were all undergraduates enrolled at the institution. Participants interacted only through a computer interface, which was programmed in z-Tree (Fischbacher, 2007). At the beginning of an experimental session, participants were seated at computers separated by dividers to ensure the privacy of decisions. They were shown video instructions which included screenshots of the interface. Upon completing the video, each subject completed a quiz to ensure comprehension. Any remaining questions were then resolved in private. Once the experiment was complete, the participants completed a short survey and were paid in private. Each session lasted approximately one-and-a-half hours. Participants earned a $Q20 \approx \$2.50$ show-up fee.[9] All other monetary amounts were denominated in experimental pesos ($E\$$) with an exchange rate of $E\$11 = Q1$. Each participant started the experiment with $E\$1,150$ to cover potential losses.[10] The average payment was $Q103.85$ with a minimum of $Q52$ and a maximum of $Q154$.

4 Results

Since the behavior of different subjects within a session may not be independent, we will use session-level data for the nonparametric tests in our analysis. Unless otherwise noted, we report p-values for one-tailed tests.

4.1 Individual expenditures

Contestants in our experiment observe two pieces of information, one per each component of the prize. While in PV and CV contests one of them is a common knowledge constant, we will refer to the sum as the "sum of signals" for simplicity. To give an overview of our data, and how it differs across valuation structures, we first compare observed expenditures to the sum of signals in each treatment. That is a natural

[9] The currency in Guatemala is the Quetzal, and this is how subjects were paid.
[10] No participants went bankrupt.

starting point because the sum of signals provides a consistent basis for comparison across valuation structures. Figure 1 contains scatterplots of observed expenditures against the sum of signals for each information structure.

In all three valuation structures, we see a pattern of behavior that is consistent with the previously discussed stylized facts from the literature. We see a significant number of expenditures at or close to zero, and many expenditures that are relatively close to the sum of signals. That is, we observe both a large number of extremely cautions expenditures, and a large number of extremely aggressive expenditures. Table 1, which contains summary statistics for both Nash and observed expenditures in all three valuation structures, illustrates that, also in line with the previous literature, the numbers and magnitudes of the aggressive bids are sufficient to ensure that, on average, bids exceed equilibrium predictions (in all cases, a Wilcoxon signed-rank test yields the same result: $z = 1.826$, $p = 0.034$).

Again referring to Table 1, note that, in line with predictions, expenditures are higher in PV contests than in CV contests (Wilcoxon rank-sum test, $z = 1.732$, $p < 0.05$). As predicted, average expenditures in PC contests lie between between those of the other valuation structures. However, no statistically significant differences are found between expenditures in PC and PV contests (Wilcoxon rank-sum test, $z = 0.289$, $n.s.$) or between PC and CV contests (Wilcoxon rank-sum test, $z = 1.155$, $n.s.$).[11]

On average, expenditures are more aggressive than predicted by equilibrium. Are they aggressive enough that contestants guarantee themselves negative payoffs? That is, are contestants choosing expenditures in excess of the expected value of the prize conditional on winning the contest? In PV contests, this would mean that bids exceed the sum of signals. Figure 1 demonstrates that such bids are not common in PV contests. That likely is driven by the fact that those contestants face no uncertainty about the value of the prize. Turning attention to the valuation structures with a common value component, however, note

[11] $n.s.$ indicates that a test is not significant at conventional levels.

that expenditures above the sum of signals are more frequent than in PV contests. In addition, in CV and PC contests the expected value of the prize conditional on winning is a more conservative basis of comparison than the sum of signals. That is because winning the contest (assuming bids are monotonically increasing in type) implies that a contestant is the highest type (v_{2i} in CV contests and s_i in PC contests).

Figure 2 compares observed expenditures directly to the expected value of the prize conditional on winning. Note that the first panel, corresponding to PV contests, is identical to that of Figure 1. In both CV and PC contests, expenditures that guarantee losses are more common than in the PV case. That result is demonstrated further in Table 2, which contains summary statistics regarding the frequency with which contestants choose expenditures above the expected value of the prize conditional on winning the contest. Relative to PV contests, such bids are more common in CV (Wilcoxon rank-sum test: $z = 2.309$, $p = 0.010$) and PC contests (Wilcoxon rank-sum test: $z = 1.443$, $p = 0.0745$). Furthermore, expenditures that guarantee losses are more common in PV contests than in PC contests (Wilcoxon rank-sum test: $z = 1.732$, $p = 0.042$).

Figure 3a illustrates how the frequency of contestants guaranteeing themselves losses evolves as they gain experience. Figure 3b shows the same information, with attention restricted to the winning contestants. In PV contests, the frequency is close to zero in the second half of the experiment. In CV contests, the frequency declines over time, but such excessive expenditures persist. The PC case lies, for the most part, between those two extremes.

The frequency with which contestants guarantee themselves negative payoffs when some uncertainty exists about the value of winning the contest is perplexing. That is particularity true since contestants must pay their chosen expenditure even if they lose the contest. The fact that subjects continue to fall victim to the winner's curse in the later periods also is puzzling. Would subjects learn to overcome the winner's curse with additional experience?

We speculate that, similar to the winner-pay case, contestants do not account for the informational content of winning. That is, they do not shade their expenditures to account for the fact that if they win, they are likely to be the highest type in the contest. However, our experimental design does not allow us to determine conclusively whether or not this is the case.

It is important to note that not accounting for the fact that the contestant with the highest type is likely to win the contest does not explain the other deviations from equilibrium behavior we observe across all three information structures. Further research is needed to understand contestant behavior.

4.2 Contestant payoffs

We now turn attention to contestant payoffs. Table 3 contains summary statistics regarding observed and predicted payoffs in all three information structures. Notice that in all cases, on average, payoffs are not only less than predicted (in all cases a Wilcoxon signed-rank test yields: $z = 1.826$, $p = 0.034$), but are negative. This is further illustrated in Figure 4, which contains scatterplots of payoffs against the sum of signals, broken down by information structure. Of note is that the frequency with which expenditures are at or close to zero results in a large number of instances for which payoffs are zero.

Interestingly, observed payoffs do not differ across information structures (In all pairwise comparisons a Wilcoxon rank-sum test yields the same result: $z = 0.289$, $n.s.$). Thus, while expenditures that guarantee losses are more common in contests with a common value component, expenditures in PV contests are, on average, aggressive enough that contestants are not better off in a private value environment.

4.3 Prize dissipation

If, as is common in many contest applications, expenditures are social losses, then comparing aggregate expenditures to the value of the prize provides a measure of how much of the prize is wasted or "dissipated" by the contest. The relevant value for this comparison is the highest value among the contestants. As such, we define prize dissipation as

$$\frac{\sum_{i \in \mathbf{N}} e_i}{P_{max}}$$

where P_{max} is the value of the prize to the contestant with the highest value. Note that in CV contests this is simply the value of the prize.

Since, on average, individual expenditures exceed predictions, prize dissipation must also exceed predictions. Table 4, which contains summary statistics regarding Nash and observed prize dissipation by valuation structure, shows that this is the case (Wilcoxon signed-rank tests for PV, PC and CV: $z = 1.826$, $p = 0.034$). In addition, since contestants are losing money on average, it is not surprising that prize dissipation also is greater than one in all cases (Wilcoxon signed-rank tests for PV, PC and CV: $z = 1.826$, $p = 0.034$).

Referring to Table 4, note that prize dissipation tends to be larger in CV contests relative to the treatments that contain a private value component. That is, prize dissipation in CV contests is significantly larger than in PV contests (Wilcoxon rank-sum test, $z = 2.309$, $p = 0.010$) and PC contests (Wilcoxon rank-sum test, $z = 2.021$, $p = 0.022$), suggesting that the presence of a private value component has a welcome effect on the extent of prize dissipation. We do not observe a significant difference in prize dissipation between PC and PV treatments (Wilcoxon rank-sum test, $z = 0.866$, $n.s.$).

5 Conclusion

In this paper we experimentally examine the role of valuation structure in perfectly discriminating contests with incomplete information. In particular, we study information structures that are pure private value, pure common value and an environment with both common and private components of the value of the prize on offer.

Our results are qualitatively in line with those from the previous experimental results on independent private value all-pay auctions. Namely, in all three valuation structures we see frequent expenditures at or close to zero and frequent expenditures significantly above predictions. On average, expenditures are in excess of predictions.

Our most striking result is that when there is a common-value component in the valuation structure, contestants often choose expenditures that exceed the expected value of winning the contest conditional on winning. That is, they guarantee themselves negative payoffs. This is analogous to the winner's curse from the winner-pay auction with common values literature. Thus, the winner's curse phenomenon persists, even when all players are required to pay their bids.

Our study represents a first step in the analysis of behavior in common-value perfectly discriminating contests with incomplete information. In all of the environments we study, player types are independent. That is a benefit of our experimental design, as it allows us to examine the propensity of contestants to guarantee themselves negative profits in as simple an environment as possible. In future research, it would be worthwhile to consider environments with correlated types under common values.

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Table 1: Summary statistics for expenditures

Valuation structure	Observed expenditures	Nash expenditures
Private	20.456	13.168
	(25.663)	(17.489)
Common	18.083	11.935
	(22.836)	(15.085)
Private and common	19.988	12.797
	(24.394)	(16.226)

Notes: Table contains means with standard deviations in parentheses.

Table 2: Summary statistics for expenditures above the expected value of the prize conditional on winning the contest

Valuation structure	Frequency for all contestants	Frequency for winning contestants
Private	0.042	0.121
	(0.200)	(0.326)
Common	0.222	0.577
	(0.416)	(0.495)
Private and common	0.123	0.310
	(0.328)	(0.463)

Notes: Table contains means with standard deviations in parentheses.

Table 3: Summary statistics for payoffs

Valuation structure	Observed payoffs	Nash payoffs
Private	-5.755	15.550
	(21.666)	(20.632)
Private and common	-5.747	2.433
	(21.197)	(3.410)
Common	-5.725	0.655
	(19.163)	(0.847)

Notes: Table contains means with standard deviations in parentheses.

Table 4: Summary statistics for prize dissipation

Valuation structure	Observed dissipation	Nash dissipation
Private	1.203	0.758
	(0.726)	(0.447)
Private and common	1.231	0.746
	(0.766)	(0.432)
Common	1.507	0.908
	(1.367)	(0.457)

Notes: Table contains means with standard deviations in parentheses.

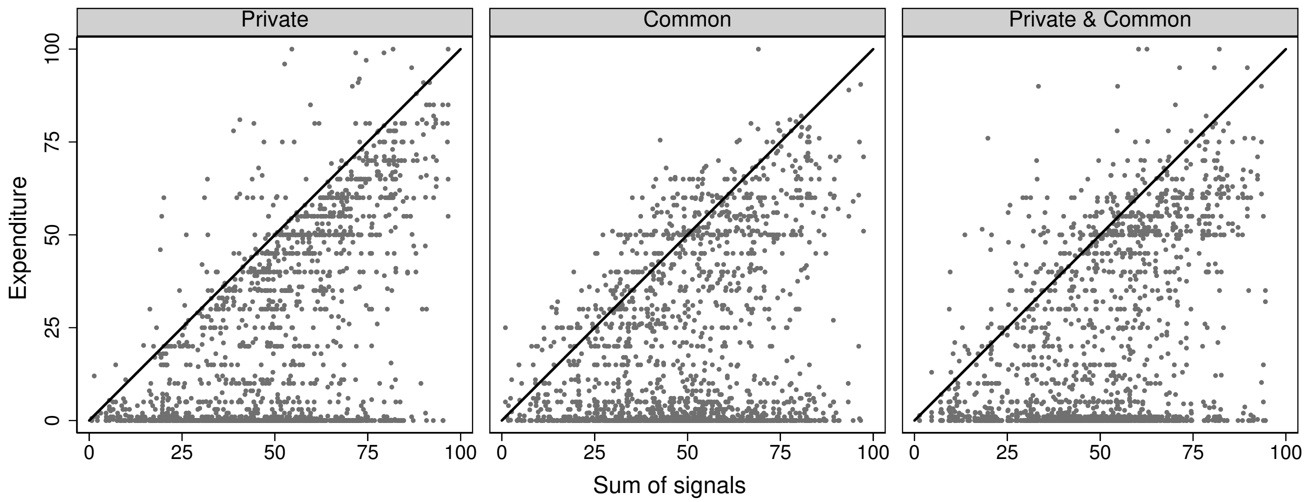


Figure 1: Observed bids by the sum of signals

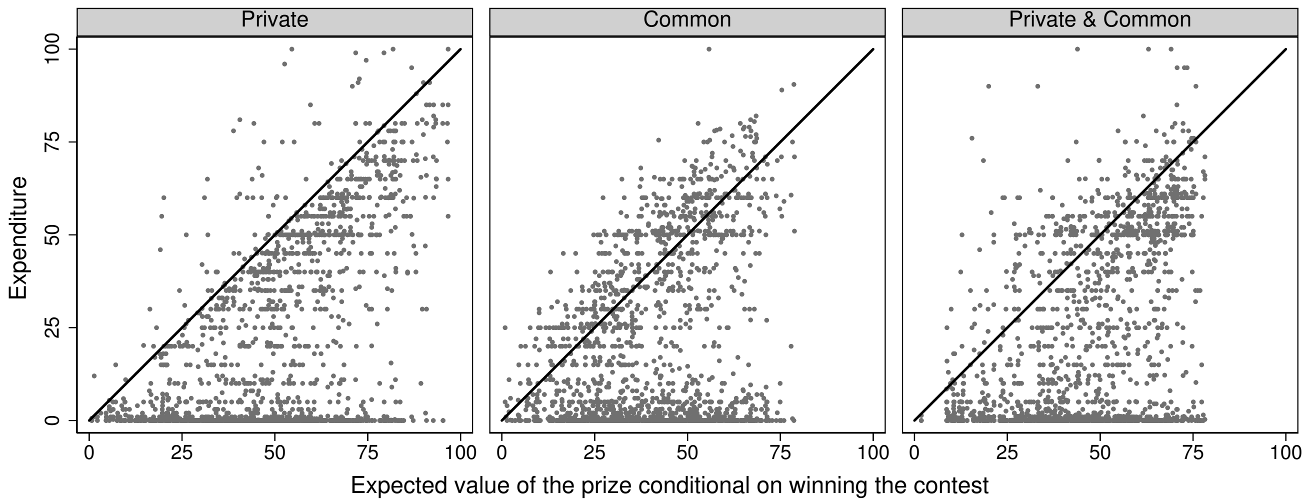
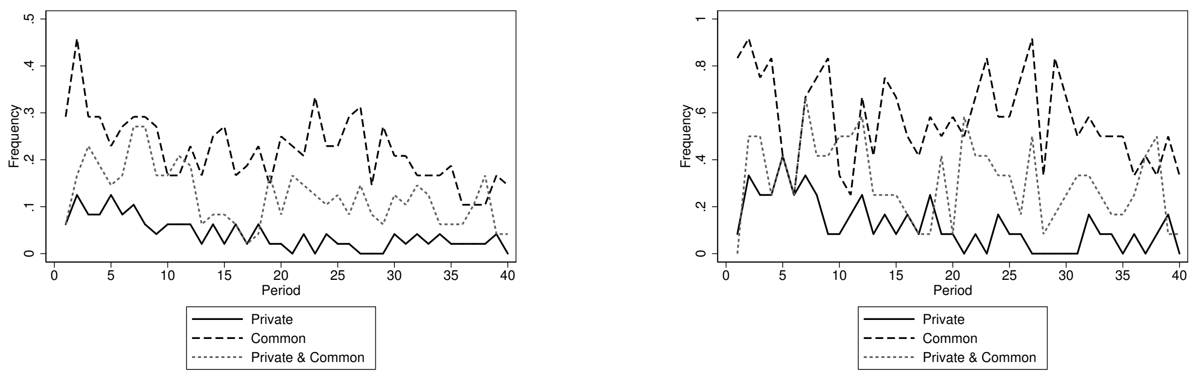


Figure 2: Observed bids by the expected value of winning the contest



(a) All contestants

(b) Winning contestants

Figure 3: Observed frequency of bids in excess of the expected value of winning the contest by treatment and period

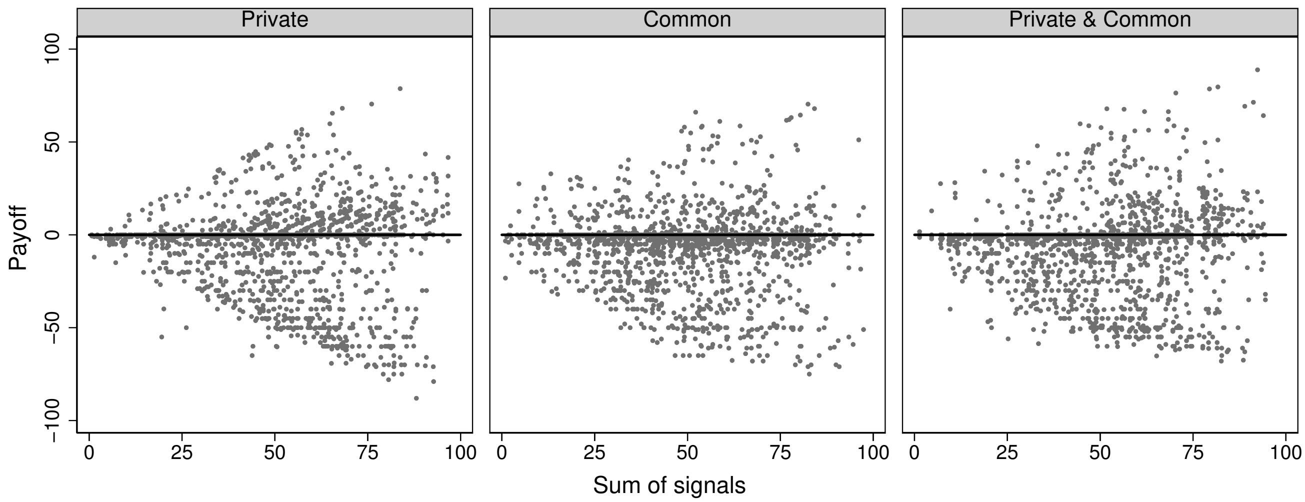


Figure 4: Observed payoffs by the sum of signals