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Rationalitätskonzepte,
Entscheidungsverhalten und
ökonomische Modellierung

No. 08-27

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December 2008

Financial support from the Deutsche Forschungsgemeinschaft, SFB 504, at the University of Mannheim, is gratefully acknowledged. We thank Giulio Bottazzi, Clemens Puppe, and Reinhard Selten for helpful comments.

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Auction Fever: Theory and Experimental Evidence*

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November 2008

It is not a secret that certain auction formats yield on average higher prices than others. The phenomenon that dynamic auctions are more likely to elicit higher bids than static one-shot auctions is often associated with the term "auction fever." On a psychological level, we consider the so-called pseudo-endowment effect as largely responsible for peoples' tendency to submit higher bids, potentially amplified by the source-dependence effect.

The phenomenon of auction fever is replicated in an experimental investigation of different auction formats within a private values framework where bidders have private but incomplete knowledge of their valuation for a hypothetical good. We suggest this assumption to be more realistic than definite private values, as assumed in the traditional IPV model. An additional experimental investigation within the traditional IPV framework does not either reveal any indication for the appearance of auction fever.

On the basis of our experimental observations we present a model of reference-dependent utility theory that comprehends the phenomenon by assuming that bidders' reference points are shifted by the pseudo-endowment and the source-dependence effect.

JEL classification: D44, C91, C92, D03

Keywords: auction fever, auction experiment, pseudo-endowment effect

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1 Introduction

The fact that many Internet auction providers and other web sites on Internet auctions advice bidders to protect themselves against auction fever and to avoid suffering from this "disease" indicates that auction fever is a widespread phenomenon.[1]

Bidding fever or auction fever may be defined as bidding over a pre-selected bidding limit (Ku, 2000) or as "the emotionally charged and frantic behavior of auction participants that can result in overbidding" (Ku, Malhotra, & Murnighan, 2005, p. 90)[2]. We differ from these definitions since we assume that, on the one hand, people usually have some idea about their valuation of the object on sale, but, on the other hand, do not really commit to a pre-selected and well-defined limit. Our interests are in the causative reasons in a technical way that result from the auction design, and to give empirical evidence for the link between these and the psychological constructs. Therefore, we see auction fever as a phenomenon, whose appearance can be influenced by the auction format and that induces bidders to bid higher in some format than in others where it does not appear or occurs less severely. In this paper we want to use this definition of auction fever as it is less detailed about the psychological background of the observed behavior and makes no assumptions about pre-selected bidding limits.

The induced difference in bidding behavior might be explained in many different ways. Possible explanations for the occurrence of auction fever are *competitive arousal*, *escalation of commitment*, and a *pseudo- or quasi-endowment effect*, or an *attachment effect*. Auction dynamics are supposed to be a precondition for these effects to occur. By auction dynamics we mean a multi-stage and multiple-bid process where bidders observe an increasing price in the auction and have the opportunity to raise their bids during the auction.

The competitive arousal hypothesis states that diverse factors in an auction (e.g., rivalry, time pressure) impact the decision-making of bidders due to increasing arousal (Ku et al., 2005). Escalation of commitment results from the justification of previous decisions by investing more instead of leaving the auction (Ku et al., 2005) or might alternatively be explained by loss aversion.[3]

Two more possible explanations for the occurrence of auction fever are based on prospect theory (Kahneman & Tversky, 1979) and an extension thereof. The first explanation is a pseudo- or quasi-endowment effect. The term pseudo-endowment effect describes an effect similar to the endowment effect (Thaler, 1980) but with the difference that there is no real ownership of the item. Nevertheless, the current high bidder might develop a psychological ownership of the item and thus have an other valuation for the item than without being the current high bidder (Ariely & Simonson, 2003). The endowment effect describes the observation that the minimum compensation that people demand to give up a good is with respect to several measures higher than the maximum amount they

[1]For example: "Set your buying limit before the auction starts DON'T get bidding fever, if the item goes above your limit, FORGET it!" (http://www.ukauctionguides.co.uk/hints_tips.htm, 11.04.2006), "It's true that 'auction fever' sometimes grips a gallery and propels bidding levels beyond the real value of certain coins. This, of course, is a plus if you happen to be the person who consigned those coins for sale, but something to be avoided if you're a buyer." (http://www.pocketchangelottery.com/article376.htm, 11.04.2006)

[2]Different from this definition, the term "auction fever" is also used to describe the attractiveness of auctions as a buying mechanism and the increased range of application of auctions.

[3]For the reinterpretation of escalation of commitment in terms of prospect theory and loss aversion see Whyte (1986).

are willing to pay to acquire the same good (the willingness to pay-willingness to accept disparity). For example the experiments of Kahneman, Knetsch, and Thaler (1990)[4] with coffee mugs and pens have shown that subjects valuate a coffee mug or a pen given to them by the experimenter on average higher than subjects that are given the possibility to buy such a mug or a pen.[5] In auction environments a related effect, called pseudo-endowment effect, is assumed to occur. When a bidder is the current high bidder in an auction she might feel a bit like already owning the item. If another bidder outbids her, she might consider this as taking away her item. To get the item that she considers as her item back, she might be willing to pay more than she was willing to pay for the item before the auction started, and before she was the high bidder for some period of time.

Another plausible explanation of auction fever, that is also related to prospect theory, bases on the model of Kőszegi and Rabin (2006). In their model of reference-dependent preferences, which is an extension of prospect theory, the reference point, from which gains and losses are measured, is determined by expectations about the outcome. Applying this approach to an auction framework leads us to the following argumentation: if a bidder is high bidder, she might expect to win the auction with higher probability. Thus, the high bidder has an other reference point than a bidder who is not high bidder. In this case auction fever would be due to an attachment effect caused by an increased subjective belief of buying the item. A higher probability of buying an item increases the sense of loss if the bidder does not win the auction. This might result in an increased willingness to pay and thus, in higher bids.[6] Following Kőszegi and Rabin (2006), we name this effect attachment effect.

Thus, the pseudo-endowment effect results from increased attachment because the item becomes part of the psychological endowment. The attachment effect results from an increase in the expected probability of winning and a resulting change of the reference point. Both effects are due to a change of the reference point and loss aversion.

Furthermore, Loewenstein and Issacharoff (1994) find, that people tend to value an item more highly, when they received this item due to a better performance in some task compared to a situation where they received it by chance.[7] They name this effect the *source-dependence effect*.

[4] For earlier experimental evidence on the endowment effect with lottery tickets see for example Knetsch and Sinden (1984), for an overview see Kahneman, Knetsch, and Thaler (1991).

[5] A recent study by Johnson, Häubl, and Keinan (2007) focuses on the psychological foundations of the endowment effect. According to their theory and their experimental results, the endowment effect is the result of different sequences of queries that sellers and buyers (choosers) pose. Queries focus on advantages and disadvantages of trade and each decision maker asks himself questions concerning his status quo first before considering the opposite state. A seller asks himself first value increasing questions considering positive aspects of the item and negative aspects of money, whereas the buyer does first focus on negative aspects of the item and positive aspects of money, which are both value decreasing. Assuming that the first query leads to suppression of answers to the second, this may lead to the endowment effect.

[6] In the consumer example of Kőszegi and Rabin (2006), the willingness to pay a given price depends on the price the consumer expects and the consumer's belief (probability) of buying the good. Thus, the willingness to pay depends on the probability which the consumer assigns to the event that the price lies below his expected price.

[7] Loewenstein and Issacharoff (1994) find a positive source effect that strengthens the endowment effect comparing situations of distributing a good by chance and distributing it dependent on a positive result in a task, but they find a negative source effect comparing situations of distributing a good by chance and distributing it dependent on a negative result in a task. In the second case of negative source dependence the endowment effect completely disappeared. In our experiment only positive source dependence may occur.

In a laboratory experiment, we test the impact of auction dynamics on the results and hypotheses on increasing bids associated with the pseudo-endowment effect and the attachment effect as well as the source-dependence effect. In the following, we do not distinguish between the pseudo-endowment effect and the attachment effect. In our experiment both effects are indistinguishable and we will refer to auction fever caused by these effects by the term pseudo-endowment effect. Nevertheless, we should not forget that the rational expectations-reference point model might be an alternative explanation.

The results of some empirical and experimental studies sustain the hypothesis that the pseudo-endowment effect occurs in auctions. Heyman, Orhun, and Ariely (2004) and Wolf, Arkes, and Muhanna (2005) examine effects of different durations of being the high bidder. Heyman et al. (2004) find in a survey-based experiment with fictitious second-price auctions and in an ascending auction of real goods with a fixed number of bidding rounds and bidding against five computerized bidding agents (unknown to the subjects), that a duration of being the high bidder manipulation results in higher bids in the group with the longer duration. Similarly, Wolf et al. (2005) find in an empirical study on eBay Motors' auctions, that people who were longer high bidder in an auction do more often re-bid, and in a laboratory experiment that people who examined a mug longer stated a higher maximum willingness to pay than those who held the mug for a short period of time in their hands. All these studies are designed from a psychological point of view.

A game theoretical model on loss averse bidders that is thus related to the pseudo-endowment, effect is the model of Dodonova and Khoroshilov (2004). They find that rational bidders, who anticipate the higher valuation of the item for them once they are high bidder, will include this anticipated change into their consideration and behave differently which has in particular effects on their entry decisions. This, in turn, has the effect that a first-bidder advantage occurs (because the second bidder of two bidders might not enter once an other bidder has already bid) and it has an impact on the optimal reserve price of the seller.

In our paper, we present a model of reference-dependent utility theory that comprehends the phenomenon of auction fever by modeling bidders' reference points being shifted by the pseudo-endowment effect and the source-dependence effect.

The paper is organized as follows. Section 2 describes two experimental settings including theoretical considerations as well as the presentation and analysis of the experimental results. In Section 3 we present our model of reference-dependent utility theory. Section 4 concludes.

2 An experiment on auction fever

In this section we present our experiment, that is designated to look into the phenomenon of auction fever. For this purpose, we investigate different auction formats within a private values framework. Beside the well-known IPV setting with well-defined private valuations we additionally focus our interest on a modified IPV setting where bidders are not fully aware of their private values at the time of the auction.

2.1 Different auction formats and the auction fever hypothesis

With our experiment we test the hypothesis that the design of an auction has an impact on individual bidding behavior in the way that some auction formats induce players to bid more conservatively while other formats induce more aggressive bidding behavior. The latter phenomenon is referred to as auction fever. Here, we distinguish between a static auction (sealed bid auction) and dynamic auctions (English style auctions), which differ with respect to the selection of current high bidders in the course of the auction.

In each auction, a hypothetical good (i.e. a ship) is offered to three bidders, each assigned the role of a shipping company owner. A limit price b_{min} of 500 Experimental Currency Units (ExCU) and a constant increment Δb equal to 5 ExCU are set. When the auction ends, the winner is paid her private valuation minus the price plus a lump-sum payment of 200 ExCU that all subjects receive. Prices are determined as second price plus one increment or a small variation thereof, such that the incentives in the four treatments match. In the following, we describe the four different auction formats, labeled by A1, A2, A3, and A4. For more details see the translation of the instructions in Appendix C.

- **Auction format A1**: In the first type of auction, participants are asked to submit their upper bidding limit only once. A bidding mechanism then outbids the bids against each other like in an English auction. Strictly speaking, bidders face a second-price or Vickrey auction in which the bidder with the highest bid receives the item and has to pay the second highest bid (Vickrey, 1961). In case of a tie, the winning bidder is randomly drawn from the set of the highest bidders and has to pay the highest bid.
  However, for this type of auction it is well known that participants tend to overbid their dominant strategies in the case of private values settings in which bidders are aware of their valuations (e.g., Kagel, Harstad, & Levin, 1987; Kagel & Levin, 1993; Kagel, 1995; Harstad, 2000). Therefore, in order to prevent such distortions, our subjects are told that they enter the bidding limit of a computerized agent who bids on their behalf in an English auction. Technically, the auction institution is a dynamic (English) proxy auction (Seifert, 2006). Even if the distortion was not completely eliminated by this procedure, the effect would work against our hypothesis. Note that the auctions in half of the groups in Treatment A1 are carried out under a pure second price rule (pricing rule 1, PR1). In other groups of this treatment, the winning bidders have to pay the second highest bid plus one increment (pricing rule 2, PR2). This differentiation is caused by the required comparability of our four auction formats.

- **Auction format A2**: In the second type of auction, we introduce dynamics to the auction design. In this Japanese-style auction, which is also called a ticker auction, the price increases incrementally and bidders are asked at every stage if they accept the current price level. If a bidder does not accept the price within 50 seconds, he has to quit the auction at this stage. Bidders are not informed about the number of remaining bidders. The bidding process stops, when at least all but one bidder have quit the auction. As before in Treatment A1, in the case that one bidder remains in the auction, this bidder receives the item and has to pay the price of the penultimate stage (PR1) or the last stage (PR2), respectively. In the case that all remaining bidders quit the auction at the same stage, the winning bidder is randomly drawn from the set of these bidders and has to pay the price of the last stage.

- **Auction format A3**: This type of auction is a variation of A2. As in auction A2, the price increases incrementally and bidders are asked at every stage if they accept the current price. Additionally, at every price level, a current high bidder is randomly chosen out of the set of accepting bidders. The process stops, when none of the other bidders accepts the next price level within 50 seconds. Then the last high bidder receives the item and has to pay the price of the stage before the auction stops, that is, the stage where she was designated as high bidder.[8]

- **Auction format A4**: This dynamic auction is a computerized form of an English (ticker) auction. As before, the price increases incrementally. On every price level, the bidder who first accepts the price is designated as current high bidder. Then the price increases by one increment and is shown for five seconds (counted downwards on the screen). After the five seconds the button to accept the new price is enabled for the other bidders. The process stops when the new price is not accepted by any other bidder within 45 seconds.

In order to assure that subjects are able to read the screen and recognize the current price, the information screen is shown for at least five seconds on every price level of the dynamic auctions A2, A3, and A4. In an A2 or A3 auction, for example, even if all bidders accept a price level in no time, the screen would not be updated before five seconds have passed. This delay is also introduced to reduce the speed in the dynamic auction such that bidders do not feel time pressure and to assure that bidders have enough time to become aware of the fact that they are the current high bidder in A3 and A4. Strahilevitz and Loewenstein (1998) find a positive influence of the duration of ownership on the endowment effect and Heyman et al. (2004) find the same in an auction environment concerning the duration of being the high bidder. As five seconds are rather short the main aspect of this feature in our experiment is not duration of ownership, but the possibility to become aware of the fact of being the current high bidder or, in the words of Strahilevitz and Loewenstein (1998): "It is not ownership per se, but awareness of ownership that causes reference point shifts."

In auctions of types A2, A3, and A4, compared to A1, bidders actively participate in a dynamic auction. Thus, according to our auction fever hypothesis, we expect higher bids in these auctions than in A1. Furthermore, in A3, we allow for the pseudo-endowment effect as the current high bidder might feel a bit like already owning the item and thus might have a higher valuation for the good than before and therefore we expect higher bids than in A2. Moreover, we intend to evoke a stronger pseudo-endowment effect in A4 than in Treatment A3, as a bidder achieves the current high bidder position by virtue of her own strength since she becomes current high bidder by being the fastest bidder in a stage of the dynamic auction. Hence, we expect an additional increase in the bids due to the source-dependence effect. Table 1 gives an overview of the four auction formats.

In the introduction we described two more factors, competitive arousal and escalation of commitment, that might lead to higher bids. We do not expect these two factors to have an impact on our results for the following reasons. Factors that might lead to competitive arousal that Ku et al. (2005) mention are uniqueness of being first, social facilitation, rivalry, and time pressure. There is no special hype about our auctions and even if there was one it would be the same for all treatments. Thus, uniqueness of an auction is not an argument here. Participants decide privately and anonymously. Social facilitation therefore should not be relevant. In addition, even if it was relevant, it would be the same in all treatments. Rivalry, in contrast to the standard competition argument

[8] Please note that the difference between the auction formats A2 and A3 is rather small, as the only difference is the random selection of the current high bidder in A3.

Table 1: Different auction formats and their expected bid-increasing effects

Auction format	Characteristics	Expected effects
A1	Proxy auction	
A2	Dynamic Japanese-style auction	Dynamics effect
A3	Dynamic auction with randomly designated current high bidder	Dynamics effect and pseudo-endowment effect
A4	Dynamic English-style auction	Dynamics effect, pseudo-endowment effect, and source-dependence effect

meaning that the less bidders are left, the more a bidder will bid,[9] should be the same in auctions of type A2–A4 and, more importantly, we only have groups of three bidders and bidders are not informed about the number of bidders left. As mentioned above, we tried to reduce time pressure in assuring that before leaving the auction every bidder had 50 seconds to think about the decision not to accept a price level. Justification of investments leading to escalation of commitment seems also not to be relevant, as even if there was a high investment in coming to our lab and thinking about the instruction, the differences between the treatments, if any, should be minor. That is, these factors might be relevant in auctions in general, but they are unlikely to be important for comparisons of treatments in our experiment.

Recapitulating, our hypothesis is, that the auction prices increase from auction format to auction format, where A1 and A2 differ with respect to auction dynamics, auction format A3 includes auction dynamics and the possibility of a pseudo-endowment effect, the dynamic auction in A4 allows for the pseudo-endowment effect and the source-dependence effect. In each case the direction of the expected effects is the direction of higher bids.

Implementation and organization of the experiment

The experiment was run at the University of Karlsruhe, Germany, with randomly selected students from various disciplines. Every subject participated in one auction with two other bidders (that is, groups of three bidders). When designing the experiment, we deliberately decided that each subject participates in one single auction only. Since we want the subjects to concentrate on one auction and since our auctions are very simple and easy to understand, we prefer this design over a setting where each subject participates in several consecutive auctions. We consider it as advantageous for our investigation, that each subject is confronted with one payoff relevant task and does not have several chances.

Altogether, we implemented seven treatments with twelve auctions (groups) per treatment (see Table 2). Each treatment is conducted in two sessions with 6 groups (18 subjects) in each session. Thus, 36 subjects participated in each treatment and altogether 252 subjects in the experiment.

As can be seen in Table 2 the treatments can be separated in the two classes “independent private valuations (IPV) with certain valuations” and “IPV with uncertain valua-

[9] The reason is that the bidder bids more aggressively when there is only one competitor left to beat because she thinks that she is closer to winning than when there are still a lot of bidders in the auction.

tions” which is indicated in the treatment names by a “c” or a “u”, respectively. In the temporal sequence of treatments the u-treatments were conducted before the c-treatments. From the experience of the u-treatments and our hypotheses on the c-treatments we concluded that auction format A3 would give no new insights, such that we neglected a possible treatment A3c. The presentation in this paper follows the logical order of first describing and discussing the c-treatments and then turning to the u-treatments.

Table 2: Number of groups (subjects) in the different treatments

Auction format	IPV with certain valuations	IPV with uncertain valuations	Sum
A1	A1c: 12 (36)	A1u: 12 (36)	24 (72)
A2	A2c: 12 (36)	A2u: 12 (36)	24 (72)
A3		A3u: 12 (36)	12 (36)
A4	A4c: 12 (36)	A4u: 12 (36)	24 (72)
Sum	36 (108)	48 (144)	84 (252)

The experiment was computerized. Each subject was seated at a computer terminal which was separated from the other subjects’ terminals. The subjects received written instructions, which were also read out by an experimental assistant (see Appendix C). Before the experiment started, each subject had to answer several questions at her/his computer terminal with respect to the instructions. After all subjects had given the right answers to all questions they were given their private information and then the auction started. No communication was permitted. Subjects could not identify which members of the session they actually interacted with. The experimental sessions lasted less than one hour. At the end of an experimental session, the subjects were paid in cash according to their profits in the game. The conversion rate was 5 Euro for 100 ExCU. The average, minimum, and maximum payments realized were €10.82, €3.85, and €18.10, respectively.

2.2 Auction fever in the IPV framework

To begin with, the first part of the experiment addresses the question whether auction fever occurs within an typical IPV framework, that is, at the time of the auction each bidder has an exact valuation of the item, which is only known to her and independent of the other bidders’ valuations.

IPV setting with certain private valuations

In this setting we initially neglect the somewhat artificial auction format A3 and restrict our analysis to the three established formats A1, A2, and A4, which we implement in an IPV environment with different private valuations. Since each bidder is aware of her valuation at the time of the auction, that is, there is *certainty* about the own valuation, these treatments are labeled by A1c, A2c, and A4c (see Table 2). Each auction (group) consists of three bidders B1, B2, and B3. Since we only conduct incentive-compatible auctions (see below), where we want subjects to concentrate on their individual values, we deliberately do not disclose the distribution of the values; subjects only know that their values are different. We conduct twelve auctions (groups) per treatment. Thus, 108 subjects participate in 36 auctions in this setting.

In each auction we use the same value configuration (see Table 3), which we choose for three reasons: First, the two low valuations 612 and 617 of B1 and B2 are very close (difference of one increment only) in order to arrange a competitive situation for the bidders who are expected to determine the price. Second, the large gap between B3's valuation of 652 and the two low values provides an environment that allows subjects of type B1 or B2, who suffer from auction fever, to "succumb this disease" and raise their bid far above their valuation, impelled by bidder B3. Third, each value lies between two possible price steps as bids are multiples of five. As a consequence, a bidder has to decide to bid below or above her valuation and cannot simply use it as an anchor.

Table 3: Bidders' private information about their individual valuations in the certainty treatments

Bidder	Valuation
B1	612
B2	617
B3	652

Theoretical considerations

To allow for comparability of the treatments, we have to assure that from a theoretical point of view a rational bidder behaves in the same way in all three different auction formats, that is, she submits the same (maximum) bid in all four treatments.

If we neglect the increment, it is well-known that in an IPV-framework each type of the here considered auction formats A1–A4 is an incentive-compatible mechanism, that is, bidding her individual valuation constitutes each bidder's (weakly) dominant strategy. As a consequence, in the equilibrium of an auction, the bidder with the highest valuation receives the item and has to pay the second highest valuation. Thus, an auction price of 617 ExCU is expected under all formats if increments are neglected.

By taking into account that in our auctions the price continuously increases by an increment of 5 ExCU, we have to adjust our theoretical considerations a little bit. The increment does not have an influence on (rational) bidding behavior in A3 and A4, but it may have in A1 and A2. In A3 and A4, the private valuation determines a bidder's benchmark, independent of the increment. Since the valuations 612, 617, and 652 lie between two auction prices, a bidder leaves the auction when the price exceeds her valuation for the first time, that is, at the auction price 615, 620, or 655, respectively. However, the rules of the auctions in A1 and A2 may induce bidders, dependent on the pricing rule, to deviate (a little bit) from their valuation. This is caused by the fact that in case of a tie the winning bidder is randomly chosen out of the set of the highest bidders. To be more precise: if the winning bidder has to pay the last announced price (pricing rule 1, PR1), she may have a small incentive to stop bidding on a price level below her valuation. On the other hand, if the unique highest bidder has to pay the penultimate price (pricing rule 2, PR2), she may have a small incentive to bid more than her valuation (at maximum one increment). Although we expect these effects as rather small and negligible, we establish both pricing rules in Treatment A1c as well in A2c by running half of the groups under PR1 and the other six groups under PR2 in order to compensate and control for these effects.

Experimental results of Treatments A1c, A2c, and A4c

First, there is no evidence that the two pricing rules PR1 and PR2, which we both use in the Treatments A1c and A2c, lead to different prices.[10] Thus, we take the liberty of pooling the two samples of Treatment A1c and of Treatment A2c, respectively.

Table 4: Average auction prices (in ExCU)

Treatment	A1c	A2c	A4c
Average price	617.08	620.42	621.25
Median price	615	615	620

Table 4 reflects the clear result of the certainty setting: the average auction prices in the three treatments are close together within an one-increment interval which also includes the theoretically predicted result. Unsurprisingly, there are no statistical differences.[11]

Table 5 reveals that 22 of 36 auctions end according to the game-theoretical prediction with an auction price of 615 or 620. Moreover, nine other auctions lead to either 610 or 625. Hence, the result of 31 auctions is considered to be (approximately) in line with theory. This observation suggests that most of the subjects are guided by their individual valuation, independent of the auction format, which is additionally supported by Table 11 and Table 12 in Appendix A. Note that 28 of 36 auctions are won by bidders of type B3 as theoretically predicted. This particularly applies for the twelve A4c-auctions, where all but one auction is won by B3 and ten A4c-auctions end “theoretically properly” (see also Table 5). This observation does not support any action fever hypotheses, but it is seen as consistent with the empirical hypothesis that the format of the English auction guides bidders to execute their dominant bidding strategy better than other formats. The applied χ^2-test, however, does not reveal significant differences in the distributions between the treatments.[12]

An analysis of the individual bids reveals that most of the subjects bid according to the dominant strategy. In Treatment A1c, 15 of 36 subjects bid exactly in line with their valuation.[13] 14 subjects bid less than their valuation, while seven subjects bid more than their valuation, where four of these submit a bid on the next price level above their valuation. In comparison to the aforementioned previous studies we do not find systematic bidding over the private values, which may be attributed to the different auction design (description of the auction as a dynamic proxy auction and nondisclosure of the distribution of valuations to the subjects).

[10] Applying U-tests, we do not find differences between the results of the PR1- and the PR2-groups in Treatment A1c and in Treatment A2c:
Treatment A1c: sample sizes: 6, 6; average prices: 618.33, 615.83; test statistics: 10; p-value: > 0.3.
Treatment A2c: sample sizes: 6, 6; average prices: 622.50, 618.33; test statistics: 10.5; p-value: > 0.3.

[11] Kruskal-Wallis one-way analysis of variance by ranks: test statistics: 2.444; p-value: 0.3.

[12] Table 5: χ^2-test: degree of freedom: 4; test statistics: 5.5; p-value > 0.2.
Table 12: χ^2-test: degree of freedom: 4; test statistics: 5.5; p-value > 0.2.

[13] In the groups of Treatment A1c under PR1 a bid is considered as in line with the valuation if it deviates by -2 or +3 from the valuation, whereas under PR2 only a deviation of -2 counts.

Table 5: Deviation of the auction price from the theoretically predicted price

		<	=	>	Sum
Treatment	A1c	4 (33.3%)	6 (50.0%)	2 (16.7%)	12
	A2c	4 (33.3%)	6 (50.0%)	2 (16.7%)	12
	A4c	0 (0%)	10 (83.3%)	2 (16.7%)	12
Sum		8 (22.2%)	22 (61.1%)	6 (16.7%)	36

The two dynamic auctions do also not induce subjects to bid more aggressively: in Treatment A2c, only two subjects are observed who exceed their valuation; in Treatment A4c, two of the three subjects, who bid more than their values, submit their last bid at the next price step above their valuation. Obviously, almost all of our subjects seem to be "healthy" and cannot be seduced by the auction format to raise their bids (far) above their valuation.

Result 1 *In an IPV-framework (with certain private valuations) there is no evidence that incentive-compatible auction formats induce bidders to systematically bid more than their valuation. Hence, there is no indication for auction fever if bidders are aware of their individual valuation.*

Furthermore, the fact, that in all auctions with certain private valuations subjects predominately bid according to their private valuation, provides evidence that the subjects understand well about the auction formats. This observation supports our decision of designing an experiment where each subject participates in one single auction only in order to concentrate her full attention to this auction.

2.3 Auction fever with private but uncertain valuations

Giving players a fixed evaluation for an object that is up for auction, is based on the classical economic model, which assumes that individuals walk through life with fixed evaluations about any commodity, which can be retrieved on demand. In a second study we base our approach on empirical research on human behavior, and assume that evaluations of objects are not fixed, but uncertain and rather subjectively constructed (Edwards, 1954, 1962; Fiske & Taylor, 1991).

For these reasons, we find it plausible rather than giving participants a fixed value as their evaluation to give them a distribution over an interval of the valuations. Here, we decide in favor for a "virtual" good with an given value distribution instead of a real good for the sake of controllability and comparability. For this purpose, in comparison to the IPV setting with certain values we change only one component of the experimental design: bidders knowledge about their private valuation at the time of the auction. Hence, we test the same auction formats as before in an IPV framework with uncertain valuations. That is, bidders are not exactly aware of their individual valuations, which, however, are still independent.

IPV setting with uncertain private valuations

In the "uncertainty treatments" bidders have private but incomplete information of their valuation at the time of the auction, that is, they know that their valuation lies uniformly distributed within a given interval which is private information. The valuation of the winning bidder is realized right after the auction ends. Due to a bidder's uncertainty about her own valuation, the treatments are labeled by A1u, A2u, A3u, and A4u. As before, three bidders participate in each auction. Since we conduct twelve auctions (groups) per treatment, 144 subjects participate in 48 auctions in this setting (see Table 2).

The three bidders B1, B2, and B3 in a group have different distributions (i.e., different intervals) and they know that they are different. However, they do not know other bidders' distributions. Note, although a bidder is uncertain about her valuation of the item (i.e., she only knows her distribution), the item does not have common value but only private values properties. This is due to the fact that a bidder is only aware of her own distribution (private information) and knows that the other bidders' distributions are different and independent. In the uncertainty treatments we use the same three different intervals in all groups (see Table 6). Note that the expected values (i.e., the means of the intervals) correspond to the private values of the certainty treatments (Table 3).

Table 6: Bidders' private information about their individual valuations in the uncertainty treatments

Bidder	Valuation interval (uniform distribution)	Expected valuation
B1	$[512, 712]$	612
B2	$[517, 717]$	617
B3	$[552, 752]$	652

Theoretical considerations

As in the certainty treatments, we have to assure, that theory predicts the same (maximum) bid of a rational bidder with a given distribution of her valuation for the item in the four auction formats, to allow for comparability of the treatments.

To show this, let $u : \mathbb{R} \to \mathbb{R}$ denote a representative bidder's von Neumann/Morgenstern utility function and let V denote the random variable of the bidder's valuation and $F(v)$ with $v \in [\underline{v}, \bar{v}]$ its distribution. Note that the valuation of the item for the bidder is determined after the auction in case the bidder is the winner. Hence, our bidder does not know the exact value of the item when she participates in the auction but she knows the distribution $F(v)$ of her value. The distribution $F(v)$ is private information of the bidder and thus not known by the other bidders and vice versa, that is, our bidder does not know other bidders' distributions. Therefore, our bidder can only build subjective beliefs about other bidders' valuations and their bidding behavior in the auction. Note that we have to take into account that a bidder's beliefs may depend on the auction format, that is, a bidder might be induced to update her beliefs during the course of a dynamic auction like the auction formats in A2, A3, and A4. A bidder's belief about the distribution of the other bidders' highest bid, denoted by the random variable R, is described by the distribution $G^k(r)$ and its derivative $g^k(r)$, where $k \in \{A1, A2, A3, A4\}$. The bidder's decision variable b is the (highest) bid she is willing to submit in the auction. Our bidder's expected utility $U(b)$ in all four types of auctions $k \in \{A1, A2, A3, A4\}$ is then given by

$$U(b) = \int_{b_{min}}^{b} \int_{\underline{v}}^{\bar{v}} u(w + v - r)\, dF(v)\, dG^k(r) + (1 - G^k(b))u(w), \tag{1}$$

where w denotes bidder's wealth position before the auction. The maximization of $U(b)$ with respect to b implies the first order condition $\partial U(b)/\partial b = 0$ which leads to the following expression

$$\int_{\underline{v}}^{\bar{v}} u(w + v - b)\, dF(v) - u(w) = 0. \tag{2}$$

Thus, the solution does not depend on the bidder's belief about other bidders' behavior, that is, the distribution of the other bidders' highest bid $G^k(\cdot)$. As a result, a bidder's optimal bid b^* has to be the same in all different auctions in our experiment. Moreover, b^* constitutes a dominant strategy (with respect to expected utility) for the bidder in the four auction formats.[14] We formulate the following statement.

Proposition 1 *In the setting with uncertain but independent private valuations, an expected utility maximizing bidder submits the same (maximum) bid in the four different auction formats of the Treatments A1u–A4u.*

For example, a risk neutral bidder, whose utility is given by $u(x) = x$, bids her expected valuation $b = \int_{\underline{v}}^{\bar{v}} v\, dF(v)$.

In the theoretical consideration we neglect the increment of 5 ExCU which is used in the auctions. By taking it into account, the theoretical considerations in Section 2.2 also apply for a bidder who computes her optimal bid b^* according to (1). In A3 and A4, b^* determines a bidder's benchmark, independent of the increment. That is, the bidder accepts every price below (or equal to) b^* and quits the auction when the price rises beyond b^*. The rules of A1 and A2, however, may induce bidders, dependent on the pricing rule, to deviate (a little bit) from b^*, as described in Section 2.2. On this account, we also make use of both pricing rules PR1 and PR2 in Treatments A1u and A2u.

Experimental results of Treatments A1u–A4u

Since the two pricing rules PR1 and PR2 lead to similar prices,[15] we again take the liberty of pooling the two samples of Treatment A1u and of Treatment A2u, respectively.

The results of the four treatments show a clear trend (Table 7): the average auction price increases from treatment to treatment. The overall comparison of the four different

[14] Note that this result also holds if the bidder updates her belief during the course of a dynamic auction. If in one of the dynamic auctions $k \in \{A2, A3, A4\}$ the auction price reaches $p > b_{min}$ with $G^k(p) > 0$, a bidder is induced to update her initial belief $G(z)$ to $G_p(z)$, for example $G_p(z) = G^k(z \mid z \geq p) = (G^k(z) - G^k(p))/(1 - G^k(p))$. It is easy to see that an update does not change condition (2). Hence, a bidder's optimal bid b^* does not depend on the price level p at which b^* is calculated. Note that this property immediately follows from the fact that b^* is a dominant strategy.

[15] Pairwise comparison of the results under the PR1- and the PR2-groups in Treatment A1u and in Treatment A2u by means of the U-test:

Treatment A1u: sample sizes: 6, 6; average prices: 611.67, 604.17; test statistics: 38.5; p-value > 0.5.

Treatment A2u: sample sizes: 6, 6; average prices: 627.50, 618.33; test statistics: 15; p-value > 0.3.

Table 7: Average auction prices (in ExCU)

Treatment	A1u	A2u	A3u	A4u
Average price	607.92	620.83	630.83	652.92
Median price	615	620	630	645

auction formats by means of the nonparametric Kruskal-Wallis test reveals significant differences between the four treatments and the additionally computed Jonckheere-Terpstra test supports the auction fever hypotheses that the auction prices rise significantly from Treatment A1u up to A4u.[16]

A closer look at the ranked prices of all groups, which are listed in Table 13 in Appendix A, supports this result. For example, four of the five highest prices belong to Treatment A4u. The highest price A2u-group is ranked on the sixth position and the highest price A1u-group on the 13th position. On the other hand, seven of the ten lowest prices belong to the Treatments A1u and A2u. The impact of the auction format also becomes evident by comparing the auction prices with a reference price. For comparability, we choose the two "risk-neutral prices" 615 and 620, which mark the theoretic prediction in the certainty setting in Section 2.2. Table 8 provides further evidence: while in Treatment A1u five auctions end below and four above the risk-neutral prediction, in Treatment A4u the relation is zero to ten.

Table 8: Deviation of the auction price from the "risk neutral price"

		$<$	$=$	$>$	Sum
Treatment	A1u	5 (41.7%)	3 (25.0%)	4 (33.3%)	12
	A2u	3 (25.0%)	4 (33.3%)	5 (41.7%)	12
	A3u	3 (25.0%)	2 (16.7%)	7 (41.7%)	12
	A4u	0 (0%)	2 (16.7%)	10 (83.3%)	12
Sum		11 (29.1%)	11 (29.1%)	26 (60.4%)	48

Remember, most of the auctions in the certainty setting are won by bidder B3, as theoretically predicted. The results in the uncertainty setting do not show such a clear picture (see Table 14 in Appendix A). Note that (only) 54.2% of the auctions are won by bidders of type B3. Although this share increases from 41.7% (A1u) up to 66.7% (A4u), the χ^2-test does not reveal significant differences in the distribution of the winning bidders between the four treatments.[17] Moreover, it is worthwhile to mention that we do not observe "irrational" bidding at all in the sense that subjects bid more than the upper bound of the distribution of their valuation.

Result 2 *The auction prices increase significantly in the uncertainty setting from A1u up to A4u. We attribute this to auction fever induced by the dynamics of the auctions*

[16] Kruskal-Wallis one-way analysis of variance by ranks: test statistics: 11.577; p-value < 0.001. Jonckheere-Terpstra test (e.g., Hollander & Wolfe, 1973): test statistics: 615; asymptotic normally distributed test statistics: 3.32; p-value < 0.001.

[17] χ^2-test: degree of freedom: 6; test statistics: 9.20; p-value > 0.1.

and the appearance of the pseudo-endowment effect and the source-dependence effect in the dynamic auctions.

Note that in the dynamic auctions not all subjects are captured by auction fever. In the auctions of A2u, we observe only five (of 36) subjects who bid above their expected valuation (i.e., they bid more than the next price step). This number increases in the auction of A3u up to ten subjects and in the auction of A4u up to 14 subjects. Notably, in the auctions of A2u, almost one third of the subjects (eleven subjects) end the auction on the price step right before or right their after expected valuation, what we denote as bidding in line with the expected valuation, while we observe only five of these in the auctions of A3u.

Let us additionally compare the results of the uncertainty treatments with their certainty counterpart.[18] Under format A1 we observe a higher average auction price in A1c than in A1u (617.08 vs. 607.92). Although this difference is not significant, it can be seen as in line with the hypothesis of risk-averse decision makers, which predicts higher auction prices under certainty than under uncertainty (in the expected utility approach, presented in Section 2.3, if the expected valuations and the certain valuations are equal). Auction format A2 induces almost the same average result to A2c and A2u (620.42 vs. 620.83). It seems that here auction fever compensates risk aversion, while the significant difference between A4c and A4u (621.25 vs. 652.92) speaks for a dominance of auction fever over risk aversion in the English auction A4.

In the following (Section 3), however, we move away from the expected utility approach and its concept of risk aversion towards an extended prospect theory framework including the concept of loss aversion. In this framework, we present a theoretical model which describes auction fever as a consequence of the pseudo-endowment effect and the attachment effect, which we consider as more appropriate for capturing the phenomenon of auction fever. However, before we feel qualified for developing and presenting this approach, we additionally investigate the impact of the real endowment effect on bidding behavior within our experimental framework.

2.4 Capturing the WTA reference point by a procurement auction

The endowment effect is associated with the well-known difference between the willingness to accept (WTA) and the willingness to pay (WTP) for the same item. For this purpose, we additionally design an experimental procurement auction in which the subjects have the possibility to sell an item (a ship), which they possess at the beginning of the auction. Remember, we assume that the course of a dynamic sales auction induces the pseudo-endowment effect (i.e., a person acts as if she would own the item although she does not). Therefore, in our setting a person's intrinsic WTP can only be measured in the one-shot auctions of Treatment A1u. Hence, we design its procurement counterpart, where subjects can sell an item in an auction, in order to record their WTA.

In this treatment, which is denoted by P1u, we run a procurement auction whose design is similar the sales auction in Treatment A1u. Participants are asked to submit their lower

[18] Pairwise comparison of the results of the certainty and uncertainty treatments by means of the U-test: A1c and A1u: sample sizes: 12, 12; average prices: 617.92, 607.08; test statistics: 65.5; p-value: > 0.2. A2c and A2u: sample sizes: 12, 12; average prices: 620.42, 620.83; test statistics: 61.5; p-value: > 0.2. A4c and A4u: sample sizes: 12, 12; average prices: 621.25, 652.92; test statistics: 20.5; p-value: < 0.01.

bidding limit once. A bidding mechanism then outbids the bids against each other starting from a high price and decreasing it by a constant decrement of 5 ExCU. Bidders face a second-price procurement auction in which the bidder with the lowest bid sells her item and is paid the second lowest bid.[19]

Treatment P1u consists of twelve groups of three bidders, who have private but incomplete information of their valuation for a hypothetical good. Right after the auction ends, the individual values realize. The distributions of subjects' valuations, presented in Table 9, differ in the position of the intervals from those used in A1u for several reasons.[20]

Table 9: Bidders' private information about their individual valuations in Treatment P1u

Bidder	Valuation Interval	Expected Valuation
B1	$[112, 312]$	212
B2	$[117, 317]$	217
B3	$[122, 322]$	222

At the end of the auction the winner sells his good at the price determined by the auction and the other bidders' valuations are drawn from their individual distributions. As the bidders are endowed with the good there is no additional lump-sum payment.

Table 10: Deviation of the individual bids b from $E[V]$ of all 36 bidders of A1u and of P1u and the twelve decisive bidders of A1u–A4u and of P1u

Treat-ment	Number of observations	Number of $b < E[V]$	Number of $b > E[V]$	Mean deviation	Median deviation
A1u	36	20	16	-17.56	-14.5
P1u	36	12	24	20.78	15.5
A1u	12	7	5	-22.00	-24.5
A2u	12	7	5	-8.25	-2
A3u	12	7	5	-4.92	-2
A4u	12	4	8	24.67	13
P1u	12	3	9	18.41	18

The results of the twelve groups are listed in Table 15 in Appendix A. Here, we compare the prices of P1u with those of Treatment A1u. For this purpose, we compute for each

[19] Since we did not find any differences between the groups under pricing rules PR1 and those under PR2 in the sales auctions (see Section 2.1), we decided to exclusively implement the second price rule (PR1) in Treatment P1u, because it is "theoretically neater" than rule PR2.

[20] Please note that we designed Treatment P1u after conducting and analyzing the Au-Treatments. Therefore, we had to find a compromise in designing the valuation intervals. We decided on the valuations in Table 9 because we wanted to avoid a negative lump-sum payment which would have been necessary if we had used the intervals of the Au-Treatments (Table 6). Moreover, since we conduct a simultaneous one-shot auction only, we need not care about the differences between the valuations. For these reasons, we decided on the three intervals in Table 9 whose expected values are different but close together.

bidder the deviation of the individual bid b from her expected value of the item $E[V]$ (see first and second row of Table 10). By applying the U-test, the hypothesis of an equal deviation of the bids from $E[V]$ in A1u and P1u is rejected.[21] The observation of this clear difference leads to the following result.

Result 3 ***WTP versus WTA:*** *Subjects' average deviation of their bid from their expected valuation significantly differs between A1u and P1u. In the sales auctions of A1u subjects tend to bid below their expected valuation, while in the procurement auctions of P1u they predominantly submit bids above their expected valuation, that is, $WTP < WTA$.*

Let us additionally have a look at the deviations of the individual bids from the expected values of all uncertainty treatments A1u–A4u and P1u. Since in Treatment A4u we can only observe the dropout price of the twelve decisive bidders (i.e., the bidders who determine the auction price), we restrict this comparison to these bidders, whose deviations are shown in the lower part of Table 10. Here, we again observe a clear trend: the average and median deviation increases from a negative value in A1u up to the positive values of A4u. Note that the average deviation in A4u is larger than in P1u, while it is the other way around for the median deviation. Moreover, while in A1u, A2u, and A3u only five of twelve decisive bidders exceed their expected valuations with their bid, eight decisive bidders in A4u and nine in P1u do so. With regard to WTP/WTA considerations, we apparently observe a continuous increase in bidders' WTP from A1u up to A4u where it reaches the WTA level of the bidders in P1u. These observations provide the basis for the theoretical model in the next section, which attributes the increase in the bidders' WTP to a change in their reference point caused by the course of a dynamic auction.

3 Modeling auction fever

In this section we present an extension of reference-dependent utility theories, as developed by Kahneman and Tversky (1979), Sugden (2003), and Kőszegi and Rabin (2006, 2007), as an alternative theoretical basis for describing bidding behavior in auctions.[22] Although different effects are suspected of being involved in provoking auction fever, we focus on the pseudo-endowment effect and the attachment effect, which is a special case of the former in our approach. These effects, which are considered of particular strength, base on the assumption, that the course of a dynamic auction shifts a bidder's reference point, and thus changes her win-loss reference position, which is crucial for a loss-averse bidder when deciding on her bid.

3.1 Reference-dependent utility theory

Let $\Omega \subset \mathbb{R}$ denote a set of consequences. Two consequences x, $y \in \Omega$ are compared by an individual according to the "gain-loss utility" $u(y,x)$, which is given by

$$u(y,x) = \varphi(c(y) - c(x))\,, \tag{3}$$

[21] A1u and P1u: sample sizes: 36, 36; average (median) deviations: -17.56 (-14.5), 20.78 (15.5); test statistics: 376; asymptotic normally distributed test statistics: 3.07; p-value: 0.001.

[22] Another example where a a model with reference-dependent preferences is used, is the work of Compte and Jehiel (2003), who apply it to bargaining situations.

with $\varphi(0) = 0$ and $\varphi(\cdot)$ being differentiable and strictly increasing. The function $c(\cdot)$ represents individual's "choiceless" or "consumption utility" and is assumed to be differentiable and strictly increasing (e.g., Loomes & Sugden, 1982; Kőszegi & Rabin, 2006). The function $\varphi(\cdot)$ describes a person's change in utility if the person changes from the riskless "reference consumption level" x to the riskless consumption of y. In the following, we consider the *loss-averse* and *reference-dependent* representation of $\varphi(\cdot)$ proposed by Sugden (2003), where $\varphi(\cdot)$ is assumed to be *strict zero-point concave*, that is, for all r, $r' \in \mathbb{R}$ and $r' < 0 < r$ it is $\varphi(r')/r' > \varphi(r)/r$. Note that this representation also includes functions with the property $\varphi(r) < -\varphi(-r)$ for all $r > 0$, which corresponds to Kahneman and Tversky's *value function*. Each strictly concave function $\varphi(\cdot)$, for example, satisfies strict zero-point concavity; the converse, however, is not true.

There exists a set of (objective) positions that a person can take, where each position is uniquely described by a lottery. The set of lotteries is denoted by Θ, where each lottery is determined by a probability measure over the set Ω of consequences. Consider a person who is in a certain position, which is called her reference position $R \in \Theta$, and who faces the decision either to change from R to position $X \in \Theta$ or to position $Y \in \Theta$. Here, we make use of the model of a *triadic* preference relation, which is assumed to be associated with a unique subjective expected utility representation (e.g., Sugden, 2003): weak reference-dependent preference is represented by

$$Y \succsim X \,|\, R \quad \Leftrightarrow \quad E[u(Y, R) - u(X, R)] \geq 0\,, \tag{4}$$

where the stochastic expectation applies to the joint probability distribution of the three lotteries X, Y, $R \in \Theta$. Strict preference $\succ$ and indifference $\sim$ are represented analogously. That is, the person strictly prefers Y to X, given the reference position R ($Y \succ X \,|\, R$), if and only if Y leads to a higher increase in the person's expected utility than X, viewed from the individual reference point R. Remember, not only the two alternative states X and Y may be associated with stochastic outcomes but also the reference point R.

3.2 Extension to a model with subjective reference points

We now extend this model by allowing the reference position also to be subjective and not to be associated with a unique lottery, like the objective opportunity positions. We suggest this extension because what exactly serves as a reference point usually can not be unambiguously defined (Kahneman & Tversky, 1979; Thaler, 1999).

Our model particularly applies to a decision problem with two alternative positions X and Y, where a person is physically (objectively) in position X and faces the opportunity to change to position Y. This, for example, describes a bidder's situation in an English auction when at certain price level she has to decide whether to bid and stay in the race, or not to bid and run the risk of losing the item.

As Kőszegi and Rabin (2006) and others, we make the somewhat extreme assumption that the person's probabilistic beliefs about the outcomes, given by the distributions of X and Y, are determined by the person's expectations before the decision and do not change during the decision process, e.g., in the course of an auction.[23]

[23] That is, we assume that during the course of an auction a bidder does not learn anything that changes her beliefs (i.e., reduces her uncertainty) about her valuation of the item. This approach differs from Rasmusen (2006), who assumes that uncertainty about private values in an auction is due to not having learned something that can be learned during the auction.

The extension bases on the idea that during the decision process the person – although (objectively) being in X – is psychologically attracted by position Y and (subjectively) imagines being in Y to a more or less large extent. Think of a bidder in a English auction who starts in position X, characterized by "no contact" with the item Y at the beginning of the auction. Then, during the course of the auction, the bidder adopts the position of the current high bidder, which subjectively brings her closer to the item Y. If she is outbidden thereafter, the high bidder experience may induce her to defend this position in order to reserve the loss of Y. In their challenging paper, Kőszegi and Rabin (2006) provide another illustrative example of a consumer who intends to buy a pair of shoes, while her willingness to pay positively depends on the probability with which she expects to buy the shoes. As mentioned before, this effect is called "attachment effect." The consumer starts from X, that is, no contact with the shoes, and comes closer to them by thinking about owing and using them. Since their actual value for the consumer presumably arises not until they are used, their value at the time of the purchase decision is modeled by a random variable Y.

These considerations lead us to an approach, in which we allow the person to look at the decision problem from two different angles: from where she actually is (X) and from where she wants to get to (Y). Hence, she compares X and Y not only from the X-perspective but also from the Y-perspective, that is, beside considering the "actual" question of moving from X to Y, the person also takes the approach of giving up Y and "returning" to X into account. In the next step, she deliberates about both perspectives by putting weight on the two different questions, in dependence of her subjective "nearness" to Y, and combines them in one decision problem. For this purpose, we model a person's reference position as a weighted combination of two the alternative positions X and Y and call it the person's subjective reference position, in which she finds herself during the decision process. Formally, the subjective reference position is described by

$$R(\lambda) = ((1-\lambda)X, \lambda Y)\,, \tag{5}$$

where $\lambda \in [0,1]$ denotes the person's "degree of nearness" to position Y. For the individual calculus, we extend the reference-dependent preference representation (4) by combining the two questions of (i) acquiring Y and (ii) of giving up Y in one calculus:

$$\begin{aligned} Y \succsim X \mid R(\lambda) \;\; &\Leftrightarrow\;\; E\left[(1-\lambda)(u(Y,X)-u(X,X)) + \lambda(u(Y,Y)-u(X,Y))\right] \geq 0 \\ &\Leftrightarrow\;\; (1-\lambda)E\left[(u(Y,X)-u(X,X))\right] + \lambda E\left[(u(Y,Y)-u(X,Y))\right] \geq 0 \\ &\Leftrightarrow\;\; (1-\lambda)E[u(Y,X)] - \lambda E[u(X,Y)] \geq 0\,. \end{aligned} \tag{6}$$

Strict preference $\succ$ and indifference $\sim$ are described analogously.[24] For $\lambda = 0$ or $\lambda = 1$ the person's reference position is X or Y, respectively. For $\lambda \in (0,1)$ the person "feels" between X and Y. The more the person considers herself as possessing Y, the more weight λ she shifts her focus from acquiring Y to not giving up or defending Y. This calculus is appositely reflected by the last line of (6), where $E[u(Y,X)]$ expresses the expected gain of changing from X to Y and $-E[u(X,Y)]$ the expected loss of giving up Y. If a person feels closely connected to Y, she adds a high weight to the latter, otherwise she mainly takes the gain of changing from X to Y into account.

[24] Note that this approach can easily be extended to three objective positions, an objective reference position (i.e., the position in which the person physically is at the time of her decision) and two alternative positions, which the person can reach from her objective reference position.

Note that a person, who is in such a pre-decision position where she notionally includes different options, will definitively leave this subjective position after the decision, since an active decision is assumed to be related to objective options only. Thus, the person will definitively change from her subjective reference position $R(\lambda)$ to one of the two objective positions X or Y, whatever she decides upon. By interpreting λ as the person's subjective probability of acquiring Y, this approach also allows to model the idea of Kőszegi and Rabin (2006).

Consider the case where the alternative position Y consists of a lottery $Z \in \Theta$ and the person has to pay price p for adopting Z, that is, $Y \equiv Z - p$. In this case, the person's subjective reference position also depends on p and hence is denoted by

$$R(\lambda, p) = ((1-\lambda)X, \lambda(Z-p))$$

for $\lambda \in [0,1]$. We now focus on the relationship of the person's willingness to pay (WTP) for adopting position Z (i.e., possessing Z) and her subjective reference position. Her WTP for Z, denoted by $\bar{p}$, is then defined as follows.

Definition 1 *The willingness to pay (WTP) $\bar{p}$ for a lottery Z of a person, whose preferences are characterized by $\succsim$, is given by*

$$\begin{aligned} Z - \bar{p} &\sim X \mid R(\lambda, \bar{p}) \\ Z - p &\succ X \mid R(\lambda, p) \ \ \textit{for} \ \ p < \bar{p} \\ Z - p &\prec X \mid R(\lambda, p) \ \ \textit{for} \ \ p > \bar{p}\,. \end{aligned}$$

We state the following result for our model.

Proposition 2 (Pseudo-endowment effect) *A loss-averse person's WTP for lottery Z exists, is unique, and depends positively on λ.*

The proof is presented in Appendix B. That is, the stronger the "degree of nearness" to Y (measured by λ) in the subjective reference position is, the more the person is willing to pay for achieving Y. This effect we refer to as the *pseudo-endowment effect*. "Pseudo" because the person, when facing the decision problem, is physically not in position Y (i.e., does not possess Y), but perceives herself as almost so.

As mentioned before, by interpreting λ as the person's subjective probability with which she expects to acquire Y, the pseudo-endowment effect also includes the attachment effect, that is, the higher the subjective probability is, the more is the person willing to pay for Y.

3.3 Reference-dependent preferences and bidding

Let us now consider dynamic auctions in more detail. In an English auction, for example, at a certain price level p, a person has to decide whether to bid or not to bid. In this situation, while feeling torn about the wish of possessing the item and the leave-taking of the item, the person has two options: by raising her hand the bidder seizes the chance to become high bidder, while by not raising her hand she runs the risk of losing the item. Here, the triadic reference relation seems to be an appropriate approach, taking a reference position and two alternatives into account.

A bidder's position before the auction begins is given by X, where the bidder only considers her WTP for the item from the point of view of not possessing it. The position of possessing the item is associated with lottery Z, to which a person comes closer in the course of the auction by bidding and adopting the current high bidder position.[25] Then, owning the item Z is only one step away. In our approach, a person's subjective reference position $R(\lambda, p)$ at price p lies between X and $Z - p$, where the "degree of nearness" to the item is reflected by the magnitude of λ in (5), which is assumed to depend on the history of the auction, particularly on its length and a bidder's "intensity of contact" with the item, caused by the experience of the high bidder position, e.g., how long the auction already lasts and how many times the person was current high bidder in the course of the auction. Proposition 2 states that a bidder's WTP positively depends on λ, that is, the stronger the "degree of nearness" to the high bidder position or the item is, the more a loss-averse bidder is willing to pay and thus to bid for the item.[26]

According to the previous section the pseudo-endowment effect is caused by a bidder's imagination of already possessing the item. Therefore, a bidder's subjective reference position includes the case of possessing the item, although by bidding she can only achieve the position of the current high bidder for sure. Hence, there is a difference between the subjective reference position and the position a bidder can adopt. We take this case into account and extend our model by distinguishing between the current high bidder position at price p, denoted by $Y(p)$, and the position of owning the item and paying p, denoted by $Z - p$, which is achieved if the bidder is not outbidden after becoming current high bidder. For this purpose, we model the lottery of the current high bidder position as

$$Y(p) = Q(p)(Z - p) + (1 - Q(p))X,$$

where

$$Q(p) = \begin{cases} 1 & : \quad q(p) \in [0, 1] \\ 0 & : \quad 1 - q(p) \end{cases}$$

describes the Bernoulli random variable of winning the auction at price p, that is, $q(p)$ is the bidder's subjective probability of not being outbidden after acquiring the high bidder position at price p. By assuming stochastic independence of $Q(p)$ and Z as well as of $Q(p)$ and X, the equivalence

$$Y(p) \succsim X \mid R(\lambda, p) \quad \Leftrightarrow \quad Z - p \succsim X \mid R(\lambda, p)$$

[25] Note that X describes a bidder's reference position in the one-shot auction A1u, while her reference position in the one-shot procurement auction P1u is given by Z.

[26] Consequently, in our one-shot auctions A1u and P1u bidders are characterized by $\lambda = 0$ and $\lambda = 1$, respectively. We additionally use the data of these two treatments for estimating the degree of loss aversion. For this purpose we apply the popular utility function

$$\varphi(x) = \begin{cases} x^\alpha & : \quad x \geq 0 \\ -\beta(-x)^\alpha & : \quad x < 0\,. \end{cases}$$

Since in experiments gains are small, we set $\alpha = 1$ in accordance with other researchers (e.g., Blondel, 2002). When the item's value V is uniformly distributed over $[\underline{v}, \bar{v}]$, we derive from condition (6) with $\lambda = 0$ the representative bid $b_{(A1u)}$ for A1u and with $\lambda = 1$ the representative bid $b_{(P1u)}$ for P1u as

$$b_{(A1u)} = E[V] - \frac{\sqrt{\beta} - 1}{\sqrt{\beta} + 1}\Delta \qquad \text{and} \qquad b_{(P1u)} = E[V] + \frac{\sqrt{\beta} - 1}{\sqrt{\beta} + 1}\Delta$$

with $E[V] = (\underline{v} + \bar{v})/2$ and $\Delta = (\bar{v} - \underline{v})/2$. Applying the method of nonlinear least square regression, the estimator for beta yields approximately 2 for both treatments (1.94 and 1.98), which is in line with other investigations (e.g., Tversky & Kahneman, 1992; Bateman, Kahneman, Munro, Starmer, & Sugden, 2005).

holds for every price level p.[27] Therefore, Proposition 2 also applies to the case that a bidder's subjective reference position $R(\lambda, p)$ includes the imagination of possessing the item $Z - p$ although she can only achieve the current high bidder position $Y(p)$ for sure. Note that the attachment effect corresponds to the case $\lambda(\cdot) \equiv q(\cdot)$, where $\lambda(p)$ is given by the person's subjective probability with which she expects to acquire Z at price p.

Let us now consider a dynamic auction with bidding stages $t = 1, 2, \ldots$, in which the price p_t increases stepwise, that is, $p_{t+1} > p_t$. The set of n bidders is denoted by $N = \{1, \ldots, n\}$. At every stage t, a bidder's information of the preceding course of the auction is described by the auction history $h(t) = (h_1, \ldots, h_{t-1})$ with $h(1) = \emptyset$. Hence, bidders' information of stage t is given by the component h_t, whose information content depends on the type of auction. In the Japanese auction A2, for example, the only useful information for a bidder is given by the price, that is, $h_t = p_t$.

The bidders are characterized by individual reference-dependent preferences (6), where a bidder's individual "nearness" parameter is assumed to be uniquely determined by the history of the auction, that is, every history $h(t)$ determines an specific value $\lambda_i(h(t)) \in [0, 1]$ for each bidder $i \in N$. It is additionally assumed that $\lambda_i(h(1)) = 0$, that is, the pseudo-endowment occurs in the course of the auction and not at its very beginning.[28] Then, in the course of the auction, the value of λ_i can change. This change, however, is assumed to be unexpected and not controllable for the bidders; it simply happens. At a certain stage, a bidder does not know her future values of λ_i and, thus, is not aware of future situations, that is, these are beyond her calculation.[29] On this presupposition, we suggest to consider a simple strategy.

Definition 2 *A bidding strategy in a dynamic auction is called myopic bidding strategy, if at every stage t, a bidder decides on bidding at price p_t only according to*

$$Y(p_t) \succsim X \mid R(\lambda_i(h(t)), p_t) \,. \tag{7}$$

Thereto, we propose the following solution concept.

Definition 3 *A constellation of myopic bidding strategies is called a myopic bidding equilibrium, if on every stage t, none of the bidders, who are still in the auction, has an incentive to deviate from her myopic bidding strategy (according to 7).*

It is obvious that the myopic bidding strategy forms such an equilibrium in our considered types of dynamic auctions, since it constitutes a bidder's "stage-wise" best reply to all possible bidding strategies of the other bidders.

Let us now consider the dynamic auctions more precisely. In the Japanese auction A2, the myopic bidding strategy induces bidders, who are still in the auction on stage t, to

[27] According to (6), we get

$$\begin{aligned} Y(p) \succsim X \mid R(\lambda, p) \;\; &\Leftrightarrow \;\; E\left[(1-\lambda)(u(Y(p), X) - u(X, X)) + \lambda(u(Y(p), Z-p) - u(X, Z-p))\right] \geq 0 \\ &\Leftrightarrow \;\; (1-\lambda)E[q(p) \cdot u(Z-p, X)] - \lambda E[q(p) \cdot u(X, Z-p)] \geq 0 \\ &\Leftrightarrow \;\; (1-\lambda)E[u(Z-p, X)] - \lambda E[u(X, Z-p)] \geq 0 \;\; \Leftrightarrow \;\; Z - p \succsim X \mid R(\lambda, p) \,. \end{aligned}$$

[28] One can additionally assume that $\lambda_i(\cdot)$ is non-decreasing in history, that is, for every history $h(t)$ and an arbitrary continuation h_{t+1}, which together lead to $h(t+1) = (h(t), h_{t+1})$, it is $\lambda_i(h(t+1)) \geq \lambda_i(h(t))$. This is particularly plausible for the case $\lambda(h(t)) = q(p_t)$, that is, a bidder's subjective probability of winning the auction increases with the auction price.

[29] This is in contrast to the assumption in the model of Dodonova and Khoroshilov (2004).

decide whether to accept p_t and stay in the auction or to leave the auction. Note that the history in a Japanese auction, denoted by $h_J(t)$, consists of a sequence of prices only, $h_J(t) = (p_1, \dots, p_{t-1})$, which then uniquely determines $\lambda_i(h_J(t))$ on stage t. Hence, if the bidders apply the myopic bidding strategy, the price path uniquely determines each bidder's exit price and, thus, a unique myopic bidding equilibrium.

In the English auction A4 things are more complex. The stages where a bidder was current high bidder has also to be included in the history $h_E(t)$, what allows us to model the impact of being current high bidder on λ_i, which we consider of paramount importance. For simplicity, let us assume that on every stage the current high bidder is identifiable for all bidders. Hence, the history is the same for all bidders and its components are given by $h_t = (p_t, i_t)$, where $i_t \in N$ denotes the current high bidder at price p_t.

We have already addressed several possible impact factors on a person's willingness to bid which depend on her experience in the history of an auction. According to our experimental results, we assign a bid increasing effect to the following factors: the award of the current high bidder position, achieving this position on her own, and being exclusive high bidder. Our experimental design, however, does not allow to directly estimate the quantitative effect of these factors. For this purpose and for the sake of simplicity, let us restrict the impact of a person's high bidder experience to the number of times the person was current high bidder. Hence, with $n_i(h_E(t))$ we denote the number of stages in the history of an English auction $h_E(t)$ where bidder i was current high bidder, $n_i(h_E(t)) \geq 0$ for all t and $n_i(\emptyset) = 0$. According to our hypothesis of the pseudo-endowment effect, we consider the number of times a bidder was current high bidder as relevant for λ_i.

Assumption 1 *Given an English auction at stage t. For two histories $h_E(t)$ and $h'_E(t)$, which both include the same price sequence $\{p_t\}$ it is: $\lambda_i(h_E(t)) = \lambda_i(h'_E(t))$ if $n_i(h_E(t)) = n_i(h'_E(t))$ and $\lambda_i(h_E(t)) \geq \lambda_i(h'_E(t))$ if $n_i(h_E(t)) > n_i(h'_E(t))$.*

Thus, the evolution of λ_i depends on the actual course of an English auction, in which bidders outbid each other. Since this usually does not follow a predetermined plan and allows different sequences of current high bidders, the bidders' λ-values and thus their decisions are not ex ante predictable, even if we exactly know their λ-functions. However, in our approach, every history determines a unique λ_i-sequence for each bidder i and thus a unique combination of myopic bidding strategies, which together form a myopic bidding equilibrium. Note that these considerations also apply to our auction format A3.

For the comparison of an English and a Japanese auction, we assume that a bidder's evolution of λ_i in the Japanese auction is equal to the evolution in the English auction if bidder i has never adopted the current high bidder position in the past.

Assumption 2 *Given an English auction and a Japanese auction with the same price sequence $\{p_t\}$. For every stage t it is: $\lambda_i(h_J(t)) = \lambda_i(h_E(t))$ if $n_i(h_E(t)) = 0$ and $\lambda_i(h_J(t)) \leq \lambda_i(h_E(t))$ if $n_i(h_E(t)) > 0$.*

As a consequence, the final price (auctioneer's revenue) in the English auction and auction A3 is greater or equal than the final price in the Japanese auction.

Moreover, in the English auction, a bidder decides according to (7) whether to bid at price p_t or not. Contrary to the Japanese auction A2 and auction A3, the latter decision does not mean that the bidder has to quit the auction. This allows a situation to occur in the English auction but not in its Japanese counterpart and in auction A3. That is, on stage t rule (7) decides against bidding, while it decides in favor of bidding on a later stage, since the value of λ_i has increased in the course of the auction. This difference additionally speaks for higher prices in the English auction than in the Japanese auction (and auction A3).

Finally, note that the one-shot second price auction A1 is captured by $\lambda_i(\emptyset) = 0$ for all $i \in N$. Here, a bidder's corresponding WTP (Proposition 2) determines her equilibrium bid as a dominant strategy. The following statement summarizes our considerations (including Assumption 1 and 2) with respect to auctioneer's revenue in the (myopic bidding) equilibrium of the second price auction π_{A1}, the Japanese auction π_{A2}, auction A3 π_{A3}, and the English auction π_{A4} which are in line with our experimental results of the IPV treatments with uncertain private valuations (Section 2.3).

Proposition 3 *For a given set of loss-averse bidders N and an identical price sequence in the dynamic auctions A2, A3, and A4, auctioneer's revenue is ranked as follows:*

$$\pi_{A4} \geq \pi_{A3} \geq \pi_{A2} \geq \pi_{A1} \,.$$

4 Conclusion

The results of our experiment support the view that auction fever occurs in an environment with private but uncertain valuations. Nevertheless, not all bidders are prone to auction fever. The effect is due to some of the bidders that determine the prices.

From our results we conclude that auction dynamics lead to higher bids, that is, multiple-stage and multiple-bid processes result in higher prices than static auctions in which bidders are only allowed to submit one bid or a bidding limit. Furthermore, we observe even higher bids in dynamic auctions when we allow for the pseudo-endowment effect. Particularly in the case that bidders have influence on becoming the high bidder (Treatment A4u), the source-dependence effect appears to be crucial.

All those effects do not occur in an experiment with certain private valuations. We introduce a model with uncertain private valuations and argue that it might be more realistic. We used this model in our experiment to retain better control of bidders' valuations compared to auctioning real items.

In addition we present a theoretical model with reference-dependent preferences und subjective reference points. The results that we deduce from that model reproduce our hypotheses on auction fever, that is, the expected ranking of auctioneer's revenues or prices. A next step might be to extend the model by including some more of the effects that are supposed to evoke auction fever besides the pseudo-endowment effect.

Note that in our model the bidder's that are prone to auction fever feel no regret after winning the item. This is in line with a hypothesis of Ku et al. (2005) which is supported by their data. In our model, from the ex-post point of view the pseudo-endowment effect does not lead to overbidding, but maybe to bidding at the upper bound of a valuation interval. Underestimating the value of owning the item ex-ante would be explained by naming a value at the lower limit of the interval when the bidder does not yet have the experience of feeling close to the item.

The results should be valuable especially for auctioneers that are interested in raising their revenue. We advise bidders in a dynamic auction to be aware of the possible change in their willingness-to-pay before deciding to participate and to develop a bidding strategy taking this into account. On the other hand, it might happen that in a sealed bid auction a bidder starts thinking about owning the item only after she submitted her bid and she might realize that she has bid too low when it is too late to raise the bid.

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Appendix

A Ranked auction results of all groups

Table 11: Ranked auction results of all groups in the certainty treatments A1c, A2c, A4c

Rank	Price [ExCU]	Treatment	Group number	Winning bidder
1	655	A2c	1	B1
	655	A4c	11	B1
3	650	A1c	7	B2
	650	A2c	12	B1
5	625	A1c	2	B3
	625	A4c	4	B3
7	620	A1c	3	B1
	620	A1c	1	B3
	620	A1c	5	B3
	620	A2c	3	B3
	620	A2c	6	B3
	620	A4c	1	B3
	620	A4c	2	B3
	620	A4c	3	B3
	620	A4c	5	B3
	620	A4c	9	B3
17	615	A1c	6	B3
	615	A1c	9	B3
	615	A1c	10	B3
	615	A2c	4	B3
	615	A2c	5	B3
	615	A2c	9	B3
	615	A2c	10	B3
	615	A4c	6	B3
	615	A4c	7	B3
	615	A4c	8	B3
	615	A4c	10	B3
	615	A4c	12	B3
29	610	A1c	8	B2
	610	A1c	4	B3
	610	A1c	11	B3
	610	A2c	2	B1
	610	A2c	7	B3
	610	A2c	8	B3
	610	A2c	11	B3
36	595	A1c	12	B1

Table 12: Distribution of winning bidders in the certainty treatments A1c, A2c, A4c

		B1	B2	B3	Sum
Treatment	A1c	2 (16.7%)	2 (16.7%)	8 (66.7%)	12
	A2c	3 (25.0%)	0 (0%)	9 (75.0%)	12
	A4c	1 (8.3%)	0 (0%)	11 (91.7%)	12
Sum		6 (16.7%)	2 (5.6%)	28 (77.8%)	36

Table 13: Ranked auction results of all groups in the uncertainty treatments A1u–A4u

Rank	Price [ExCU]	Treatment	Group number	Winning bidder
1	710	A4u	4	B3
2	700	A4u	10	B3
3	695	A3u	4	B2
4	690	A4u	1	B3
5	670	A4u	6	B1
6	660	A2u	1	B2
	660	A3u	10	B3
8	655	A3u	1	B1
9	655	A4u	9	B2
10	650	A2u	12	B3
	650	A3u	7	B3
	650	A4u	11	B3
13	640	A1u	11	B2
	640	A2u	5	B2
	640	A4u	5	B2
16	635	A2u	8	B3
	635	A3u	5	B3
	635	A4u	7	B3
19	630	A3u	11	B3
	630	A3u	12	B2
21	625	A1u	5	B3
	625	A1u	6	B3
	625	A1u	9	B3
	625	A2u	3	B3
	625	A4u	3	B3
	625	A4u	12	B3
27	620	A1u	10	B1
	620	A2u	2	B3
	620	A2u	9	B3
	620	A3u	2	B3
	620	A3u	3	B2
	620	A4u	8	B2
33	615	A1u	4	B1
	615	A1u	8	B1
	615	A2u	4	B2
	615	A2u	10	B3
	615	A4u	2	B3
38	610	A1u	1	B2
39	605	A1u	3	B1
	605	A2u	6	B3
	605	A2u	7	B2
42	600	A3u	9	B3
43	590	A1u	2	B3
	590	A3u	8	B1
45	585	A3u	6	B2
46	575	A1u	7	B3
47	560	A2u	11	B2
48	550	A1u	12	B1

Table 14: Distribution of winning bidders in the uncertainty treatments A1u–A4u

		B1	B2	B3	Sum
Treatment	A1u	5 (41.7%)	2 (16.7%)	5 (41.7%)	12
	A2u	0 (0.0%)	5 (41.7%)	7 (58.3%)	12
	A3u	2 (16.7%)	4 (33.3%)	6 (50.0%)	12
	A4u	1 (8.3%)	3 (25.0%)	8 (66.7%)	12
Sum		8 (16.7%)	14 (29.2%)	26 (54.2%)	48

Table 15: Ranked auction results of all groups in the uncertainty treatment P1u

Rank	Price [ExCU]	Group number	Winning bidder
1	285	2	B1
2	275	6	B2
3	255	9	B2
4	250	12	B1
5	240	11	B1
6	235	1	B3
7	225	7	B1
	225	10	B2
9	220	5	B3
10	210	3	B2
11	200	4	B3
	200	8	B1

B Theoretical addenda

B.1 Proof of Proposition 2

By introducing the function

$$U(\lambda, p) = (1-\lambda)E[u(Z-p, X)] - \lambda E[u(X, Z-p)]\,, \tag{8}$$

condition (6) can be written as

$$Z - p \succsim (\precsim)\; X \,|\, R(\lambda, p) \quad \Leftrightarrow \quad U(\lambda, p) \geq (\leq)\; 0\,.$$

According to (3), the expected gain-loss utilities with regard to the random variables X and Z are given by

$$\begin{aligned} E[u(Z-p, X)] &= E[\varphi(c(Z-p) - c(X))] \quad \text{and} \\ E[u(X, Z-p)] &= E[\varphi(c(X) - c(Z-p))]\,, \end{aligned}$$

and their derivatives with respect to p by

$$\begin{aligned} \frac{\partial E[u(Z-p, X)]}{\partial p} &= -E[\varphi'(c(Z-p) - c(X)) \cdot c'(Z-p)] < 0 \quad \text{and} \\ \frac{\partial E[u(X, Z-p)]}{\partial p} &= E[\varphi'(c(X) - c(Z-p)) \cdot c'(Z-p)] > 0\,, \end{aligned}$$

because $\varphi(\cdot)$ and $c(\cdot)$ are strictly increasing functions. Thus, the derivative of (8) with respect to p is given by

$$\frac{\partial U(\lambda,p)}{\partial p} = (1-\lambda)\frac{\partial E[u(Z-p,X)]}{\partial p} - \lambda\frac{\partial E[u(X,Z-p)]}{\partial p} < 0 \tag{9}$$

and the derivative with respect to λ by

$$\frac{\partial U(\lambda,p)}{\partial \lambda} = -E[u(Z-p,X)] - E[u(X,Z-p)]\,. \tag{10}$$

A person's WTP $\bar{p}$ for adopting Z as described in Definition 1 implies

$$U(\lambda,\bar{p}) = 0 \tag{11}$$

and

$$U(\lambda,p)\begin{cases} > 0 & \text{for } p < \bar{p} \\ < 0 & \text{for } p > \bar{p}\,. \end{cases} \tag{12}$$

Due to (8), condition (11) can only be fulfilled for $\lambda \in (0,1)$ if either

$$E[u(Z-\bar{p},X)] > 0 \quad \text{and} \quad E[u(X,Z-\bar{p})] > 0\,, \tag{13}$$

or

$$E[u(Z-\bar{p},X)] < 0 \quad \text{and} \quad E[u(X,Z-\bar{p})] < 0\,. \tag{14}$$

Here, we make use of Theorem 3 of Sugden (2003), which states that, if $\varphi(\cdot)$ is strictly zero-point concave, as assumed, the preferences are strictly *exchange-averse*, what implies

$$Z-p \succsim X\,|\,X \;\;\Rightarrow\;\; Z-p \succ X\,|\,Z-p \tag{15}$$

and

$$Z-p \precsim X\,|\,Z-p \;\;\Rightarrow\;\; Z-p \prec X\,|\,X \tag{16}$$

for all p. According to (4), (15) is equivalent to

$$E[u(Z-p,X) - u(X,X)] \geq 0 \;\;\Rightarrow\;\; E[u(Z-p,Z-p) - u(X,Z-p)] > 0$$

and hence to

$$E[u(Z-p,X)] \geq 0 \;\;\Rightarrow\;\; E[u(X,Z-p)] < 0\,, \tag{17}$$

and (16) is equivalent to

$$E[u(Z-p,Z-p) - u(X,Z-p)] \leq 0 \;\;\Rightarrow\;\; E[u(Z-p,X) - u(X,X)] < 0$$

and hence to

$$E[u(X,Z-p)] \geq 0 \;\;\Rightarrow\;\; E[u(Z-p,X)] < 0\,. \tag{18}$$

From (13) and (14) combined with (17) and (18) follows that these relationships only allow for (14), what implies that (10) is strictly positive for $\lambda \in (0,1)$. If $\lambda \in \{0,1\}$, either condition $E[u(Z-\bar{p},X)] = 0$ or condition $E[u(X,Z-\bar{p})] = 0$ determines $\bar{p}$. It follows from (17) for $\lambda = 0$ and from (18) for $\lambda = 1$ that in both cases (10) is strictly positive. Applying the implicit function theorem to the situation where a person is indifferent between buying and nor buying described by (11), together with (9) we then have

$$\frac{d\bar{p}}{d\lambda} = -\frac{\frac{\partial U(\lambda,\bar{p})}{\partial \lambda}}{\frac{\partial U(\lambda,\bar{p})}{\partial p}} > 0$$

for $\lambda \in [0,1]$.

Finally, we have to show that $\bar{p}$ exists and is unique. Since we restrict our considerations to non-negative WTP, condition $Z \succsim X \mid X$ applies, that is, a person, who is in X, prefers Z to X, if the price for Z is zero. Since this case corresponds to (17) with $p = 0$, (8) induces $U(\lambda, p = 0) > 0$ for $\lambda \in [0,1]$. The strictly negative derivative (9) together with function $\varphi(\cdot)$'s property of strict zero-point concavity then implies that there exists a unique $\bar{p} > 0$ that fulfills the conditions (11) and (12), which completes the proof.

C Translation of instructions

Instructions in all treatments consist of two pages each. The instructions for treatments A1c, A2c, and A4c as well as those for treatments A1u–A4u share a common first page, respectively. Treatments A1c and A1u, A2c and A2u, as well as A4c and A4u, each have the same second page, respectively. In treatments A1c, A2c, A1u, and A2u we distinguished between two pricing rules, such that in these cases we have two variants of the second page of the instruction. In Treatment P1u we conduct a procurement auction and, thus, the instruction differs from the other instructions.

C.1 First page of Treatments A1c, A2c, and A4c

Instructions

In the following you are going to participate in an experiment on auctions. At this, you will make your decisions as bidder isolated from the other participants at your computer terminal. In the auction you may earn money in cash. How much you will earn depends on your decisions and on the decisions of the other participants. The monetary units of account in the experiment are so-called currency units (CU).

Point of Departure

Imagine to be the owner of a ship who offers cruises. That is why you participate in an auction in that the cruise ship "One World" is auctioned **once**. Besides you, 2 other bidders participate in this auction.

In case you purchase the ship by the auction, its value **W** will turn out by the use in your fleet. Your value **W** will be announced to you directly before the auction at your screen.

Please note: the value **W** is different for every bidder and neither do you know the values of the other bidders nor do they know your value.

In addition you have a lump-sum payment **F** of 200 CU at your disposal.

Payoff

1. In case **you** are awarded the ship for the price **P**, your profit from the auction G is calculated with your value **W** as:

   $$\mathbf{G} = \mathbf{W} - \mathbf{P}$$

   Please note: If you pay more for the ship than it is worth to you, that is, $\mathbf{P} > \mathbf{W}$, then your profit from the auction will be negative, that is, $\mathbf{G} < \mathbf{0}$.

2. In case you are not awarded the ship your profit from the action equals zero, i.e.:

   $$\mathbf{G} = \mathbf{0}$$

The payoff you receive is your lump-sum payment **F** plus your profit G from the auction, i.e.:

$$\text{Payoff} = \mathbf{F} + \mathbf{G}$$

Your payoff will be converted into Euro and paid cash to you at the end of the experiment, whereby 1 CU corresponds to 5 Euro Cent. The payment will be individually and anonymously.

C.2 First page of Treatments A1u–A4u

Instructions

In the following you are going to participate in an experiment on auctions. At this, you will make your decisions as bidder isolated from the other participants at your computer terminal. In the auction you may earn money in cash. How much you will earn depends on your decisions and on the decisions of the other participants. The monetary units of account in the experiment are so-called currency units (CU).

Point of Departure

Imagine to be the owner of a ship who offers cruises. That is why you participate in an auction in that the cruise ship "One World" is auctioned **once**. Besides you, 2 other bidders participate in this auction.

In case you purchase the ship by the auction, its value $\mathbf{W}$ will turn out only by the use in your fleet. However, calculations show that the value $\mathbf{W}$ of the ship for you lies uniformly distributed between $\mathbf{W_0}$ and $\mathbf{W_1}$. This means, that the ship has at least a value of $\mathbf{W_0}$ and at most a value of $\mathbf{W_1}$ for you, whereby all values (integers) from $\mathbf{W_0}$ to $\mathbf{W_1}$ have equal probability.

Please note: the boundaries $\mathbf{W_0}$ and $\mathbf{W_1}$ are different for every bidder. Your individual boundaries $\mathbf{W_0}$ and $\mathbf{W_1}$ will be communicated to you directly before the auction on your screen; the boundaries of the other bidders however are unknown to you.

In addition you have a lump-sum payment $\mathbf{F}$ of 200 CU at your disposal.

Payoff

1. In case **you** are awarded the ship for the price $\mathbf{P}$, the value of the ship for you will be determined immediately after the auction by drawing a value $\mathbf{W}$ out of the uniform distribution over $\mathbf{W_0}$ to $\mathbf{W_1}$. Your profit from the auction is then calculated as:

   $$\mathbf{G = W - P}$$

   Please note: If you pay more for the ship than it is worth to you, that is, $\mathbf{P > W}$, then your profit from the auction will be negative, that is, $\mathbf{G < 0}$.

2. In case you are not awarded the ship your profit from the action equals zero, i.e.:

   $$\mathbf{G = 0}$$

The payoff you receive is your lump-sum payment $\mathbf{F}$ plus your profit G from the auction, i.e.:

$$\text{Payoff} = \mathbf{F + G}$$

Your payoff will be converted into Euro and paid cash to you at the end of the experiment, whereby 1 CU corresponds to 5 Euro Cent. The payment will be individually and anonymously.

C.3 Second page of Treatments A1c and A1u, pricing rule 1

Auction

The auction by which the ship is to be sold has the following rules.

You submit exactly **once** at the beginning of the auction a bid $\mathbf{B}$. Your bid expresses how many CU you are maximal willing to pay for the ship.

The minimum bid $\mathbf{B_{min}}$ for the ship is **500 CU**. That means that you have to bid at least 500 CU, that is, $\mathbf{B} \geq \mathbf{B_{min}} = 500$. Thereby bids have to be **a multiple of 5 CU**, that is, $\mathbf{B} = 500, 505, 510, 515, 520, \ldots$
When submitting your bid you do not know the bids of the other bidders nor do they know your bid.
When all 3 bidders have submitted their bids, the automatical bidding process, which outbids the bids against each other, starts, and thereby determines the bidder who is awarded the ship. At this the auction price starts at the minimum bid of $\mathbf{B_{min}} = 500$.
The auction price is gradually increased by 5 CU at any one time. If a bid is exceeded by the auction price it quits the auction. The bidding process may end in two ways depending on the bids:

1. If the highest bid and the second highest bid differ, the bidding process stops when the auction price exceeds the second highest bid. We denote the remaining highest bid with $\mathbf{B}^*$ and with $\mathbf{P}$ the price at which the bidding process has stopped whereby $\mathbf{P}$ equals the second highest bid plus 5 CU. The bidder who submitted the bid $\mathbf{B}^*$ is awarded the ship and has to pay the price $\mathbf{P}$. In this case $\mathbf{P} \leq \mathbf{B}^*$. That means, that the bidder has to pay his bid $\mathbf{B}^*$ or less depending on the price $\mathbf{P}$ at which the bidding process stops.

2. If at least two bidders have submitted the same bid $\mathbf{B}^*$ which is the highest bid, the bidding process stops at the price $\mathbf{P} = \mathbf{B}^*$. Then one of these bidders is randomly selected to be awarded the ship at the price $\mathbf{P} = \mathbf{B}^*$. In this case the bidder who is awarded the ship has to pay his bid.

Please note: in this auction you are only allowed to submit a bid **once**, which may not be changed afterwards!
Before the auction begins, you are asked some questions on the screen concerning the rules. This is to assure that all participants have understood the instructions.

C.4 Second page of Treatments A1c and A1u, pricing rule 2

Auction

The auction by which the ship is to be sold has the following rules.
You submit exactly **once** at the beginning of the auction a bid $\mathbf{B}$. Your bid expresses how many CU you are maximal willing to pay for the ship.
The minimum bid $\mathbf{B_{min}}$ for the ship is **500 CU**. That means that you have to bid at least 500 CU, that is, $\mathbf{B} \geq \mathbf{B_{min}} = 500$. Thereby bids have to be **a multiple of 5 CU**, that is, $\mathbf{B} = 500, 505, 510, 515, 520, \ldots$
When submitting your bid you do not know the bids of the other bidders nor do they know your bid.
When all 3 bidders have submitted their bids, the automatical bidding process, which outbids the bids against each other, starts, and thereby determines the bidder who is awarded the ship. At this the auction price starts at the minimum bid of $\mathbf{B_{min}} = 500$.
The auction price is gradually increased by 5 CU at any one time. If a bid is exceeded by the auction price it quits the auction. The bidding process may end in two ways depending on the bids:

1. If the highest bid and the second highest bid differ, the bidding process stops when the auction price exceeds the second highest bid. We denote the remaining highest bid with $\mathbf{B}^*$ and with $\mathbf{P}$ the price at which the bidding process has stopped whereby $\mathbf{P}$ equals the second highest bid. The bidder who submitted the bid $\mathbf{B}^*$ is awarded the ship and has to pay the price $\mathbf{P}$. In this case $\mathbf{P} < \mathbf{B}^*$. That means, that the bidder has to pay less than his bid $\mathbf{B}^*$.

2. If at least two bidders have submitted the same bid $\mathbf{B}^*$ which is the highest bid, the bidding process stops at the price $\mathbf{P} = \mathbf{B}^*$. Then one of these bidders is randomly selected to be awarded the ship at the price $\mathbf{P} = \mathbf{B}^*$. In this case the bidder who is awarded the ship has to pay his bid.

Please note: in this auction you are only allowed to submit a bid **once**, which may not be changed afterwards!
Before the auction begins, you are asked some questions on the screen concerning the rules. This is to assure that all participants have understood the instructions.

C.5 Second page of Treatments A2c and A2u, pricing rule 1

Auction

The auction by which the ship is to be sold has the following rules.
The auction starts with a price of **500 CU**. You will be asked on your screen, if you are willing to pay this price for the ship. If this is the case, click on the OK-button on your screen or press the enter key. You have 50 seconds to do this. If you are not willing to pay this price, do nothing until the 50 seconds passed. In doing this, you automatically quit the auction. On your screen you can always see, how many seconds are left until the 50 seconds have expired. Every bidder makes his decision without knowing the decisions the decisions of the other two bidders.
If at least two bidders are willing to pay the price of 500 CU, the auction price is raised by **5 CU**. The bidders that are still in the auction then again have 50 seconds to decide, if they are willing to pay 505 CU for the ship. If again at least two bidders accept, the auction price will be raised by another 5 CU and so on. The bidding process may end in two ways depending on the bids:

1. The auction price is raised stepwise by 5 CU until at a price $\mathbf{P}$ only one bidder is still in the auction. That is, there is only one bidder who is willing to buy the ship at the actual auction price $\mathbf{P}$. This bidder is awarded the ship and has to pay the price $\mathbf{P}$.

2. The auction price is raised stepwise by 5 CU until at a price $\mathbf{P}$ at least two bidders are still in the auction, who, however, all quit at the next price $\mathbf{P} + \mathbf{5}$ **CU**. One of these bidders is randomly selected to be awarded the ship for the price $\mathbf{P}$.

Before the auction begins, you are asked some questions on the screen concerning the rules. This is to assure that all participants have understood the instructions.

C.6 Second page of Treatments A2c and A2u, pricing rule 2

Auction

The auction by which the ship is to be sold has the following rules.
The auction starts with a price of **500 CU**. You will be asked on your screen, if you are willing to pay this price for the ship. If this is the case, click on the OK-button on your screen or press the enter key. You have 50 seconds to do this. If you are not willing to pay this price, do nothing until the 50 seconds passed. In doing this, you automatically quit the auction. On your screen you can always see, how many seconds are left until the 50 seconds have expired. Every bidder makes his decision without knowing the decisions the decisions of the other two bidders.
If at least two bidders are willing to pay the price of 500 CU, the auction price is raised by **5 CU**. The bidders that are still in the auction then again have 50 seconds to decide, if they are willing to pay 505 CU for the ship. If again at least two bidders accept, the auction price will be raised by another 5 CU.
The auction price is raised stepwise by 5 CU until at a price $\mathbf{P}$ at least two bidders are still in the auction, at the next price $\mathbf{P} + \mathbf{5}$ **CU**, however, only one bidder or no bidder is left. That

is, at the price $\mathbf{P + 5}$ **CU** either all or all but one bidder quit. The bidding process stops and the high bidder or one of the high bidders, if there are more than one, is then awarded the ship. The price for the ship equals in both cases **P CU**.

1. If there is only one high bidder, that is, at the price $\mathbf{P + 5}$ **CU** all but one bidders quit, this remaining bidder is awarded the ship and has to pay the price **P**.
2. If there are several high bidders, who all quit at the price $\mathbf{P + 5}$ **CU**, one of these is randomly selected to be awarded the ship for the price **P**.

Before the auction begins, you are asked some questions on the screen concerning the rules. This is to assure that all participants have understood the instructions.

C.7 Second page of Treatments A3c and A3u

Auction

The auction by which the ship is to be sold has the following rules.
The auction starts with a price of **500 CU**. You will be asked on your screen, if you are willing to pay this price for the ship. If this is the case, click on the OK-button on your screen or press the enter key. You have 50 seconds to do this. If you are not willing to pay this price, do nothing until the 50 seconds passed. In doing this, you automatically quit the auction. On your screen you can always see, how many seconds are left until the 50 seconds have expired. Every bidder makes his decision without knowing the decisions the decisions of the other two bidders.
If two or more bidders are willing to pay the price of 500 CU, one of these bidders is randomly selected as current **high bidder**, which we refer to as **HB500**. You are always informed if you are the current high bidder or not.
The auction price is then raised by **5 CU**. The bidders that are still in the auction then have 50 seconds to overbid the current high bidder **HB500** by accepting the auction price 505 CU. The current high bidder **HB500** is at this not allowed to bid but he remains in the auction, as a matter of course.
If at the price 505 CU no bidder signals his willingness to buy the ship at this price, the current high bidder **HB500** is awarded the ship and has to pay 500 CU.
If one or several bidders signal their willingness to pay 505 CU, one amongst these is randomly selected as new current **high bidder HB505**. After that the auction price is again raised by 5 CU to 510 CU. The bidders that remained in the auction including the former high bidder **HB500** have then again 50 seconds to overbid the current high bidder **HB505** by accepting the auction price 510 CU.
If at least one bidder accepts the auction price 510 CU, the auction price increases to 515 CU, and so on.
Before the auction begins, you are asked some questions on the screen concerning the rules. This is to assure that all participants have understood the instructions.

C.8 Second page of Treatments A4c and A4u

Auction

The auction by which the ship is to be sold has the following rules.
The auction starts with a price of **500 CU**. This price is displayed to you for 5 seconds on your screen. After that, you will be asked, if you are willing to pay this price for the ship. If this is the case, click on the OK-button on your screen or press the enter key. You have 45 seconds to do this. On your screen you can always see, how many seconds are left until the 45 seconds have expired.

The bidder, who accepts the price 500 CU first, becomes current **high bidder**. We refer to this bidder as **HB500**. The other bidders may not accept the price 500 CU anymore. You are always informed if you are the current high bidder or not.
The auction price is then raised by **5 CU**, even if the 45 seconds have not expired, and the new state of the auction is shown to you on your screen for 5 seconds. The bidders then have up to 45 seconds to overbid the current high bidder **HB500** by accepting the auction price 505 CU. The current high bidder **HB500** is at this not allowed to bid.
If at the price 505 CU no bidder signals his willingness to buy the ship at this price, the current high bidder **HB500** is awarded the ship and has to pay 500 CU.
If a bidder signals his willingness to pay 505 CU, this bidder becomes new current **high bidder HB505**. After that the auction price is again raised by 5 CU to 510 CU. Again all bidders but **HB505** can bid at this price and the one who accepts first becomes new high bidder. If, on the other hand, no bidder accepts at 510 CU, the current high bidder **HB505** a awarded the ship and has to pay 505 CU.
If a bidder bids 510 CU, he becomes new current **high bidder HB510** and the auction price increases to 515 CU, and so on.
Before the auction begins, you are asked some questions on the screen concerning the rules. This is to assure that all participants have understood the instructions.

C.9 Treatment P1u

Instructions

In the following you are going to participate in an experiment on selling. At this, you will make your decisions as bidder isolated from the other participants at your computer terminal. You may earn money in cash. How much you will earn depends on your decisions and on the decisions of the other participants. The monetary units of account in the experiment are so-called currency units (CU).

Point of Departure

Imagine that you are the owner of a cruise ship. By its usage this ship yields profits and, thus, has some value for you. You also have the possibility to sell the ship via a selling process, that will be explained to you in detail in the following. Besides you, 2 other ship owners, who each own one ship, participate in this selling process, but only **one** ship can be sold.
In case you do not sell the ship, its value **W** for you will turn out only by its usage. Calculations show, that the value **W** of the ship for you lies uniformly distributed between $\mathbf{W_0}$ and $\mathbf{W_1}$. This means, that the ship has at least a value of $\mathbf{W_0}$ and at most a value of $\mathbf{W_1}$ for you, whereby all values (integers) from $\mathbf{W_0}$ to $\mathbf{W_1}$ have equal probability.
Please note: the boundaries $\mathbf{W_0}$ and $\mathbf{W_1}$ are different for every ship owner. Your individual boundaries $\mathbf{W_0}$ and $\mathbf{W_1}$ will be communicated to you directly before the selling process on your screen; the boundaries of the other bidders however are unknown to you.

Payoff

1. In case you do **not** sell your ship, the value of the ship for you will be determined by drawing a value **W** out of your uniform distribution over $\mathbf{W_0}$ to $\mathbf{W_1}$, which then corresponds to your **payoff**.
2. In case you sell your ship at price P, this selling price corresponds to your **payoff**.

Your payoff will be converted into Euro and paid cash to you at the end of the experiment, whereby 1 CU corresponds to 5 Euro Cent. The payment will be individually and anonymously.

Selling process

The process by which the ship is to be sold has the following rules.
You submit exactly **once** at the beginning of the selling process an offer **A**. With this offer you express how many CU you want to have **at least** for the ship.
Offers have to be **a multiples of 5 CU**, that is, $\mathbf{A} = 100, 105, 110, 115, 120, \ldots$
When submitting your offer you do not know the offers of the other two vendors nor do they know your offer.
When all 3 vendors have submitted their offers, the automatical selling process, which outbids the offers against each other, starts and thereby determines the vendor who is selling the ship.
Hereby, the selling process starts at the highest offer, which is thus eliminated. Then the price is gradually decreased by 5 CU at any one time. If an other offer is reached by the price, this offer also quits the process. The selling process may end in two ways depending on the offers:

1. If the lowest and the second lowest offer differ, the selling process stops when the price reaches the second lowest offer. We denote the remaining lowest offer with $\mathbf{A}^*$ and with $\mathbf{P}$ the price at which the selling process has stopped whereby $\mathbf{P}$ equals the second lowest offer. The vendor who submitted the offer $\mathbf{A}^*$ is accepted as seller and sells his ship for the price $\mathbf{P}$. In this case $\mathbf{P} > \mathbf{A}^*$. That means, that the seller receives for his ship more than what he asked for by his offer $\mathbf{A}^*$.

2. If at least two vendors have submitted the lowest offer $\mathbf{A}^*$, the process stops at the price $\mathbf{P} = \mathbf{A}^*$. Then one of these vendors is randomly selected as seller at the price $\mathbf{P} = \mathbf{A}^*$. In this case the selling price equals the offer of the vendor who sells the ship.

Please note: you are only allowed to submit **once** an offer at the beginning of the selling process, which may not be changed afterwards!
Before the selling process begins, you are asked some questions on the screen concerning the rules. This is to assure that all participants have understood the instructions.

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