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Bidding in common value fair division games: The winner's curse or even worse?

Alice Becker* Tobias Brünner†

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Abstract

A unique indivisible commodity with an unknown common value is owned by group of individuals and should be allocated to one of them while compensating the others monetarily. We study the so-called fair division game (Güth, Ivanova-Stenzel, Königstein, and Strobel (2002, 2005)) theoretically and experimentally for the common value case and compare our results to the corresponding common value auction. Whereas symmetric risk neutral Nash equilibria are rather similar for both games, behavior differs strikingly. Implementing auctions and fair division games in the lab in a repeated setting under first- and second-price rule, we find that overall behavior is much more dispersed for the fair division games than for the auctions. Winners' profit margins and shading rates are on average slightly lower for the fair division game. Moreover, we find that behavior in the fair division game separates into extreme over- and underbidding.

JEL Classification: C73, C91, D44

Key words: common value auction, winner's curse, fair division game

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1 Introduction

Auctions and fair division games are used to allocate indivisible goods among a group of bidders. Whereas in an auction this indivisible good is owned by an external party and bidders seek to buy it from that party, in a fair division game the good is collectively owned by the group ex ante. Each bidder has the same legal right to get the good, therefore if one bidder gets acceptance, the price she pays is equally shared among the bidders. Fair division games are usually used in conflict settlements, e.g. in case of inheritance, divorce, or the dissolution of a joint venture, where the owner after the bidding has to compensate the others. We study the special case of common values, where the inherited object, the formerly mutually owned possessions within the marriage or the joint venture shares, have the same value to all bidders ex post, which is unknown when the bidding takes place. Instead each bidder has private information on what the future value might be.

Previous experimental studies on auctions with common values have shown that actual behavior differs substantially from what theory predicts. Winning bidders systematically overbid the (unknown) true value of the item and end up earning negative payoffs. This phenomenon, also referred to as the 'winner's curse', occurs as winning bidders ignore the fact that their private information on the true value is an overestimation, conditional on the event of winning. In order to account for this adverse selection problem they should place a bid lower than their signal. The winners' curse phenomenon has been studied extensively in the lab. It is especially distinct with inexperienced bidders, but barely vanishes with experience either. Moreover, it is pervasive under first- and second-price rule. Theory predicts a decrease in bids when the number of bidders bidding for the same object increases for both price rules. Contrary to this prediction an increased number of bidders leads to more aggressive bidding under first-price rule, whereas there is no change in bidding behavior under second-price rule. These experimental results have been confirmed in a number of field studies. Oil companies claim that they fell prey to the winner's curse in early OCS lease sales (Capen, Clapp, and Campell, 1971; Lorenz and Dougherty, 1983). Similar claims have been made e.g. in auctions for book publications (Dessauer, 1981), professional baseball's free agency markets (Cassing and Douglas, 1980) and recently in auctioning off the rights for the Universal Mobile Telecommunications System (UMTS) in Europe (van Damme, 2002).

Fair division games have so far only been studied with private values. Güth, Ivanova-

Stenzel, Königstein, and Strobel (2002, 2005) compare repeated first- and second-price auctions and fair division games, and analyse to what extent learning is influenced by the structural differences between the two games. They find for both games that learning does not drive bidding towards the benchmark solution.
The present study is the first to analyze fair division games in a common value environment experimentally. We provide the symmetric risk neutral equilibrium strategies and – in order to allow for the winner's curse – also the χ-cursed equilibrium strategies for both first- and second-price fair division games. Based on this theoretical investigation of the fair division game with common values and independently and identically distributed private signals, we study experimentally the extent of the winner's curse and its development over time, in a repeated game setting with full feedback. In addition, we compare the bidding behavior between fair division games and auctions.

The remainder of this paper is organized as follows. Section 2 presents the symmetric risk neutral Nash and the $\chi-$cursed equilibrium strategies of the fair division games and auctions. Section 3 provides the definition of the winner's curse and presents our hypotheses. The experimental design and procedures are described in Section 4. Our experimental results are presented in Section 5 and Section 6 concludes. The detailed derivation of the equilibrium strategies of the fair division game is deferred to the appendix.

2 Games and theoretical solutions

This study focuses on sealed bid common value auctions and fair division games in which a single indivisible object is awarded to the highest among n bidders. The true value of the object v is not known at the time bids are placed and uniformly distributed on $[\underline{v}, \overline{v}]$. Each bidder receives a private information signal x about the true value. Four different games are investigated: the first- and second-price auction and the first- and second-price fair division game. In the auction setting the highest bidder earns a profit equal to the value of the object less its price; whereas all other bidders receive zero. In the fair division setting all bidders have ex ante the same legal rights concerning the object. The highest bidder therefore earns the value of the item, but has to compensate the losers at the same time. The highest bidder pays the n-th share of the price to each of the other group members and thus earns the value of the object less $\frac{n-1}{n}$ times its price.

This logic results in the following payoff functions for $i = 1, ..., n$, which are common knowledge,

$$\Pi_i^{AUC}(b) = \begin{cases} v - p & \text{if} \quad i = w \\ 0 & \text{otherwise} \end{cases} \tag{1}$$

$$\Pi_i^{FD}(b) = \begin{cases} v - \frac{n-1}{n}p & \text{if} \quad i = w \\ \frac{p}{n} & \text{otherwise,} \end{cases} \tag{2}$$

where index w denotes the highest bidder and p equals the highest bid under the first-price rule and second-highest bid under the second-price rule.

2.1 Symmetric risk neutral Nash equilibria

First-price and second-price auction

The theoretical solutions for the first- and second-price auction with common values are available in the literature and can be directly adapted (see, e.g., Milgrom and Weber (1982), Kagel and Levin (2002)).

Common values v are uniformly distributed on $[\underline{v}, \overline{v}]$. The signals x_i, for $i = 1, ..., n$, are independently and identically distributed on $U[v - \epsilon, v + \epsilon]$. The parameter values $\underline{v}, \overline{v}$ and ϵ are common knowledge. For signals in the region of $x_i \in [\underline{v} + \epsilon, \overline{v} - \epsilon]$, i.e. without corner cases, the symmetric risk neutral Nash equilibrium (SRNNE) strategy is given by

$$b^{FPA}(x_i) = x_i - \epsilon + \frac{2\epsilon}{n+1} \exp\{-\frac{n}{2\epsilon}[x_i - (\underline{v} + \epsilon)]\} \tag{3}$$

for the first-price auction, and

$$b^{SPA}(x_i) = x_i - \epsilon + \frac{2\epsilon}{n} \tag{4}$$

for the second-price auction.

	Auction	**Fair division game**
first-price	$b^*(x) = x - 15 + \kappa_1\,,$	$b^*(x) = x - \frac{105}{8} + \kappa_2\,,$
	$\kappa_1 = 6\exp(-\frac{2}{15}(x-65))$	$\kappa_2 = \frac{675}{152}\exp(-\frac{8}{45}(x-65))$
second-price	$b^*(x) = x - \frac{15}{2}$	$b^*(x) = x - \frac{45}{8} + \kappa_3\,,$
		$\kappa_3 = -8.070 \times 10^{-34}\exp(\frac{8}{15}x)$

Table 1: SRNNE equilibrium strategies

Note: $n = 4$, $v \sim U[50, 150]$, $x_i \sim U[v-15, v+15]$, $x \in [65, 135]$

First-price and second-price fair division game

For the same distribution of the random variables and the same region of signals ($x_i \in [\underline{v}+\epsilon, \overline{v}-\epsilon]$), we obtain the SRNNE bidding strategy[1]

$$b^{FPF}(x_i) = x_i - \epsilon + \frac{2\epsilon}{n^2} + \kappa \tag{5}$$

for the first-price fair division game, where $\kappa = \frac{2\epsilon(n^3-n^2-n+1)}{n^2(n^2+n-1)}\, exp\{-\frac{n^2}{2\epsilon(n-1)}(x_i - (\underline{v}+\epsilon))\}$, and

$$b^{SPF}(x_i) = x_i - \epsilon + \frac{2\epsilon(n+1)}{n^2} + C_0\, exp\{\frac{n^2}{2\epsilon}\, x_i\} \tag{6}$$

for the second-price fair division game.[2] Table 1 summarizes the SRNNE equilibrium strategies of these four games for the parameter values employed in the experiment, $\underline{v} = 50, \overline{v} = 150, \epsilon = 15$ and $n = 4$ in the region $x \in [65, 135]$. Figure 1 represents the solutions graphically. For a given price rule and a given signal the equilibrium bid in the fair division game is slightly higher than in the corresponding auction. Figure 1 shows that the nonlinearities at both ends of the range of signals we consider are rather small. This suggests that the exponential term in the equilibrium bidding functions is negligible in that region. Consequently we will frequently omit the exponential term in the following analysis.

[1]Theoretical solutions for the fair division game are derived in the Appendix. Solutions to a similar problem are derived in Engelbrecht-Wiggans (1994).

[2]Note that there is no analytical solution for the constant C_0.

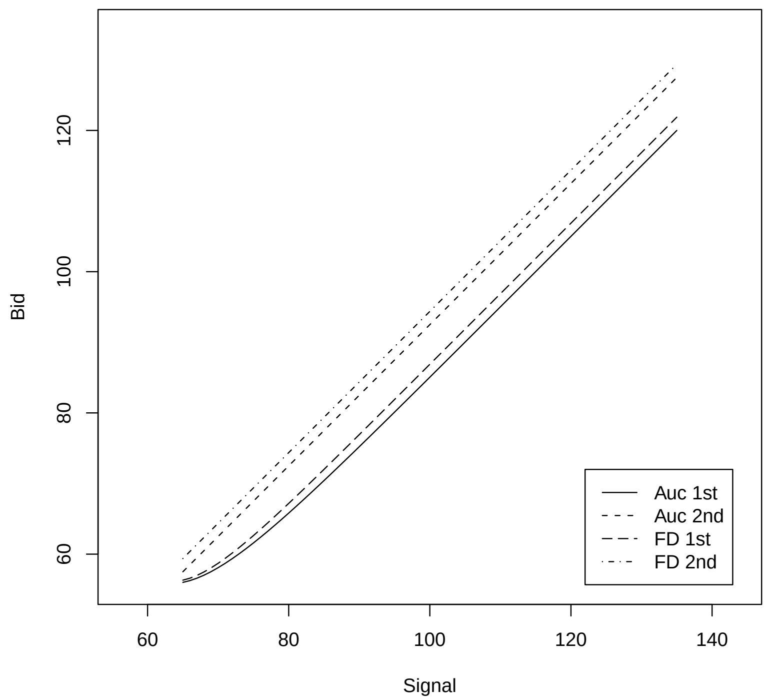

Figure 1: SRNNE bidding functions for the auction and fair division games

Note: $n = 4$, $v \sim U[50, 150]$, $x_i \sim U[v - 15, v + 15]$, $x \in [65, 135]$, FD 1st/2nd: Fair division game under first/second-price rule, Auc 1st/2nd: Auction under first/second-price rule

	Auc1st	**Auc2nd**	**FD1st**	**FD2nd**
$b^*_\chi(x)$	$x - 15 + \chi\frac{15}{2}$	$x - \frac{15}{2} + \chi\frac{15}{2}$	$x - \frac{105}{8} + \chi\frac{15}{2}$	$x - \frac{45}{8} + \chi\frac{15}{2}$
$E(v-p)$	$6 - \chi\frac{15}{2}$	$\frac{9}{2} - \chi\frac{15}{2}$	$\frac{33}{8} - \chi\frac{15}{2}$	$\frac{21}{8} - \chi\frac{15}{2}$
χ_{crit}	0.80	0.60	0.55	0.35
$b_{\chi_{crit}}(x)$	$x-9$	$x-3$	$x-9$	$x-3$

Table 2: χ-cursed equilibrium bidding functions, critical χ's and break even bids

Note: $n = 4$, $\underline{v} = 50, \overline{v} = 150, \epsilon = 15$, $x \in [65, 135]$, FD 1st/2nd: Fair division game under first/second-price rule, Auc 1st/2nd: Auction under first/second-price rule

2.2 χ-cursed equilibrium

There is no winner's curse in the symmetric risk neutral Nash equilibrium, because bidders realize that winning the auction or fair division game means that it is likely that their signal is an overestimation of the true value and they discount their signals accordingly. However, as the examples in the introduction show the winner's curse is a prevalent phenomenon in both field studies and experiments.

Eyster and Rabin (2002, 2005) account for this phenomenon in their χ-cursed equilibrium by assuming that bidders correctly predict the strategies of their opponents and best respond to these strategies, but that they underestimate the relation between the other bidders' strategies and those bidders' signals. If in the first- and second-price auction bidders are fully cursed, i.e. $\chi = 1$, they do not see any correlation between the other bidders' strategies and the true value and act as if in a private value environment. Their expected value of the item conditional on winning is $E(v|x_i)$. If $\chi = 0$, bidders are perfectly rational and their expectation of the true value conditional on winning is $E(v|x_i, x_i \geq x_j\ , \forall j)$. Consequently, they play the SRNNE strategies. Eyster and Rabin show that if $n > 3$ there exists a χ_{crit} such that bidders suffer the winner's curse in the χ-cursed equilibrium whenever $\chi > \chi_{crit}$. The χ-cursed equilibrium bidding functions for the first- and second-price fair division game can be obtained in a similar fashion (see Appendix B for the derivation). Table 2 (line 1) summarizes the χ-cursed equilibrium bidding functions of all four games.[3]

[3]The exponential terms are neglected.

3 The winner's curse - Behavioral predictions

For our analyses in the remainder of this paper we apply the following definition of the winner's curse:

Definition 1 *The winner of the auction or fair division game suffers the winner's curse if the true value of the object is less than its price, or* $(v - p) < 0$.

This definition of the winner's curse is fairly common for auctions (see, e.g., Bazerman and Samuelson, 1983). For the fair division game, however, this definition deserves some explanation. Assume a first-price fair division game with $n = 4$ bidders where the highest bidder bids slightly above the true value, $b_w = v+\delta$ and the second-highest bid is sufficiently below the true value, $b_j = v - 4\delta$. The winner receives $v - \frac{3}{4}(v + \delta) = \frac{v-3\delta}{4} > 0$ for small δ. If the highest bidder had bid less than $b_j = v - 4\delta$ she loses the game and her payoff is $\frac{1}{4}(v - 4\delta) = \frac{v}{4} - \delta$, which is less than her payoff from winning. Thus, she prefers her winning bid ex post although the price exceeds the true value. This example demonstrates that the winner's curse can have less dramatic consequences for the winner in fair division games than in auctions where the winner's curse always implies a negative payoff for the winner and zero payoffs for the other bidders.

The reason why the winner's curse does not necessarily lead to negative expected total profits in the fair division game is that Definition 1 is based on the profit margin, $v - p$, and not total profits, which are given by the profit margin times the share of the object that switches ownership plus initial endowment. Thus, in the fair division game total profits of a winner are given by $(v-p)\frac{n-1}{n} + \frac{1}{n}v$ while in auctions the winner's total profits are equal to the profit margin.

Table 2 (line 2) provides the expected profit margin implied by the χ-cursed equilibrium strategies. Since the bidding strategies depend on the degree of cursedness the expected profit margin is a function of χ. The third line in Table 2 shows the critical level of cursedness, χ_{crit}, for which the expected equilibrium price equals the expected true value, and that therefore renders the expected profit margin, $E(v - p)$, equal to zero. For the first-price auction bidders have to be considerably cursed to fall prey to the winner's curse,

$\chi_{crit} > 0.8$, less so for the second-price auction and even less for the fair division games. In the second-price fair division game moderate degrees of cursedness are enough for the winner's curse to arise. The last line of Table 2 shows the bidding functions that result from the corresponding critical levels of cursedness. For the first-price auction this is the same expression as the "break even" bid that was introduced in Kagel and Levin (2002) to refer to the bidding strategy in a first-price auction that makes the bidder indifferent between winning and losing the auction. Therefore, we will refer to the strategies in the last line of Table 2 as break even bids.

Based on the definition of the winner's curse and the predictions of the χ-cursed equilibrium summarized in Table 2 we formulate the following hypotheses:

Hypothesis 1 *Since the winner's curse has less dramatic effects on payoffs in fair division games than in auctions there are more occurrences of the winner's curse in fair division games than in auctions.*

Previous experiments show that the winner's curse is less frequent with experienced bidders (see, e.g., Kagel and Richard (2001)). Eyster and Rabin (2005) estimate the level of cursedness for inexperienced and experienced subjects and find that χ decreases with experience. While it is unlikely that the experimental subjects will eventually be fully rational, i.e. $\chi = 0$, experience might lead subjects to avoid expected negative profit margins. We therefore use the break even bids as a benchmark ultimately achieved by the learning process. Since χ_{crit} is smaller for both fair division games than for the auctions, subjects will learn to avoid the winner's curse quicker for the auctions than for the fair division games. We derive the following hypothesis:

Hypothesis 2 *Time and experience will affect the shading rates and profit margins positively for all games and price rules.*

Even though it has been shown that the winner's curse is a prevalent phenomenon in auction experiments the SRRNE benchmark solution should give a tendency on how behavior differs between auctions and fair division games. Both games are structurally similar, however they differ in one important aspect: also losers earn something in the fair division games. Due to this difference the theoretically optimal bid in the fair division games lies above the theoretically optimal bid for the auctions for both price rules. Thus, we derive the following hypothesis:

Hypothesis 3 *For each price rule shading rates are lower in the fair division game than in the auction.*

The central difference between auctions and fair division games is that in the former the object to be auctioned off is owned by the auctioneer while in the latter the group of bidders collectively owns the object. Therefore, in fair division games the winner has to compensate the other bidders and not a third party. Thus, in contrast to auctions, in fair division games the losing bidders benefit from the winner's curse. A bidder who realizes that other participants are subject to the winner's curse can respond by submitting very uncompetitive bids, hoping to receive an excessive price for her share of the object. As a result we might have two groups: one group whose bidders compete heavily for the object and thereby fall prey to the winner's curse and another group that intentionally loses the game in order to exploit the other group's excessive bidding. In order to formalize this we define the number of excess wins of a subject as the number of times she actually won the object minus how often she had the highest signal, i.e. how often she should have won the game. A high positive number of excess wins indicates that a subject has bid aggressively while a low negative number suggests that a subject has intentionally lost some of the games. Therefore, we derive our last hypothesis:

Hypothesis 4 *The distribution of the number of excess wins is more dispersed in fair division games than in auctions.*

4 Experimental design and procedures

In our experiment subjects bid in groups of $n = 4$. The true values were randomly drawn from the interval $v \in [50, 150]$ and the private signals from the interval $x_i \in [v-15, v+15]$. Subjects were asked to place a single bid $b_i \in [0, 200]$ in each round. All values are denoted

Treatm.	period 1-20	period 21-40	no. of subjects
1	FD 1st	FD 2nd	28
2	FD 2nd	FD 1st	28
3	Auc 1st	Auc 2nd	32
4	Auc 2nd	Auc 1st	32

Table 3: Experimental design

Note: FD 1st/2nd: Fair division game under first/second-price rule, Auc 1st/2nd: Auction under first/second-price rule

in a fictitious currency ECU (Experimental Currency Unit). In order to keep monetary incentives in both games approximately constant we varied the exchange rate (100 ECU = 14 Euro in the Auction, 100 ECU = 1 Euro in the fair division game).[4] We conducted 4 sessions, 2 with fair division games and 2 with auctions. In each session each subject played 40 rounds, 20 rounds under first-price rule and 20 rounds under second-price rule. We reversed the order of the price rules for the same game to check for order effects. Bidding groups were rematched after each round within fixed matching groups[5]. See Table 3 for a summary of the experimental design.

Subjects took part in only one of the sessions, therefore either played the auction or the fair division game. In the invitation to this experiment they were informed that it would be possible to make losses during the experiment. When entering the laboratory the possibility of losses was announced once more, together with the information that a loss would not be charged in monetary terms but in form of a simple task that the regarding subjects would have to perform after the experiment. The length of this task would depend on how much loss they made.[6] Furthermore, subjects were told that it would still be possible to leave, in case they do not agree. However, only one out of 121 subjects did so.

[4]Güth et al. (2002, 2005) face the same problem of unequal incentives for both games. Due to the lack of previous data on fair division games with common values we accommodated our adjustment of the exchange rate to theirs of private values.

[5]In the auctions we had four matching groups of 8 subjects and in the fair division games two matching groups of 8 and one of 12 subjects.

[6]The task consisted of searching for the letter ’a’ in a document produced by a random words generator. This was however only revealed to the subjects that were actually concerned.

The computerized experiment was conducted in October/November 2007 at the laboratory of the Max-Planck-Institute of Economics in Jena using z-Tree (Fischbacher, 2007). We recruited 120 undergraduate students from various fields such as economics, biology, law and informatics from Jena University, using the ORSEE software (Greiner, 2004). After reading aloud the instructions (see Appendix A) several control questions had to be solved to make sure that the participants understood the game. The experiment lasted for approximately 2 hours.

5 Results

Consistent with the theoretical discussion in Section 2, we will throughout the analysis only consider bids that are based on signals within the inner region of v, i.e. $x \in [\underline{v} + \epsilon, \overline{v} - \epsilon]$. Signals outside of this region were not per se excluded from the experiment, however they contain additional information regarding the true value which possibly change the bidding behavior for those signals.

Table 4 presents a general picture of the data. It provides mean shading rates, optimal shading rates, signal overbidding, winners' profit margins, and the degree of cursedness that explains the winner's bidding behavior in equilibrium.[7] The shading rate measures the amount that the bid falls short of the signal relative to a measure of the dispersion of signals. Formally, the shading rate is defined by $\frac{x-b}{\epsilon}$. Equilibrium shading rates, i.e. $(x - b^*(x))/\epsilon$, with $b^*(x)$ as the SRNNE bidding function, are around 0.85 for the first-price fair division game, 0.375 for the second-price fair division game and a bit higher for the auction with around 0.95 for the first-price auction and 0.5 for the second-price auction. Profit margins are calculated as the difference between the true value and the price, although this means for the fair division game that even if profit margins are negative the winner may still receive a positive payoff. The degree of cursedness is calculated by the equation $\pi_{actual} = \chi\, \pi_{\chi=1} + (1 - \chi)\, \pi_{\chi=0}$.

[7] Due to our matching structure, averages are calculated per matching group. Since we had 4 constant matching groups for the auction treatments and 3 matching groups for the fair division games, the data points in the following graphs represent averages over at least 8 individuals.

First of all we checked whether the order of the two price rules made a difference in behavior. Results from a Mann-Whitney U-test on group means of shading rates support an order effect for both games, except the first-price auctions (FD1st (p=0.2), FD2nd (p=1), Auc1st (p=0.05714), Auc2nd (p=0.4857)). However, we decided not to pool the data and to present the results for all games and price rule separately. For each game and price rules we have two columns, one for experienced and one for inexperienced bidders, where experience means that the subjects have played the same game under a different price rule before.

	FD1st	FD2nd	FD2nd	FD1st	Auc1st	Auc2nd	Auc2nd	Auc1st
treatment	1 (inexp.)	1 (exp.)	2 (inexp.)	2 (exp.)	3 (inexp.)	3 (exp.)	4 (inexp.)	4 (exp.)
all bidders								
obs.	385	392	360	428	433	468	472	496
signal overbidding	15.84%	36.47%	51.38%	26.16%	10.16%	37.6%	39.61%	5.04%
mean shading rate	0.7786	0.0813	-0.018	0.4476	0.5354	0.1853	0.1542	0.6248
mean equil. shading rate	0.8566	0.375	0.375	0.8494	0.9581	0.5	0.5	0.9517
only winners								
obs.	97	92	92	104	101	111	114	126
winner's curse (p>v)	64.95%	63.04%	70.65%	74.04%	70.29%	50.54%	56.14%	61.11%
winners with highest signal	48.45%	48.91%	59.78%	50.56%	71.28%	66.66%	55.26%	69.84%
signal overbidding	40.2%	70.65%	78.26%	56.73%	21.78%	57.65%	71.05%	13.49%
mean shading rate	0.1445	-0.6521	-0.5281	-0.0201	0.2916	-0.1006	-0.2413	0.4508
mean profit margin	-3.084	-2.284	-4.050	-5.885	-2.888	0.098	-1.113	-1.363
mean equil. profit margin	7.662	3.943	4.882	7.191	7.179	2.959	3.429	6.277
χ	0.856	0.636	0.989	1.397	1.095	0.628	0.847	0.853
only losers								
obs.	288	300	268	324	332	357	358	370
signal overbidding	7.64%	26.0%	42.16%	16.35%	6.62%	31.37%	29.6%	2.16%
mean shading rate	0.985	0.301	0.1627	0.5906	0.6014	0.2808	0.2816	0.6898

Table 4: Descriptives

Note: FD 1st/2nd: Fair division game under first/second-price rule, Auc 1st/2nd: Auction under first/second-price rule

Considering all bidders we find that for all games and price rules average shading rates are below their equilibrium predictions. Looking at winners and losers separately provides a more detailed picture. In both games losers bid relatively close to the optimum, whereas winners' bids lie dramatically below the optimal discount rate. The difference between winners' and losers' discount rates is, somewhat surprisingly, much higher for fair division games compared to auctions. As a result there are more occurrences of the winner's curse in the fair division games than in the auctions. With the exception of the first-price rule with inexperienced bidders where the fair division game shows (insignificantly) less occurrences of the winner's curse than the corresponding auction, fair division games have significantly more occurrences of the winner's curse.[8] Thus, we accept Hypothesis 1 in three out of the four situations considered.

Result 1 *Except for inexperienced bidders under the first-price rule, the fair division game always leads to more occurrences of the winner's curse than the corresponding auction.*

Consistent with Eyster and Rabin (2005) we find that the degree of cursedness is typically smaller for experienced bidders. The only exception is the first-price fair division game where the estimated χ is roughly 1.4 for experienced bidders compared to 0.86 for inexperienced bidders.

Figure 2 shows the development of the shading rates (averaged over the matching groups) graphically. The upper horizontal line in each of the four graphs indicates the shading rate implied by the SRNNE bidding strategy. The lower horizontal line displays the shading rate implied by the break even bid, i.e., the shading rate that leads to an expected profit margin of zero. Figure 2 suggests that bidding behavior in auctions converges to the region around the break even shading rate, whereas behavior in the fair division games is more dispersed and does not converge. Table 5 presents the results from a mixed effects model, taking into account fixed effects on the treatment variables and their interactions, as well as random effects on the individual level. The endogenous variables in these regressions are the shading rate (column 1 and 2) and the profit margin (column 3 and 4). For each endogenous variable there are two regressions: one for the fair division games and one for

[8] The p-values of a Mann-Whitney U-test are 0.036 for second-price rule and experienced bidders, 0.016 for second-price rule with inexperienced bidders and 0.019 for the first-price rule with experienced bidders.

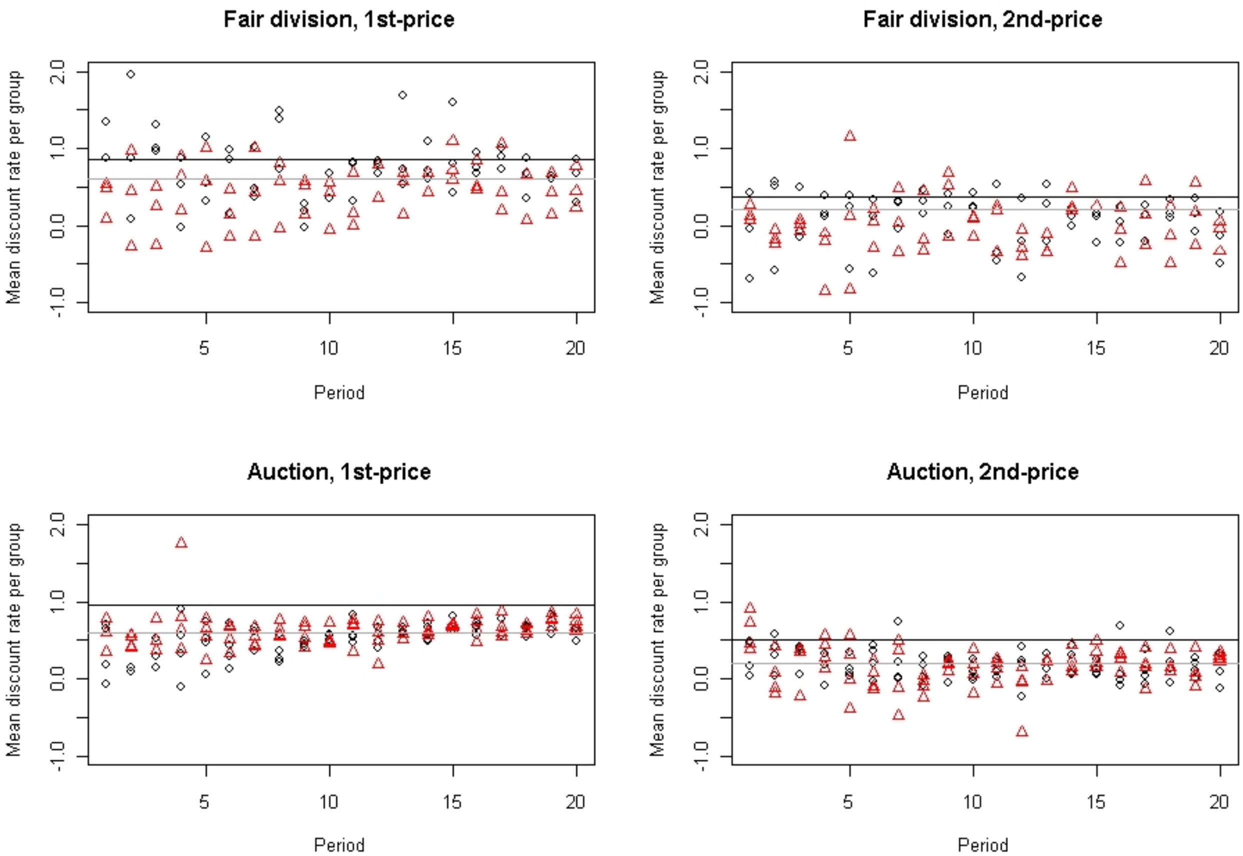

Figure 2: Mean shading rates over time (matching group level)

Note: ○ - inexperienced players, △ - experienced players, '-' equilibrium behavior, '-' break even strategy

Dep. variable	shading rate		winners' profit margin	
Data	**Fair Division**	**Auction**	**Fair Division**	**Auction**
	Coef.	Coef.	Coef.	Coef.
(Intercept)	0.9431***	0.3096***	-6.5694***	-6.4743***
2nd-price	-0.9439***	-0.1423	1.5371	6.1368***
period	-0.0140	0.0200***	0.3222**	0.3314***
experience	-0.6866***	0.2366**	-3.0961*	-1.3988
2nd-price:period	0.0112	-0.0213***	-0.2800	-0.4053***
2nd-price:experience	0.8153**	-0.1693	4.8157	-0.5083
period:experience	0.0293**	-0.0119*		
2nd-price:period:experience	-0.0305*	0.0055		
obs	1565	1869	385	452

*** $p < 0.001$ ** $p < 0.01$ * $p < 0.05$

Table 5: Within games comparison of shading rates and winner profit margins (mixed effects model with random effects on the individual level)

the auctions. The number of periods played has a significant positive effect on shading rates in auctions but not in fair division games. This, however, is only true for first-price auctions; for second-price auctions this effect is canceled out by the negative and significant coefficient of the interaction term of the dummy for the second-price rule and the number of periods. For the fair division game time only increases shading rates for experienced subjects. But again, the significant positive effect holds only for the first-price rule. While the effect of experience on shading rates is significantly positive in auctions, the effect is significantly negative in the first-price fair division game and slightly positive for the second-price fair division game. The winners' profit margins increase over time for the first-price rule in both games; but especially for the auction this is not true for the second-price rule.

Result 2 *Time and experience have a positive effect on shading rates and profit margins for auctions under the first-price rule. For the fair division game under the first-price rule only time has a positive effect, while the effect of experience is even negative. There are no significant effects under second-price rule for both games.*

Dep. variable	shading rate	
Data	**1st price-rule**	**2nd price-rule**
	Coef.	Coef.
(Intercept)	0.7798***	-0.0529
auction	-0.1767	0.2206
experience	-0.2344*	0.0869*
auction:experience	0.3094*	-0.1372*
obs	886	852

*** $p < 0.001$ ** $p < 0.01$ * $p < 0.05$

Table 6: Within rule comparison of shading rates and winner profits (mixed effects model with random effects on the individual level)

The influence of time under first-price rule suggests that some learning is going on, but it naturally seems to decrease after about half of the periods (see figure 2). We will for our next analysis only consider the last ten rounds, assuming that most of the learning has taken place in the first ten rounds. We look at how the shading rates differ between the two games after learning. Indeed, the effect of 'period' becomes insignificant when considering only the last ten rounds. We have therefore regressed the shading rate on 'experience' and the game type, plus their interaction. Table 6 provides the results of two regressions (which are again mixed effects models with random effects on the individual level), one for the first-price rule and one for the second-price rule. They suggest that the discount is higher for the auctions under first-price rule, but only for experienced subjects. The contrary is true for the second-price rule, where experienced subjects show lower shading rates in the auctions than in the fair division games. Therefore, we have to reject our third hypotheses, except for experienced subjects under first-price rule.

Result 3 *Shading rates are lower in the fair division games than in the auctions under first-price rule only for experienced subjects. Under second-price rule shading rates are for experienced subjects higher in the fair division games than for the auctions. There is no difference in shading rates between the games for inexperienced subjects.*

In order to test for our last hypothesis, we calculated the number of excess wins for each subject. Figure 3 shows the histograms of the participants' number of excess wins for all

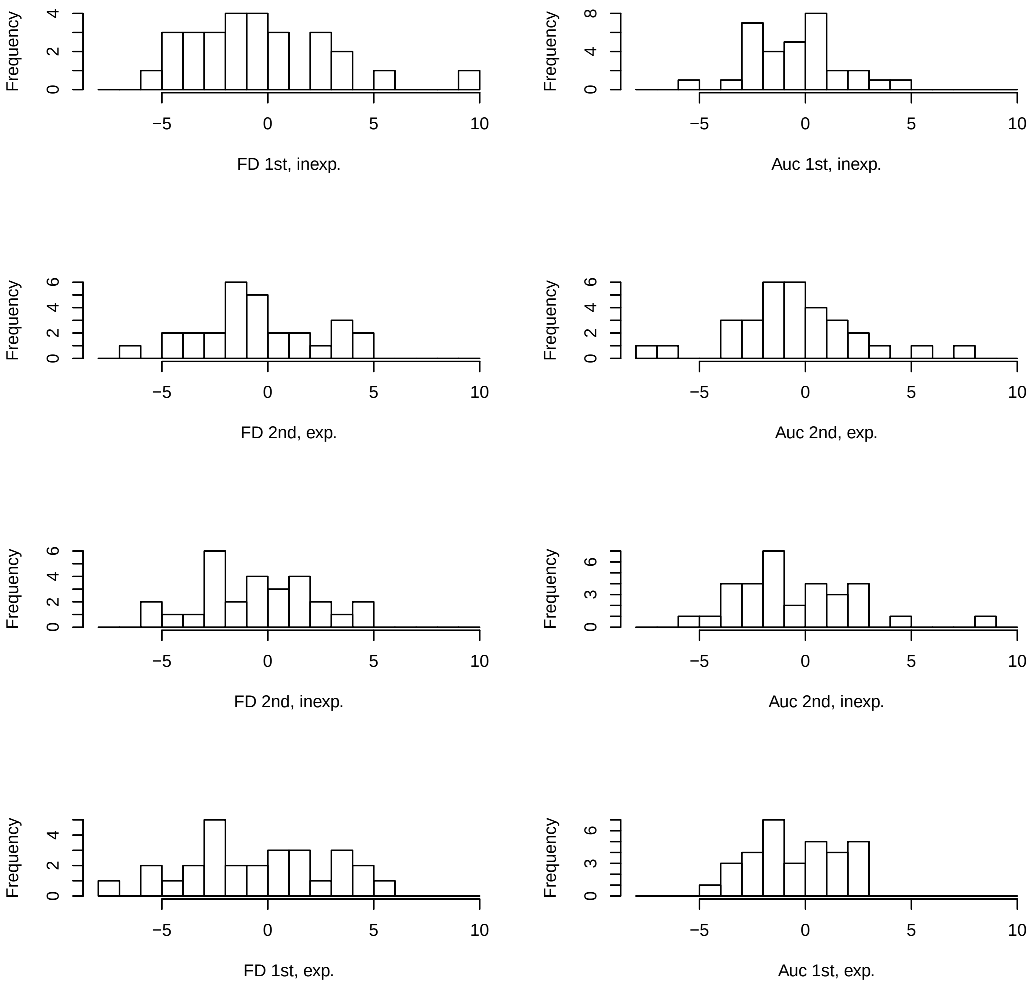

Figure 3: Histograms of excess wins per subject
(♯ excess wins =♯ actual wins - ♯ highest signal)

	1st-price(inexp)	1st-price(exp)	2nd-price(inexp)	2nd-price(exp)
Fair division	3.410	3.485	2.749	2.851
Auction	2.136	2.064	2.885	3.005
p-value[a]	0.055	0.007	0.956	0.916

Table 7: Standard deviations of the number of excess wins

Note: [a]p-values corresponding to a Brown-Forsythe test for equality of variances

four games and divided by whether they had gained experience under a different price rule before or not. This statistic is by construction centered around zero, since in equilibrium the number of excess wins per subjects should be zero. There are, however, differences in the dispersion of the frequency distributions for the different games, especially for the first-price rule. The number of excess wins varies between -6 and 10 for inexperienced subjects in the first-price fair division game, whereas for the first-price auction all but four of the (inexperienced) subjects lie between -3 and 3. For experienced subjects this difference in dispersion seems to be even more pronounced. Table 6 confirms this observation. The standard deviation of excess wins is significantly greater for the first-price fair division game compared to the first-price auction. For the second-price rule standard deviations are very similar across the games and there are no significant differences. Thus, we have our last result:

Result 4 *The distribution of the number of excess wins is more dispersed in fair division games for the first-price rule but not for the second-price rule.*

6 Discussion and conclusions

Before we discuss our results and their implications we summarize our main findings. First, we observe more occurrences of the winner's curse in fair division games than in auctions. Note, however, that the winner's curse does not necessarily lead to negative profits in fair division games since bidders start with an initial endowment, namely the $n-$th share of the object. Second, there is little improvement in bidding behavior over time in the fair division game (except for experienced subjects under the first-price rule). Experience with another price rule itself even reduces profit margins, at least for the first-price fair division game. Shading rates do not differ systematically between the games. Finally, we find evidence that bidders in the first-price fair division game are more dispersed in terms of how often they have won the object than in auctions.

One might be tempted to explain differences between auctions and fair division games with social considerations. In the fair division game the money that the winner overpays is not given to the experimenter but shared among the other bidders. If the experimental subjects harbor reservations towards the experimenter or are altruistic with respect to their fellow participants they might bid less cautious which results in more occurrences of the winner's curse. We do not think that this is a likely explanation since the experimental auction literature typically finds that participants bid quite aggressively which even led to the introduction of the *spite motive* to explain overbidding in private value auctions (Morgan, Steiglitz, and Reis, 2003). The framing of our fair division treatment is neutral and as close as possible to the auction situation and therefore we do not expect a sudden emergence of altruistic feelings.

The fact that experience has a negative effect on shading rates in the first-price fair division game and a positive effect in the second-price fair division game might be explained with a sluggish adjustment to the new price rule. The equilibrium shading rate is greater under the first-price rule than under the second-price rule. If subjects keep playing according to the old price rule for the first couple of periods in which the new price rule is in place and then slowly adjust their bidding, we would get the observed pattern: a positive effect going from the first- to the second price rule and negative effect when going from the second- to the first-price rule. For the auction, however, we do not observe such a slow adjustment.

Our last result about the frequency of the number of excess wins highlights that in fair division games some bidders exploit the excessive bidding of other bidders and thereby profit from the winner's curse. Notice that this is only true for the first-price rule. In the second-price fair division game two cursed players are necessary to push the price above the value of the object. If three players remain passive and attempt to exploit the winner, the winner pays only a rather low price. Moreover, by placing a high bid it is even possible for a bidder to increase the price she receives for her share. This strategy of influencing the price one receives, however, entails the risk of winning the object.

Since fair division games are advocated in situations of conflicts about who should get an object and how other parties involved should be compensated, one can ask whether they are an appropriate mechanism to solve such a conflict. The results of this experiment suggest that fair division games are not an appropriate mechanism in a common value environment. Although the winner's curse might not lead to a negative payoff for the winner, her payoff will be lower than the expected value of her initial share of the object. Anticipating this, bidders might veto the mechanism. But even if all conflict parties participate, they might –in expectation of excessive bidding by some parties– place very low bids that do not reflect their signals very well. Consequently, the price will not be an unbiased estimator of the common value and the fair division game will not efficiently aggregate the privately owned signals.

Appendix

A Derivation of SRNN and χ-cursed equilibrium bidding strategies

We use the framework introduced by Milgrom and Weber (1982) and extended by Eyster and Rabin (2005) to incorporate χ-cursed equilibria to find the equilibrium bidding strategies for all games and price rules.

An indivisible object is auctioned off to $n \geq 3$ risk neutral bidders.[9] The vector $(x_1, ..., x_n) \in [\underline{x}, \overline{x}]^n \subset \mathbb{R}^n$ is a profile of private signals held by the individual bidders and $v \in \mathbb{R}$ is an additional possibly payoff relevant random variable with density $h(v)$. We assume that for every i, $g(x_i|v)$ satisfies the monotone-likelihood property. In our common value environment the signals held by different bidders are uncorrelated given v. Thus, the joint density of $x_1, ..., x_n, v$ is $f(x_1, ..., x_n, v) = \prod_{i=1}^{n} g(x_i|v)h(v)$. The value of the object to a bidder is $u(x_1, ..., x_n, v)$ which is continuous and increasing in the signals x_i and v. We further assume that bidders are symmetric, i.e., $u(x_1, ..., x_n, v)$ is symmetric in the private signals x_i.

Let Y_{-i} and Z_{-i} be the highest and second-highest signals among all bidders except i. Following Milgrom and Weber (1982) we define the following two functions: $r(x_i) = E[u(x_1, ..., x_n, v)|x_i]$ is the expectation of the object's value given the private signal x_i and $\nu(x_i, y) = E[u(x_1, ..., x_n, v)|x_i, Y_{-i} = y]$ is the expectation of the object's value given the private signal x_i and given that the highest signal of the other bidders is y.

A.1 First-price auction

In the first-price auction the bidder with the highest bid wins the auction. She receives the object and pays the amount of her own bid. Milgrom and Weber (1982) show that bidder

[9] For the first- and second-price auction and the first-price fair division game the minimum number of bidders is 2. For our presentation of the second-price fair division game we require that $n \geq 3$.

i's equilibrium bidding strategy solves[10]

$$\max_b \int_{\underline{x}}^{b^{*-1}(b)} (\nu(x,y) - b) f_Y(y|x)\, dy \tag{7}$$

for every x, where $f_Y(y|x)$ is the density of the highest bid of the other bidders given that bidder i observes x.

Eyster and Rabin (2002, 2005) extend this framework to allow for *cursed* bidders, i.e., bidders that fail to fully understand the relationship between the strategies of other bidders and their private signals and thus the value of the object. A χ-cursed equilibrium for this first-price auction solves for every x

$$\max_b \int_{\underline{x}}^{b^{*-1}(b)} ((1-\chi)\nu(x,y) + \chi r(x) - b) f_Y(y|x)\, dy\,. \tag{8}$$

For $\chi = 0$ this expression is the same as the approach by Milgrom and Weber (1982). However, for $\chi > 0$ bidders underestimate the informational consequences that the event of winning the auction contains about the common value of the object. Since the traditional, uncursed equilibrium is part of in the χ-cursed equilibrium we will in the following only solve for the χ-cursed equilibrium.

The solution to problem (8) is the differential equation

$$b^{*'}(x) = ((1-\chi)\nu(x,x) + \chi r(x) - b^*(x))\frac{f_Y(x|x)}{F_Y(x|x)}\,, \tag{9}$$

together with the boundary condition $b^*(\underline{x}) = (1-\chi)\nu(\underline{x},\underline{x}) + \chi r(\underline{x})$.

For our setting, where $u(x_1, ..., x_n, v) = v$, $v \sim U[\underline{v}, \overline{v}]$ and $x_i \sim U[v-\epsilon, v+\epsilon]$ we have the following expressions for $r(x), \nu(x,x)$ and $f_Y(y|x)$:

	$\mathbf{x} \in [\underline{\mathbf{v}} - \epsilon, \underline{\mathbf{v}} + \epsilon]$	$\mathbf{x} \in [\underline{\mathbf{v}} + \epsilon, \overline{\mathbf{v}} - \epsilon]$	$\mathbf{x} \in [\overline{\mathbf{v}} - \epsilon, \overline{\mathbf{v}} + \epsilon]$
$\mathbf{r(x)}$	$\frac{x+\epsilon+\underline{v}}{2}$	x	$\frac{x-\epsilon+\overline{v}}{2}$
$\nu(\mathbf{x},\mathbf{x})$	$\underline{v} + \frac{x+\epsilon-\underline{v}}{n}$	$x - \epsilon + \frac{2\epsilon}{n}$	$\overline{v} + \frac{(x-\epsilon-\overline{v})(2\epsilon)^{n-1} + ((2\epsilon)^n - (x-\overline{v}+\epsilon)^n)/n}{(2\epsilon)^{n-1} - (x-\overline{v}+\epsilon)^{n-1}}$
$\mathbf{f_Y(y\|x)}$	$(\frac{y+\epsilon-\underline{v}}{2\epsilon})^{n-1} \frac{1}{x+\epsilon-\underline{v}}$	$\frac{(y-x+2\epsilon)^{n-1} - (y-x)^{n-1}}{(2\epsilon)^n}$	

Following much of the experimental literature we focus our analysis on the interior region, i.e., where $x \in [\underline{v} + \epsilon, \overline{v} - \epsilon]$.

[10] Since all equilibria we discuss in the following are symmetric we drop the index i.

Eyster and Rabin (2002) show that this leads to the χ-cursed equilibrium bidding strategy

$$b^*(x) = x - \epsilon + \chi\,\epsilon\,\frac{n-2}{n} + \frac{2\epsilon\,(1-\frac{n-1}{n}\chi)}{n+1}\,\exp(-\frac{n(x-\underline{v}-\epsilon)}{2\,\epsilon}) \tag{10}$$

for $x \in [\underline{v}+\epsilon, \overline{v}-\epsilon]$.

A.2 Second-price auction

In the second-price auction the bidder with the highest bid wins and pays the bid of the second-highest bidder. The χ-cursed equilibrium bidding strategy b^* is the solution to

$$\max_b \int_{\underline{x}}^{b^{*-1}(b)} ((1-\chi)\nu(x,y) + \chi r(x) - b^*(y)) f_Y(y|x)\,dy\,, \tag{11}$$

for every x. This leads to the general bidding function

$$b^*(x) = ((1-\chi)\nu(x,x) + \chi r(x) \tag{12}$$

and for our particular choices of densities $v \sim U[\underline{v},\overline{v}]$ and $x_i \sim U[v-\epsilon, v+\epsilon]$ we obtain

$$b^*(x) = x - (1-\chi)\epsilon\,\frac{n-2}{n} \tag{13}$$

for $x \in [\underline{v}+\epsilon, \overline{v}-\epsilon]$.

A.3 First-price fair division game

In the first-price fair division game the bidder with the highest bid wins and pays her own bid. In contrast to the auction, however, she does not pay the price to an auctioneer but to all bidders, including herself, in equal parts. Therefore, a bidder receives some positive payoff even if she is not the highest bidder. A χ-cursed bidder with private signal x maximizes the expected payoff

$$\begin{aligned} \max_b &\int_{\underline{x}}^{b^{*-1}(b)} ((1-\chi)\nu(x,y) + \chi r(x) - \frac{n-1}{n}\,b) f_Y(y|x)\,dy \\ &+ \int_{b^{*-1}(b)}^{\overline{x}} \frac{b^*(y)}{n} f_Y(y|x)\,dy\,. \end{aligned} \tag{14}$$

The solution to problem (14) is the differential equation

$$b^{*'}(x) = \frac{n}{n-1}((1-\chi)\nu(x,x) + \chi r(x) - b^*(x))\frac{f_Y(x|x)}{F_Y(x|x)}\,. \tag{15}$$

For our example the general solution of this differential equation is

$$b^*(x) = \begin{cases} \frac{n(x+\epsilon)+n^2\underline{v}-\underline{v}}{n^2+n-1} - \chi\frac{\underline{v}(n^3-n^2-3n+2)}{n(n^2+n-1)} + C_1\,(x+\epsilon-\underline{v})^{(-\frac{n^2}{n-1})} & \text{for} \quad x\in[\underline{v}-\epsilon,\underline{v}+\epsilon]\,, \\ x-\epsilon+\frac{2\epsilon}{n^2}+\chi\epsilon\frac{n-2}{n}+C_2\,exp(-\frac{n^2x}{2\epsilon(n-1)}) & \text{for} \quad x\in[\underline{v}+\epsilon,\overline{v}-\epsilon]\,, \\ \text{no analytical solution} & \text{for} \quad x\in[\overline{v}-\epsilon,\overline{v}+\epsilon]\,. \end{cases} \tag{16}$$

Since we require b^* to be continuous everywhere on $[\underline{v}-\epsilon,\overline{v}+\epsilon]$ the constant C_1 has to be zero. Equating the first and second line in equation (16) at $x=\underline{v}+\epsilon$ we can determine C_2 and get

$$b^*(x) = x-\epsilon+\frac{2\epsilon}{n^2}+\chi\epsilon\frac{n-2}{n}+\kappa\,, \tag{17}$$

where $\kappa = \frac{2\epsilon(n^3-n^2-n+1)-\chi(\underline{v}+\epsilon)n(n^3-n^2-3n+2)}{n^2(n^2+n-1)}\,exp(-\frac{n^2}{2\epsilon(n-1)}(x-\underline{v}-\epsilon))$ in the region of $x\in[\underline{v}+\epsilon,\overline{v}-\epsilon]$.

A.4 Second-price fair division game

In the second-price fair division game the highest bidder receives the object and has to pay the second-highest bid to all bidders in equal parts. A bidder who does not win the object might therefore receive one nth of her own bid, if she is the second-highest bidder or she receives one nth of the second-highest bid of the other $n-1$ bidders, if her bid is below this bid. Thus, the χ-cursed equilibrium strategy solves

$$\begin{aligned} \max_b \int_{\underline{x}}^{b^{*-1}(b)} &((1-\chi)\nu(x,y)+\chi r(x)-\frac{n-1}{n}\,b^*(y))f_Y(y|x)\,dy \\ &+\int_{b^{*-1}(b)}^{\overline{x}}\int_{\underline{x}}^{b^{*-1}(b)}\frac{b}{n}f_{Y,Z}(y,z|x)\,dz\,dy \\ &+\int_{b^{*-1}(b)}^{\overline{x}}\int_{b^{*-1}(b)}^{\overline{x}}\frac{b^*(y)}{n}f_{Y,Z}(y,z|x)\,dz\,dy\,, \end{aligned} \tag{18}$$

where $f_{Y,Z}(y,z|x)$ is the joint density of the highest and second-highest signal of the other $n-1$ bidders given that bidder i observes x. The solution to problem (18) is the differential equation

$$b^{*'}(x) = -n\,((1-\chi)\nu(x,x)+\chi r(x)-b^*(x))\frac{f_Y(x|x)}{F_{Y,Z}(\overline{x},x|x)-F_{Y,Z}(x,x|x)}\,. \tag{19}$$

The boundary condition that we used for the first-price auction, $b^*(\underline{x})=(1-\chi)\nu(\underline{x},\underline{x})+\chi r(\underline{x})$, is not applicable for the second-price fair division game. Since equilibrium bidding strategies are strictly increasing in signals a bidder who observes $x = \underline{x}$ knows that she has the lowest bid and can increase her expected payoff by raising her bid slightly above $(1-\chi)\nu(\underline{x},\underline{x}) + \chi r(\underline{x})$. By doing this she will still not win the object but she increases the probability of being the second-highest bidder and, thus, increase her payment in case of losing. Instead, we use the condition $b^*(\overline{x}) = (1-\chi)\nu(\overline{x},\overline{x}) + \chi r(\overline{x})$. A bidder with the highest possible signal knows that she is the highest bidder. Increasing her bid further does not change her expected payoff and reducing her bid increases the probability of not winning the object and receiving a smaller payment.[11]

Solving the differential equation in equation (19) for our setting yields

$$b^*(x) = x - \epsilon + \frac{2\epsilon(n+1)}{n^2} + \chi\epsilon\frac{n-2}{n} + C_3\, exp(\frac{n^2 x}{2\epsilon}) \tag{20}$$

for $x \in [\underline{v}+\epsilon, \overline{v}-\epsilon]$.[12] Unfortunately, there is again no analytical solution for the region of $x \in [\overline{v}-\epsilon, \overline{v}+\epsilon]$ and we cannot apply the boundary condition $b^*(\overline{v}+\epsilon) = \overline{v}$ to determine the constant C_3 for the more general case. From the numerical solution for the specific values $\chi = 0, n = 4, \epsilon = 15$ and $\overline{v} = 150$ we obtain $C_3 = -8.070 \times 10^{-34}$. Plotting the bidding function in equation (20) with these parameters on the range $x \in [65, 135]$ gives an almost straight line, which suggest that the exponential term is negligible.

The χ-cursed equilibrium strategies of these four games for our parameter values, $\underline{v} = 50.\overline{v} = 150, \epsilon = 15$ and $n = 4$ in the region $x \in [65, 135]$ are summarized in Table 8.

[11] For our specific example we obtain that a bidder with the lowest possible signal $\underline{v} - \epsilon$, and who therefore knows that $v = \underline{v}$, bids $\underline{v}$ in the first-price fair division game and above $\underline{v}$ in the second-price fair division game. Conversely, a bidder with the highest possible signal $\overline{v} + \epsilon$ knows that $v = \overline{v}$ and bids $\overline{v}$ in the second-price fair division game and below $\overline{v}$ in the first-price fair division game. This parallels the result in Güth and van Damme (1986) that the first-price rule guarantees overbidding proofness and the second-price rule guarantees underbidding proofness in fair division games in a private value environment.

[12] Here, we used the additional result that $F_{Y,Z}(y,x|x) = \frac{2\,(2\epsilon)^n - (x-y+2\epsilon)^n}{(2\epsilon)^n\, n}$ for $y \geq x$.

	Auction	Fair division game
first-price	$b^*(x) = x - 15 + \chi\frac{15}{2} + \kappa_1$,	$b^*(x) = x - \frac{105}{8} + \chi\frac{15}{2} + \kappa_2$,
	$\kappa_1 = 6(1 - \chi\frac{3}{4})\exp(-\frac{2}{15}(x - 65))$	$\kappa_2 = (\frac{675}{152} - \chi\frac{65}{2})\exp(-\frac{8}{45}(x - 65))$
second-price	$b^*(x) = x - \frac{15}{2} + \chi\frac{15}{2}$	$b^*(x) = x - \frac{45}{8} + \chi\frac{15}{2} + \kappa_3$,
		$\kappa_3 = C(\chi)\exp(\frac{8}{15}x)$

Table 8: Summary table of χ-cursed equilibrium strategies for the values $v \sim U[50, 150]$ and $x_i \sim U[v - 15, v + 15]$ and $n = 4$ for the region $x \in [65, 135]$. Note that there is no analytical solution for the constant $C(\chi)$.

References

Bazerman, M. H., and W. F. Samuelson (1983): "I won the auction but I don't want the prize," *Journal of Conflict Resolution*, 27, 618–634.

Capen, E. C., R. V. Clapp, and W. M. Campell (1971): "Competitive Bidding in High-Risk Situations," *Journal of Petroleum Technology*, 23, 641–653.

Cassing, J., and R. W. Douglas (1980): "Implications of the Auction Mechanism in Baseball's Free Agent Draft," *Southern Economic Journal*, 46, 110–121.

Dessauer, J. P. (1981): *Book Publishing*. Bowker, New York.

Engelbrecht-Wiggans, R. (1994): "Auctions with price-proportional benefits to bidders," *Games and Economics Behavior*, 6, 339–346.

Eyster, E., and M. Rabin (2002): "Cursed equilibrium," Working Paper E02-320, IBER, UC Berkley.

——— (2005): "Cursed equilibrium," *Econometrica*, 73(5), 1623–1672.

Fischbacher, U. (2007): "z-Tree: Zurich Toolbox for Ready-made Economic experiments," *Experimental Economics*, 10(2), 171–178.

Greiner, B. (2004): "The Online Recruitment System ORSEE 2.0 - A Guide for the Organization of Experiments in Economics," Working paper series in economics, University of Cologne, Department of Economics.

Güth, W., R. Ivanova-Stenzel, M. Königstein, and M. Strobel (2002): "Bid Functions in Auctions and Fair Division Games: Experimental Evidence," *German Economic Review*, 3(4), 461–484.

——— (2005): "Learning to bid - An Experimental Study of Bid Function Adjustments in Auctions and fair Division Games," Sonderforschungsbereich 373, Humboldt Universitaet Berlin.

Güth, W., and E. van Damme (1986): "A comparison of pricing rules for auctions and fair division games," *Social Choice and Welfare*, 3, 177–198.

Kagel, J., and D. Levin (2002): *Common Value Auctions and the Winner's Curse,*chap. Bidding in Common Value Auctions: A Survey of Experimental Research, pp. 1–84. Princeton University Press, Princeton.

Kagel, J. H., and J.-F. Richard (2001): "Super-experienced bidders in first-price common-value auctions: Rules of thumb, Nash equilibrium bidding, and the winner's curse," *Review of Economics and Statistics*, 83(3), 408–419.

Lorenz, J., and E. Dougherty (1983): "Bonus Bidding and Bottom Lines: Federal Offshore Oil and Gas," 58th Anual Fall Technical Conference SPE 12024, Society of Petroleum Engineers.

Milgrom, P. R., and R. J. Weber (1982): "A theory of auctions and competitive bidding," *Econometrica*, 50(5), 1089–1122.

Morgan, J., K. Steiglitz, and G. Reis (2003): "The spite motive and equilibrium behavior in auctions," *Contributions to Economic Analysis & Policy*, 2(1), Article 5.

van Damme, E. (2002): "The European UMTS-auctions," *European Economic Review*, 46, 846–858.