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Abstract

Exclusion in the All-Pay Auction: An Experimental Investigation

by Dietmar Fehr and Julia Schmid*

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

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

JEL classification: C72, C92, D84

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1 Introduction

Superstars attract attention. In recent years, many sports saw the presence of dominant athletes, such as Roger Federer on the Tennis ATP Tour or Tiger Woods on the Golf PGA Tour. These athletes typically create a lot of attention and serve as face of their sport. However, too great a dominance by one athlete might also lead to boredom and a lower level 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 (BBC 2002).[1] These examples illustrate the trade-off between the inclusion of superstars and contest homogeneity.

Situations in which the contest designer cares about the closeness of the competition not only appear in sports but are pervasive in our society, see e.g. Frank (1995). Firms install promotion tournaments and sales competitions, lobbyists compete for influence by donating money to political parties, or 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 of the bidders.

Given the potential adverse effects of heterogeneous contests, the composition of the contest is an important parameter for the contest designer. Indeed, Baye, Kovenock, and de Vries (1993) show theoretically that excluding the strongest bidder under specific assumptions can lead to higher revenues for the contest designer (*exclusion principle*). In contests with one prize, the presence of a strong bidder may not only decrease the bids of the weaker bidders but in turn reduces the bid of the strongest bidder. As a consequence this possibly leads to a lower overall performance.[2] The idea behind the *exclusion principle* is to increase bids of the remaining bidders by creating a smaller but more homogeneous contest.

This paper presents an experimental test of the *exclusion principle*. That is, we attempt to answer the question, whether a heterogeneous group with one strong bidder or a smaller but more homogeneous group maximizes total revenue for the contest designer. We implemented a

[1]Likewise, US professional sport leagues (e.g. the NBA, NFL, NHL or MLB) put a lot of effort into creating homogeneity among the competing teams. For example, the rookie drafting system tries to ensure a more balanced competition in the medium to long run through allocating the right to select rookies from the pool of the best junior prospectives first to the weaker teams from the past season.

[2]Using data from the PGA Tour, Brown (2011) shows that the participation of Tiger Woods leads to a worse performance (more strokes) of other participating high-skilled professionals compared to when Tiger Woods is not participating in the tournament.

repeated all-pay auction with three bidders and complete information about bidders' valuations of the prize. The valuations in a bidding group were heterogeneous, i.e., a group consisted of one strong bidder and two weaker bidders. In order to test the *exclusion principle* we randomly varied the participation of the strongest bidder in a bidding group and compare total revenues when there is no exclusion of the strongest bidder with total revenues in the smaller homogeneous contest.

We find only partial support for the theoretical predictions. If the contest is not too heterogeneous, i.e., in the treatment in which exclusion is never beneficial, we indeed find that revenues are higher with three bidders than with the exclusion of the strongest bidder. In contrast, we find no support for the *exclusion principle*. Excluding the strongest bidder is on average not beneficial in the treatment where exclusion should be always profitable for the contest designer. This is despite the fact that the valuations of strongest bidder are on average more than twice as high as the valuations of the strongest competitor.

The main reason for the failure of the *exclusion principle* is the behavior of the strongest bidders as they considerably overbid when they participate in the contest. Although the weaker bidders increase their effort significantly when the strongest bidder is excluded, they cannot compensate for the lost revenue of the strongest bidder. In fact, the strongest bidders often choose a strategy guaranteeing them to win the prize, which involves bids equal to or higher than the valuation of the second-strongest bidder. Thus, strong bidders are willing to give up a quite substantial portion of their rent just to avoid losing the auction.

Subjects are more likely to choose this "*safe*" strategy if the rent from playing this strategy is larger. In other words, the larger the difference in the valuations of the strongest and second-strongest bidder, the more often we observe the use of the *safe* strategy. We explain this kind of behavior with regret aversion. A regret averse bidder prefers a smaller but secure pay-off over a larger 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.

The results presented in this paper are linked to a large experimental literature on contests (for a comprehensive survey see Dechenaux, Kovenock, and Sheremeta 2012). While this literature puts much emphasis on tournaments, Tullock contests and incomplete information all-pay auctions, only a few papers focus on complete information all-pay auctions (e.g., Davis and Reilly 1998, Gneezy and Smorodinsky 2006, Lugovskyy, Puzello, and Tucker 2010 or Ernst and

Thöni 2013).[3] In all-pay auctions with complete information all equilibria are in mixed strategies, and with the exception of Davis and Reilly (1998) all these papers investigate symmetric all-pay auctions. There are two noteworthy observations that emerge from these previously mentioned studies. First, subjects tend to overbid in comparison to the Nash equilibrium.[4] Second, bidding behavior is bimodal. That is, while subjects seem to randomize their bids, they typically place too much weight on zero or low bids as well as on high bids.[5] Our results provide further support for these two observations. We find significant overdissipation by the strongest bidder (similar to Davis and Reilly 1998) as well as evidence that weaker bidders frequently drop out of the auction. We contribute to this literature by investigating asymmetric all-pay auctions and, in particular, by testing the *exclusion principle*. That is, we are mainly interested in whether the exclusion of the strongest bidder increases total revenues for the contest designer.

Our paper also makes a methodological contribution. In our main treatments subjects receive new valuations in each period. While this allows us to observe behavior and the *exclusion principle* within a broad set of parameters, it arguably complicates subjects' decision task and changes the equilibrium prediction in each period. Therefore we ran a control treatment in which we fixed the valuations for the three bidders in a group throughout the experiment to reduce complexity. The results of the control treatment corroborate all our earlier findings. In particular, we find that exclusion of the strongest bidder is still not profitable when bidders in a group face the same valuations in each period. Again, this can be attributed to the substantial overbidding by the strongest bidder, which is manifested in the frequent use of the *safe* strategy. The results from the control treatment indicate that at least in our setup, it did not matter whether subjects face the same set of valuations in each period or whether they get new valuations in each period.

The rest of the paper is organized as follows. The next section provides a short outline of the theory and describes the experimental procedures. Section 3 presents the results from the main and control treatment and offers a theoretical explanation for the results. Section 4 concludes.

[3]Hillman and Riley (1989) and Baye, Kovenock, and de Vries (1996) provide a theoretical account for all-pay auctions with complete information and Konrad (2009) provides an extensive review of the theoretical literature on contests.

[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.

[5]Bimodal bidding is also frequently observed in all-pay auctions with incomplete information, in which subjects tend to bid only if their valuation are above a certain cut-off level and abstain from bidding otherwise (see e.g., Müller and Schotter 2010, Noussair and Silver 2006 or Barut, Kovenock, and Noussair 2002).

2 Theory 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 are assumed to be risk neutral and they value the prize differently, where a high valuation can alternatively be interpreted as a bidder 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 x_i. The bidder with the highest bid x_i wins the auction, receives the prize that she values v_i, and pays her bid x_i. All other bidders lose their bid without gaining anything. Ties are broken randomly.

In this setup, 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 participating bidders. 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 $G_2(x) = 1 - v_2/v_1 + x/v_1$. The expected bid of the bidder with the highest valuation in a period is $\mathbb{E}[x_1] = v_2/2$ and the expected bid of the bidder with the second-highest valuation in a period is $\mathbb{E}[x_2] = (v_2)^2 / 2v_1$.

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

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

Thus, in order to maximize the auctioneer's revenue, the bidder 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 bidder 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. Thus, the auctioneer might prefer a contest with individually weaker but more homogeneous bidders 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 Design

The experiment consists of two treatments, which differ with respect to the composition of valuations in the auctions as described below. In each treatment we first elicited subjects' willingness to take risk and then we ran the all-pay auction with complete information.

The theoretical model assumes risk-neutral players, but risk aversion is an often proposed candidate to explain overbidding in auctions. In order to have a measure for subjects' risk attitudes, we directly elicit risk preferences using a binary lottery procedure (see e.g. Holt and Laury 2002, Dohmen and Falk 2011). 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 increased from €0.25 to €3.75 in steps of 25 cents. A weakly risk-averse person would prefer the safe option over the lottery for safe options lower or equal to €2.[6]

After the first task subjects play the all-pay auction in bidding groups of three. The bidders differ only with respect to their randomly drawn valuations $v_{H(igh)} > v_{M(edium)} > v_{L(ow)}$, i.e., each bidding group consists of a high, medium and low type. The two valuations v_M and v_L are drawn from the discrete uniform distribution over the interval $[11, 20]$. The third valuation v_H is drawn

[6]This holds for subjects with monotonic preferences. In our data, 25 out of 144 subjects (17 percent) switched multiple times between the safe option and the lottery. These subjects are excluded in our analysis when we rely on this measure for the willingness to take risks.

from a discrete distribution over the interval $[15, 55]$. All valuations were drawn before the experiment and we constructed two treatments based on these valuations. That is, in one treatment the valuations are sufficiently heterogeneous such that the exclusion of the high type v_H is always profitable for the contest designer (in the following treatment EXP – *EX*clusion *P*rofitable). In the second treatment, the composition of groups is more homogeneous and excluding the high type should result in lower revenues than letting all bidders participate in the auction (in the following treatment *EXUP* – *EX*clusion *U*n*P*rofitable). In *EXP*, the average valuations are $v_H = 35.3$, $v_M = 16$ and $v_L = 14.7$. In *EXUP*, these averages are $v_H = 30.9$, $v_M = 17.9$ and $v_L = 13$.

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 $p = 0.5$. Our aim is primarily to compare the revenue of an auction with two "*homogeneous*" bidders with valuation v_M and v_L (exclusion condition) to the revenue of an auction with all three bidders with valuations $v_H > v_M > v_L$ (no-exclusion condition). Because the theory specifies the condition in which the *exclusion principle* should hold and in which it should not hold, we implemented treatment *EXP* and *EXUP*. Accordingly, we should find exclusion to pay off in terms of revenue in treatment *EXP*, whereas in treatment *EXUP* excluding the bidder with the highest valuation should be detrimental to the revenue.

For both treatments the course of action is identical, as they only differ with respect to the composition of valuations. In both treatments the all-pay auction was repeated 51 times (including one trial period). In the beginning we randomly assigned subjects to a six-person group (matching group), which was fixed for the rest of the experiment. Within a matching group we randomly matched subjects into two bidding groups of three in each period. Because the behavior over time is likely to depend on previous interactions, we treat a matching group as an independent observation in our statistical analysis below. At the beginning of each period, the subjects in each bidding group were randomly assigned a valuation. Therefore, subjects experienced each bidder role (v_H,v_M and v_L) over time, which should alleviate the understanding of the strategic aspects of the auction. The valuations in the bidding group were made public knowledge before bidding started and subjects learned whether the high type was participating in a particular period, which was randomly determined by the computer with probability $p = 0.5$. Therefore, subjects were aware of all valuations in their group and whether the auction was run among two or three bidders when placing their bids. Bids were unrestricted and subjects could use a resolution up to three decimal places. At the end of each period they were informed about their earnings and the winning bid. Bidders who were excluded from participation were also informed about the winning bid, but did not earn anything in that period.

In our design, bidders face different sets of valuations in each period. This allows us to analyze the *exclusion principle* and bidding behavior in a rich environment that is not idiosyncratic to a specific choice of valuations. Furthermore, it hampers collusive behavior, which is more difficult if valuations change over time. On the other hand, subjects are confronted with a new strategic situation in each period and finding the optimal bidding strategy is a rather difficult task that has to be accomplished again for each new valuation composition. In order to check whether our results are robust, we run a control treatment in which we fix v_H, v_M, and v_L for 50 periods (for details see Section 3.3).

We conducted eight computerized sessions with 18 participants each at the experimental laboratory at the TU Berlin (four sessions each in November 2008 and in April 2011) using the software tool kit *z-Tree* (Fischbacher 2007). Subjects were recruited from a large database (ORSEE) where students can voluntarily register for participating in experiments (Greiner 2004). Upon entering the lab, subjects were randomly assigned to their computer terminals. First, the instructions for the lottery choice procedure were displayed on their computer screen. At that point subjects had no information about their task in the second part of the experiment. After completing the lottery choice task, subjects received written instructions for the all-pay auction, including a test to confirm their understanding. We only proceeded with the second part after all subjects had answered all test questions correctly. At the end of the second part of the experiment we publicly and randomly drew eight out of the 50 periods to determine subjects' earnings. The sum of points in these eight periods plus the earnings from the lottery choice task were exchanged at a rate of 10 points = 1 Euro. Additionally, the participants received an initial endowment of €10 to cover potential losses. In total 144 students (81 males and 63 females) from various disciplines participated in the experiment (including the control sessions). Sessions lasted about two hours and subjects' average earnings were about €15.3.

3 Results

3.1 Aggregate Results and the Exclusion Principle

We begin our analysis by looking at the variables of greatest interest to the contest designer: the revenue of the contest. Table 1 presents the summary statistics for both treatments along with the theoretical predictions broken down into the exclusion and no-exclusion condition.[7] The exclusion condition consists of all situations in which the bidder with the highest valuation (v_H) is excluded from participation in the auction, whereas in the no-exclusion condition all three bidders participate. According to the exclusion principle, we would expect that exclusion increases revenues for the contest designer in *EXP*, but not in *EXUP* where revenues should be lower with exclusion.

Indeed, Table 1 shows that revenues are lower when the high type v_H is excluded from participation in both *EXUP* and *EXP*. While this is in line with the qualitative prediction for *EXUP*, it is in strong contrast to the prediction for *EXP* that exclusion increases revenues relative to no-exclusion. In *EXUP*, the sum of bids is, on average, 21.55 when all three bidders participate compared to 13.63 when only the two weaker bidders participate. The difference in the sum of bids in the two conditions (exclusion and no-exclusion) is statistically significant according to a Wilcoxon signed-rank test ($z = 2.201$, $p < 0.03$, $n = 6$).[8] In contrast, in *EXP* the sum of bids is larger when all bidders participate in the auction (18.48) than when the high type is excluded (14.02). This result is not due to weak high types. In fact, high types value the prize on average more than two times than their strongest competitor. We can reject the hypothesis of equal revenues in the two conditions (Wilcoxon signed-rank test $z = 2.201$, $p < 0.03$, $n = 6$), albeit not in favor of our alternative hypothesis.

It is apparent that, on average, the sum of bids is always higher than predicted (overbidding) except in the exclusion condition in *EXP*. When the high type v_H is excluded, we observe that the sum of bids in *EXUP* is about 1.2 times higher than predicted, whereas the sum of bids is about 1.5 times higher than predicted in the no-exclusion condition of both treatments (158% in *EXP* and 148% in *EXUP*). Recall that by construction of the treatments, *EXP* is more heterogeneous than *EXUP* when all three bidders participate. Therefore, the average sum of bids should be lower in *EXP* than in *EXUP* in the no-exclusion condition. Similarly, *EXP* is more homogeneous than *EXUP* when the strongest bidder is excluded and thus the average sum of bids should be higher in *EXP* (see also predicted sum of bids in Table 1). However, due to the overbidding, we do not find any significant differences in bidding when we compare the conditions across treatments.

[7] Due to a programming mistake we implemented the same valuation for v_M and v_L in 20 percent of cases in treatment *EXP*. Recall that the theory requires $v_H > v_M > v_L$. Excluding these cases yield qualitatively the same results and thus we include this data throughout our analysis. Note also that five out of 3600 individual bids are significantly larger than 55. We exclude the data of the whole bidding group from these periods throughout our analysis.

[8] In all non-parametric tests we use a matching group as an independent observation because individual behavior is likely affected by observing others behavior over time. This leaves us with six observations per treatment, which constitutes a conservative way to compare between-treatment or within-treatment variations.

Table 1: Sum of bids in *EXP* and *EXUP*

	EXUP		***EXP***	
	no exclusion (3 bidders)	exclusion (2 bidders)	no exclusion (3 bidders)	exclusion (2 bidders)
avg. sum of bids (observed)	21.55	13.63	18.48	14.02
	(11.58)	(8.27)	(10.88)	(8.72)
avg. sum of bid (predicted)	14.60	11.43	11.72	14.27
	(2.22)	(2.24)	(2.39)	(2.63)
minimum bid	0	0	0	0
maximum bid	50	40	55	40
N	*284*	*312*	*299*	*300*

Notes: Standard deviations in parentheses. We excluded the sum of bids if $x_i > 55$. This was the case in 5 out of 3600 individual bids.

Neither for the no-exclusion condition (Mann-Whitney test $z = 1.121$, $p > 0.26$, $n = 6$), nor for the exclusion condition (Mann-Whitney test $z = 0.480$, $p > 0.63$, $n = 6$).

The observed patterns are stable over time in both treatments and conditions. The sum of bids is slightly higher in the first half (periods 1–25) than in the second half of the experiment (periods 26–50) in all but in the exclusion condition in *EXUP*. However, the differences are never statistically significant.[9]

Why is it the case that exclusion does not lead to higher revenues in *EXP*? We have seen that there is substantial overbidding in the presence of three bidders and we can ask whether exclusion would have been profitable if the strongest bidders would have behaved as prescribed by theory. For this thought experiment, we calculate the revenues in the no-exclusion condition in *EXP* using the actual bids of the two weaker bidders and the theoretical bids of the strongest bidders. As predicted by the *exclusion principle*, this calculation shows that revenues would be lower than with exclusion in *EXP* (12.82 vs. 14.02). Although the difference in revenues is not statistically different (Wilcoxon signed-rank test $z = 0.943$, $p > 0.34$, $n = 6$). This counterfactual analysis suggests that the behavior of the strongest bidder plays a major role that the theory is not predictive in *EXP*.

Intuitively, one would expect that exclusion is more profitable the more heterogeneous the group is (i.e., the stronger v_H is). However, our results suggest that exclusion is not profitable

[9]In the exclusion condition of *EXUP*, the average sum of bids is 13.6 in periods 1–25 and 13.7 in periods 26–50, whereas in the no-exclusion conditions of *EXUP*, the average sum of bids is 22.6 in periods 1–25 and 20.5 in periods 26–50. Similarly, in the exclusion condition of *EXP*, the average sum of bids is 14.9 in periods 1–25 and 13.4 in periods 26–50. In the no-exclusion conditions of *EXP*, the average sum of bids is 19.2 in periods 1–25 and 17.6 in periods 26–50. Regressing the sum of bids on a dummy variable equalling 1 for periods 1–25 and clustering errors on matching groups yields insignificant coefficient estimates in all four cases.

Table 2: Summary statistics of individual bids of bidder types

	EXP			***EXUP***		
bidder type	High	Medium	Low	High	Medium	Low
avg. bid	13.56	2.24	2.67	15.84	3.50	2.18
no exclusion	(6.43)	(5.30)	(6.81)	(5.87)	(7.66)	(6.29)
avg. predicted bid	7.92	3.81	0.00	8.98	5.58	0.00
no exclusion	(1.19)	(1.42)	(0.00)	(0.84)	(1.70)	(0.00)
avg. bid	-	8.40	5.63	-	9.69	3.94
exclusion		(6.06)	(6.47)		(5.55)	(5.77)
avg. predicted bid	-	7.43	6.84	-	6.54	4.88
exclusion		(1.26)	(1.39)		(0.96)	(1.30)
minimum bid	0	0	0	0	0	0
maximum bid	47	40	40	32	50	50

Notes: Standard deviations in parentheses. We excluded bids $x_i > 55$. This was the case in 5 out of 3600 individual bids.

for a large range of valuations in *EXP*, because of the prevalent overbidding in the no-exclusion condition. The sum of bids is in about 80 percent of cases higher than predicted in the no-exclusion condition and we observe a significant correlation of overbidding and the distance in valuations between the strongest and second-strongest bidder ($\rho = 0.17$, $p < 0.01$). A more detailed look into average valuations reveals that overbidding occurred in particular when the valuation of the strongest bidder was high. On average, the valuations in a group in cases with overbidding are $v_H = 36.3$, $v_M = 15.7$ and $v_L = 14.3$ compared to $v_H = 33.0$, $v_M = 16.3$ and $v_L = 15.0$ in groups with sum of bids that are equal or lower than predicted. The sum of bids when no overbidding occurred is, on average, 6.51. This is not only significantly lower than the predicted sum of bids of 12.46, but also lower than the predicted as well as the actual sum of bids in the exclusion condition of *EXP*. This suggests that the *exclusion principle* may be profitable if the strongest bidder is not too strong.

3.2 Individual Behavior

The preceding analysis has shown that overbidding plays an important role that exclusion is not profitable in *EXP*. To get a deeper insight in the underlying reasons, we will now turn to a more thorough analysis of the three bidder types. Table 2 provides a first overview of the average bids of each bidder type in the no-exclusion condition (top panel) and the exclusion condition (bottom panel) for each treatment.

The strong overbidding by the strongest bidder is striking. In both treatments high types bid, on average, almost twice as much as predicted by theory if they participate in the auction (Table 2, top panel). The difference between actual bids and predicted bids is statistically significant in both treatments (Wilcoxon signed-rank test, $z = 2.201$, $p < 0.03$, $n = 6$ for both treatments). As a consequence, the strongest bidders forgo a substantial part of their rent in order to increase their chance of winning. In particular, they win about 82% of the auctions in both treatments, which is about 10 percentage points more often than predicted. But they only earn about 80 percent of the expected profits. This overbidding by the high type seems not to be triggered by excessive bidding of the weaker types. In fact, we observe that the weaker types often drop out of the bidding process in the no-exclusion condition. For example, medium types abstain from bidding (placing a zero bid) in 64 percent of cases in *EXP* and *EXUP*. On the other hand, low types who should never place a positive bid in the no-exclusion condition, only place zero bids in 71 percent of cases. Accordingly, we observe on average strictly positive bids of low types (2.67 and 2.18, see Table 2) and similar bids of the medium types (2.24 and 3.50).

In the exclusion condition, it is the bidder with the second-highest valuation (medium type) who bids on average more than predicted. The overbidding is, however, only statistically significant in *EXUP* (Wilcoxon signed-rank test, $z = 2.201$, $p < 0.03$, $n = 6$) but not in *EXP* (Wilcoxon signed-rank test, $z = 1.363$, $p = 0.17$, $n = 6$).

We now focus on the behavior of the strongest bidder in a bidding group, which is either the bidder with v_H in the no-exclusion condition or the bidder with second-highest valuation v_M in the exclusion condition. According to theory, the strongest bidders' bid should be uniformly distributed over the interval $[0, v_2]$, where v_2 denotes the valuation of the bidder with the second-highest valuation (either the medium type in the no-exclusion condition or the low type in the exclusion condition). Over the periods, there should not be any mass points or bids at or above v_2. But we observe behavior completely distinct from this prediction. Figure 1 shows on the left-hand side the cumulative distribution of the bids of high types x_H relative to the valuation of the medium type v_M (no-exclusion condition) and on the right-hand side the bids of the medium type x_M relative to the valuation of the low type v_L (exclusion condition). The figure also shows the theoretical benchmark for the strongest bidder (45-degree line).[10]

[10] Note that the predicted bid of the strongest bidder (either the high or medium type) depends on the valuation of the second-strongest bidder v_2 (either the medium or low type) and is uniformly distributed over the interval $[0, v_2]$. Since v_2 varies in each period, we transform the distribution such that the support is independent of v_2 in order to draw the cumulative distribution function (cdf) of the observed bids: the strongest bidder should never bid more than v_2 and thus the maximum ratio of her bid relative to v_2 is one. All bids lower than v_2 are chosen with equal probability. This

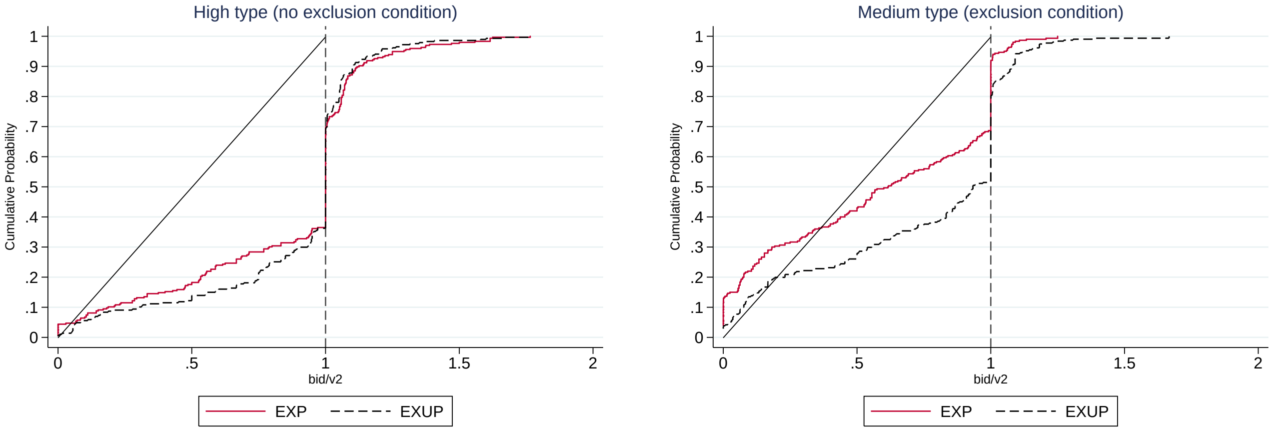

Figure 1: Distribution of cumulative bids relative to the second highest valuation in *EXP* and *EXUP*.

It is apparent that in the no-exclusion condition of both *EXP* and *EXUP* (Figure 1, left-hand panel) almost two-thirds of high types' bids (64 percent) are equal or above the valuation of the medium type, i.e., $x_1/v_2 \geq 1$. We refer to such behavior as "*safe*" strategy as a bidder applying this strategy should win for sure. To a lower extent, a similar picture emerges for medium types in the exclusion condition, who use the *safe* strategy too. About 32 percent of medium types in *EXP* and about 48 percent of medium types in *EXUP* choose the *safe* strategy when they are the strongest bidder. The difference in using the *safe* strategy in *EXP* and *EXUP* is not statistically significant (Mann-Whitney test $z = 1.281$, $p > 0.20$). However, the difference in the fraction of the *safe* strategy between high and medium types is statistically significant in both *EXP* (Wilcoxon signed-rank test $z = 2.201$, $p < 0.03$) and *EXUP* (Wilcoxon signed-rank test $z = 1.992$, $p < 0.047$). Overall, playing the *safe* strategy is certainly not in line with the theory which predicts no mass point at v_2. In fact, we observe that across the two treatments 35 percent of the bids of the strongest bidders are even strictly higher than v_2. However, the majority of these bids (83 percent) are in a comparatively small interval $(v_2, v_2 + 2]$.

This unpredicted behavior hardly changes over time, as can be seen in Figure 2. The figure shows histograms of the bids of the strongest bidder relative to the valuation of the second-strongest bidder in a group. The top panel shows the relative bids of high types in the no-exclusion condition for periods 1–25 (left top panel) and periods 26–50 (right top panel) pooled for both *EXP* and *EXUP*. Similarly, the bottom panel shows the relative bids of medium types in the exclusion condition for periods 1–25 (left bottom panel) and periods 26–50 (right bottom panel) pooled for

implies that the strongest bidder's bid relative to v_2 is uniformly distributed over the unit interval: $(x_1/v_2) \sim Uni[0,1]$.

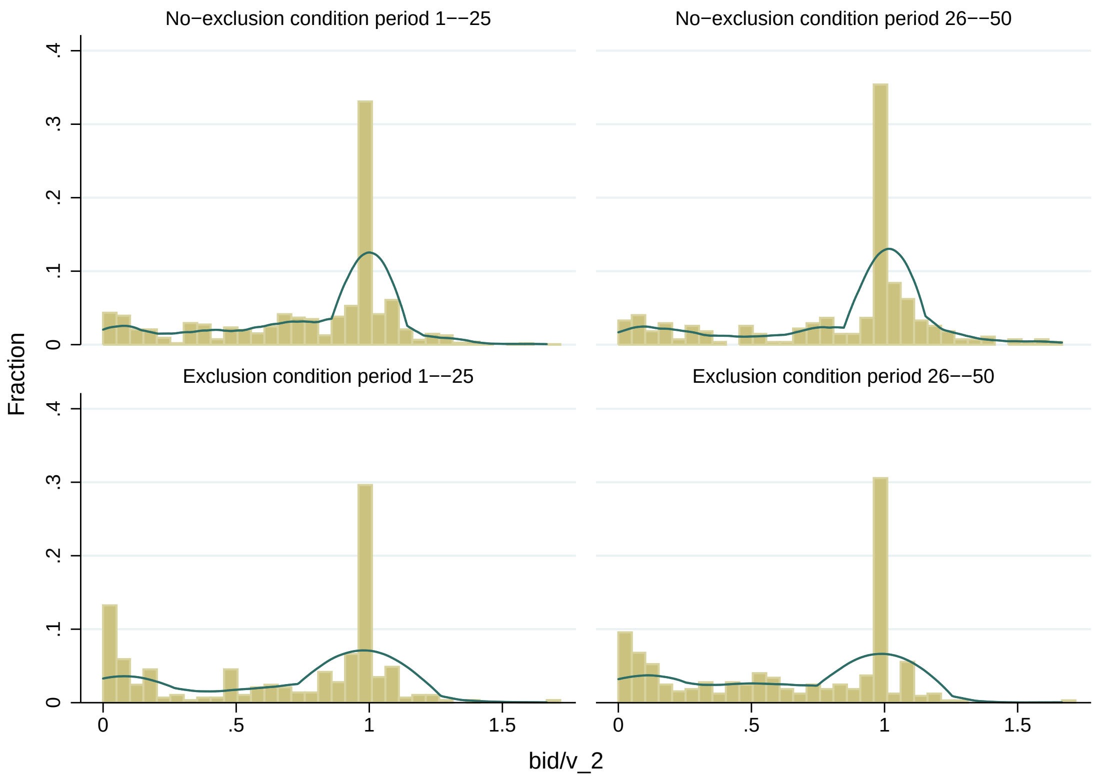

Figure 2: Fraction of the strongest bidders' bids relative to the second highest valuation over time.

both *EXP* and *EXUP*. The value on the x-axis equals (is higher than) one if a bidders' bid matches (exceeds) the second-highest valuation. The figure also plots the kernel density estimate for each condition and the first and second half of periods. The figure reveals little differences in the frequency of *safe* behavior and the kernel densities in the first and second half of the conditions. For example, high types choose the *safe* strategy ($x/v_2 \geq 1$) in about 65 percent of cases in the first half and in about 63 percent of cases in the second half of the experiment. Similarly, there is no difference in *safe* strategy play for medium types over time (41 percent vs. 39 percent).

Given the (anticipated) behavior of their opponents, many of the strongest bidders in the no-exclusion and exclusion condition seem not to be indifferent with respect to their bids, but prefer to play a pure strategy by bidding at least the valuation of their strongest opponent. By playing this *safe* strategy, they can be sure to win the auction and thereby generate a positive profit. Given their bid is infinitesimally larger or equal to v_2 their profit is $v_1 - v_2$, which corresponds to the expected payoff when playing a mixed strategy. 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.

Why is the *safe* strategy so prevalent among high types in *EXP* and *EXUP*? One possible reason could be that high types face two almost equally strong competitors and thus a different strategic situation. In contrast, medium types in the exclusion condition compete with only one other opponent who has a slightly lower valuation. Another possible reason is that the differences in valuations between the high type and his strongest competitor is larger than the differences between a medium type and his strongest competitor. This implies that the "certain" profit that the high types potentially forgo by not playing the *safe* strategy is larger. In other words, high types have more to lose in case they play a mixed strategy instead of the *safe* strategy, and thus have more to regret in case they place a bid lower than v_2 and lose the auction.

To get a sense for the importance of the different reasons for choosing the *safe* strategy, we run probit regressions. In all specifications the dependent variable is a binary variable for playing the *safe* strategy. This variable equals one if the strongest bidder has chosen a bid that is at least as high as the respective second-highest valuation, i.e., in the no-exclusion condition *safe* equals one, if $x_H \geq v_M$, and in the exclusion condition *safe* is one if $x_M \geq v_L$. We are only interested in the behavior of the strongest bidder in a group; either the high type in the no-exclusion condition or the medium type in the exclusion condition. Note also that we pool the data across treatments, since we observe similar behavioral patterns in both treatments. The results are displayed in Table 3.

In column (1) we include a dummy variable "Three bidders", which captures the effect of facing two opponents versus one opponent. The coefficient estimate confirms the earlier result that the use of the *safe* strategy is more prevalent in three bidder groups, i.e., when high types participate in the auction. However, this effect does not persist if we include variables to capture the differences in valuation of the strongest and the second strongest bidder. The variable "Distance in valuation" is $(v_H - v_M)$ for the high type and $(v_M - v_L)$ for the medium type in the exclusion condition. The variable "Squared distance in valuation" is defined accordingly. Column (2) shows a positive and significant effect for the distance in the valuations and a small negative and significant effect for the squared distance. This indicates that with an increasing distance in valuations bidders are more likely to choose the *safe* strategy, but also that this effect is diminishing after a certain point. A one-point higher difference in valuations is associated with a 3 percentage point increase in the likelihood of playing *safe*. In column (3) we additionally control for risk aversion by including a dummy variable, which equals one if a subject prefers safe options smaller or equal

Table 3: Regression: Choice of the *safe* strategy

Dependent variable:	Safe strategy of the strongest bidder.			
	(1) (high/med type)	(1) (high/med type)	(2) (high/med type)	(3) (high/med type)
Three bidders (D)	0.231***	−0.011	0.020	
	(0.040)	(0.061)	(0.062)	
Ten period blocks	−0.008	−0.008	−0.008	−0.028*
	(0.014)	(0.014)	(0.011)	(0.017)
Distance in valuation		0.032***	0.032***	0.037**
		(0.006)	(0.006)	(0.015)
Squared distance		−0.001***	−0.001***	
		(0.000)	(0.000)	
Risk averse (D)			0.097	
			(0.103)	
Avg. bid as med/low type				0.019**
				(0.009)
N	1198	1198	888	141
Pseudo R^2	0.04	0.07	0.09	0.24

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
Probit regressions (average marginal effects) with standard errors clustered on matching group level (in parentheses). The dummy variable ”Three bidders” equals one in the no-exclusion condition. The variable ”Ten period blocks” divides the 50 periods in five ten period blocks and captures time effects. ”Distance in valuations” and ”Squared distance” denotes the difference between the strongest and the second strongest valuation and the squared difference, respectively. ”Risk averse” is dummy variable, which equals one if a subject prefers safe options smaller or equal to the expected value of the lottery. The variable ”Avg. bid as med/low type in period 1-5” captures subjects’ own behavior as a weak type in the first five periods. (D) denotes dummy variable.

to the expected value of the lottery. The coefficient for risk aversion indicates that risk averse subjects are more likely to play the *safe* strategy, but it is not significant. For all three specifications we find no evidence for a time trend. Overall, the findings corroborate the earlier conjecture that the strongest bidders resort to the *safe* strategy because they have more certain profit to lose.

In the last column we examine how *safe* behavior is driven by the bidding behavior of the other (weak) types. Note that in our setup, subjects only learn the winning bid and thus they only get information about others bidding behavior in case they lose the auction. However, it is likely that the strongest bidders draw inferences about the behavior of their competitors from their own behavior as a weak type. In order to look at this potential channel, we examine how own bidding behavior as medium or low type in early periods affects subjects' inclination to play the *safe* strategy as a strongest bidder in later periods. Note that we concentrate here only on those subjects who had no experience as strongest bidder in the first five periods, which results in a significantly smaller sample.[11] The variable of interest here is "Avg. bid as med/low type", which indicates a positive and significant impact of own bidding behavior on playing the *safe* strategy. This suggests that early experience in the role of the weak types has an influence on playing *safe* as a strongest bidder in later periods. If we assume that subjects project their experience as a weak type onto others, this result provides support for the conjecture that the behavior of the weak types triggers in part the *safe* strategy of the strongest bidders.

3.3 A Control Treatment

Remember that in both treatments (*EXP* and *EXUP*) subjects received new valuations in each periods. While this allows us to examine bidding behavior for a broad set of parameter values, there are trade offs. First, subjects are always confronted with a new strategic situation, and second, the theoretical prediction changes in each period. Both add more complexity to the task. In order to check whether subjects behave differently when they always face the same set of valuations for the three types, we run a control treatment with fixed valuations in all periods.

More specifically, we ran two sessions with the valuation set $v \in \{30, 16, 15\}$ and two sessions with the set $v \in \{51, 16, 15\}$. Every other detail is the same as in the main treatments (*EXP* and *EXUP*). In particular, subject experience all three player roles (v_H, v_M, v_L) and in every period v_H is excluded with probability $p = 0.5$. Four features of the valuation sets used are

[11]The choice of five periods reflects the trade off between the number of observation (subjects) and a sufficient time to experience the different bidder roles. For example, extending the initial periods to 10 reduces the observations from 141 to 35.

noteworthy.

First, both sets imply that exclusion would be always beneficial for the auctioneer. This allows us to test the *exclusion principle* with a fixed set of valuations. Given these valuations, we only compare the results to treatment *EXP*. Second, the valuation for the medium type ($v_M = 16$) and the low type ($v_L = 15$) correspond to the average valuation of these two types in treatment *EXP*. Third, the prediction for high types is the same for both sets of valuation, as their behavior should only depend on v_M. Fourth, the choice of $v_H = 51$ and $v_H = 30$ reflect our previous observations from *EXP* that the *safe* strategy is more common for large differences in $v_1 - v_2$ and that overbidding is less prevalent if the advantage of the strongest bidder is not too big. Therefore, if our results are robust we expect to see that the *exclusion principle* is more likely to hold in C30 and that the use of the *safe* strategy is more prominent in C51 than in C30. In the following we denote the sessions with set $v = \{30, 16, 15\}$ as C30 and sessions with the set $v = \{51, 16, 15\}$ as C51.

We first look at the aggregated sum of bids in the control treatment and compare the results to treatment *EXP*. The average sum of bids in the four sessions of the control treatment is about 16.6 with exclusion and about 17.8 without exclusion (for details see Table 5 in the Appendix). The difference in the sum of bids is statistically insignificant (Wilcoxon signed-rank test, $z = 0.706$, $p = 0.48$, $n = 6$). Thus it is clear that exclusion is not profitable in the control treatment.

Similar to *EXP*, the average sum of bids is above the prediction in both the exclusion and no-exclusion condition. Overbidding is substantial, which amounts to 156 percent of the predicted sum of bids in the no-exclusion condition and to 114 percent in the exclusion condition. The sum of bids is higher than predicted in 81 percent of cases in the no-exclusion condition and in 74 percent in the exclusion condition. If we assume that high types would have bid according to the prediction in the control treatment, then the revenues in the no-exclusion condition would have been 11.82, which is clearly lower than the observed sum of bids with exclusion (16.6). Again, this suggests that the massive overbidding by the high type in the no-exclusion condition renders exclusion unprofitable in the control.

The previous analysis in Section 3.1 revealed that overbidding is less likely when the advantage of the high type is not too big. Accordingly, we should observe that the exclusion principle holds in C30 but not in C51. Indeed, the average sum of bids with exclusion is somewhat higher than without exclusion in C30 as predicted by the *exclusion principle* (18.57 vs 17.71). Again, there is substantial overbidding of high types in the no-exclusion condition, but also in the smaller group

Table 4: Bidding behavior of the strongest bidder in the control treatment.

		Percentage of bid x								
		$x = 0$	$0 < x < v_2$	$x = v_2$	$x > v_2$	N		$x = v_2$	$x > v_2$	N
High type	C30	0%	40.7%	6.7%	52.7%	300	EXP30	9%	46.5%	99
Medium type		1.3%	69.0%	11.7%	18.0%	300		7.4%	23.1%	121
High type	C51	0.3%	31.6%	8.5%	59.6%	282	EXP51	12.5%	55.5%	200
Medium type		1.9%	75.1%	12.3%	10.7%	318		7.4%	23.1%	121

Notes: The high type is the strongest bidder in the no-exclusion condition and the medium type is the strongest bidder in the exclusion condition in C30 and C51. EXP30 and EXP51 denotes observations in which $v_H \leq 30$ and $v_H > 30$, respectively, in treatment *EXP*.

when the high type is excluded. The difference between the no-exclusion and exclusion condition is, however, not statistically significant (Wilcoxon signed-rank test, $z = 0.943$, $p > 0.34$, $n = 6$). In contrast, we observe a similar pattern in C51 as in *EXP*. That is, a significantly higher average sum of bids without exclusion than with exclusion (Wilcoxon signed-rank test, $z = 1.572$, $p < 0.06$, $n = 6$ one-sided).

We now turn to the question whether we observe the same pattern of *safe* bidding of the strongest bidder in the control treatment. Table 4 displays the distribution of bids in four intervals ($x = 0$, $0 < x < v_2$, $x = v_2$ and $x > v_2$) for the two conditions (exclusion and no-exclusion) in both C30 and C50.

It is striking that the *safe* strategy is also a popular choice in the control treatment. The fraction of bids above v_2 (34 percent) is the same as in the main treatments and, again, the majority of these bids (83 percent) lie in the interval $(v_2, v_2 + 2]$. High types choose the *safe* strategy more often in C51 (68 percent) than in C30 (60 percent). This indicates that a larger distance in the valuation of the strongest bidders to the valuation of the second strongest bidder plays a role, though the difference is not statistically significant. When the medium type is the strongest bidder, we observe the *safe* strategy in about 30 percent of cases in C30 and 23 percent of cases in C51. Again, the difference between C30 and C51 is not significant statistically (Mann-Whitney test $z = 0.48$, $p > 0.63$, $n = 6$). Nevertheless the fraction of playing the *safe* strategy for medium types is remarkable since it implies a payoff of only 1 in both C30 and C51. As in *EXP*, the difference in choosing the *safe* strategy between high and medium types is statistically significant in both C30 and C51 (Wilcoxon sign-rank test, $z = 2.201$, $p < 0.03$, $n = 6$ for both C30 and C51).

Figure 3 shows the cumulative distribution of bids for high types in the left panel and for medium types in the right panel along with the theoretical benchmark (45-degree line). Note that

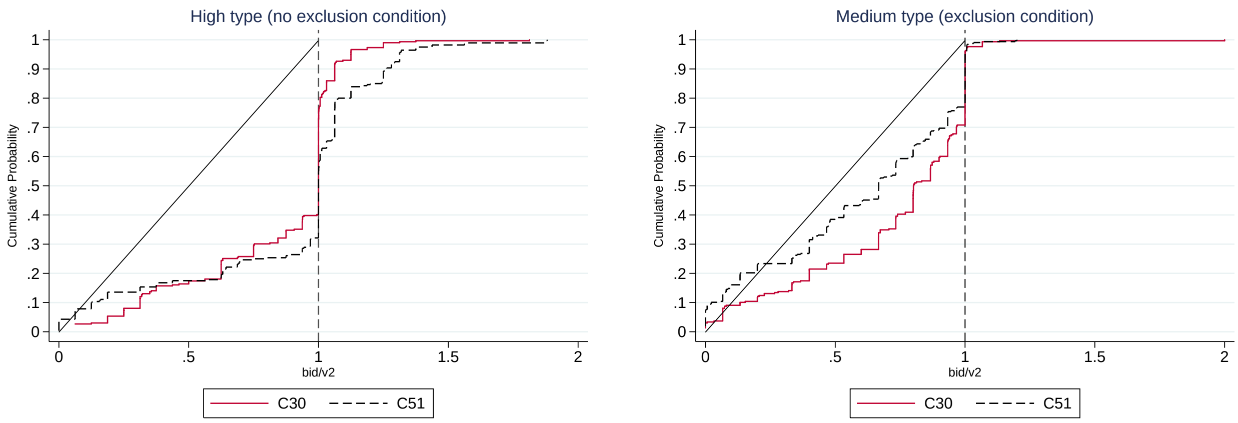

Figure 3: Distribution of cumulative bids in control treatment.

for ease of comparison with Figure 1 we display the distribution of bids on the unit interval. It is clear that the observed distribution of bids is far from uniform for both high and medium types. A comparison with Figure 1 reveals the same qualitative pattern regarding the distribution of bids and the choice of *safe* strategy in *EXP* and the control treatment.

To summarize, the evidence from the control treatment supports our findings from *EXP* that exclusion is not profitable. Moreover, individual behavior in the control treatment is qualitatively similar to behavior in *EXP*. In particular, we find that the *safe* strategy is used to a similar extent when valuations are fixed as when they change from period to period. Therefore, in our context it does not seem to matter whether valuations are randomly drawn for each period or whether the valuations are the same in each period.

3.4 A Theoretical Explanation for Overbidding

The observed behavior of the strongest bidders could be explained by regret aversion of some players. While regret has been analyzed in auction settings, in all-pay auctions with complete information and heterogeneous players it has not yet been analyzed. In our setup it is natural to assume a slightly different notion of regret than in the literature on symmetric auctions.[12] We assume that the utility function of subjects with regret aversion takes the following form:

[12] In symmetric auctions it is typically assumed that a bidder's 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, Baye, Kovenock, and de Vries 2012 or Hyndman, Ozbay, and Sujarittanonta 2012). 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.

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

where $\gamma \geq 0$.

A subject who is a high type can decide to "gamble" by bidding less than v_2 and thereby generating a high profit in case she wins or she can play safe and secure a smaller profit. However, if she "gambles" and 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. Thus, this variant of regret gives a lower bound of the regret feeling as compared to situations in which regret depends on winning bid (as in symmetric auctions). By the design of our experiment, winner regret is excluded as the subjects do not learn the losing bids.

Given that the 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, this is not revealed by our data. 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_2. 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.[13] With this assumption, we can explain the difference in the use of

[13] This assumption is supported by the significant and positive effect of *distance* on the likelihood of the *safe* strategy

the *safe* strategy between high and the medium types. For example, if $\gamma > 0$ for $v_1 - v_2 > 1$, we should observe more *safe* behavior for 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, in 97% of cases the difference in valuations between a high type and his strongest opponent is substantially larger than $v_H - v_M = 1$. In contrast a medium player faces such a weak opponent (i.e., $v_H - v_M > 1$) only 30% of the time.

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 need to be 66% regret averse players in order to explain the observed *safe* play of 64% for the high types in *EXP*. For the medium types there should be 59% regret averse players to explain the 40% *safe* choices in *EXP*. 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 has been used to explain the observed overbidding behavior (e.g., Müller and Schotter 2010, Ernst and Thöni 2013). 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 which implies that loss aversion cannot fully explain our results. Like a regret averse bidder, a loss averse bidder would prefer the safe small prospect over the risk of making a loss. Thus, 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.

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 investigated the effect of excluding superstars from the contest and thereby creating a more homogeneous participant pool. We find that in our setting excluding the strongest bidder is in general not beneficial for the contest designer.

The main reason for this result is the massive overbidding of the strongest bidders when

to be chosen as shown in the regression results in Table 3.

they participate in the all-pay auction. In particular, we find that these "superstars" often apply a strategy which guarantees them to win the auction. That is, they bid at least the valuation of their most powerful competitor, which implies that they prefer to give up a substantial part of their rent in order to avoid losing the auction.

The tendency of the strongest bidders to choose the *safe* strategy increases if the payoff that can be secured by this strategy is higher. We explain the use of the *safe* strategy with regret aversion. Choosing a strategy that entails the possibility of losing the auction may create feelings of regret because the strongest bidder could have ensured winning the auction by bidding the valuation of the strongest competitor. This guarantees them a positive payoff, which corresponds most of the time to the expected payoff from playing a mixed strategy. This kind of regret is specific to the complete information environment since it presumes that the valuations of the competitors are public knowledge.

Some of our results are related to previous results from all-pay auctions with incomplete information (e.g., Müller and Schotter 2010, Noussair and Silver 2006 or Barut, Kovenock, and Noussair 2002). For example, we find that the substantial overbidding of superstars leads to dropouts of weaker bidders. While in principle this dropout behavior provides a rational for designing a homogeneous contest without a superstar, our results show that the increased effort of the weaker bidders in the absence of the strongest bidder cannot compensate for the superstars' effort.

Our paper also makes an important methodological point. While we essentially assigned new valuations to the three bidders in each period in the main treatments, we fixed the valuations in each period in the control treatment. The control treatment shows that our results are robust to how we assigned valuations in the different periods.

An advantage of using a broad set of valuations is the possibility to investigate the *exclusion principle* in a rich environment that is not subject to specific choices of valuations. Subsequently, our analysis provided some suggestive evidence that the *exclusion principle* may only hold within a certain parameter range. As long as the strongest bidder is not too advantaged exclusion may be profitable for the contest designer, but if the rent to lose for the strongest bidder is becoming large they tend to overbid in which case exclusion is not profitable anymore. Because this is not accounted for in theory, it provides an interesting direction for future research.

We find no support for the *exclusion principle*. But one implication of our result is that if the contest designer is solely interested in increasing total revenue, he may make sure that the bidders valuations are public knowledge and exploit the potential regret aversion of superstars. Although this does not contribute to a more homogeneous contest, the regret of giving up a sure rent may induce them to overexert and consequently increase revenues. Of course, regret aversion only has an effect on superstars bidding behavior as long as the other competitors have a sufficiently realistic chance to win the contest.

More generally, the fact that regret aversion can explain overbidding in our setting may indicate that subjects are reluctant to play mixed strategies because they regret their decision afterwards. This opens interesting questions for future research.

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A Appendix

A.1 Summary Statistics for the Control Treatment

Table 5 summarizes the aggregated results of the control treatment for both valuation sets. In C30 we observe that the sum of bids is lower in the no-exclusion condition than in the exclusion condition as predicted by the *exclusion principle*, albeit the difference is not statistically different (Wilcoxon signed-rank test, $z = 0.943, p > 0.34$). As in *EXP*, we observe that the sum of bids is higher in the no-exclusion condition than in the exclusion condition in C51. But again the difference is not significant (Wilcoxon signed-rank test, $z = 1.572, p > 0.11$). Across treatments the sum of bids (and also the bids) are not statistically different in the no-exclusion condition (Mann-Whitney test $z = 0.32, p > 0.74$). However, in the exclusion condition the sum of bids are higher in C30 than in C51 (Mann-Whitney test $z = 2.242, p = 0.025$). In line with the results of *EXP*, we find no evidence that exclusion pays off for the auctioneer. Interestingly, behavior in the exclusion condition differs substantially between C30 (18.57) and C51 (14.70) although the two participating bidders face the same strategic situation. The only difference is that in C50 the excluded bidder was stronger than in C31. It is also noteworthy that the results for C30 and C51 are in line with the previous observations from treatment *EXP* that high types resort to the *safe* strategy in particular when the difference in valuations between v_H and v_M is large.

Table 5: Summary statistics of bids in the control treatment

	Pooled		**C30**		**C51**	
	No excl.	Excl.	No excl.	Excl.	No excl.	Excl.
avg. sum of bids	17.81	16.58	17.71	18.57	17.91	14.70
	(9.07)	(8.51)	(8.72)	(8.44)	(9.43)	(8.14)
pred. sum of bid	11.42	14.53	12.27	14.53	10.51	14.53
	(0.88)	(0)	(0)	(0)	(0)	(0)
N	*580*	617	*299*	*300*	*281*	*317*
average bid	5.93	8.29	5.89	9.29	5.98	7.36
	(7.52)	(6.36)	(7.12)	(6.65)	(7.93)	(5.92)
predicted bid	3.81	7.27	4.09	7.27	3.50	7.27
	(3.32)	(0.23)	(3.27)	(0.23)	(3.34)	(0.23)
minimum bid	0	0	0	0	0	0
maximum bid	35	50	29	50	35	31
N	*1740*	*1234*	*897*	*600*	*843*	*634*

Notes: Standard deviations in parentheses. No exclusion refers to situations in which all three bidders participate and exclusion refers to situations where only the medium and low type participate.

A.2 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. Thus 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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