Expectations in first-price auctions*

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Abstract

Bids in private value first price auctions consistently deviate from risk neutral symmetric equilibrium bids. It is difficult to explain this deviation with risk aversion. We propose and test two other explanations: (1) Bidders do not form correct expectations. (2) Bidders do not play a best reply against their expectations.

We present a novel experimental setup which allows to observe bids and expectations separately. We extensively test the internal validity of this setup. We find that off equilibrium expectations explain, if at all, underbidding. Off equilibrium bids do not seem to be due to wrong expectations but due to deviations from a best reply.

Keywords: Experiments, Auction, Expectations.

(JEL C92, D44)

1 Introduction

In this paper we study bidding behaviour in first-price auctions with private values. Auctions of this kind have been analysed theoretically and with several laboratory experiments since Coppinger, Smith, and Titus (1980) and Cox, Roberson, and Smith (1982). A robust finding in all these studies is that bidders consistently deviate from the risk neutral symmetric Bayesian Nash equilibrium bids. There is overbidding for large valuations (Cox, Smith, and Walker, 1983, 1985, 1988) and underbidding for small valuations (see Kirchkamp and Reiß, 2004).

Understanding the reason behind off equilibrium bids helps us to find better bidding strategies, but also helps to improve market institutions.

One tempting explanation for overbidding is risk aversion. If bidders are risk averse symmetric Bayesian Nash equilibrium bids are higher than equilibrium bids of risk neutral

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players. What looks like overbidding in a risk neutral can be interpreted as an equilibrium in a world where bidders are risk averse.

The term ‘overbidding’ stuck nevertheless, perhaps since risk aversion is not always a convincing explanation for bids which are higher than risk neutral equilibrium bids. Overbidding due to risk aversion should disappear when bidders are paid with lottery tickets. This does not happen (see Cox, Smith, and Walker, 1985). Furthermore, if bidders are risk averse they should underbid in third price auctions, which is not always the case (see Kagel and Levin, 1993). Harrison (1989) concludes that risk aversion is not a convincing explanation for deviations from equilibrium bids. But if risk aversion does not explain off equilibrium bids, what can then be an explanation?

To answer this question we consider two elements of the reasoning of a rational player: When determining an optimal bid a rational bidder must first form expectations about their opponents’ bidding behaviour. Then, given these expectations, the own bidding function is determined as a best reply. Equilibrium is reached when all bidders form correct expectations about the bidding behaviour of their opponents and all play a best reply.

Deviations from equilibrium bids can, thus, be related to two types of mistakes: Either bidders form the wrong expectations about their opponents’ bids or they fail to determine correctly their own best reply. The aim of the paper is to distinguish between these two kinds of mistakes.

In the following we will describe an experiment that allows us to elicit bidding functions and expectations separately in a simple and natural way. We directly observe bidding functions in a way similar to Selten and Buchta (1999), Güth, Ivanova-Stenzel, Königstein, and Strobel (2003), Kirchkamp and Reiß (2004), and Kirchkamp, Poen, and Reiß (2004). We show how such a setup can be modified to also observe expectations. We briefly summarise the equilibrium model in section 2. The experimental treatments are discussed in section 3 and internal validity of our setup is checked in section 4. We present results in section 5 and conclude in section 6.

2 Model

We will study a private value first-price sealed-bid auction with two bidders i and j. Bidders’ valuations x_i and x_j are independently distributed according to a distribution function $F()$ which is the same for each bidder. In this section we briefly summarise the derivation of risk neutral symmetric Bayesian Nash equilibria. The derivation is standard and shown only to make the reader familiar with the notation. Bidder i with valuation x_i expects the opponent to follow a monotonically increasing bidding function $b^{\exp}(x_j)$ with inverse $b^{\exp(-1)}(\cdot)$ (see figure 1). Let us assume that bidder i makes a bid $b(x_i)$. This bidder gains $x_i - b(x_i)$ if and only if the own bid $b(x_i)$ is larger than the opponents bid $b^{\exp}(x_j)$, i.e. if $b^{\exp(-1)}(b(x_i)) \geq x_j$. Thus, the probability of winning is $F(b^{\exp(-1)}(b(x_i)))$ and the expected profit is $u = (x_i - b(x_i)) \cdot F(b^{\exp(-1)}(b(x_i)))$. Bidders choose their individual bidding function b_i to maximise u given their expected opponents’ bidding function $b^{\exp}$. It is straightforward to show (Vickrey, 1961) that with $F()$ being a uniform distribution

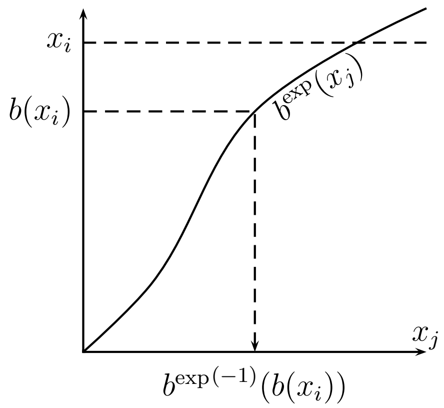


FIGURE 1: The maximisation problem of bidder i given the expected bidding function $b^{\exp}$ of bidder j

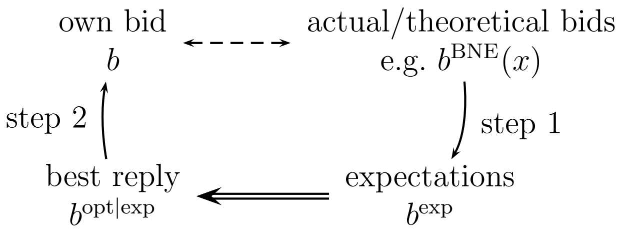


FIGURE 2: Steps in determining a bidding function

over some interval $[0, \bar{x}]$ both bidders have the bidding function given by

$$b^*(x) = \frac{1}{2}x \tag{1}$$

in the symmetric equilibrium. From numerous experiments we know that this is not what bidders do. We also know (see the discussion of Cox, Smith, and Walker (1985) and Kagel and Levin (1993) above) that risk aversion is not always a satisfactory explanation for off equilibrium bids.

In the above derivation of equilibrium bids we divide the reasoning of an individual into two steps. Figure 2 explains these steps. We start with bidders who have some model of the world. This world could be a Bayesian equilibrium world where bids are Bayesian Nash equilibria b^{BNE} or it could be any other world.

- In step 1 bidders form expectations $b^{\exp}$. Knowing the expectations $b^{\exp}$ a rational bidder also knows the best reply against them, i.e. $b^{\mathrm{opt}|\exp}$. Figure 3 shows a few examples of expected opponent's bidding functions $b^{\exp}$ together with the best reply $b^{\mathrm{opt}|\exp}$ against them.

- In step 2 bidders choose a bid b, which may or may not take into account $b^{\mathrm{opt}|\exp}$.

In a symmetric equilibrium bidders form expectations $b^{\exp}$ which coincide with the true bidding function b. Furthermore, the true bid b coincides with the best reply $b^{\mathrm{opt}|\exp}$. Our

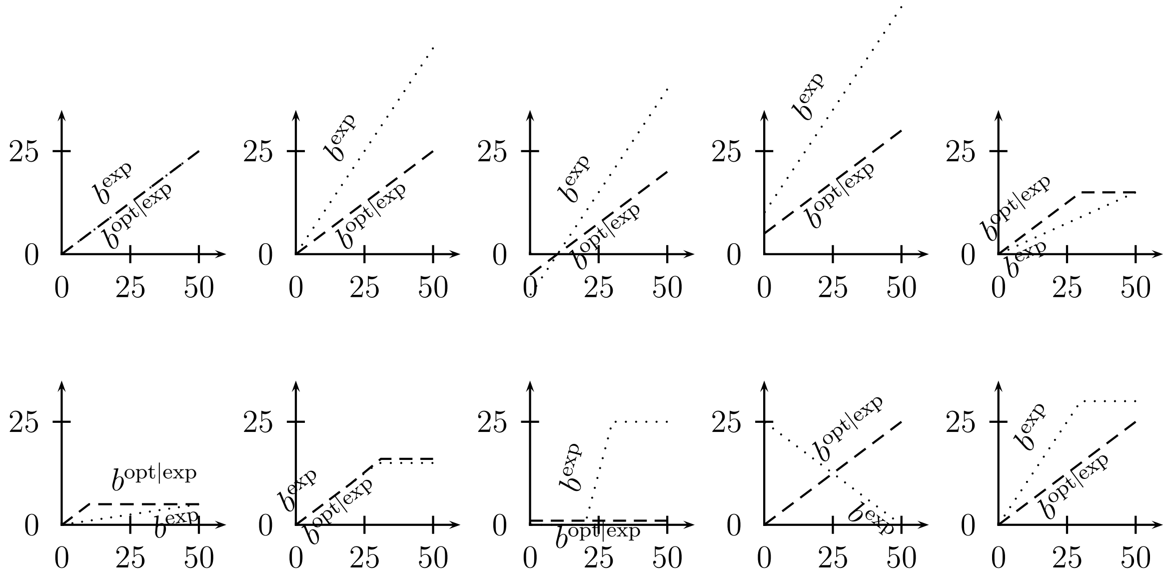


FIGURE 3: Examples of expected bids b^{exp} and best replies $b^{opt|exp}$

plan is now to derive an experimental setup that allows us to observe the two steps of this process, i.e. the expectations b^{exp} (which define $b^{opt|exp}$) together with bids b. Once we can do this, we can determine where the process which is described in figure 2 breaks. Is it that bidders just form expectations which are systematically wrong (i.e. $b^{exp} \neq b$) but the best reply against these expectations is correct. Or are their bids not best replies to their otherwise correct expectations (i.e. $b \neq b^{opt|exp}$).

The reader should note that we do not aim at providing a complete and correct description of the thought process of real individuals. Since we are following the structure of equilibrium derivation we can only find out where the equilibrium model of bidding behaviour provides a good approximation of human behaviour and where it does not. By dividing this model into two steps we can, however, learn a little bit more than what we could by only observing bids without expectations.

3 Experimental setup

In the experiment we want to distinguish between bids and expected opponent's bids. To do this, we compare three treatments:

- In one treatment we only elicit bids. This is our baseline treatment which we also call the 'no expectations' treatment. The only payoff in the treatment is the gain in the auctions.

- In one treatment we elicit bids and expectations. We call this the 'expectations' treatment. The payoff in this treatment is the gain in the auctions and a reward for precision of expectations.

- In one treatment we elicit bids and expectations and give feedback about the precise bidding function of the opponents. We call this the 'expectations with info'

treatment	independent observations	participants
no expectations	36	330
expectations	8	74
expectations w. info	11	102

TABLE 1: Overview over different treatments

treatment. As in the previous treatment the payoff in this treatment is the gain in the auctions and a reward for precision of expectations.

Experiments were conducted between 12/2003 and 05/2005 in the experimental laboratory of the SFB 504 in Mannheim and in the experimental laboratory MaXLab in Magdeburg. A total of 506 subjects participated in these experiments. Table 1 gives an overview. A detailed list of the treatments is provided in appendix A, instructions are presented in appendix D. The software we used was z-Tree (Fischbacher, 1999).

In each treatment subjects first received written instructions, then they answered a quiz on the computer screen to make sure that they understood the instructions. Thereafter they played twelve rounds of the actual experiment. All treatments concluded with a questionnaire and the payment of subjects in cash.

In the no expectations treatment each round consists of two stages. In the expectations treatments there are three stages in each round.

Input of bidding functions: This stage was common to all treatments. Subjects would submit a bid function for a range of valuations from 50 to 100. When we present results below we will always consider normalised valuations where the valuation lies in the interval $[0, 50]$. A typical input screen for the no expectation treatment is shown in figure 4. A typical input screen for the two treatments with expectations is shown in figure 5.

In each round participants enter bids for six valuations which are equally spaced between 50 and 100. Bids for all other valuations are interpolated linearly.

Auction feedback: When all participants have determined their bidding functions they move to the auction feedback stage. In this stage we play five independent auctions, i.e. we draw five random and independent valuations for each participant. Each of these five random draws corresponds to one auction for which the winner is determined and the gain of each player is calculated. The sum of the gain of these five auctions determines the total gain from this round. We play five auctions, and not only one, to reduce the effects of risk aversion in the experiment and to give players a stronger motivation to think carefully about all parts of their bidding function. Players got feedback similar to the one shown in figure 6.

Expectation feedback: In the expectation treatments players get feedback about their expectations in the last stage of each round.

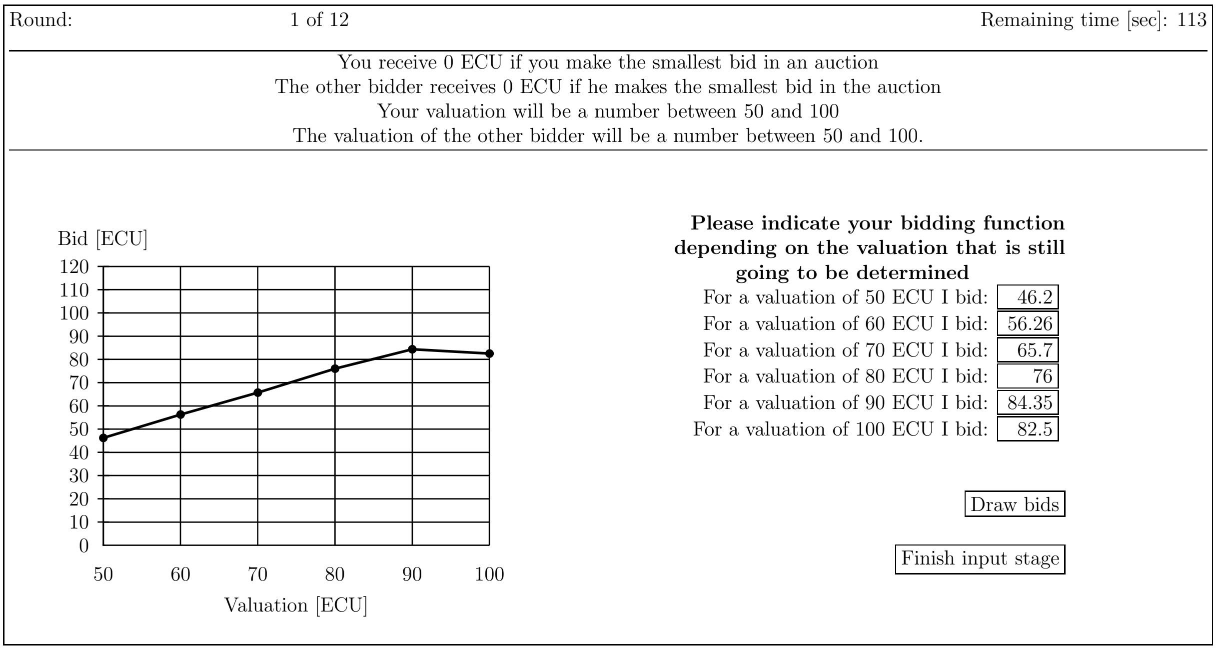


FIGURE 4: Stage 1: A typical input screen in the 'no expectations' treatment (translated into English)

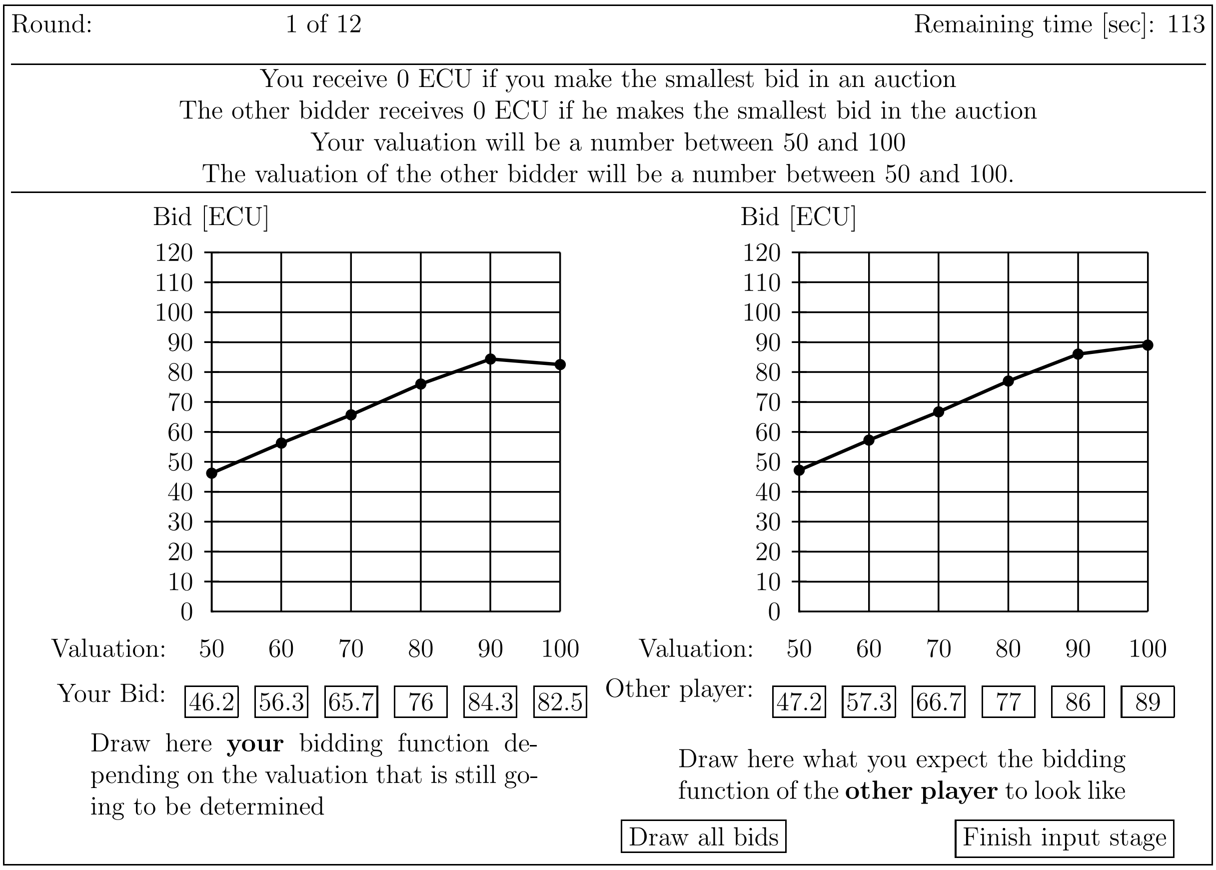


FIGURE 5: Stage 1: A typical input screen in the two 'expectations' treatments (translated into English)

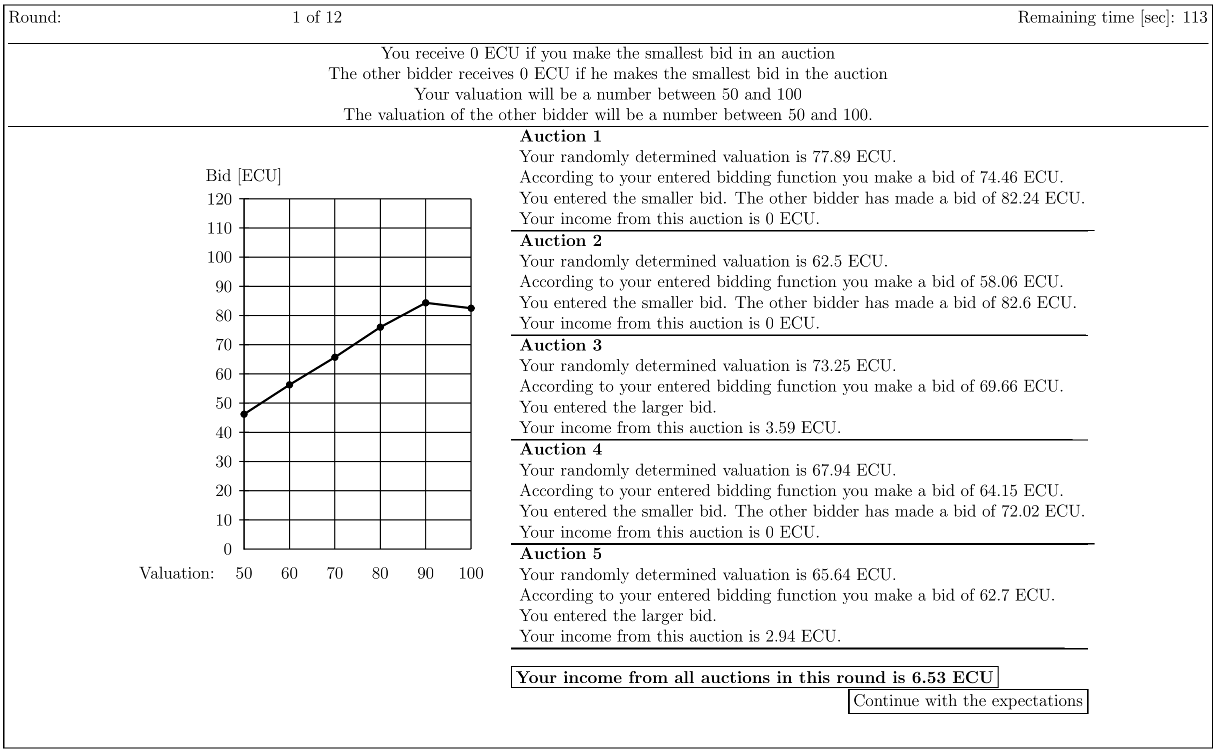


FIGURE 6: Stage 2: A typical feedback screen (translated into English)

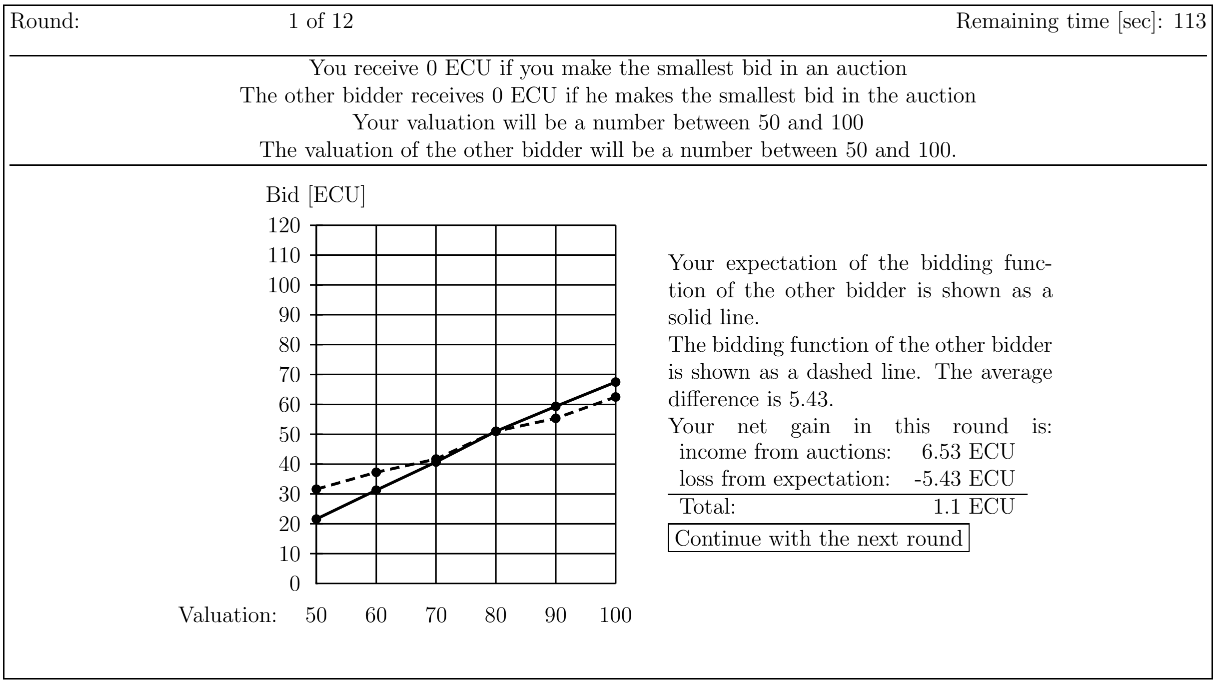


FIGURE 7: Stage 3: Expectation feedback in the expectation with info treatment

- In the baseline treatment the last screen only shows the total payoff of the current round.
- In the expectation treatment the last screen shows the average difference between the expected bid of their opponent and the actual bid and the resulting payoffs. The screen looks similar to the one shown in figure 7, except that it shows only the player's own expectation and not show the actual bidding function of the opponent.
- In the expectation treatment with info the last screen looked similar to the one shown in figure 7. In particular also the actual bidding function of the opponent was shown together with the own expectation in the graph.

As a measure for correctness of expectations in the expectation treatments we look at the average of absolute differences between the actual bid of the opponent and the expected bid at the six points where bids and expectations were made.

$$\frac{1}{6} \sum_{x \in \{50,60,70,80,90,100\}} |b_x - b^e_x|$$

In the expectation treatments this average is deduced from the auction profit.

3.1 Point expectations and random expected bidding functions

In the above discussion we made the implicit assumption that one individual expects the opponent to have one specific bidding function b^{exp}. We will call this a point expectation, even if the point is one in the space of all bidding functions. What, if a player is uncertain about the bidding function of the opponent? A player might, e.g., expect to face an opponent with a bidding function b_1^{exp} with probability $\frac{1}{2}$ and to face an opponent with another bidding function b_2^{exp} again with probability $\frac{1}{2}$. A player might, actually, have an entire distribution over the space of all opponent's bidding functions in mind. How should such a player behave in our experiment? Should this player report expectations which, if interpreted as point expectations, are not consistent with this player's best reply?

In appendix B we describe the optimal (point) expectations a bidder should report to minimise the penalty when this bidder actually expects random bidding functions. We also describe the (point) expectations which are consistent with a best reply against random expected bidding functions.

The optimal point bidding function to report (minimising the penalty) is the median bidding function, the optimal point bidding function to optimise against is a mean bidding function. Thus, for a bidder without point expectations there can be a difference between the point bidding functions this bidder should report for expectations and the point bidding function this bidder should use for determining the best reply. However, as long as the difference between median and mean bidding functions can be regarded small, the problem should be small.

A bidder who has no point expectations of opponent's bids might reduce payoff variance through hedging, i.e. through reporting biased expectations and biased optimal bids. However, since the loss for reporting other than median expectations and optimising

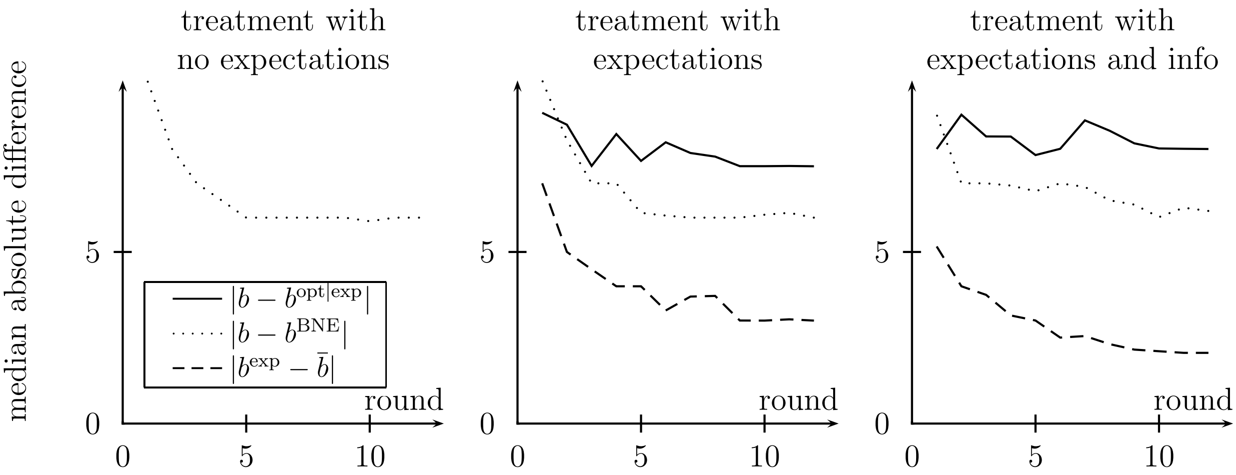


Figure 8: Convergence of bids and expectations

against other than mean expectations is significant, and the gain from hedging is very low, in particular since we are playing several auctions in each round, we do not expect hedging to be a problem.

In the following we will disregard the problem of distributions of expectations and assume that bidders have point expectations of opponent's bidding functions.

4 Internal validity

Before we come to the actual results of our experiment we have to check whether our experimental setup actually measures what it is supposed to measure. Does participants' behaviour converge during the experiment, have participants carefully thought about their expectations, and do they take their expectations into account when they construct their bids? In section 4.1 we will check convergence of behaviour. Section 4.2 looks at treatment effects. In 4.3 we see whether participants in the experiments form reasonable expectations and section 4.4 will check whether bids follow actually best replies to these expectations.

4.1 Convergence

Our experiment is lasting for 12 rounds. In figure 8 we look at convergence of bids and expectations for the three different treatments.

One possible description of players' behaviour is that their bids b are Bayesian Nash equilibrium bids b^{BNE}. Then the absolute difference $|b - b^{\text{BNE}}|$ should be zero. The dotted line in figure 8 shows the median of $|b - b^{\text{BNE}}|$ over time. While the distance between experimental bids and equilibrium decreases during the first three or four rounds of the experiment it does not change very much during the second half of the experiment and remains at a high level. This is consistent with the persistent overbidding which has been observed in many previous experiments.

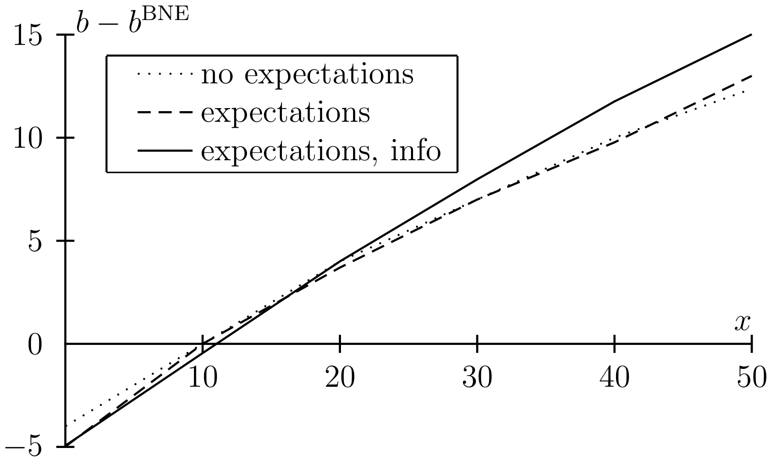


FIGURE 9: Median overbidding

Another ingredient of players' behaviour is formation of expectations? Are expectations correct? If they are not correct, are they increasing in precision? A payoff maximizing player in our experiment who knows the true distribution function of all bidding functions will report the median bidding function as the expected bid. In figure 8 we compare the median bid $\bar{b}$ with the expectation b^{exp}. The dashed line shows the median of $|b^{\text{exp}} - \bar{b}|$. If expectations were perfect then this difference should be zero. Again, the difference decreases during the first few rounds of the experiment and becomes more stable towards the end.

Based on bidders' expectations b^{exp} we can for each bidder and each period determine a best reply bid $b^{\text{opt}|\text{exp}}$ (examples are shown in figure 3). With players who always play a bid b which is a best reply $b^{\text{opt}|\text{exp}}$ given their expectations the difference $|b - b^{\text{opt}|\text{exp}}|$ should be zero. The solid line in figure 8 shows the median of $|b - b^{\text{opt}|\text{exp}}|$. Also this difference remains stable during the second half of the experiment.

We will discuss expectations b^{exp} and bids b below in more detail. The purpose of this section is to show convergence of our results. In the following we will restrict our analysis to the second half of the experiment where behaviour is fairly stable.

4.2 Treatment effects

In all laboratory experiments we must be aware of the fact that whatever method we use to measure behaviour, the method itself might actually influence behaviour. In this section we investigate how much bids are affected by our attempt to measure expectations. Figure 9 compares median overbidding under the three different treatments. In equilibrium there would be no overbidding at all, i.e. we should observe a horizontal line. The increasing lines for the three treatments show that there is overbidding for large valuations in all treatments. We see that overbidding is, if at all, even more pronounced under the expectation with info treatment. To test this formally we look at the difference between actual bids $b(x)$ under the expectation treatments and the median bids $\bar{b}^{\text{noexp}}(x)$

expectations; 8 independent obs.					
	β	σ	t	$P_{>t}$	95%conf. interval
x	$-.0016$	.02209	-0.072	0.944	$-.05384, .05064$
β_0	$-.8499$	.87882	-0.967	0.366	$-2.928, 1.2282$

expectations, info; 11 independent obs.					
	β	σ	t	$P_{>t}$	95%conf. interval
x	.04762	.02164	2.200	0.052	$-.00061, .09584$
β_0	-1.7251	.39805	-4.334	0.001	$-2.612, -.83819$

Table 2: Estimation of equation (2) for the two expectation treatments

for different valuations x in the no expectation treatments.[1] If introducing expectations in the experiment does not affect bids these differences should be zero. We estimate the following equation:

$$b(x) - \bar{b}^{\text{noexp}}(x) = \beta_x x + \beta_0 \qquad (2)$$

Estimation results are given in table 2.[2] We see that introducing expectations without information about the bidding function of the opponent does not have a significant impact. Introducing expectations with information about the opponent's bidding function significantly increases overbidding for large valuations measured as β_x and also increases underbidding for small valuations (β_0). Thus, at least for the treatment with information we do find an (albeit small) treatment effect. However, the effect does not diminish the deviation from symmetric risk neutral Bayesian Nash equilibria. On the contrary, in this treatment the deviation from equilibria is even stronger.

4.3 Quality of expectations

In our experiment subjects have an incentive to give precise expectations. The larger the deviation of their expectation from their opponent's true bidding function, the smaller is their payoff. Does this, indeed, induce them to make good and precise estimates? First we will test whether expectations are good. Then we test why they are good, i.e. whether they result from mere introspection or whether information about other bidding functions plays a role as well.

Figure 10 shows median bidding functions and medians of expected bids for the two expectation treatments. We see that expectations are, indeed, very close to bids. To check

[1] We did the same exercise with mean bids to obtain basically the same result. Since medians are less vulnerable to outliers we are concentrating on medians here. The structure of equation (2) does not require overbidding to be linear in x (though it requires the treatment effect to be linear). One can impose such linear relationship between x and the amount of overbidding and obtains very similar results.

[2] When calculating levels of standard deviations and levels of significance we have to take into account that observations within our experimental sessions may be correlated. We can safely assume that covariances of observations from different sessions are zero. Covariances of observations from the same experiment are replaced by the appropriate product of the residuals (Rogers, 1993). We will use this approach throughout the paper to calculate standard errors.

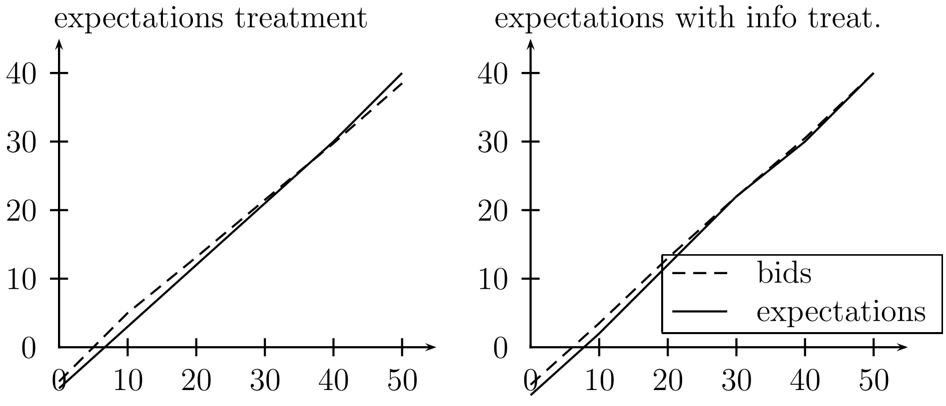


FIGURE 10: Median bids and median expectations

	n	$\beta^1 - 1$	t	$P_{>\|t\|}$	P_{bin}
expectations	8	.0736	2.59	0.036	0.070
expectations, info	11	.0291	2.01	0.072	0.227
all	19	.0478	3.16	0.005	0.019

TABLE 3: Testing $\beta_i^1 - 1 = 0$ for equation (3)

this more formally we determine for each period, treatment, and valuation the median bidding function $\bar{b}_t(x)$. Ideally, this is what participants should expect in each period.[3] For each individual i we estimate now

$$b_i^{\exp}(x) = \beta_i^1 \bar{b}_t(x) + \beta_i^0 + u\,. \tag{3}$$

Table 3 reports a t-tests as well as a binomial test for $\beta_i^1 = 1$. Expected bidding functions are slightly steeper than actual bidding functions, the difference is also significant, but small.

The estimation of equation (3) can tell us how good expectations are, but it does not reveal the causality between bids and expectations. Do participants really have a good model of the behaviour of the population in mind and use this to form good expectations, or do participants follow a naïve procedure: not knowing at all what they should expect they simply copy their own bid into the expectation graph?

To answer this question one might suggest to regress individual expectations on individual bids. However, this is a difficult exercise since expectations already causally affect bids. Disentangling the two directions of causality can be hard. As an alternative and, perhaps, simpler approach we use the data from our 'expectation with info' treatment. We can use the opponent's bid in this treatment as an explanatory variable for expectations

[3]As above we did the same exercise with mean bids to obtain basically the same result. Since medians are less vulnerable to outliers we are concentrating on medians here.

	n	β	t	$P_{>\|t\|}$	P_{bin}
	11	.0373	2.916	0.015	0.065

TABLE 4: Test for the coefficient of $\Delta_{t-1}b_j$ in equation (4)

	β	σ	t	$P_{>t}$	95%conf. interval
$\Delta_{t-1}b_j$	.02566	.00826	3.106	0.011	.00725, .04406
$\Delta_t b_i$	.4922	.15471	3.181	0.010	.14749, .83692
β_0	.23205	.04485	5.174	0.000	.13211, .33198
independent obs.	11				

TABLE 5: Estimation of equation (5)

and estimate the following equation in first differences[4]:

$$\Delta_t\, b_i^{\text{exp}} = \beta_j \cdot \Delta_{t-1}b_j + \beta_0 + u \tag{4}$$

How large the coefficient β in equation (4) should be depends on the prior expectations of the bidder. A bidder with no prior expectations should have a β close to one. A bidder with strong prior expectations who is convinced that nothing new can be learned from the current opponent should have a $\beta = 0$. The result of estimating the coefficient β is shown in table 4. We see that the coefficient of $\Delta_{t-1}b_j$ is positive and significantly different from zero. Thus, changes in an opponents individual bidding function seem to have an effect on a bidder's expectations for the next period.

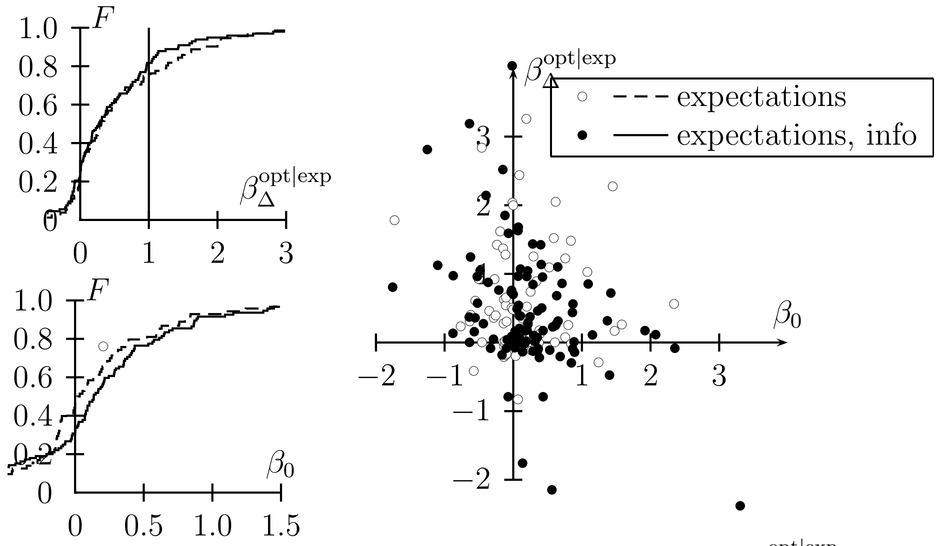
Could it be that a positive coefficient of $\Delta_{t-1}b_j$ in equation (4) arises due to an indirect effect: Naïve bidders see opponents' bids rise, in response they increase their own bids (without thinking about expectations), and, when asked about expectations, they simply use their own bids as expectations. To test this, we add $\Delta_t b_i$ as an explanatory variable in equation (5).

$$\Delta_t\, b_i^{\text{exp}} = \beta_j \cdot \Delta_{t-1}b_j + \beta_i \cdot \Delta_t b_i + \beta_0 + u \tag{5}$$

Table 5 reports estimation results. We see that, even if we allow bidders to follow the above naïve strategy, the coefficient of $\Delta_{t-1}b_j$ is still significantly positive, i.e. bids of opponents do directly affect expectations. A positive and significant coefficient for $\Delta_t b_i$ is no confirmation of the above naïve model. Also with rational players there should be a relationship between b and b^{exp}.

Summarising this section we find that bidders in the experiment make expectations which are close to actual bids and they seem to use available information to form expectations in a sensible way.

[4]Since b_i^{exp} and b_j are likely to be correlated we can not use absolute values.



The two diagrams on the left show the cumulative distribution for the estimation of $\beta_\Delta^{\mathrm{opt|exp}}$ and β_0 of each player. The diagram on the right shows the joint distribution with one dot for each player.

FIGURE 11: Estimation of equation (6)

4.4 Quality of reactions to expectations

Whatever the expectations are, can we assume that bidders make optimal bids given these expectations. To answer this question we construct for each bidder and each period the best reply given this bidder's expectations $b^E(x)$. We call this best reply $b^{\mathrm{opt|exp}}(x)$. Since we have to derive this best reply under the constraint that bids are stepwise linear with support points $\{0, 10, 20, 30, 40, 50\}$ we use a numerical procedure to find $b^{\mathrm{opt|exp}}(x)$. The general idea behind this procedure is summarised in appendix C. We then compare actual bids b with best replies $b^{\mathrm{opt|exp}}$. We will do this in two different ways. We estimate

$$\Delta b_i(x) = \beta_\Delta^{\mathrm{opt|exp}} \cdot \Delta b^{\mathrm{opt|exp}} + \beta_0 + u\,. \tag{6}$$

A rational bidder should have $\beta_\Delta^{\mathrm{opt|exp}} = 1$. A bidder who is slow in adapting and who also takes past experience into account should have $\beta_\Delta^{\mathrm{opt|exp}} < 1$. Results of estimating equation (6) for each bidder individually are shown in figure 11. A formal test is given in table 6. The coefficient $\beta_\Delta^{\mathrm{opt|exp}}$ is significantly positive, i.e. bidders indeed take the best

	n	$\beta_\Delta^{\mathrm{opt\|exp}}$	t	$P_{>\|t\|}$	P_{bin}
info	8	.5698	5.373	0.001	0.008
info, exp.	11	.4357	4.243	0.002	0.001
all	19	.4921	6.599	0.000	0.000

TABLE 6: Test of $\beta_\Delta^{\mathrm{opt|exp}} = 0$ from equation (6)

reply $b^{\mathrm{opt|exp}}$ into account when choosing their bid b.

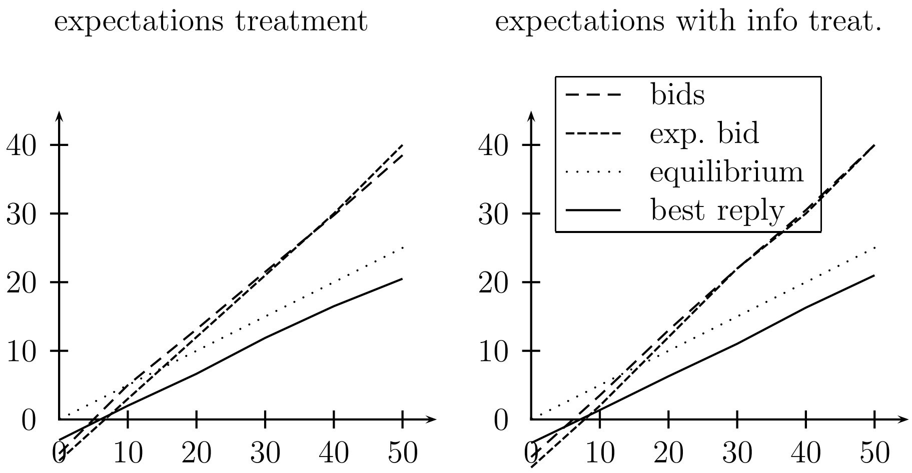


FIGURE 12: Median bids and median best replies

5 Results

In the previous section we have tested the reliability of our experimental framework. Next, we want to find out whether and how far expectations explain deviations of bids from Bayesian Nash Equilibrium $b^{\text{BNE}}(x)$. As already stated above we do not aim at providing a complete and correct description of the thought process of real individuals. We are deliberately restricting ourselves to following the structure of equilibrium derivation. In terms of figure 2 on page 3 we want to explore what happens on the way from $b^{\text{BNE}}(x)$ to $b^{\text{opt}|\text{exp}}$. In a second step we want to measure whether deviations between actual and equilibrium bids are rather due to off equilibrium expectations or whether they are due to wrong best replies. In terms of figure 2 this would be the path from $b^{\text{opt}|\text{exp}}$ to the actual bid b. We estimate the following two equations:

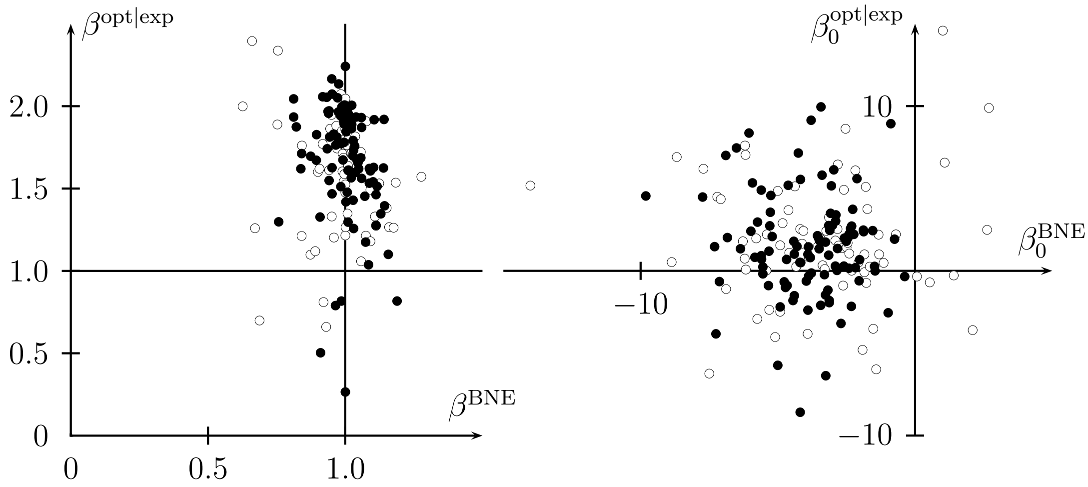
$$b_i^{\text{opt}|\text{exp}}(x) = \beta^{\text{BNE}} \cdot b^{\text{BNE}}(x) + \beta_0^{\text{BNE}} + u \tag{7}$$

$$b_i(x) = \beta^{\text{opt}|\text{exp}} \cdot b_i^{\text{opt}|\text{exp}}(x) + \beta_0^{\text{opt}|\text{exp}} + u \tag{8}$$

In equation (7) we regress the best reply bid $b^{\text{opt}|\text{exp}}(x)$ on the Bayesian Nash equilibrium bid $b^{\text{BNE}}(x)$. If participants expect the others use equilibrium bids, then the coefficient β^{BNE} should be one. The more a player's expectations deviate from equilibrium bids, the more β^{BNE} will be different from one.

In equation (8) we regress the actual bid $b_i(x)$ on the best reply bid $b^{\text{opt}|\text{exp}}(x)$. If a player chooses always the best reply given the expected opponent's bid then $\beta^{\text{opt}|\text{exp}}$ should be one. The more a players actual bid deviates from the best reply bid, the more $\beta^{\text{opt}|\text{exp}}$ will be different from one.

Figure 13 and 14 show the distribution of the estimated coefficients. Let us start with equation (7), the relation between expectations and equilibrium bids. In the bottom part of figure 14 we see that β^{BNE} is closely centered around one, though the constant β_0^{BNE} is smaller than zero. What we estimate for β^{BNE} and β_0^{BNE} is also reflected in the median best replies in figure 12: The solid line which shows the median of the best replies is almost parallel to the equilibrium bid (dotted line), but slightly below. In other words:



The coefficients of the linear terms are shown on the left, those of the constants are on the rights.

FIGURE 13: Estimating equations (7) and (8).

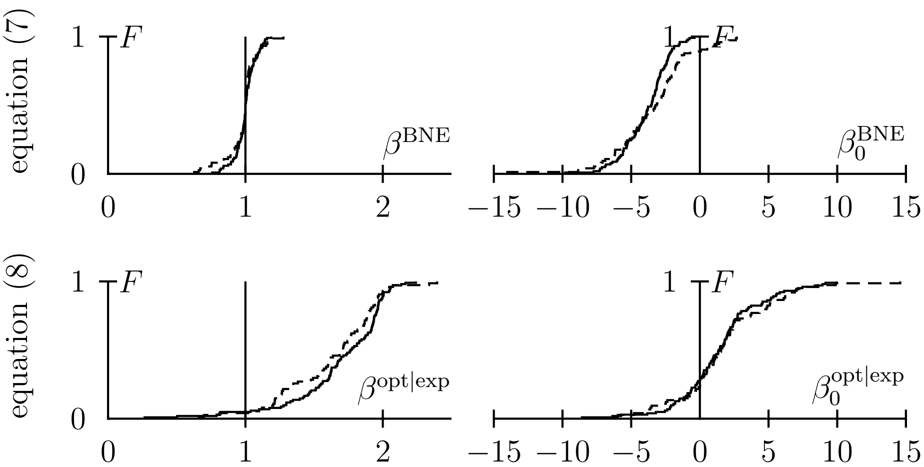


FIGURE 14: Cumulative distribution of coefficients from equation (7) and (8).

	n	$\beta^{\text{BNE}} - 1$	t	$P_{>\|t\|}$	P_{bin}
expectations	8	-.0167	-1.254	0.250	0.727
expectations, info	11	.0021	0.201	0.844	0.549
all	19	-.0058	-0.694	0.497	0.359
	n	$\beta^{\text{opt}\|\text{exp}} - 1$	t	$P_{>\|t\|}$	P_{bin}
expectations	8	.6297	14.400	0.000	0.008
expectations, info	11	.6943	13.833	0.000	0.001
all	19	.6671	19.569	0.000	0.000

TABLE 7: Testing $\beta^{\text{BNE}} = 1$ for equation (7) and $\beta^{\text{opt}|\text{exp}} = 1$ for equation (8)

Bidders do seem to deviate in their expectations consistently from equilibrium bids, the deviation we find, however, is clearly in the direction of underbidding, not overbidding. How can it be, then, that most experimental bids are over, and not under the equilibrium bids?

The way how overbidding enters becomes more clear when we look at the estimation results for equation (8). The upper part of figure 14 shows the cumulative distribution of $\beta^{\text{opt}|\text{exp}}$. We see that $\beta^{\text{opt}|\text{exp}}$ is larger than one for most bidders. The constant $\beta_0^{\text{opt}|\text{exp}}$ is close to zero. Tests are reported in table 7.

Let us summarise: We find that there are two effects which determine bidding behaviour. The way bidders form expectations would rather lead to underbidding. The way bidders take actually into account the best reply against their expectations leads to overbidding. Furthermore, the second effect is stronger than the first, so that in the end most bids are larger than equilibrium bids.

6 Concluding remarks

In this paper we want to find out whether deviations from equilibrium bidding behaviour is due to a systematic failure to form correct expectations, or due to the failure to follow the best reply against these expectations.

Given the novelty of the approach we have taken particular care checking the internal validity of our setup. We found that bids and expectations do converge in section 4.1. In section 4.2 we have seen that introducing expectations has, if at all, only a small effect on actual bidding behaviour. In section 4.3 we checked that expectations, indeed, react to information about bids. We have also seen in section 4.4 that best replies to expectations play a significant role in determining individual bids.

The main result is what we found in section 5: Most of the deviations from equilibrium bids seem to be due to a deviation from the best reply — deviations from equilibrium bids can hardly be explained by mistakes in expectations. Expectations are biased away from equilibrium bids, however, this bias would only explain underbidding and is more than compensated by deviations from the best reply. We think that it is important to interpret this observation together with our finding from section 4.4. It is not that bidders simply do not understand how to connect expectations and their best reply to these expectations. On the contrary, the findings from section 4.4 demonstrate that bidders are well aware how expectations translate into best replies. Only, and as we see in section 5, bidders overshoot in translating expectations into best replies. This, in turn, leads to off equilibrium bids.

When we observe good expectations and bad best replies in the lab we should keep in mind that forming precise expectations about opponents' bids is easier in the lab than it is in a real world auction. Still, if the difference between bids and best replies is large in the lab we should expect this difference to be significant in the field as well. Many electronic marketplaces assist bidders in forming their expectations by providing detailed data about past and current bids. Given the evidence from our experiment it might be an even more desirable feature of future marketplaces to assist bidders in determining their best replies.

References

Coppinger, V. M., V. L. Smith, and J. A. Titus, 1980, Incentives and behavior in English, Dutch and sealed-bid auctions, *Economic Inquiry*, 43, 1–22.

Cox, J. C., B. Roberson, and V. L. Smith, 1982, Theory and behavior of single object auctions, in *Research in experimental economics*, ed. by V. L. Smith. JAI Press, Greenwich, Conn.

Cox, J. C., V. L. Smith, and J. M. Walker, 1983, Test of a Heterogeneous Bidder's Theory of First Price Auctions, *Economic Letters*, 12(3-4), 207–212.

——— , 1985, Experimental Development of Sealed-Bid Auction Theory: Calibrating Controls for Risk Aversion, *American Economic Review*, 75(2), 160–165.

Cox, J. C., V. L. Smith, and J. M. Walker, 1988, Theory and Individual Behavior of First-Price Auctions, *Journal of Risk and Uncertainty*, 1, 61–99.

Fischbacher, U., 1999, z-Tree. Toolbox for Readymade Economic Experiments, Working paper 21, IEW, University of Zurich.

Güth, W., R. Ivanova-Stenzel, M. Königstein, and M. Strobel, 2003, Learning to bid - An experimental study of bid function adjustments in auctions and fair division games, *Economic Journal*, 113(487), 477–494.

Harrison, G. W., 1989, Theory and Misbehavior of First-Price Auctions, *American Economic Review*, 79(4), 749–762.

Kagel, J. H., and D. Levin, 1993, Independent private value auctions: Bidder behavior in first-, second- and third-price auctions with varying numbers of bidders., *Economic Journal*, 103, 868–879.

Kirchkamp, O., E. Poen, and J. P. Reiß, 2004, Bidding with Outside Options, Discussion Paper 04-21, SFB 504, Universität Mannheim, http://www.kirchkamp.de/.

Kirchkamp, O., and J. P. Reiß, 2004, The overbidding-myth and the underbidding-bias in first-price auctions, Discussion Paper 04-32, SFB 504, Universität Mannheim, http://www.kirchkamp.de/.

Rogers, W. H., 1993, Regression standard errors in clustered samples, in *Stata Technical Bulletin*, vol. 13, pp. 19–23. Stata, Reprinted in Stata Technical Bulletins, vol. 3, 88-94.

Selten, R., and J. Buchta, 1999, Experimental Sealed Bid First Price Auctions with Directly Observed Bid Functions., in *Games and Human Behaviour*, ed. by D. Bodescu, I. Erev, and R. Zwick, pp. 79–102. Lawrence Erlbaum Aussociates Inc., Mahwah (NJ).

Vickrey, W., 1961, Counterspeculation, auctions and competitive sealed tenders, *Journal of Finance*, 16, 8–37.

A List of independent observations

date	treatment	participants		
20040517-12:21-0	no expectations	Mannheim	-50	8
20040517-12:21-1	no expectations	Mannheim	-50	6
20040517-17:17-0	no expectations	Mannheim	-50	8
20040517-17:17-1	no expectations	Mannheim	-50	8
20031211-18:23-0	no expectations	Mannheim	0	14
20031212-10:45-0	no expectations	Mannheim	0	14
20040519-15:53-0	no expectations	Mannheim	0	8
20040519-15:53-1	no expectations	Mannheim	0	10
20050414-08:55-0	no expectations	Magdeburg	0	10
20050414-08:55-1	no expectations	Magdeburg	0	10
20050414-13:17-0	no expectations	Magdeburg	0	10
20050414-13:17-1	no expectations	Magdeburg	0	10
20050613-08:39-0	no expectations	Magdeburg	0	10
20050613-08:39-1	no expectations	Magdeburg	0	8
20050613-10:27-0	no expectations	Magdeburg	0	10
20050613-10:27-1	no expectations	Magdeburg	0	8
20050613-14:39-0	no expectations	Magdeburg	0	10
20050613-14:39-1	no expectations	Magdeburg	0	8
20050614-08:45-0	no expectations	Magdeburg	0	8
20050614-08:45-1	no expectations	Magdeburg	0	8
20050614-10:41-0	no expectations	Magdeburg	0	10
20050614-10:41-1	no expectations	Magdeburg	0	8
20050614-14:41-0	no expectations	Magdeburg	0	10
20050614-14:41-1	no expectations	Magdeburg	0	10

continued on next page

date	treatment	participants		
20050615-08:49-0	no expectations	Magdeburg	0	10
20050615-08:49-1	no expectations	Magdeburg	0	8
20050615-10:41-0	no expectations	Magdeburg	0	10
20050615-10:41-1	no expectations	Magdeburg	0	8
20050615-14:45-0	no expectations	Magdeburg	0	8
20050615-14:45-1	no expectations	Magdeburg	0	8
20050616-08:53-0	no expectations	Magdeburg	0	10
20050616-08:53-1	no expectations	Magdeburg	0	8
20050616-10:17-0	no expectations	Magdeburg	0	8
20050616-10:17-1	no expectations	Magdeburg	0	8
20050616-14:39-0	no expectations	Magdeburg	0	10
20050616-14:39-1	no expectations	Magdeburg	0	10
20050207-10:53-0	expectations w. info	Mannheim	-50	8
20050209-14:09-0	expectations w. info	Mannheim	-50	12
20050209-16:11-0	expectations w. info	Mannheim	-50	6
20050414-10:37-0	expectations w. info	Magdeburg	-50	10
20050414-10:37-1	expectations w. info	Magdeburg	-50	10
20050414-16:35-0	expectations w. info	Magdeburg	-50	10
20050414-16:35-1	expectations w. info	Magdeburg	-50	10
20050415-08:59-0	expectations w. info	Magdeburg	-50	8
20050415-08:59-1	expectations w. info	Magdeburg	-50	8
20050415-11:11-0	expectations w. info	Magdeburg	-50	10
20050415-11:11-1	expectations w. info	Magdeburg	-50	10
20050511-10:51-0	expectations	Magdeburg	-50	10
20050511-10:51-1	expectations	Magdeburg	-50	10
20050511-14:55-0	expectations	Magdeburg	-50	10
20050511-14:55-1	expectations	Magdeburg	-50	10
20050512-09:01-0	expectations	Magdeburg	-50	10
20050512-09:01-1	expectations	Magdeburg	-50	8
20050512-12:59-0	expectations	Magdeburg	-50	8
20050512-12:59-1	expectations	Magdeburg	-50	8

B Point expectations and random expected bidding functions

In most of the above discussion we made the implicit assumption that one individual expects the opponent to have a specific bidding function $b^{\exp}$. Of course, uncertainty might exist. A player might, e.g. expect to face an opponent with bidding function $b_1^{\exp}$ with probability $\frac{1}{3}$ and to face an opponent with different bidding function $b_2^{\exp}$ with probability $\frac{2}{3}$. A player might actually have an entire distribution over bidding functions in mind. How should such a player behave in our experiment?

One can show that, with some regularity assumptions, the behaviour of such a player would not be too different from a player who only forms point distributions.

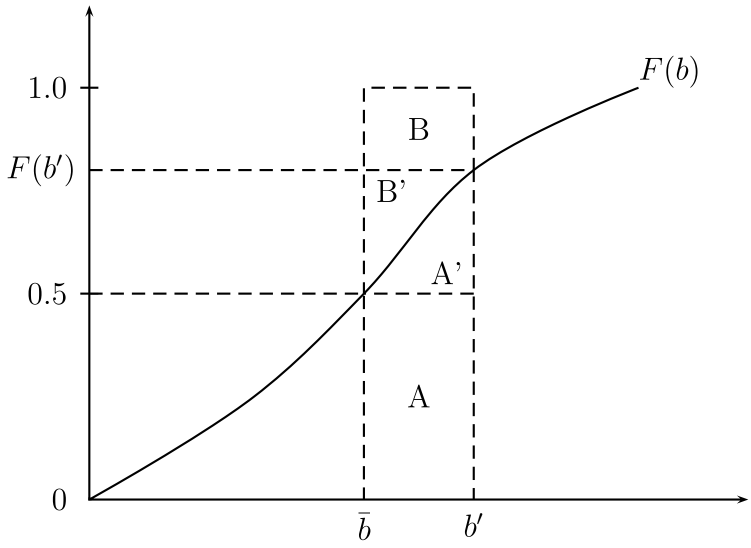


FIGURE 15: Median expectations

Let us first look at the expectation such a player reports. A payoff maximizing player in our experiment who knows the true distribution function of all bidding functions will report the median bidding function as the expected bid. Figure 15 describes the situation of a bidder who expects bids (for a given valuation) to be distributed according to the cumulative distribution function $F(b)$. The median bid is $\bar{b}$. What happens if this bidder does not report $\bar{b}$, but instead b'? For all realisations of the opponent bid smaller than $\bar{b}$ the penalty increases by $b' - \bar{b}$. This is described by the rectangle A. For all realisations of the opponent bid which are still larger than $\bar{b}$ the penalty decreases by $b' - \bar{b}$. This is described by the rectangle B. For all realisations of the opponents bid between $\bar{b}$ and b things are a bit more complicated. Sometimes our bidder gains (B'), sometimes the bidder looses (A'). Since the size of A is equal to $B + B' + A'$ the bidder can only loose from increasing the reported expectations to b'. Similarly one can show that the bidder can only loose from decreasing the reported expectation. The smallest penalty is obtained when the bidder reports the median expectation. The argument can be extended from a bid for a single valuation (as in the example in figure 15) to a vector of bids of valuations (as in the experiment).

Figure 16 is similar to figure 1, it only adds some uncertainty about b^{exp}. Let us look at the situation of a bidder who determines the probability to win an auction with a bid $\hat{b}$. Let us assume for simplicity that this bidder expects with probability $\frac{1}{2}$ an opponent with bidding function b_1^{exp} and with probability $\frac{1}{2}$ an opponent with bidding function b_2^{exp}. The pobability to win with a bid $\hat{b}$ is, thus, given by $\frac{1}{2}F(b_1^*) + \frac{1}{2}F(b_2^*)$. Since in our experiment b is uniformly distributed and b_1^{exp} and b_2^{exp} are increasing the probability is equal to $F(\frac{1}{2}b_1^* + \frac{1}{2}b_2^*)$, i.e. our bidder can behave as if the expected bidding function was a point function b_*^{exp}, which is the horizontal average of the expected bidding functions. One can generalise this argument to arbitrary distributions of bidding functions, as long as these

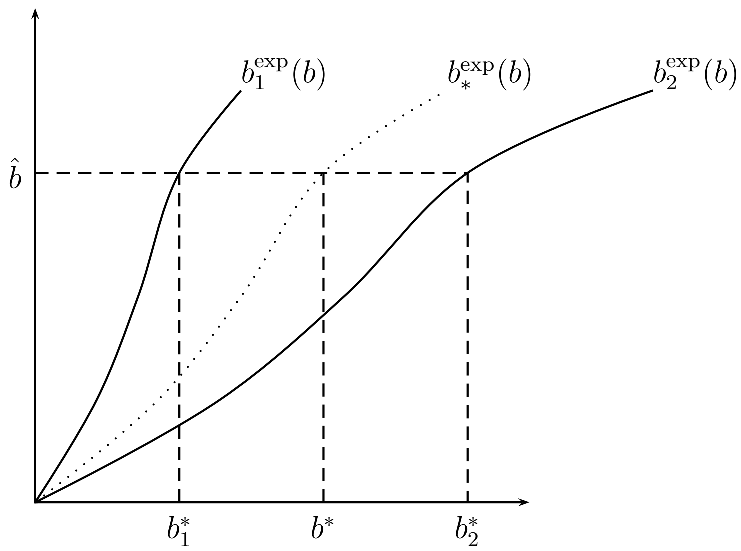


FIGURE 16: Optimality against random bidding functions

bidding functions are monotonically increasing. Thus, a bidder who faces uncertainty about an opponent's increasing bidding functions solves an optimisation problem that is equivalent to the one of a bidder who expects the mean bidding function (the mean being taken horizontally as in the example).

C Finding best reply bidding functions

In this section we describe how to find an optimal stepwise linear bidding function in a first price auction, given a stepwise linear bidding function of the opponent. We take a numerical approach.

Idea Our bidding function is parameterised by a vector $\vec{b} = (b_0, b_1, \ldots, b_5)$. This vector determines a bidding function $b(x)$. Our opponent has a bidding function $\vec{c} = (c_0, c_1, \ldots, c_5)$. We maximise over b our expected utility $u(\vec{b}, \vec{c})$ for a given $\vec{c}$. This can be done by separating the problem into 25 smaller problems.

Let us assume that our valuation is in a range $[x_0, x_0 + 10]$ where $x_0 \in \{0, 10, 20, \ldots, 40\}$. Let us furthermore assume that our opponent's valuation is in a range $[y_0, y_0 + 10]$. Call the corresponding elements of $\vec{b}$ here $b_0 = b(x_0)$ and $b_1 = b(x_1)$ where b_0 and b_1 need not be identical with the b_0 and b_1 from the previous paragraph. Similarly we call the elements of $\vec{c}$ here $c_0 = c(y_0)$ and $c_1 = c(y_1)$.

From a valuation x we can construct a bid $b(x) = b_0 + \frac{x - x_0}{10}(b_1 - b_0)$. Be b^{-1} the inverse bidding function $b^{-1}(b) \equiv x_0 + 10\frac{b - b_0}{b_1 - b_0}$. Similarly be $p_c^{-1}(b) \equiv \frac{b - c_{\min}}{c_{\max} - c_{\min}}$ the probability to win with a bid b (provided that my opponent's valuation is in $[y_0, y_1]$).

Figure 17 illustrates some special cases. Whatever our bids b_0 and b_1 are, there is

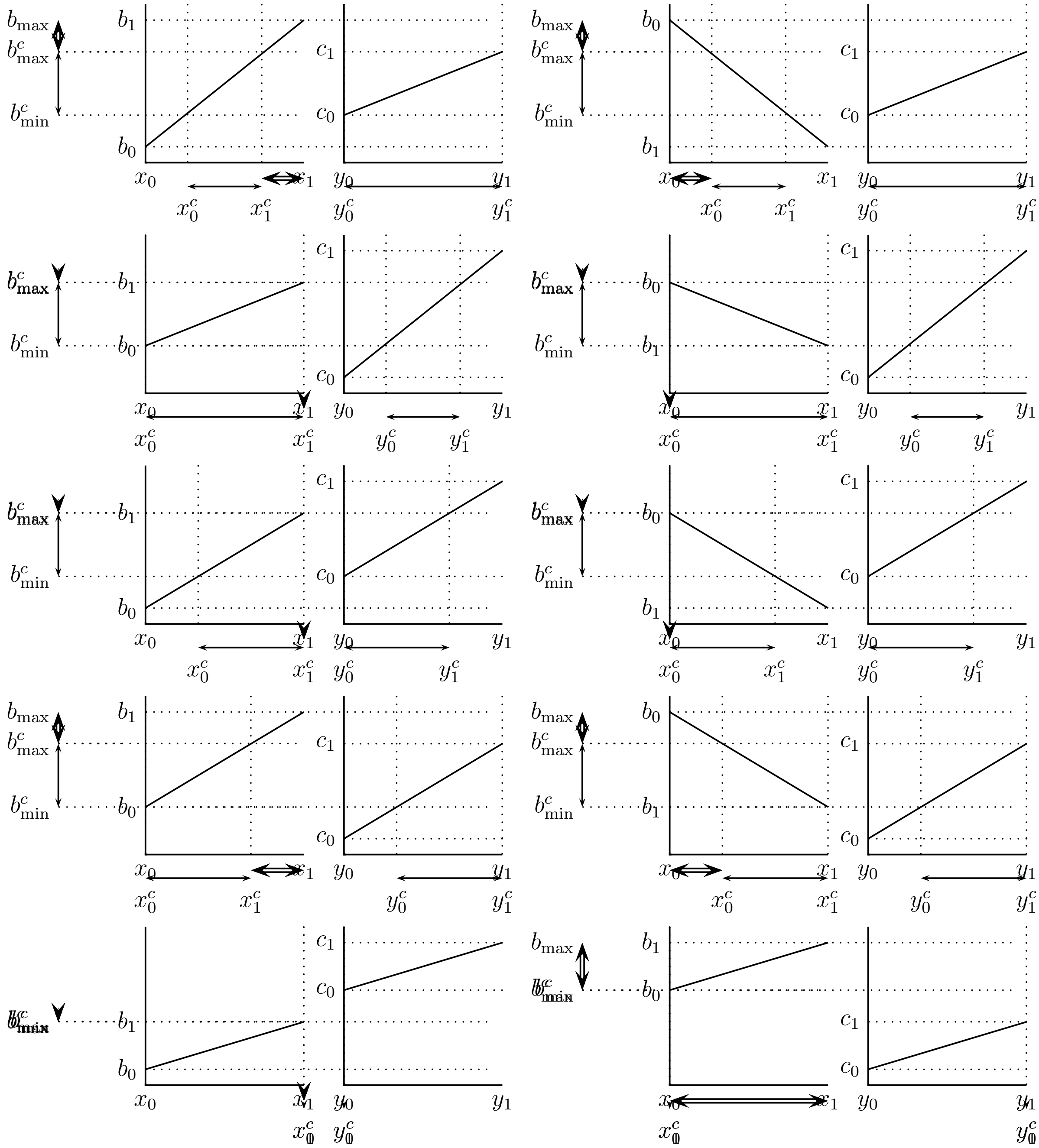


FIGURE 17: Some special cases

always a range of bids $B^c = [b^c_{\min}, b^c_{\max}]$ where we sometimes win and sometimes loose. There is also a range where we always win $B^a = [b^c_{\max}, b_{\max}]$. These ranges correspond to valuations $X^c \equiv [x^c_{\min}, x^c_{\max}]$ and $X^a \equiv [x^a_{\min}, x^a_{\max}]$.

To determine these ranges we define first $b_{\max} = \max(b_0, b_1)$ and $b_{\min} = \min(b_0, b_1)$. Similarly $c_{\max} = \max(c_0, c_1)$ and $c_{\min} = \min(c_0, c_1)$. Now $b^c_{\max} = \min(b_{\max}, c_{\max})$ and $b^c_{\min} = \max(b_{\min}, c_{\min})$.

(1) If $b_{\max} < c_{\min}$ then all ranges $B^c = B^a = X^c = X^a$ are empty.

(2) If $b_{\min} > c_{\max}$ we always win. $B^c = X^c = \emptyset$. Define $x^a_{\min} \equiv x_0$ and $x^a_{\max} \equiv x_0 + 10$ in this case.

(3) Otherwise: Then the range of valuations x which correspond to the conditional range is $[x^c_{\min}, x^c_{\max}]$ where $x^c_{\min} \equiv \min(b^{-1}(b^c_{\min}), b^{-1}(b^c_{\max}))$ and $x^c_{\max} \equiv \max(b^{-1}(b^c_{\min}), b^{-1}(b^c_{\max}))$.

(3a) If $b_0 \leq b_1$ then the range where we always win is given by $x^a_{\min} = x^c_{\max}$ and $x^a_{\max} = x_0 + 10$.

(3b) Otherwise $x^a_{\min} = x_0$ and $x^a_{\max} = x^c_{\min}$

$$u_c = \int_{x \in X^c} (x - b(x)) \cdot p_c^{-1}(b(x))\, dx \tag{9}$$

$$u_a = \int_{x \in X^a} (x - b(x))\, dx \tag{10}$$

D Conducting the experiment and instructions

Participants were recruited by email and could register for the experiment on the internet. At the beginning of the experiment participants drew balls from an urn to determine their allocation to seats. Being seated participants then obtained written instructions in German. These instructions very slightly depending on the treatment. In the following we give a translation of the instructions.

After answering control questions on the screen subjects entered the treatment described in the instructions. After completing the treatment they answered a short questionnaire on the screen and where then paid in cash. The experiment was done with the help of z-Tree (Fischbacher (1999)).

D.1 General information

You are participating in a scientific experiment that is sponsored by the Deutsche Forschungsgemeinschaft (German Research Foundation). If you read the following instructions carefully then you can—depending on your decision—gain a considerable amount of money. It is, hence, very important that you read the instructions carefully.

The instructions that you have received are only for your private information. **During the experiment no communication is permitted.** Whenever you have questions, please raise your hand. We will then answer your question at your seat. Not following this rule leads to exclusion from the experiment and all payments.

During the experiment we are not talking about Euro, but about ECU (Experimental Currency Unit). Your entire income will first be determined in ECU. The total amount of ECU that you have obtained during the experiment will be converted into Euro at the end and paid to you in **cash**. The conversion rate will be shown on your screen at the beginning of the experiment.

D.2 Information regarding the experiment

Today you are participating in an experiment on auctions. The experiment is divided into separate rounds. We will conduct **12 rounds**. In the following we explain what happens in each round.

In each round you bid for an object that is being auctioned. Together with you another participant is also bidding for the same object. Hence, in each round, there are **two bidders**. In each round you will be allocated randomly to another participant for the auction. *Your co-bidder in the auction changes in every round.* The bidder with the highest bid has obtained the object. If bids are the same the object will be allocated randomly.

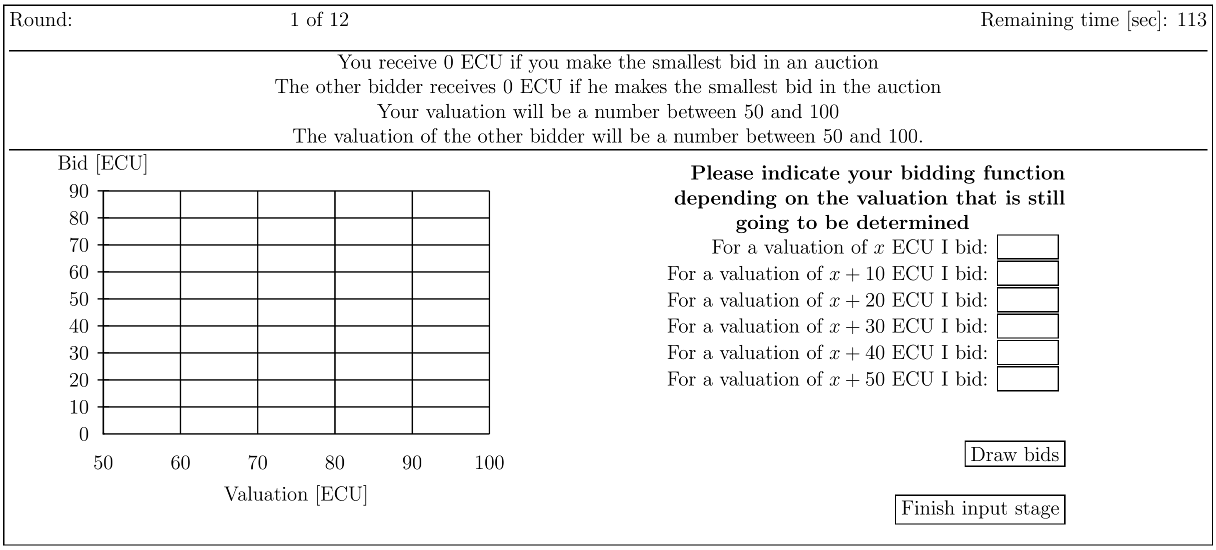
For the auctioned object you have a valuation in ECU. This valuation lies between x and $x + 50$ ECU and is determined randomly in each round. The range from x to $x + 50$ will be shown to you at the beginning of the experiment on the screen and is the same in each round. **From this range you will obtain in each round new and random valuations for the object.** The other bidder in the auction also has a valuation for the object. The valuation that the other bidder attributes to the object is determined by the same rules as your valuation and changes in each round, too. All possible valuations of the other bidder are also in the interval from x to $x + 50$ from which also your valuations are drawn. All valuations between x and $x + 50$ are equally probable. Your valuations and those of the other player are determined independently. You will be told your valuation in each round. *You will not know the valuation of the other bidder.*

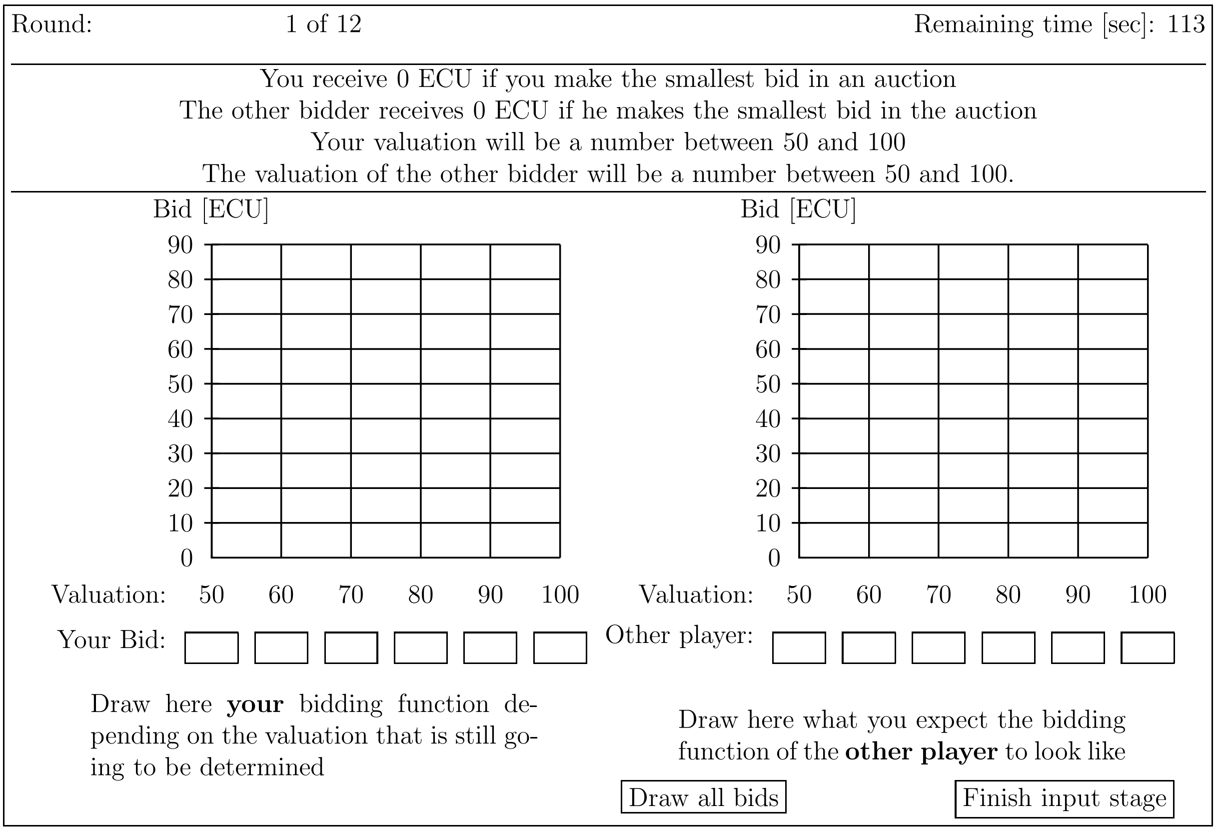
D.2.1 Experimental procedure

The experimental procedure is the same in each round and will be described in the following. Each round in the experiment has two stages.

1. Stage

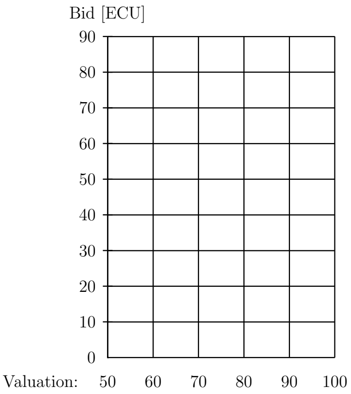
In the first stage of the experiment you see the following screen:





Round: 1 of 12 Remaining time [sec]: 113

You receive 0 ECU if you make the smallest bid in an auction
The other bidder receives 0 ECU if he makes the smallest bid in the auction
Your valuation will be a number between 50 and 100
The valuation of the other bidder will be a number between 50 and 100.



Auction 1
Your randomly determined valuation is ... ECU.
According to your entered bidding function you make a bid of ... ECU.
You entered the smaller bid. The other bidder has made a bid of ... ECU.
Your income from this auction is 0 ECU.

Auction 2
Your randomly determined valuation is ... ECU.
According to your entered bidding function you make a bid of ... ECU.
You entered the smaller bid. The other bidder has made a bid of ... ECU.
Your income from this auction is 0 ECU.

Auction 3
Your randomly determined valuation is ... ECU.
According to your entered bidding function you make a bid of ... ECU.
You entered the larger bid.
Your income from this auction is ... ECU.

Auction 4
Your randomly determined valuation is ... ECU.
According to your entered bidding function you make a bid of ... ECU.
You entered the larger bid.
Your income from this auction is ... ECU.

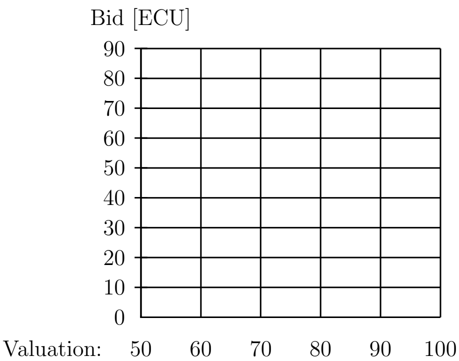
Auction 5
Your randomly determined valuation is ... ECU.
According to your entered bidding function you make a bid of ... ECU.
You entered the larger bid.
Your income from this auction is ... ECU.

Your income from all auctions in this round is ... ECU

Continue with the expectations

Round: 1 of 12 Remaining time [sec]: 113

You receive 0 ECU if you make the smallest bid in an auction
The other bidder receives 0 ECU if he makes the smallest bid in the auction
Your valuation will be a number between 50 and 100
The valuation of the other bidder will be a number between 50 and 100.



Your expectation of the bidding function of the other bidder is shown as a solid line.
The bidding function of the other bidder is shown as a dashed line. The average difference is ...
Your net gain in this round is:

income from auctions:	... ECU
loss from expectation:	... ECU
Total:	... ECU

Continue with the next round

The "difference" between the two bidding function—the expected and the actual bidding function of the other bidder—is simply the average absolute difference at the 6 entered points:

$$\frac{1}{6} \sum_{x \in \{50,60,70,80,90,100\}} |b_x - b_x^e|$$

At that stage **you do not know your own valuation for the object in this round.** On the right side of the screen you are asked to enter a bid for **six hypothetical valuations** that you might have for the object. These six hypothetical valuations are x, $x + 10$, $x + 20$, $x + 30$, $x + 40$, and $x + 50$ ECU. Your input into this table will be shown in the graph on the left side of the screen when you click on "draw bids". In the graph the hypothetical valuation is shown on the horizontal axis, the bids are shown on the vertical axis. Your input in the table is shown as six points in the diagram. **Neighbouring points are connected with a line automatically.** These lines determine your bid for all valuations *between* the six points for those you have made an input. For the other bidder the screen in the first stage looks the same and there are as well bids for six hypothetical valuations. The other bidder can not see your input.

2. Stage

The actual auction takes place in the second stage of each round. In each round we will play not only a single auction but **five auctions**. This is done as follows: **Five times a random valuation is determined** that you have for the object. Similarly for the other bidder five random valuations are determined. You see the following screen:[5]

[5]In the instructions the following figure was shown. This figure does not show the bidding function in the graph and the specific bids, gains and losses that would be shown during the experiment.

For each of your five valuations the computer determines your bid according to the graph from stage 1. If a valuation is precisely at x, $x + 10$, $x + 20$, $x + 30$, $x + 40$, or $x + 50$ the computer takes the bid that you gave for this valuation. If a valuation is between these points your bid is determined according to the joining line. In the same way the bids of the other bidder are determined for his five valuations. Your bid is compared with the one of the other bidder. The bidder with the higher bid has obtained the object.

Your income from the auction:

For each of the five auctions the following holds:

- The bidder with the higher bid obtains the valuation he had for the object in this auction added to his account minus his bid for the object.
- If the bidder with the higher bid has a negative valuation for the object, the ECU account is reduced by this amount.
- If the bid of bidder with the higher is a negative number, the amount is added to his ECU account.
- The bidder with the smaller bid obtains **no income** from this auction.

You total income in a round is **the sum of the ECU income from those auctions in this round where you have made the higher bid.**

This ends one round of the experiment and you see in the next round again the input screen from stage 1.

At the end of the experiment your total ECU income from all rounds will be converted into Euro and paid to you in cash together with your Show-Up Fee of 3.00 Euro.

Please raise your hand if you have questions.