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Exclusion in the All-Pay Auction: An Experimental Investigation

Dietmar Fehr*
Julia Schmid*

* Wissenschaftszentrum Berlin für Sozialforschung (WZB), Germany

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Dietmar Fehr Julia Schmid

Social Science Research Center (WZB) Berlin

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Abstract

Contest or auction designers who want to maximize the overall revenue are frequently concerned with a trade-off between contest homogeneity and inclusion of contestants with high valuations. In our experimental study, we find that it is not profitable to exclude the most able contestant in favor of greater homogeneity among the remaining contestants, even if the theoretical exclusion principle predicts otherwise. This is because the strongest contestants considerably overexert. A possible explanation is that these contestants are afraid they will regret a low but risky bid if they lose and thus prefer a strategy which gives them a low but secure pay-off.

Keywords: experiments, contests, all-pay auction, heterogeneity, regret aversion

JEL classification numbers: C72, C92, D84

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1 Introduction

There are many sports with dominant athletes, such as Roger Federer in the Tennis ATP Tour or Tiger Woods in the Golf PGA Tour, which attract a lot of attention and cause the 'superstars' to serve as a leading force for their sports. However, too great a dominance by one participant might also lead to boredom and a lower niveau of the competition. For example, due to Michael Schumacher's dominance in the Formula One races, the viewing figures dropped and consequently the FIA changed several of their rules to make the races more tense.[1] Likewise, US professional sport leagues (e.g. the NBA, NFL, NHL or MLB) apply a rookie drafting system that gives homogeneity among the competing teams a good chance, as the weakest team first gets the right to pick the "rookies" out of the pool of the most promising junior players. These examples show the two sides of the coin the participation of a superior contest participant has.

Contests not only appear in sports but are pervasive in our society (see e.g. Frank (1995)). Firms install effort tournaments, lobbyists compete for influence by donating money to political parties, and researchers compete for research grants. All these examples have in common that rewards are allocated based on relative rather than on absolute performance, that the effort of the losers is lost and that the contest designer's main focus is the overall performance. Hence, there are many situations in which the composition of a competing group matters. In this paper, we attempt to answer the question, whether the presence of one strong contestant or a more homogeneous contest maximizes the total revenue. To do this, we employ a series of laboratory experiments.

Baye, Kovenock, and de Vries (1993) show in a theoretical contribution that a trade-off between the inclusion of contestants with high valuations and contest homogeneity exists. They analyze an all-pay auction in a complete information framework with several bidders who have potentially different valuations.[2] With one prize, the presence of a strong contestant might induce other contestants to reduce their effort, since their individual probability of winning the contest is low. This in turn leads the strongest contestant to lower her effort and possibly, as a result, to a lower overall performance. For certain heterogenous group compositions it is beneficial for the contest designer to exclude the strongest contestant, thereby creating a more homogeneous contest among the remaining participants and generating higher expected total efforts. This so-called *exclusion principle* implies that selecting the participants can be an important issue in terms

[1] See BBC (2002).

[2] As the all-pay auction with complete information is the limiting case of a contest, we will use the terms auction and contest interchangeably, as well as the expressions bidder and contestant.

of revenue. Indeed, Brown (2008) provides empirical evidence for lower performance of competitors in the presence of one dominant contestant. She uses data from the PGA Tour and finds that the presence of Tiger Woods leads other high-skilled professionals to need more strokes to complete the course than when Tiger Woods is absent.

In this paper we experimentally test the exclusion principle by Baye, Kovenock, and de Vries (1993), i.e. we investigate whether exclusion indeed leads to an increase in overall revenue when the bidders are heterogenous in their valuations. We find that in our setup excluding the strongest bidder is never beneficial. This finding can be mainly attributed to the behavior of the strongest contestants as they considerably overexert. The weaker bidders increase their effort significantly when the strongest bidder is excluded, but cannot compensate for the revenue generated by the strongest bidder.

In fact, the bidders with the respective highest valuation in one group often choose a strategy guaranteeing them to win the prize, which involves bids higher than the valuation of the second-strongest bidder. Hence, subjects seem willing to give up quite a substantial portion of their rent just to avoid losing the auction. Furthermore, the subjects are more likely to choose this "winning-for-sure" strategy if the rent from playing this strategy is bigger. We explain this kind of behavior with regret aversion. A regret averse bidder prefers a small but secure pay-off over a large but uncertain payoff because she tries to avoid the regret about foregone rents that she would feel if she chose a risky strategy instead and lost the auction.

There is a large experimental literature on tournaments and auctions either with private values or common values with homogeneous contestants.[3] Two quite robust findings occur in these experiments. First, subjects show significant overexertion in comparison to the Nash equilibrium.[4] This is the case in all-pay auctions with incomplete information (e.g. Müller and Schotter (2010), or Noussair and Silver (2006)), as well as in the most simple setting of a common value auction with symmetric bidders (Gneezy and Smorodinsky (2006)). Despite the observed overdissipation on average, there is typically a dichotomy in bidding behavior on the individual level in all-pay auctions with incomplete information. Agents with valuations below an individual cut-off level (or high costs) drop out in the sense that they exert efforts close to zero, whereas agents with

[3] There are several experimental studies which test the Tullock rent-seeking contest (e.g. Davis and Reilly (1998); Millner and Pratt (1989)). The vast majority of these papers find larger rent-seeking expenditures than predicted by theory.

[4] Anderson, Goeree, and Holt (1998) show that this overdissipation pattern can be explained by a logit equilibrium in which agents commit mistakes by choosing bidding strategies that do not give the highest expected payoff.

high valuations (or low costs) exceed the equilibrium effort level by far (see Barut, Kovenock, and Noussair (2002); Müller and Schotter (2010)). Also in all-pay auctions with identical and commonly known valuations, bimodal bidding can be observed (Ernst and Thöni (2009)). These findings can be explained by subjects displaying risk aversion with respect to gains and risk-seeking behavior in the loss domain, as modeled by prospect theory (Tversky and Kahnemann (1992)).

To our knowledge, this is the first experiment on all-pay auctions that combines heterogeneity and complete information. Hence, the tendency of players to opt for a strategy that guarantees them winning the prize and a positive rent at the same time has not been observed in the experimental auction literature so far. In the existing experiments on all-pay auctions with complete information the bidders were symmetric with respect to their valuations, which rules out the existence of a strategy guaranteeing a positive payoff. In auction experiments with incomplete information a bidder can never be sure of being the one with the highest valuation (or lowest cost of effort).

The paper is organized as follows. The next section provides a short outline of the theory and introduces the experimental procedures. Section 3 presents the main results and Section 4 discusses these results and concludes.

2 Theoretical Prediction and Experimental Design

2.1 Theoretical prediction

We consider the case of an all-pay auction with complete information as analyzed by Hillman and Riley (1989) and Baye, Kovenock, and de Vries (1993) with one prize and up to three bidders. All participants in the auction value the prize differently, where a high valuation can alternatively be interpreted as a contestant having low costs of exerting effort in the contest. The valuations $v_i, i \in \{1, 2, 3\}$, are commonly known and heterogeneous in our setup, such that they can be ordered as $v_1 > v_2 > v_3$. All participating bidders simultaneously submit their bid. The bidder with the highest bid wins the auction, receives the prize that she values v_i, and pays her bid. All other bidders lose their bid without gaining anything. Ties are broken randomly. In this case, a unique mixed strategy equilibrium exists that is described in the following. With one prize, only the two bidders with the highest valuations actively participate in the auction. The bidder with the third-highest valuation remains inactive, as his expected value from participating in the contest is negative. The bidder with the highest valuation in the contest randomizes continuously and uniformly over $[0, v_2]$,

where v_2 denotes the second-highest valuation among the bidders participating. The bids of the bidder with the second-highest valuation v_2 are also uniformly distributed, given that he submits a positive bid. However, he remains inactive, i.e. bids zero, with probability $(1 - v_2/v_1)$, where v_1 denotes the highest valuation among the participating bidders. Therefore, the strongest bidder randomizes according to the distribution function $G_1(x) = x/v_2$ and the second-strongest bidder according to $G_2(x) = 1 - v_2/v_1 + x/v_1$. Hence, the expected bid of the bidder with the highest valuation in a round is $E[x_1] = v_2/2$ and the expected bid of the bidder with the second-highest valuation in a round is $E[x_2] = (v_2)^2/2v_1$.

In expectation, the strongest bidder in the auction receives a payoff of $v_1 - v_2$, whereas the expected payoff of the second-strongest bidder is zero. The expected sum of bids, i.e. the revenue of the auction, adds up to

$$E(v_1, v_2) = \left(1 + \frac{v_2}{v_1}\right)\frac{v_2}{2},$$

Thus, in order to maximize the auctioneer's revenue, the contestant with the highest valuation, v_1, should be excluded from the auction whenever

$$\left(1 + \frac{v_2}{v_1}\right)\frac{v_2}{2} < \left(1 + \frac{v_3}{v_2}\right)\frac{v_3}{2}.$$

This inequation is fulfilled if $v_1 >> v_2 \geq v_3$, i.e. if v_1 is sufficiently large compared to the other valuations. The intuition behind this result is straightforward. The presence of a very strong contestant discourages the others. If there are three bidders with valuations $v_1 > v_2 > v_3$, only the two strongest bidders actively participate in the auction. Furthermore, the probability that the second-strongest bidder submits a strictly positive bid decreases in v_1 and so does his expected bid. Hence, the auctioneer might prefer a contest with individually weaker but more homogeneous contestants and thus might want to exclude the bidder with the highest valuation in absolute terms, v_1, from the auction. In the remainder we will refer to the bidder with valuation v_1 as the high type or in short v_H. The bidders with valuations v_2 and v_3 are referred to as medium type (v_M) and low type (v_L), respectively.

2.2 Experimental Design

The experiment consists of two treatments which differ with respect to the composition of valuations in the auctions as described below. Each of the treatments includes two parts.

In the first part we elicit the risk preferences of our subjects by using a binary lottery procedure (see e.g. Holt and Laury (2002)). The procedure includes 15 decisions between a binary

lottery and a safe option. The binary lottery is always the same, paying €4 or nothing with a 50 percent chance each, while the safe option increases from €0.25 to €3.75 in steps of 25 cents.[5] Thus, the higher the fixed amount at which a subject switches from the lottery to the guaranteed payment, the less risk-averse this person is. A person who is risk-neutral should prefer the lottery up to an amount of €1.75 and choose the safe option at €2 and thereafter.

In the second part subjects play the all-pay auction in groups of three. For each bidding group, the valuations are drawn randomly in advance, such that $v_H > v_M > v_L$, i.e. the bidders differ with respect to their valuations. Two valuations are drawn from the discrete uniform distribution over the interval $[11, 20]$. The third valuation is drawn from a discrete distribution over the interval $[15, 55]$, that is constructed such that the exclusion of the strongest bidder is beneficial with probability $p = 0.5$, given that the two other valuations are drawn from the discrete uniform distribution over the interval $[11, 20]$. We constructed our two treatments from these valuations. In treatment (EXP) the valuations were sufficiently heterogenous such that the exclusion of the high type is always expected to pay off for the contest designer. In treatment (EXW) the composition of groups is more homogenous and excluding the high type should be worse than letting all bidders participate in the auction. As we want to investigate the exclusion principle by Baye, Kovenock, and de Vries (1993), the bidder with valuation v_H is excluded from the auction with $p = 0.5$. The aim is then to compare in each treatment the revenue of an auction with two homogeneous bidders with valuation v_M and v_L to the revenue of an auction with all three bidders with $v_H > v_M > v_L$. Note that when the bidder with the highest valuation v_H is excluded from the auction, the bidder with the originally second-highest valuation v_M has the highest valuation among the participating bidders who both submit a positive bid in expectation.

As the two treatments differ only with respect to the composition of valuations, the course of action is identical. In both treatments the all-pay auction was repeated 50 times, including one trial period. At the beginning of each round, the subjects in each bidding group were randomly assigned a valuation. Thus, subjects experienced to be the high-, medium- and low-type bidder over time. The valuations in the bidding group were made common knowledge, then the computer decided with probability $p = 0.5$ whether the high type was participating in a particular round. Whether or not this was the case was also commonly known. Hence, before submitting their bids, the subjects were aware of all valuations in their group and whether the auction was run among two or three bidders. At the end of each round they learned of their earnings and the winning bid.

[5] We adapted this particular setting from Domen and Falk (2006).

Bidders who were excluded from participation were also informed about the winning bid, but did not earn anything in the round.

We employed a random matching protocol in groups of six in each round, i.e. we randomly assigned six subjects to two groups of three. Therefore, a matching group of six subjects is one independent observation. At the end of the second part of the experiment we publicly and randomly drew eight out of the 50 rounds to determine subjects' earnings. The sum of points in these eight periods were exchanged at a rate of 10 points = 1 Euro. Additionally, the participants received an initial endowment of €10 to cover potential losses.

We conducted four sessions with 18 participants each (two sessions for EXP and two sessions for EXW) in the computer lab at Technische Universität Berlin using the software tool kit *z-Tree*, developed by Fischbacher (2007). We recruited subjects using the recruiting tool ORSEE, developed by Greiner (2004). Upon entering the lab, subjects were randomly assigned to their computer terminals. At first, the instructions for the lottery choice procedure were displayed on their computer screen. At that point subjects were not aware of the second task. After completing the lottery choice task, subjects received written instructions for the all-pay auction, including a test to confirm understanding. We only proceeded with the second part after all subjects had answered all the questions correctly. In total 72 students (40 males and 32 females) from various disciplines participated in the eight sessions. Sessions lasted about two hours and subjects' average earnings were about €20.

3 Results

In this section we will present our main findings. First, we look at some aggregate results. Second, we analyze the behavior with respect to exclusion and the different individual valuations. In the third subsection we look at the distribution of bids of the different types.

3.1 Aggregate results and group level behavior

We begin our analysis by looking at the variables of greatest interest to the contest designer: the bids of the contestants and the revenue of the contest. Table 1 presents the summary statistics of the behavior in the two treatments and the respective theoretical predictions. "NoExcl." refers to rounds in which all three bidders participated in the contest, whereas "Excl." describes the statistics of those rounds, when the high type was excluded from participation.

	EXP		**EXW**	
	NoExcl.	Excl.	NoExcl.	Excl.
ave. sum of bids	18.75	14.02	22.54	13.63
	(11.83)	(8.72)	(14.36)	(8.27)
ave. predicted sum of bid	11.72	14.27	14.56	11.43
	(2.39)	(2.63)	(2.22)	(2.24)
average bid	6.25	7.01	7.51	6.81
	(8.69)	(6.42)	(10.39)	(6.34)
average predicted bid	3.90	7.13	4.85	5.71
	(3.40)	(1.36)	(3.86)	(1.41)
minimum bid	0	0	0	0
maximum bid	100	40	100	40
N	900	600	864	624

Notes: Standard deviations in parentheses

Table 1: Summary Statistics of Bids in EXP and EXW

Comparing the average sum of bids in the no-exclusion condition with the average sum of bids in the exclusion condition reveals that on average exclusion does not pay off with regard to the auctioneer's revenue, even if it theoretically should in treatment EXP. However, the average bid increases in EXP when exclusion takes place, which is a necessary but not a sufficient condition for exclusion to be profitable. Still, the drop in the sum of bids is significantly greater in EXW than in EXP (see regression below), such that it can be concluded that excluding the strongest bidder is less harmful if bidders have rather heterogeneous valuations as in EXP.

The reason for exclusion not being profitable could be the heavy overbidding which is observed when three bidders are participating in the auction. A Wilcoxon signed-rank test between the observed and the predicted sum of bids under the conservative assumption that the average bid averaged over all periods within a matching group is one independent observation, yields a significant difference at a 5-percent level in both treatments (EXP and EXW: $z = 2.201, p < 0.027, n = 6$). This behavioral pattern of overexertion is analogous to the results of previous studies on all-pay auctions in related different environments, e.g. Gneezy and Smorodinsky (2006), Barut, Kovenock, and Noussair (2002) or Noussair and Silver (2006). If the high type is excluded,

the difference between observed and predicted bids is not significant. The difference in the sum of bids between EXP and EXW is neither significant in the exclusion nor the no-exclusion condition.[6]

To get a deeper insight into the reasons for exclusion not being profitable, we run a regression both for the sum of all bids and the sum of only the medium and low types' bids as dependent variables. In doing this we get a notion of whether it is the high type or rather the medium and low types that drive this finding. As explanatory variables we include a treatment dummy equal to one when the treatment is EXW, a dummy variable *exclusion*, that is equal to one when the high type was excluded from the auction in a particular round, and an interaction term of the two dummies. The baseline treatment is EXP without exclusion. In this treatment exclusion is predicted to pay off. For both regressions we apply the random-effects panel method to control for the repeated decisions of an individual in a matching group, taking each matching group as a cluster. The results are displayed in table 2.

	dependent variable			
	sum of bids		sum of bids of medium and low type	
EXW (D)	3.713**	(1.97)	1.456	(1.40)
exclusion (D)	-5.029***	(0.86)	8.891***	(0.75)
EXW*ex	-4.030***	(1.23)	-1.80*	(1.07)
Constant	18.906***	(1.39)	5.022***	(0.99)
R^2	0.098		0.159	
$\chi^2_{(1)}$	142.34		225.67	
N	1200		1200	

Notes: robust standard errors in parentheses (clustered for matching groups),

*,**,*** Significant at 10-, 5-, 1-percent level.

Table 2: Regression: Sum of Bids

It can be inferred from the regression given that all three bidders participate in the auction that the revenue of the auction is significantly higher when valuations are more homogeneous (in EXW). This holds, though the valuation of the highest bidders is on average greater in EXP due

[6] At least in the no-exclusion condition this is probably due to the small number of observations (Mann-Whitney test in the no-exclusion condition $z = -1.44, p < 0.149, n = 12$).

to the construction of the treatments. This observation is in line with the theory. However, the revenue drops significantly in EXP when the strongest bidder is excluded. Hence, exclusion is not profitable in this setup. This drop is even bigger in the EXW treatment. Thus, exclusion is worse when valuations are more homogeneous as in EXW compared to the more heterogeneous composition in EXP.

Observation 1 *Exclusion of the strongest bidder never pays off in terms of revenue. However, exclusion is less detrimental if the strongest bidder is far superior.*

In the presence of a very strong bidder, the sum of bids of the two weaker bidders should be lower compared to the case when they compete with a less predominant high type as in EXW. However, the second regression reveals no difference in the treatments with three bidders. Hence, this prerequisite for the exclusion principle to work is not given. In line with theory, the sum of bids of the medium and low type increases significantly if the high type is excluded. This increase is lower in the EXW treatment, but the coefficient of EXW*ex is only significant on a 10%-level. The differences in the treatments seem to be driven only slightly by the behavior of the medium and low type, and mainly by the high type. Thus, the exclusion principle seems to have no bite, as the medium and low type do not compensate the auction designer for the loss in effort when the high type is excluded. To understand how the aggregate behavior emerges, we analyze the behavior of the different bidders' types in the next section.

3.2 Behavior of different types

Our preceding analysis has shown that excluding the high type from participation does not pay off. To get a deeper insight into why this is the case, we will now turn to an analysis of the three types of players. The following table 3 provides an overview of their average bids in the different treatments with respect to exclusion.

The massive overbidding by the high types is striking. In both treatments they bid almost twice as much as predicted by theory if they participate in the auction. A Wilcoxon signed-rank test reveals the difference to be significant at the one percent level (EXP and EXW: $z = 2.882, p < 0.0039, n = 12$) under the conservative assumption of one average observation per matching group. The high types tend to forgo a substantial part of their rent in order to increase their chance of winning. In particular, they win over 80% of the auctions in both treatments which is about 15% more often that predicted, and earn 25% less than predicted. Consequently, excluding the high

	EXP			EXW		
	High type	Med. type	Low type	High type	Med. type	Low type
Bid w/o Exclusion	13.84	2.12	2.78	16.13	4.22	2.18
	(8.13)	(5.17)	(6.89)	(7.67)	(10.59)	(6.29)
Predicted Bid w/o Exclusion	7.91	3.80	0.00	8.98	5.58	0.00
	(1.19)	(1.42)	(0.00)	(0.84)	(1.70)	(0.00)
Bid with Exclusion	-	8.50	5.52	-	9.68	3.94
		(6.04)	(6.46)		(5.55)	(5.77)
Predicted Bid with Exclusion	-	7.43	6.84	-	6.54	4.88
		(1.26)	(1.39)		(0.96)	(1.30)
minimum bid	0	0	0	0	0	0
maximum bid	100	40	55	100	100	40

Notes: Standard deviations in parentheses.

Table 3: Summary Statistics according to bidders' types

type is detrimental to the auction's revenue. In cases when the high type is excluded, it is the medium type who bids more than predicted. Again, this difference is significant in both treatments (in EXP at the 10%−level with $z = 1.922, p < 0.054, n = 12$, and in EXW at the 1%−level with $z = 2.822, p < 0.0039, n = 12$). Hence, also the medium types bid too aggressively when they are the bidder with the highest valuation. However, with respect to the magnitude their overbidding is not as strong as that of the high types.

Observation 2 *Independent of the composition of valuations, the respective strongest bidder in an auction overbids.*

As in our setup the subjects not only know their own valuation, but also the valuations of the two other group members, we can analyze how their bids in the two treatments are influenced by the composition of the valuations within their groups. Remember, only two bidders should be active in the auction as there is just one prize. The expected bid of the stronger bidder should not depend on her own but only on her opponent's valuation, i.e. the bid of the high type should increase in v_M and the bid of the medium type should increase in v_L if the high type is excluded and she herself is the stronger bidder. The expected bid of the weaker bidder should increase in

his own and decrease in his opponent's valuation, i.e. the medium type's bid should increase in v_M and decrease in v_H and the low type's bid should increase in v_L and decrease in v_M if the high type is excluded. This implies that independently of whether or not the high type is excluded, the valuations have an unambiguous effect on the expected bids from the theoretical point of view.

In order to investigate whether the different types react to the valuations as predicted, we run a random effects panel regression with the bids of the respective bidders as dependent variables, taking a matching group as a cluster. As explanatory variables we include (in addition the valuations and the above introduced dummy variables) a lagged variable *win_type* equal to one when the subject won the auction the last time she was in exactly the same situation. For example, this dummy is one when in a particular round a subject is the medium type and the high type is excluded and she won the prize the last time she was in exactly this situation. In doing this, we get a hint whether subjects adjust their behavior according to their type. Recall that valuations and thus types are allocated randomly to the subjects.

In contrast to the literature on standard auctions, less is known as to how risk-averse people behave in all-pay auctions, in particular under complete information. In first-price auctions risk-averse bidders bid more aggressively than risk-neutral bidders, because they are afraid of not winning the prize. Fibich, Gavious, and Sela (2006) theoretically show that this result concerning risk aversion partly carries over to an all-pay auction with independent private values under incomplete information. They show that risk-averse contestants with low valuations bid less aggressively and contestants with high valuations bid more aggressively compared to risk-neutral contestants. Whereas in their framework bidders play pure strategies, in a complete information setup as ours the equilibrium is in mixed strategies. A common interpretation of mixed strategies is that they reflect the uncertainty about others' choice of a pure strategy (Harsanyi (1973)). According to Harsanyi's purification theorem the mixed strategy equilibria in our game can be treated as a limiting case of a game with incomplete information. Therefore, the results of Fibich, Gavious, and Sela (2006) might also hold in our setup. The investigate this, we include a dummy variable for risk aversion which is one when a subject displayed some degree of risk aversion in the above explained lottery choice procedure and zero otherwise[7], as well as an interaction term of the risk aversion and the exclusion dummy. When subjects displayed unsystematic behavior by switching several times between the lottery and the fixed payment, they were excluded from the regression. This was the

[7] All subjects who prefer the safe choice over the lottery at the amount of €2 and thereafter, are not categorized as risk averse, whereas all others with a switching point at €1.75 or earlier are.

case for 18 out of 72 subjects.

	dependent variable:					
	Bid of High		Bid of Med		Bid of Min	
v_H	0.144***	(0.039)	0.015	(0.025)	−0.009	(0.022)
v_M	0.747***	(0.263)	0.307*	(0.160)	0.020	(0.141)
v_L	−0.220	(0.251)	−0.183	(0.150)	0.106	(0.131)
$EXW(D)$	0.662	(2.170)	0.384	(0.836)	0.572	(0.740)
$exclusion(D)$	–		5.219***	(0.757)	2.100***	(0.582)
$EXW * exclusion(D)$	–		−0.496	(0.843)	−0.958	(0.736)
$(win\_type)_{t-1}\ (D)$	1.300	(0.889)	10.865***	(1.076)	7.511***	(1.050)
$(win\_type)_{t-1} * ex(D)$	–		−8.205***	(1.259)	−2.874**	(1.211)
$risk\ aversion(D)$	1.733*	(0.951)	−1.810***	(0.704)	−1.343**	(0.607)
$ex * risk\ aversion(D)$			1.438	(0.973)	−0.274	(0.865)
$Constant$	−1.764	(3.185)	−1.716	(1.773)	−0.293	(1.597)
R^2	0.12		0.31		0.18	
χ^2	41.38		370.57		175.50	
N	385		803		797	

Notes: robust standard errors in parentheses (clustered for matching groups),

*,**,*** Significant at 10-, 5-, 1-percent level.

Table 4: Regressions according to bidders' types

As can be inferred from table 4, the valuations do not influence the bids as predicted. The bids of the medium and the low type seem to be very little influenced by the valuations. In fact, on a 10%-level, one cannot reject the hypothesis that the joint impact of the valuations is zero. If at all, the medium type increases her bid in her own valuation, which is in line with the theory. The high type's bids seem to depend too much on the valuations. In line with theory, they are positively influenced by the medium valuation. However, her own valuation also has a significant positive impact, though it should not have any.

Observation 3 *For the medium and the low type, the valuations hardly play a role in determining their bids, whereas the high type's bid depends both on her own and the medium valuation.*

As expected, the medium and low type significantly increase their bids when the high type is excluded. But as we have seen above, this increase cannot make up for the loss due to the exclusion of the high type. As the coefficient of win_type_{t-1} is significant for the medium and low type, subjects seem well to be aware of their position within their bidding group and the outcome of their bidding strategies. In fact, the experience of the preceding round heavily increases the bids of the medium and low type when the high type is part of the auction. The increase is still significant but smaller in its magnitude when the high type is excluded, as the hypothesis that $win\_type_{t-1} + win\_type_{t-1} * ex(D) = 0$ can safely be rejected (Wald test statistic for the medium type: $\chi^2_{(1)} = 16.86, p < 0.001$, and for the low type: $\chi^2_{(1)} = 58.33, p < 0.001$). Thus, medium- and low-type subjects, who were successful in winning the auction, bid more aggressively in the following round in which the high type takes part. One has to take into account that the medium- and low-type bidders win the auction rarely (i.e. win_type was only rarely equal to one). But if it happens, they seem to enjoy winning such that they want to replicate this outcome by substantially increasing their bids.

The influence of the risk-aversion dummy differs according to the subject's type. For the high type, risk aversion leads to substantially higher bids and vice versa for the other types in the no-exclusion condition. The hypothesis that $ra + ex * ra = 0$ cannot be rejected for the medium type. So, unlike the high type, a risk-averse medium type does not bid more aggressively when he is the stronger bidder, but at least he does not lower his bid.[8] Hence, in large part our findings match the predictions of Fibich, Gavious, and Sela (2006).

Observation 4 *Risk aversion leads to (weakly) higher bids of the stronger bidder and to lower bids of the weaker bidder.*

3.3 Distribution of bids

3.3.1 Bids of the strongest bidders in a round

In this section we only look at the behavior of the respective strongest bidder in a group, which is particularly revealing. This bidder can be either of the high type, or of the medium type in case the high type has been excluded. According to theory, the strongest bidders' bid should be uniformly

[8] Analyzing the dependent variables without controlling for risk attitudes and thus including all subjects into the regression does not qualitatively change the results, except that the coefficient of v_M for the medium type becomes insignificant.

distributed over the interval $[0, v_2]$, where v_2 denotes the valuation of the bidder with the respective second-highest valuation. Over the rounds, there should not be any mass points or bids above v_2, or at least only occasionally. But we observe a behavior completely distinct from this prediction, summarized in the following table 5.

	Percentage of bids with				Total
	$bid = 0$	$0 < bid < v_2$	$bid = v_2$	$bid > v_2$	N
High type in the No-Exclusion condition	0.5%	35.5%	17%	47%	588
Medium type in the Exclusion condition	3.4%	56%	16.2%	24.5%	612

Table 5: Bidding Behavior of the respective high types

When the high type took part in the auction, she chose a bid at least as high as the valuation of the medium type in 64% of the cases. If the high type was excluded, the medium type adopted a similar strategy, in 40% of the cases playing the "safe" strategy. This is certainly not in line with the theory which predicts no mass point at v_2. In fact, 35% of the bids were even strictly higher than v_2 , while this should never occur according to theory. Also, this behavior hardly changes over time, as can be inferred from Figure 1. The picture shows histograms of the bids of the high types relative to the second-highest valuation in the top panel, and the same for the medium type under the exclusion condition in the bottom panel. That is, the value on the x-axis equals (is higher than) one if a bidders' bid matches (exceeds) the second-highest valuation. These relative bids are summarized over the first and second half of the experiment (left and right panel) in order to illustrate the change over time.

As subjects are supposed to play mixed strategies, it is revealing to look at the cumulative distributions of the bids. The theoretical cumulative distribution function (cdf) of the high type's bid x_H depends on the medium valuation v_M as x_H is uniformly distributed over the interval $[0, v_M]$. As v_M varies in our experimental design, we cannot directly draw the cumulative distribution function of the bids jointly for all rounds. However, we can transform the distribution such that the support is independent of v_M: A high type should never bid more than the medium's type valuation. The maximum ratio of her bid relative to v_M is thus one. All bids lower than v_M are chosen with equal probability. This implies that the high type's bid relative to the medium valuation is uniformly distributed over the unit interval: $(x_H/v_M) \sim U[0, 1]$. Hence, we can compare the observed cumulative distribution of relative bids jointly for all values of v_M with the theoretical

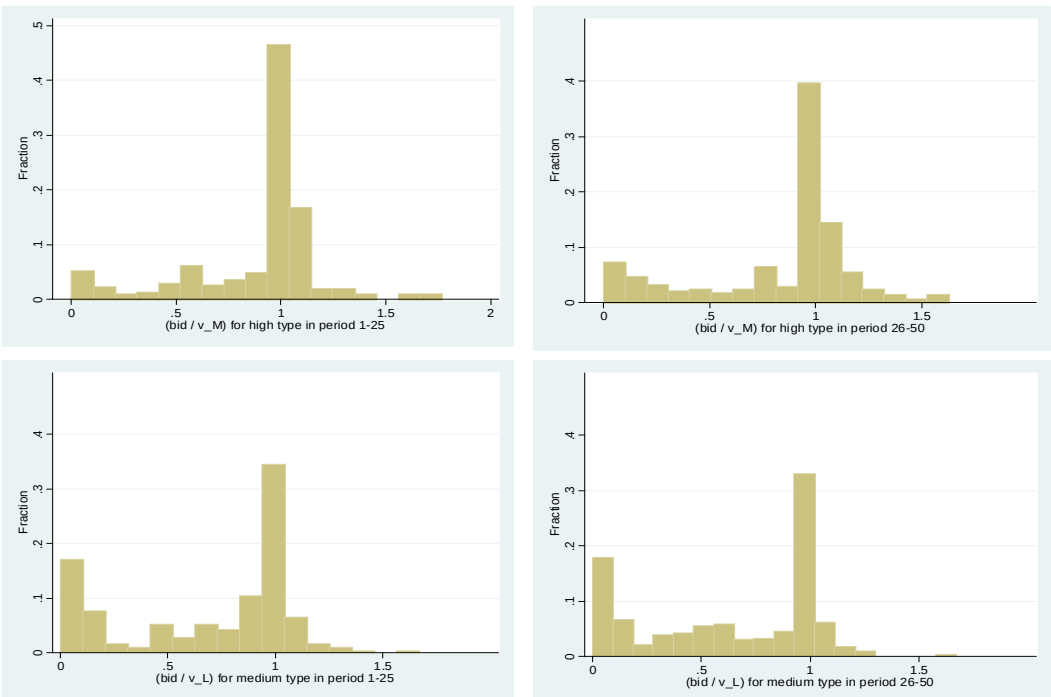

Figure 1: Fraction of the strongest bidders' bids relative to the second highest valuation

prediction. The same argument holds when the medium type is the strongest bidder. The following Figure 2 shows on the left-hand the cumulative distribution of the relative bids for the high type and on the right-hand for the medium type when the high type was excluded, as well as the respective predicted cdfs.

The theoretical prediction describes behavior far from adequately. A Kolmogorov-Smirnov test validates that both observed distributions are significantly different from a uniform distribution ($p-values < 0.001$). Both observed distributions have a mass point where the respective bid equals the second-highest valuation. In addition, the bids often exceed the second-highest valuations, i.e. the bids are beyond the theoretical support. Also, the observed distributions are different from each other on a one-percent significance level (Kolmogorov-Smirnov test, $p - value < 0.001$). The distribution of the high type's bids first-order stochastically dominates the one of the medium type's bids, i.e. the likelihood that a bidder chooses a bid smaller than a certain value is lower for the high type.

Given the (anticipated) behavior of their opponents, many of the respective strongest types seem not to be indifferent with respect to their bids, but prefer to play a pure strategy by bidding

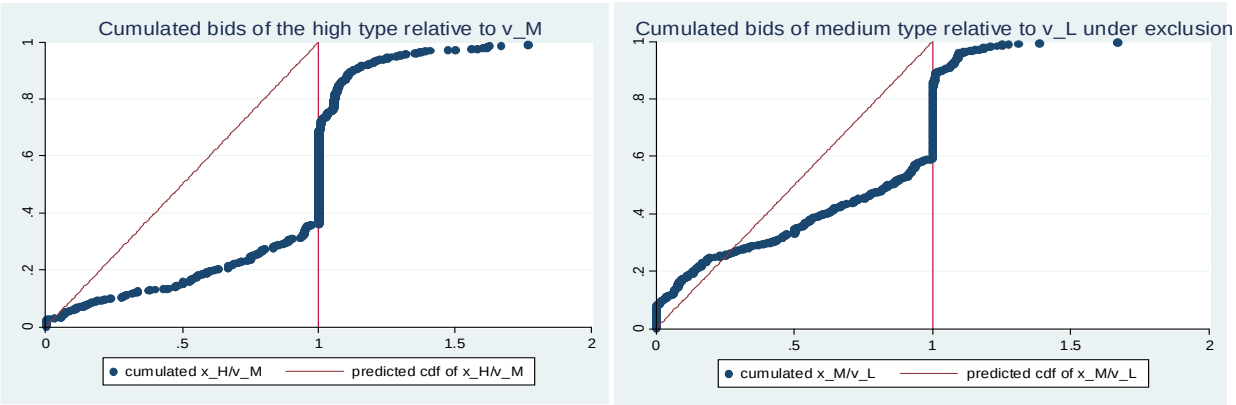

Figure 2: Cumulated relative bids of the strongest bidder

at least the valuation of their strongest opponent. By playing this "safe" strategy, they can be (almost) sure to win the auction and thereby generate a positive profit. Apparently, the chance of making a higher profit accompanied by the risk of losing the auction and thus their bid, seems not as attractive to many of the strongest bidders. The high types are even more prone to play this "safe" winning strategy than the medium types. Hence, the behavior of the subjects seems to differ depending on whether they are the high or the medium type, though they are the strongest bidders in both cases.

To show whether the behavior of the high and the medium type with respect to the safe strategy is significantly different, we run a panel probit regression, with the dummy "*safe*" as the dependent variable. This variable equals one if the subject with the highest valuation of the participating bidders in this round chooses a bid, that is at least as high as the respective second-highest valuation, i.e. for the high type *safe* equals one, if $x_H \geq v_M$, and for the medium type *safe* is one if $x_M \geq v_L$ and the high type is excluded. Recall that we are only interested in the behavior of the respective strongest bidders in a group. The independent variable *high* is equal to one, if the subject is the high type and zero if he is the medium type. As before, we take the matching groups as a cluster. Results are shown in the left panel of table 6. The regression confirms the impression in that a strongest bidder of the high type is significantly more likely to choose the safe strategy than a strongest bidder of the medium type.

The difference in behavior between the two types could be due to the differences in the situations the strongest bidders are confronted with. First, most of the time the high types compete

against comparatively weaker opponents than the medium types do. Hence, the more frequent choice of the safe strategy by the high types could be due to the fact that the distance between their own valuation and the valuation of the second-strongest bidder is larger than for the medium types. Second, the high types always face two opponents, whereas the medium type has just one, given she is the strongest bidder. In order to judge which of these differences better explains the difference in behavior, we run second a panel probit regression, with the same dependent variable. As independent variables we include again a dummy variable for *high*, which equals one if the subject is the high type and zero otherwise. This dummy is now supposed to capture the effect of facing two opponents versus one as we introduce a second explanatory variable, *distance*, that should capture the distance in valuations. This *distance* variable is $(v_H - v_M)$ for the high types and $(v_M - v_L)$ for the medium types. To capture the effect of an increasing distance in valuations we also include the square of *distance*. In addition, we run the regression only for the subsample of observations where $v_H - v_M \leq 9$, as nine is the maximum amount the medium types' valuation can be larger than the low types' one and hence for all distances larger than nine *high* always equals one. The results are shown in the medium column of table 6.

	Dependent Variable: *safe*					
high	0.596***	(0.114)	0.119	(0.143)	-	
distance	-		0.321***	(0.105)	0.052**	(0.022)
distance^2	-		-0.026**	(0.010)	-0.0006	(0.0004)
constant	-0.239*	(0.131)	-0.854***	(0.197)	-0.271	(0.248)
Pseudo R^2	0.040		0.040		0.038	
N	1200		760		588	

Notes: robust standard errors in parentheses (clustered for matching groups),

*,**,*** Significant at 10-, 5-, 1-percent level.

Table 6: Choice of the safe strategy

As the coefficient for *high* becomes insignificant, when the distance variables are included, it seems that it is the degree of her superiority that drives a bidder to choose the safe bidding strategy rather than the number of (weaker) opponents. The stronger a bidder is compared to her keenest competitor, the more likely she is to bid at least as much as the other's valuation. This increase in likelihood attenuates as the distance in valuations becomes larger, as the coefficient of

distance^2 is significantly negative.

The last column of table 6 displays the probit regression for the high types only, for the full range of valuations. On a 5%-significance level *distance* has a positive impact on the probability of playing *safe*.

Observation 5 *The strongest bidders often submit bids that ensure winning the auction, i.e. bids that are at least as high as the valuation of the next strongest bidder. The probability of choosing such a safe strategy increases as the superiority with respect to the second-strongest bidder increases.*

The observed behavior of the strongest bidders could be explained by regret aversion of some players, such that their utility function takes the following form:

$$u_1(v_1, v_2, x_1) = \begin{cases} (v_1 - x_1) & \text{if bidder 1 wins} \\ -x_1 - \gamma\,(v_1 - v_2) & \text{if bidder 1 loses} \end{cases},$$

where $\gamma \geq 0$. Loser regret in all-pay auctions with complete information and heterogeneous players has not yet been analyzed. In symmetric auctions it is assumed that a bidders' regret depends on the difference between her valuation and the bid she should have placed in order to win the auction (see e.g. Filiz-Ozbay and Ozbay (2007), or Baye, Kovenock, and de Vries (2010)). Unlike in our setting, in symmetric auctions there is no possibility for the bidders to generate a secure positive payoff; the amount of regret the bidder experiences in the case of a loss depends on the winning bid of their opponent.

In our setup it is natural to assume a slightly different notion of regret. A subject who is a high type can decide to "gamble" by bidding less than v_M and thus generating a higher profit should she win. If she then loses the auction, she might well regret her decision to gamble instead of going for the safe prospect. Thus, regret is a function of the difference between the bidder's own valuation and the valuation of the opponent (not the winning bid). It captures the idea that the strongest bidder decides upfront whether to gamble or not, and the regret she feels about her decision afterwards when she chose to gamble and lost. This notion does not point out the regret a bidder might feel because he chose too low a bid when playing a mixed strategy but because he chose a mixed strategy at all. Hence, this variant of regret gives a lower bound of the regret feeling as compared to the mentioned case of symmetric auctions. By the design of our experiment, winner regret is excluded as the subjects do not learn the losing bids.

Given that the respective second-strongest bidders play the equilibrium strategy that makes bidders without regret indifferent with regard to their bids, all bidders who have feelings of regret,

$\gamma > 0$, will prefer to bid the valuation of their opponent v_2. This follows directly from the fact that in the standard mixed equilibrium the high type is indifferent between all his actions as all of them give him an expected payoff of $(v_1 - v_2)$, whereas with regret all actions except $x_1 = v_2$ lead to an expected payoff lower than $(v_1 - v_2)$ as they entail the chance of losing and therefore the additional disutility from regret. Certainly, the bidder with the second-highest valuation could anticipate the preferences of the strongest bidder and deviate from the standard equilibrium strategy by randomizing in a way such that the strongest bidder is indifferent between her bids. However, by looking at the data, this is not what the inferior bidders do, as we will demonstrate in section 3.3.2. Instead their behavior seems close to the theoretical prediction with risk aversion. Also, when the aversion to regret of a high type is strong enough, she will always bid the valuation of the second-strongest bidder, as long as there is a small probability that she will lose the auction by bidding less than v_M. The same holds for the medium types when the high type is excluded.

It is plausible that regret aversion only matters if the amount that is to be regretted in case of a loss is sufficiently large.[9] Accepting this, the difference in behavior regarding the safe strategy between the high and the medium type can be explained. For example, if γ is only positive, if $(v_1 - v_2) > 1$, we should observe more "safe" behavior for the high types because their valuation tends to be far greater than their opponent's, whereas the medium type is often only a little superior to the other bidder. In fact, 97% of the time the high types are confronted with a second-strongest player whose valuation is lower than their own by more than one. In contrast, a medium player faces such a weak opponent only 30% of the time. Also, it is unlikely that all subjects exhibit regret aversion. Given that the critical value above which a regret averse player chooses the safe option is one, there needs to be 66% regret averse players in order to explain the observed safe play of 64% for the high types. For the medium types there should be 59% regret averse players to explain the 40% safe choices. Given that it is not exactly the same subjects who are in the position of the strongest bidder as high and medium type, the percentage of regret-averse players (66% vs. 59%) seems reasonably close to consistently explain the behavior.

In some all-pay auction experiments, loss aversion serves as an explanation for observed overbidding behavior (Müller and Schotter (2010); Ernst and Thöni (2009)). With loss aversion, utility in case of a loss would be $u_1(v_1, x_1) = (-x_1 - \lambda x_1)$, $\lambda > 0$. The disutility from losing is independent of the valuations what implies that loss aversion cannot fully explain our results. Like

[9] This assumption is supported by the significant and positive effect of *distance* on the likelihood of the safe stragey to be chosen as shown in the regression results in table 6.

a regret averse bidder, a loss averse bidder would prefer the safe small prospect over the risk of making a loss. Hence, loss averse bidders would also choose the safe strategy given that a player with standard preferences is indifferent. But the behavior of high and medium types as strongest bidders should not differ as the losses are the same for both types whereas the regret bidders possibly feel is greater for the high type.

3.3.2 Behavior of the second-strongest bidders in a round

In this section, we look at the behavior of the second-strongest bidder, i.e. the medium type when the high type took part in the auction or the low type when the high type was excluded. As the theoretical distribution of the bids of the second-strongest bidders depends on both her own and the strongest bidder's valuation, we have to compare the observed distribution with an average cumulative distribution function. Recall that the second-strongest bidder bids zero with probability $(1 - v_2/v_1)$ and submits a positive bid with probability (v_2/v_1). Conditional on her active participation, her bid is uniformly distributed over the interval $[0, v_2]$. As in the previous section, we normalize the support of the distribution function to $[0, 1]$ by looking at the distribution of the bids relative to v_2, i.e. the own valuation of the second-strongest bidder. We compare the observed cumulative distribution of these relative bids with the theoretical prediction based on the average probability of a bidder submitting a positive bid, given the valuations v_2 and v_1. This average entry probability equals 0.544 when the medium type is the second-strongest bidder and 0.823 when the low type is the second-strongest bidder. Again the observed distribution differs substantially from the theoretical prediction. Both the medium and the low type submit too many zero bids, i.e. they drop out of the competition. But given that they have entered the auction, a uniform distribution of bids seems to be quite a good approximation. Given that the inferior bidders understand that there are regret-averse opponents who almost always bid them out, their best reply to this strategy is to bid zero. This could explain the larger portion of zero bidding compared to the theoretical prediction.

Applying the concept of regret aversion the way we defined it for the strongest bidders to the second-strongest bidders should not alter their strategies as there is no safe gain and thus no regret. But risk aversion might bias the bids downwards as seen in table 4. Also, loss aversion could be part of the explanation as it leads to more zero bidding.

Surprisingly, the second-strongest bidder frequently submits a bid higher than her own valuation (7.5%). With standard preferences this is hard to explain as even if the auction is

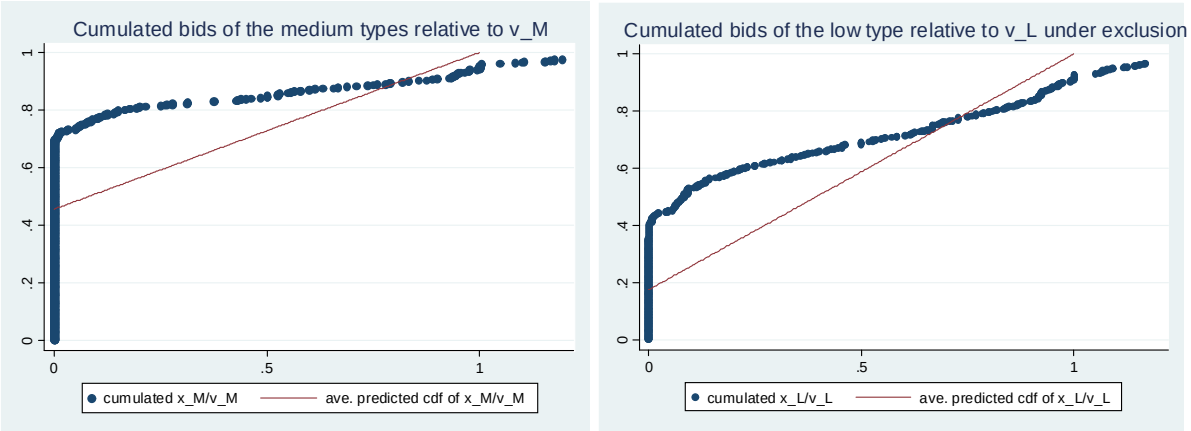

Figure 3: Cumulated relative bids of the weaker bidder

won there is a loss in terms of income. However, this behavior has also been observed in other experiments and could be explained for example by emotions (see Kräkel (2008)). The strong increase in bids of the medium and low type after they won the auction could be an indicator of emotions (see table 4). In the model of the all-pay auction the joy of winning increases the support of the second-strongest bidder's bid function and consequently also the support of the high type's bid function. Hence, emotions by some bidders can also explain those bids of the high types that are above v_2.

4 Conclusion

Superstars can have a major impact on the attractiveness of contests, but at the same time their presence can be detrimental for their competitors' willingness to exert effort. In this paper, we experimentally investigate the effect of excluding superstars from the contest and thereby creating a more homogenous participant pool. We find that in our setting excluding the strongest bidder is never beneficial for the contest designer. The main reason for this result is the massive overbidding of superstars when they participate in the all-pay auction. They prefer to give up a substantial part of their rent in order to avoid losing the auction. Without a superstar, a more homogeneous but individually weaker group of bidders cannot make up for this.

We very frequently observe that the strongest contestants, both with and without exclusion, choose pure strategies instead of mixed strategies as theory would predict. In fact, they make sure of winning the auction by bidding at least the valuation of their most powerful competitor. Moreover,

the tendency of choosing a "winning-for-sure" strategy increases if the payoff that can be secured by this strategy is higher. We explain this behavior with regret aversion. Choosing a strategy that entails the possibility of losing the auction may create feelings of regret because the strongest contestant could have ensured that she wins the auction by bidding the valuation of the strongest competitor, which guarantees a positive payoff.

The substantial overbidding of superstars also leads to many dropouts of the weaker contestants. While the dropout behavior could provide an argument for designing a homogenous contest without a superstar, we do not find support for this in terms of revenue. The increased effort of the weaker contestants in the absence of the strongest contestant cannot compensate for the superstars' effort. The substantial dropout can just be explained by loss aversion. Regression results also indicate that risk aversion leads to the weaker contestants making lower bids.

We presented evidence that a behavioral bias, such as regret, can explain overbidding. This result might also indicate the subjects are reluctant to play mixed strategies because they might regret their decision afterwards. This opens interesting questions for future research.

Appendix

In the following, we present you the translated instructions that were given to the subjects to explain the all-pay auction. The subjects also had to answer some questions to confirm understanding. These questions are also given below. The instructions for the lottery choice procedure are available on request.

Instructions for the all-pay auction

General

The second part of the experiment consists of 50 periods in each of which you have to make a decision. Through your decision you can earn points. These points constitute your income which is exchanged to Euro according to the conversion rate stated below. Your earnings from the first part of the experiment and from this part will be paid in cash to you at the end of the session.

In each of the 50 periods you are randomly matched with two other participants to form a group. From now on we label these two participants as group members. You and the other group members do not learn the identity of each other at any point of time. In the following we explain the different decisions you have to make and the procedure of the experiment.

Decision in one period

In each period the computer randomly generates and assigns a number to you and the other group members. One of these number will be drawn from the set $\{15, 16, \ldots., 55\}$ and the other two numbers from the set $\{11, 12, \ldots.., 20\}$. In the beginning of each period you learn your number and the two numbers of the other group members. In the remainder, we will refer to these numbers as "random numbers".

Before you make your decision, the computer randomly decides with a probability of 50% whether the group member with the highest random number is excluded from this period. This means that on average in 5 out of 10 cases the group member with the highest random number actively participates in that period. Also, in 5 out of 10 cases the group member with the highest random number is excluded and will not receive an income in that period. If it is not you who has the highest random number in a period you definitely participate. You will learn in each period, whether the group member with the highest random number is being excluded or not.

Every participating group member has to choose an arbitrary number. The number can have up to three decimal and has to be non-negative (zero is possible). All group member choose their number simultaneously. We denote this number "decision number".

Calculation of your income in one period

Your income depends on your decision number, as well as the decision number of the other group members and your random number.

After the decisions of all group members were made, the computer compares and ranks the three decision numbers.

- If your decision number is the highest number, you earn your random number minus your decision number in this period.

  period income = random number − decision number

- If your decision number is not the highest number, you earn zero minus your decision number in this period.

  period income = 0 − decision number

In case of a tie, the highest number is determined randomly.

Please note: The decision number you have chosen will be deducted from your period income independent from the rank of your decision number, i.e. your income will in any case be reduced by your decision number.

If you choose a high decision number, you increase the probability that your decision number is the highest. But a high decision number also reduces your income, since a higher number is deducted from your random number. If your decision number is not the highest, your income is also reduced by your decision number. At the end of a period you learn your income in this period. If your decision number was not the highest, you additionally learn the highest decision number. If your decision number was the highest number you only learn your income in this period.

Example for calculation of the income in one period

Consider the following situation:

Your random number is 28 and you learn the random of the other group members. The computer decides that all group members participate in this period. You choose 16 as your decision number.

a) In case you have the highest decision number, you earn your „random number“ minus your decision number, i.e. your income in this period is 28 – 16 = 12

b) In case your decision number is not the highest decision number, you earn zero minus your decision number, i.e. your income in this period is 0 – 16 = -16

Please note, that your income depends on your random number, your decision number and the decision numbers of the other two group members.

Consider now the following situation:

Your „random number“ is 28 and you learn the random of the other group members. You find out that your decision number is not the highest number in the group. Hence you participate in any case in this period. The computer decides, that the group members with the highest „random number“ is excluded in this period. You choose 16 as your decision number.

a) In case you have the highest decision number, you earn your „random number“ minus your decision number, i.e. your income in this period is 28 – 16 = 12

b) In case your decision number is not the highest decision number, you earn zero minus your decision number, i.e. your income in this period is 0 – 16 = -16

Please note, that your income depends on your random number, your decision number and the decision numbers of the other two group members.

Consider now the following situation:

Your „random number“ is 28 and you learn the random of the other group members. You find out that your decision number is the highest number in the group. The computer decides, that the group member with the highest random number is excluded in this period. This means for you that this period is finished for you and that you do not get an income in this period.

After the first period, we repeat this procedure in period 2, period 3, through period 50. In each of the 50 periods you will be randomly matched with two other participants. You are assigned a random number and learn the random numbers of the other two group members. Then the computer decides whether the group member with the highest random number participates in this period. All participating group members simultaneously choose their decision number and learn their income at the end of the period.

Calculation of the total income of the second part of the experiment

In the beginning you receive a lump-sum payment of 100 points. At the end of the experiment the computer randomly draws 10 periods which determine your income. The points you earned in this period are then added up.

Your total income = 100 + sum of points in 10 randomly drawn periods

Your total income will be converted into to Euro at a rate of ten points for one Euro.

Trial period

Before we begin, you participate in a trial period that is not relevant for your earnings.

Quiz for the all-pay auction

Please answer the following questions and mark of fill in the correct answers.

1. Suppose your random number is 19 and your decision number is 12. Your decision number is the highest in your group. Your income in this period is:

   (a) 19

   (b) 12

   (c) 7

   (d) -12

2. Suppose your random number is 15 and your decision number is 6. Your decision number is not the highest in your group. Your income in this period is:

   (a) 9

   (b) – 6

   (c) – 9

   (d) – 15

3. Suppose your random number is 19 and your decision number is 12. All three group members participate in this period.

   (a) If your decision number is the highest in your group, you get _____ points minus _____ points. Your income in points in this period is _____.

   (b) If your decision number is the second highest in your group, you get _____ points minus _____ points. Your income in points in this period is _____.

4. What is your income in 3a) and 3b), when the group member with the highest „random number“ is excluded and you participate in this period?

   (a) Income in situation 3a: _____

   (b) Income in situation 3b: _____

5. In each period you will be randomly matched with two other participants.

   (a) correct

   (b) wrong

6. If you participate in a period, is the decision number deducted from your income independent of the decision numbers of the other group members?

   (a) Yes

   (b) No

7. The probability of an exclusion of the group member with the highest random number in a period is 30%.

   (a) correct

   (b) wrong

8. A group member with the second or the third highest random number is not excluded in any period.

   (a) correct

   (b) wrong

9. In case two or more decision numbers are the highest number, the highest number is randomly determined.

   (a) correct

   (b) wrong

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