Shill Bidding and Information in eBay Auctions: A Laboratory Study[*]

Jim Ingebretsen Carlson[‡] and Tingting Wu[§]

Abstract

In online auction platforms, like eBay, sellers have frequently been observed to bid on their item to artificially increase its price, and this is known as shill bidding. We represent the eBay auction in a sequential auctions environment using lab experiments and study the behavioral consequences of sellers being able to participate as shill bidders and of being informed about buyers' past bidding histories. We find that the possibility of shill bidding in ongoing and future auctions benefits sellers, affects mostly high private-value buyers. At the same time, buyers seem to overreact to the threat of shill bidding in the future auctions by biding too high in the current auction. However, providing sellers with buyers' bidding histories between auctions has little impact on auction outcomes and players' bidding behavior. Moreover, there are significant differences between buyers' and sellers' dynamic bidding behavior during auctions, which can be used to identify shill bidding sellers from buyers.

Keywords— Shill Bidding, eBay Auction, Information Disclosure, Lab Experiment
JEL Classification— C92 D44 D83 D90

[*]We are thankful for the constructive comments received from Ola Andersson, Jordi Brandts, Dan Levin, Antonio Miralles, Rosemarie Nagel, Erik Wengström and seminar participants at Universitat Autònoma de Barcelona, Lund University and at the CNEE 2017 meeting in Lund. We also thank Lluis Puig for helping us in conducting the experimental sessions. We gratefully acknowledge financial support from the Jan Wallander and Tom Hedelius Foundation [P2016-0126:1].

[†]Faculty of Information and Communication Science, Universitat Oberta de Catalunya, Spain
[‡]PredictBy Research and Consulting, Spain
[§]Singapore-ETH Centre, Future Resilient Systems Programme, Singapore

1 Introduction

Online auction platforms are widely used all over the world. eBay is one of the world's largest e-markets and its auction platform is a core business. One of the reasons why eBay has a large share of the online auction market is because of its millions of active users and relatively good reputation among its competitors like Amazon, eBid, uBid, etc.[1] However, it has been frequently observed that sellers bid on their own item with the aim to artificially increase its price in online auctions (see, e.g., Engelberg and Williams (2009); Grether et al. (2015); Kauffman and Wood (2005)). This practice is known as shill bidding. Since shill bidding harms the buyers' surplus, auction houses, such as eBay, have said that they spend money and time in order to detect and prevent shill bidding. If an auction platform could not protect its users from shill bidding, then the users may easily switch to another platform. In fact, eBay even has a shill bidding policy where they inform buyers regarding this issue.[2] However, online shill bidding is easy to organize (e.g., with a large set of paid colluders, a rotating scheme with peer sellers, or through the use of an alternative online identity) and hard to detect. In response to this, computer scientists are developing and improving machine learning algorithms that consistently identify shill bidders on eBay (see, e.g., Alzahrani and Sadaoui (2020); Dong et al. (2012); Ganguly and Sadaoui (2018)).

Another reason why shill bidding is common in eBay auctions may be that the price of the item is determined by the second highest bid submitted in the auction. This is known as the second price rule and allows for a seller to increase the price of an item without winning it. Specifically, shill bidding sellers can strategically drive up the second highest bid in the auction by submitting a shill bid that is greater than the current second highest bid submitted in the auctions and smaller than the winning bid. Moreover, shill bidding is mostly effective when the number of participating buyers is low since the margin between the winning and second highest bid becomes smaller as the number of buyers increase. This could make eBay auctions attractive for shill bidders since Einav et al. (2015) find that the average number of buyers in eBay auctions is 2.7, when analyzing a large random sample among 350 million eBay listings. At the eBay auction platform, it is common to find similar items that are listed in separate auctions that start and end at different points in time, which is similar to the sequential auctions environment. The fact that buyers might encounter the possible shill bidding in eBay auctions, as discussed above, introduces a threat of shill bidding in both ongoing and future auctions that buyers may participate in. It is important to address this feature to study shill bidding in the eBay auction since it may have important effects on behaviors and outcomes. Moreover, this feature has not been captured by any previous studies of shill bidding. Meanwhile, we single out the future threat from the current threat by not allowing shill bidding in the first ongoing auction and we do not impose penalties on shill bidders. In one ongoing auction, without future auctions, shill bidding should not change buyers' final bids when buyers have private values (see, e.g., Graham et al. (1990); Izmalkov (2004); Riley and Samuelson (1981)). This, together with the second-price rule, gives a seller incentives to shill bid in an ongoing auction since this can increase earnings. However, when similar items are auctioned sequentially,

[1] eBay is scored 79 in the most recent American Customer Satisfaction Index (ACSI) for internet retails (see reference at this website).

[2] eBay's shill bidding policy can be found at this page on eBay.

shill bidding in future auctions may affect behavior in ongoing auctions. Since the purpose of shill bidding is to extract more surplus from buyers, the buyers may take the threat of shill bidding from future auctions into consideration by raising their final bids to win the ongoing auction. They would do this in order to account for the higher expected price in the future auction, which is due to the submitted shill bids, as suggested by Milgrom and Weber (2000); Gong et al. (2014). Through the threat of shill bidding from future auctions itself, a seller may, thus, also increase earnings in the earlier auctions, even without the actual participation. Therefore, we identify the threat of shill bidding in ongoing and future auctions separately to study how shill bidding affects buyers' and sellers' behavior as well as auction outcomes.

eBay and other online auction houses make the bidding history from finished and ongoing auctions public.[3] Hence, shill bidding sellers can potentially extract more surplus from buyers by using the bidding information from past auctions to calibrate their shill bids in ongoing auctions.[4] Previous studies present both theoretical and empirical evidence that bidding information indeed affects auction players' strategies in different auction environments (see, e.g., Cason et al. (2011) Milgrom and Weber (2000)). These studies mainly focus on the effects of bidding information from buyers to buyers. However, it is important to study the effects of the bidding information on both buyers' and sellers' behavior when sellers receive information and may act as shill bidders in auctions. Such effects have not been mentioned by either policymakers at eBay nor other shill bidding studies. As a response to shill bidding sellers using buyers' bidding histories from past auctions to extract surplus from buyers in future auctions, buyers may change their ongoing auction bidding strategies to hide their private value from sellers. This effect is similar to what is typically found in the voluntary information disclosure literature where agents partially disclose private information (See, e.g., Dye (1985); Jin et al. (2017); Jansen and Pollak (2014)). Thus, when sellers are allowed to shill bid in future auctions and are informed of buyers' ongoing auction bids, the buyers who may participate in both auctions face a trade-off between the needs to increase their ongoing auction bid to account for the higher expected price in the future auction and to lower their ongoing auction bid to hide their private value information. Furthermore, the threat of shill bidding and the public bidding histories may both affect prices and earnings of buyers and sellers.

In this paper we experimentally investigate the effects of shill bidding in future and ongoing auctions as well as of publicly disclosing bidding history information to sellers in the eBay auction format. In particular, we investigate how buyers in an ongoing auction react to the threat from shill bidding in a future auction, and how this affects outcomes in ongoing and future auctions. In addition to this, we study the impact of providing the sellers with different amounts of buyers' bidding histories from the early auction before they decide whether or not to shill bid in the future

[3]In the eBay bidding history, each buyer is assigned an anonymous ID. However, this ID is kept the same in all auctions, thus making it possible to track individual buyers and their bids.

[4]In an eBay auction, sellers can also choose to set up private listings of their item in which the bids and the name of buyers will be hidden, and only the sellers themselves can see this information with the main purpose of hiding the buyers' identity information for high-value items. In this case, the bidding history information cannot be seen by other buyers and other sellers who are selling a similar item. However, if sellers set up several private listing auctions of similar items, then they get access to bidding history, which can be used to calibrate shill bids in the later auctions. Information of private listings can be found at this eBay listing info page .

auctions. Laboratory experiments are well-suited for investigating shill bidding and information disclosure to sellers since they offer control and observability of shill bidders' behavior. These are two characteristics that naturally occurring data typically do not have.

The experiment comprises 20 rounds of sequential auction games played by randomly matched sellers and buyers. Two items are sold using two distinct and sequentially carried out auctions in each round of our experiment. The auction format in our experiment was chosen to replicate the eBay auction environment closely. In each auction, the bidders can choose to submit as many upwarding bids as they wish during one minute. As on eBay, the auctions use the second price rule: the bidder who wins the item pays a price which is equal to the second highest bid submitted by a different bidder. Therefore, a shill bidding seller can increase the price without winning the item by submitting the second highest bid and, thereby, increase earnings. We employ the following between-subjects experimental design with three treatments: The seller cannot shill bid in the first auction in any treatment. In the baseline treatment the seller cannot shill bid in the second auction either. In the other two treatments, the seller can choose to participate and submit shill bids in the second auction. The two shill bidding treatments differ by the amount of information that is provided to the seller. The seller is provided with either the complete buyer bidding history or no information at all from the first auction. When provided, the information is given to the sellers before they choose whether or not to participate as shill bidders in the second auction. We do not allow the sellers to shill bid in the first auction in order to separate the threat of shill bidding in future auctions from the information effect of showing the bidding history to the sellers since the sellers would otherwise observe the bidding information during the first auction. Furthermore, the trade-off between increasing the first auction bid due to the threat of shill bidding in future auctions and decreasing the first auction bid to hide the private value information remains regardless if the seller can shill bid in the first auction or not. Therefore, we believe that the treatment in which the seller can shill bid in the second auction and is provided with the complete buyer bidding history approximates the real-world situation at eBay fairly well.[5]

Our main contributions to the literature are as follows: We are the first to present empirical evidence that the possibility of shill bidding in future and ongoing auctions increases prices and hurt buyers' earnings and benefits sellers. Interestingly, we observe that buyers overreact to the threat of shill bidding in future auctions by submitting higher early auction bids than expected in theory and by the observed shill bids. Therefore, sellers manage to increase their earnings in the early auctions without having to submit high shill bids in the future auctions. Moreover, the threat of shill bidding increases the efficiency of early auctions. However, we find no significant effect on buyers' final bid behavior of making the bidding history from the first auction public to sellers between the two shill bidding treatments. Studying an auction format similar to the eBay auction also allows us to conduct a dynamic bidding analysis as bidders are allowed to submit several upward bids during an auction. We observe that most buyers (more than 70%) submitted multiple bids during auctions. We also find that buyers' dynamic bidding behavior differs substantially across time within an auction. Moreover, buyers submit higher bids in the early auctions when

[5]Shill bidding in the first auction could have the effect that buyers with low private values would not bid in the auction since the shill bid would be higher than their desired bid.

there is a threat of future shill bidding compared to when there is not. Finally, we present empirical evidence that buyers and sellers bid differently in many aspects, i.e, timing, numbers of bids. It may, thus, be possible for buyers and auction houses to detect whether or not a seller is submitting shill bids during an auction. However, buyers in our data do not react differently to a bid submitted by a seller or another buyer.

1.1 Related literature

Our study differs from the existing literature in several ways. To the best of our knowledge, we are the first to study shill bidding experimentally in sequential auctions, that is to conduct at least two auctions in each experimental round in which the same players participate and where buyer's private values are unchanged. While several studies investigate information effects in auctions, they typically involve information from buyers or sellers to buyers. We differ from the literature by studying information given from buyers to shill bidding sellers. Finally, we investigate shill bidding in an open outcry auction format that closely replicates the eBay auction format.

To the best of our knowledge, Kosmopoulou and De Silva (2007) and McCannon and Minuci (2020) have conducted the only experimental studies on shill bidding.[6] Kosmopoulou and De Silva (2007) investigated shill bidding when a single unit was auctioned in an ascending clock auction format with bidders having common values. The study supports their theoretical prediction that shill bidding is harmful to sellers as prices decrease. This is different from our study, in which sellers may profit from shill bidding since buyers have private values for the items. Moreover, information effects are crucial in common value auctions with shill bidding since the seller's shill bids make buyers revise their bids upwards. In the shill bidding treatment of Kosmopoulou and De Silva (2007), this effect occurs within an auction and the information is transmitted from sellers to buyers. In contrast, we study the information effect of how buyers react when they provide information to sellers between auctions and estimate this effect between treatments. McCannon and Minuci (2020) study shill bidding and trust when a single unit is auctioned by either a first- or second price auction with bidders having private values. They find that buyers bid lower due to shill bidding, which partly can be explained by their level of trust and expectations of others' trust.

The issue of information disclosure in auctions is a more studied topic (See, e.g., Dufwenberg and Gneezy (2002); Kannan (2010); Cason et al. (2011); Katuščák et al. (2015)). The experimental study by Grebe et al. (2021) involves information disclosed from buyers to sellers when sellers can set Buy-It-Now prices in single eBay auctions. They find that sellers react to buyers' past bidding histories when deciding on their Buy-It-Now prices. Cason et al. (2011) study how buyers learn and prevent other buyers to learn from buyers' bidding histories in sequential first price auctions. Similar to our study, the authors investigate an information effect on buyers between auctions. But in contrast to us, sellers cannot shill bid and information is revealed from buyers to buyers. The authors find an information effect since buyers pool to hide their private values. We believe that we do not find an information effect because we only informed the buyers about the

[6] Ockenfels et al. (2006) also summarized other papers related to shill bidding. Nevertheless, only some of them are the main references for our project.

information condition in the instructions and since the information was given to a different kind of player (a seller). This was intentional in order to replicate the eBay environment since there is nothing reminding the buyers that the sellers can use their information during a real eBay auction. Differently in Cason et al. (2011), buyers are constantly reminded that the other buyers can use their bids since they receive, and themselves use, the bidding information between each auction to figure out the other buyers' private values. This connection is not as clear in our setting. While previous studies have investigated information that is transmitted between auctions, they differ to our study since we look at how buyers react when their information is revealed to sellers.

Several studies have conducted experiments with sequential auctions (see, e.g., Février et al. (2007); Leufkens et al. (2012); Neugebauer and Pezanis-Christou (2007)), but none of these study shill bidding or the type of information effect employed in this study. In addition, Wang (2006) studied the strategic similarity of sequential eBay and second price auctions without shill bidding sellers, when the two highest bids from the early auctions are revealed to the bidders. The experimental results suggest that buyers bid similarly in the two auction formats. Ariely et al. (2005) have also studied the eBay auction experimentally. However, the authors did not allow sellers to shill bid and they implemented a version of the eBay auction in which time was discrete. This is different from our environment where subjects are given one minute to bid for the items.[7]

Shill bidding has been studied theoretically in single auctions where buyers have independent private values by, e.g., Izmalkov (2004); Graham et al. (1990). Both studies show that shill bidding can be profitable for the seller. In contrast, Chakraborty and Kosmopoulou (2004) show that shill bidding may be harmful to sellers when buyers have common values. Even though shill bidding raises the buyers' bids, the authors show that sellers are better off if there exists an institution that credibly prevents shill bidding since buyers lower their bids when they expect shill bidding. In line with this result, Lamy (2009) shows that shill bidding is harmful to sellers in second price auctions when buyers have affiliated values and signals are independent. Finally, both Bose and Daripa (2017) and Barbaro and Bracht (2021) show that buyers snipe in equilibrium as a response to shill bidding in the eBay auction.

The outline of this paper is as follows: Section 2 explains the experimental design and the hypotheses that we will test using the experimental data. The results from the laboratory experiment are presented and discussed in Section 3. Finally, Section 4 concludes the paper.

2 Experimental design and hypotheses

In this section we explain the design of the experiment and our hypotheses. We start by outlining the auction environment, which is used in all treatments of the experiment, in Section 2.1. In Section 2.2 we explain the different treatments employed in the laboratory study. Then, in Section 2.3, we state and discuss our hypotheses. Finally, the details of the experiment are presented in Section 2.4.

[7] This auction format is often named an out-cry auction since the buyers can submit any number of bids during the auction. For more studies that implement a version of the out-cry auction. see, e.g., Elmaghraby et al. (2012); Gonçalves and Hey (2011); Kwasnica and Katok (2007); Sherstyuk and Dulatre (2008); Strecker (2010).

2.1 Experimental auction environment

We use the z-Tree software (Fischbacher, 2007) to program and replicate the eBay auction in the laboratory. An alternative would be to use the eBay interface for a lab-in-the-field experiment. However, using the eBay interface would not serve our purpose since we would not be able to eliminate the possibility of shill bidding and the bidding information in the experiment.

The experimental environment is the following: At the start of each round of the experiment, subjects are randomly matched into groups of five, which consist of one seller and four buyers.[8] Hence, the seller is also a subject. We refer to such a group as a Market. The seller is selling two identical items using two auctions. The two auctions are conducted sequentially, which means that the second auction (SA) is conducted once the first auction (FA) is completed. Before the start of a round, each buyer receives a private value, which is the same for the two items that are to be sold in the FA and the SA. It is publicly known that the buyers' private values are randomly and independently drawn from a uniform distribution of integers between 0 to 100 experimental currency units (ECUs). A buyer's private value is displayed on their screen during the auctions.[9] Buyers have unit demand, which implies that the winner of the FA will not participate in the SA. All subjects start with a budget of 100 ECUs and they maintain their roles throughout the experiment.

Both the FA and the SA are designed to replicate features of the eBay auction, in which shill bidding has been frequently observed empirically. In our experimental auctions, bidders are allowed to submit any number of bids for the item during one minute.[10] The auctions use the second price rule: the bidder who submits the highest bid, before the end of the one minute, wins the auction and pays a price equal to the second highest bid that is submitted by a different bidder.[11] A winning buyer receives ECUs equal to his/her private value minus the price of the item and the losing buyers get zero

In order for a bid to be accepted it must be greater than any previously accepted bid that was submitted by that subject. In addition to this, the bid needs to be greater than the current price, which equals the second highest bid at that moment. The current price starts at 1 ECU in any auction. The current price is displayed on the bidders' screens and is continuously updated as new bids are accepted. The bidding history, consisting of all past current prices from the auction, is displayed to the bidders as well. However, the bids are anonymous.[12] Moreover, the bidding history is continuously updated as bidders submit more bids. If a subject has submitted the highest bid at any moment, then he is informed that he is currently winning the auction. Otherwise, he is

[8]Four (three in the second auction) buyers are chosen in order to avoid the potential problem of collusion. We follow Dufwenberg and Gneezy (2000), whose experimental evidence suggests that three buyers are enough to avoid collusion.

[9]See Appendix D for screenshots from the different interfaces the subjects were shown during the experiment.

[10]A fixed deadline is chosen to closer replicate the eBay auction.

[11]In the case of several bidders submitting the same highest bid, the bidder who submitted it first wins the item.

[12]This differs from the eBay auction and is done in order to ensure a seller is not to easily detected when submitting a shill bid in the second auction. See D for the screenshot of the bidding screen in our experiment.

informed that he is currently not winning the auction.

After completing any auction, the buyers are informed whether they have won the item or not, of their payoffs and their updated balance in ECU. If a buyer incurred losses after the completion of an auction, a message to warn the buyer of this appears. Between the FA and the SA, buyers will be informed whether or not they will participate in the SA. The sellers receive a payoff equal to the price of the item in one of the FA or SA. A lottery with equal probability assigned to each auction is used to determine this payoff. This is done in order to minimize the wealth effect of the FA price on the sellers' shill bidding behavior. If the seller gets the price from the SA as a payoff and won the SA by shill bidding, then as the seller pays the price to himself, the payoff is 0. The sellers will be informed about their payoffs and balances at the end of each round.

2.2 Treatments

The experiment has three distinct treatments to which subjects are randomly assigned. All treatment differences are with respect to the sellers and the specifics of a treatment are only told to the buyers of that treatment in the instructions.[13] The treatments differ in whether or not the seller can shill bid in the SA and which information the seller is given from the FA. In all three treatments, the seller is not allowed to participate in or watch the FA. As we are partly investigating how shill bidding in future auctions, and information, affect behavior in ongoing auctions, the seller is only allowed to shill bid in the SA in the shill bidding treatments. Table 1 gives an overview of the treatments and their differences.

Table 1: Overview of the treatments employed in the experiment

Treatment	Shill bid FA	Information	Shill bid SA
Baseline	No	Yes	No
Treatment 1	No	Yes	Yes
Treatment 2	No	No	Yes

Notes: Deciding to shill bid is the sellers' choice and Information refers to the complete bidding history of all current prices from the FA and whether this is displayed to the seller before deciding to shill bid in the SA.

Baseline treatment: No shill bidding in the SA and bidding history information from the FA shown to the seller.

The sellers cannot actively participate in any of the auctions. During the FA, the sellers will be shown a blank screen. Between the FA and the SA, the complete anonymous bidding history of all current prices (any bid that was ever the second highest bid) from the FA is provided to the

[13] The instructions can be see in Appendix C. A questionnaire also checked that the subjects had understood the specifics of the treatment they were in. See Appendix D for more details.

seller. The seller watches the bidding live during the SA.[14]

Treatment 1: Shill bidding in the SA and bidding history information from the FA shown to the seller.

During the FA, the sellers will be shown a blank screen. The complete anonymous bidding history of all current prices from the FA is displayed to the seller between the FA and the SA. Before the start of the SA, the sellers can choose to participate in the SA, in which they can choose to submit shill bids. Participating in the SA costs 1 ECU and is introduced in order to more clearly identify sellers who have an intent to shill bid and to reduce possible experimenter demand effects. Based on the real-world situation, we believe that the cost of participation is small since sellers only need to make calls to ask for relatives help or just register another account to do this by themselves. Moreover, eBay charges a fee on the price that ranges from 0-12%. We did not include such a fee and its effect on the optimal shill bid is small in theory, as discussed in Section 2.3. The rules for bidding, as well as the information displayed, are the same for the sellers as for the buyers. The buyers are informed that it is the seller's choice whether or not to participate and submit shill bids in the SA. This information is only given to the buyers in the instructions. If a seller chooses not to participate in the SA, then the seller watches the bidding live during the SA.

Treatment 2: Shill bidding in the SA and no bidding history information from the FA shown to the seller.

This treatment is identical to Treatment 1 except that the complete anonymous bidding history of all current prices from the FA is not displayed to the seller between the FA and the SA. Between the FA and the SA, the seller is only informed whether or not the item in the FA was sold.

Treatment 1 is the environment that resembles the situation in online auctions today. Therefore, when comparing Treatment 2 to the baseline we can distinguish a "shill bidding effect" and by comparing Treatment 1 to Treatment 2, it is possible to single out an "information effect" when sellers can shill bid.

2.3 Theoretical conjectures and hypotheses

We present our research hypotheses in this section. To have better testable hypotheses, we derive theoretical conjectures, using a sealed-bid assumption, that motivate our hypotheses. For the sake of brevity, we put the complete theoretical model and all proofs in Appendix A. Furthermore, similar results as the ones presented here can be found in other papers (see, e.g., Milgrom and Weber (2000); Katsenos (2010); Gong et al. (2014)). Consequently, proofs in Appendix A are provided for completeness.

[14] We did not conduct a second baseline treatment in which the sellers had no information and in which they could not shill bid. The reason is that we believe that the behavior in the Baseline treatment should not differ much from such a second baseline treatment since the only difference is that the non-participating seller is observing the buyers' FA bids. As three other buyers already observe a buyer's bids in the FA, and since these bids are anonymous, we believe that the additional observation effect of the non-participating seller is small.

Since the exact model of the eBay auction is difficult to analyze and we are more focused on testing the experimental treatments rather than the theory, we make the simplifying assumption that the two auctions are of the sealed-bid auction format. The main difference between the eBay auction and a sealed-bid auction is that the eBay auction allows for dynamic bidding as the bids can be revised upwards during the course of the auction. Bidders only submit one bid and at the same time in a sealed-bid auction. At each point of time in the eBay auction, the bidders can submit any bid they want above the current price, and they do not know how many active bidders are left. They only know the history of current prices up until that point of time in the auction. In this sense, the eBay auction is similar to a sealed-bid auction bounded from below by the current price at a given point in time. Furthermore, the eBay auction uses a fixed ending time. Ariely et al. (2005) and Roth and Ockenfels (2002) show that bidders frequently "snipe" in eBay auctions, since they submit their bids in the last minute of the auctions.[15] This implies that if all bidders snipe, and submit their final bid at the end of the auction, then the eBay auction essentially becomes a sealed-bid auction. Since we are mostly interested in analyzing buyers' final bids, as they determine prices and outcomes, we believe that results derived from a theoretical model using the sealed-bid assumption may be useful as conjectures for hypotheses regarding behavior and outcomes in the eBay auction.[16]

Consequently, we make this simplifying assumption that each auction is conducted as a second price sealed-bid auction. A seller is selling two items by means of two sequential sealed-bid auctions with $n \geq 3$ participating buyers. The buyers have unit demand and the winner of the FA will therefore not participate in the SA. Each buyer i has a private value, v_i, which is the same for both items. The buyers' private values are randomly and independently drawn from a uniform distribution on (0,1). Let $\beta_1(v_i)$ be a bidding function determining how much a buyer with private value v_i bids in the FA. Similarly, $\beta_2(v_i)$ is a bidding function for the SA. We assume that $\beta_1(v_i)$ and $\beta_2(v_i)$ are symmetric and strictly increasing. This implies that the buyer with the highest private value wins the FA and the buyer with the second highest private value wins the SA. The seller's private values for the items are assumed to be 0. Starting from the SA, the buyers have a dominant strategy to submit a bid equal to their private value. This is unaffected by whether or not the seller is shill bidding in the SA, since for any shill bid submitted by the seller, the buyers can do no better than bidding their private value, as long as this is not lower than the current

[15] In their empirical data, they observe that approximately 50% of the bids are sniping bids as they are submitted during the last five minutes of the auctions. In our data, we find that 65.2% of the buyers' final bids are submitted in the last five seconds of the auctions.

[16] An alternative would be to model the eBay auction as an English ascending auction. The main reason for this is that the English auction also allows for dynamic bidding. However, in the English ascending auction there is a clock that increases the price by a fixed amount at some predetermined time interval and at each price the bidders can only choose to either stay in the auction or drop out. In the eBay auction on the other hand, the submitted bids can be any number greater than the current price and this is determined by another bidder's bid and not by a clock. Differently to the eBay auction, the English ascending auction is typically modeled with the bidders knowing the number of active bidders at any price (see , e.g., Milgrom and Weber (1982, 2000)). When there is only one active bidder left, the auction stops, and this bidder buys the item at the current price. However, if the English ascending auction is modeled without the buyers knowing the number of active bidders during any step in the auction, then the derived bidding functions coincide with the ones presented in this section.

price (see Graham et al. (1990); Izmalkov (2004); Riley and Samuelson (1981)). Consequently, $\beta_2(v_i) = v_i$ in our three treatments. Turning to the FA, a buyer is trading off the possibility of winning an item now or waiting to possibly acquire an item in the SA. If the seller cannot shill bid, then the buyers' optimal strategy is:

$$\beta_1(v_i) = \frac{n-2}{n-1} * v_i \tag{1}$$

This implies that the buyers who participate in the Baseline treatment should bid below their private value in the FA to account for less competition in the SA. Allowing the seller to submit a shill bid, s, in the SA, but not displaying the complete bidding history from the FA to the seller, gives rise to a "shill bidding effect". The buyers should still submit a FA bid equal to the expected payment in the SA, but now they take into account that the seller's possible shill bid raises the expected price. Moreover, for any bidder with $v_i \leq s$, the FA is essentially the last auction, which means that they will submit a bid equal to their private value in the FA. The buyers optimal strategy in Treatment 2 is:

$$\beta_1(v_i) = \begin{cases} \frac{n-2}{n-1} * v_i + \frac{s^{n-1}}{v_i^{n-2}(n-1)} & \text{if } v_i > s \\ v_i & \text{if } v_i \leq s \end{cases} \tag{2}$$

When the seller chooses the shill bid s in the SA, it has an obvious effect on the seller's expected payoff in the SA. However, a higher shill bid also raises the expected FA price and payoff since it raises the buyers' FA bids. If the seller could commit to the shill bid and take both these effects into account, then we find that the seller's optimal shill bid in Treatment 2, equals $\frac{1}{2}$. However, if the seller cannot commit and submits the shill bid by only taking into account the effect it has on the SA payoff, then the optimal shill bid equals $\frac{1}{3}$. As mentioned previously, eBay uses a $0 - 12\%$ fee on the price depending on the product. However, the optimal shill bid would be 0.47 or 0.32 with a 12% fee on the price, which suggests that its effect is small, at least in theory.

Now we turn to the situation in Treatment 1 in which, before submitting a shill bid in the SA, the seller can observe all bids that were ever the current price in the FA. It turns out that there cannot exist any symmetric and strictly increasing $\beta_1(v_i)$ in this case. The reason is that if the buyers follow such a bidding function, then the seller knows this and can infer the private values of the buyers from the FA bidding history by inverting the bidding function. Therefore, the buyers expect a payoff of 0 in the SA in this case. Consequently, the buyers have an incentive to under-report their private value in order to increase their possible earnings in the SA. Proposition 1 states the result.

Proposition 1. *If the seller shill bids and is given the complete bidding history from the FA, then there does not exist a strictly increasing symmetric bidding function $\beta_1(v_i)$ for any buyer i.*

The derived bidding functions in Equation 1 and Equation 2 as well as the optimal shill bids give rise to conjectures regarding prices and earnings. Table 2 displays the conjectures adapted to our experimental setting by multiplying the values by 100. We display both when the seller chooses $s = 50$ and $s = 33.33$ for Treatment 2.

Table 2: Theoretically derived conjectures using sealed-bid assumption

	Baseline	T1(& Info)	T2(& No Info) - $s = 50$	T2(& No Info) - $s = 33.33$
FA buyer final bids	$\frac{2}{3} * v_i$	-	$\frac{2}{3} * v_i + \frac{S^3}{v_i^2 * 3}$ if $v_i > s$ v_i if $v_i \leq s$	
SA buyer final bids	v_i	v_i	v_i	
SA seller final bid	-	-	50	33.3
FA price	40	-	50	44.2
SA price	40	-	45	42.7
Seller FA payoff	40	-	50	44.2
Seller SA payoff	40	-	38.75	41.5
Buyer FA payoff	10		7.5	9
Buyer SA payoff	5	-	2.5	4

Notes: Entries are multiplied by 100 to match the outcomes in the experiment.

Buyer earnings refer to winning buyer's earnings.

We base our first four hypotheses on the theoretically derived conjectures in Table 2:

Hypothesis 1. ***The shill-bidding effect on final price:*** *When the sellers are allowed to shill bid in the SA auction, but are not given the FA bidding history, then the final prices are higher in both the FA and the SA compared to when the sellers are not allowed to shill bid in the SA.*

The only prediction for which the two optimal shill bids differ is the sellers' SA payoff. The reason is that it is optimal for the seller to give up some payoff in the SA in order to earn more in the FA when taking both auctions into account. This effect is not present when only taking the SA payoff into account. However, since the seller cannot affect the FA bids when shill bidding in the SA, we base the hypothesis on the prediction when $s = 33.33$.

Hypothesis 2. ***The shill-bidding effect on sellers' payoff****: When the sellers are allowed to shill bid in the SA, but are not given the FA bidding history, then the FA and SA payoffs are higher for sellers compared to when the sellers are not allowed to shill bid in the SA.*

Hypothesis 3. ***The shill-bidding effect on buyers' payoff****: When the sellers are allowed to shill bid in the SA, but are not given the FA bidding history, then the buyers' FA and SA payoffs are lower than when the sellers are not allowed to shill bid in the SA.*

Hypothesis 3 may seem to be equivalent to Hypothesis 1. However, it is possible to find higher prices without lower buyer payoffs between treatments. This would occur if the difference in winning buyers' private values between treatments is greater than the difference in prices.

As $n = 4$ in all our experimental treatments, we expect all buyers to bid $\frac{2}{3} * v_i$ in the Baseline. In Treatment 2, we expect buyers to bid $\frac{2}{3} * v_i + \frac{s}{v_i^2 * 3}$ if $v_i > s$, since they expect a higher SA price. Moreover, for buyers with $v_i \leq s$ we expect them to submit a final bid equal to v_i since the optimal shill bid of s converts the FA into the last auctions for these buyers. Consequently, we expect that the FA bids are higher in Treatment 2 than in the Baseline both if $s = \frac{1}{2}$ or $s = \frac{1}{3}$.

Hypothesis 4. ***The shill-bidding effect on buyers' FA bids:*** *When the sellers are allowed to shill bid in the SA, but are not given the FA bidding history, then the buyers' FA final bids are higher than when the sellers are not allowed to shill bid in the SA.*

Since we have not been able to characterize the mixed-strategy equilibria in Treatment 1, we do not have any theoretically derived conjecture of the buyers' behavior in this treatment. The participation of the shill bidding seller creates a market effect as it increases the expected payment in the SA auction, which in turn increases buyers' FA bids similar to Treatment 2. However, based on the results from the literature on voluntary information disclosure (See, e.g.,Teoh (1997); Denker et al. (2014); Ertac et al. (2017); Guttman et al. (2014); Jansen and Pollak (2014); Jin et al. (2017)) and the buyers' incentive to under-report their private value, we believe that revealing the FA bidding history to the sellers makes buyers decrease their FA bids. Consequently, we conjecture that buyers will bid lower in Treatment 1 than in Treatment 2.

Conjecture 1. ***The information effect on buyers' FA bids:*** *When the sellers are allowed to shill bid in the SA and are given the FA bidding history, then the buyers' FA final bids are lower than when the shill bidding seller has no such information.*

In addition to the buyers, the sellers themselves may be affected by being shown the bidding history from the FA. Our experimental setting allows us to analyze the effects of information on sellers' behavior since the sellers are subjects and not programmed by a computer. The study by Grebe et al. (2021) shows that sellers respond strategically to bidding information when choosing Buy-It-Now prices. Therefore, we conjecture that there is a higher correlation between the price in the FA and the sellers' SA bids in Treatment 1 than in Treatment 2:

Conjecture 2. ***The information effect on sellers' bids****: There is a higher correlation between the price in the FA and the sellers' final SA bid when the sellers are given the FA bidding history than when shill bidding sellers are not provided with this information.*

2.4 Details of the experiment

We ran nine sessions during April 2017 at the Autonomous University of Barcelona. Each session consisted of 20 participants and we had 180 participants in total. Participants were students at the Autonomous University of Barcelona and were recruited using the Online Recruitment System for Economic Experiments (ORSEE). All sessions were computerized and programmed using the z-Tree software (Fischbacher, 2007). Instructions were read aloud, questions were answered in private, and no communication was allowed between subjects. Before starting the experiment, subjects had to pass a comprehension test and complete two test rounds (See Appendix C for the instructions and Appendix D for the comprehension test). The experiment consisted of 20 rounds, for which the subjects were paid. To increase the number of independent observations, we created, within each session, two groups of ten subjects with two sellers and eight buyers in each. Throughout the paper, we will refer to any such independent observation as a Group. After the end of an experimental round, subjects were randomly re-matched within their Group while maintaining their roles. Subjects were told that they were re-matched, but not about the specifics of the rematching procedure. At the end of the experiment, 100 ECU was converted to 1 euro for buyers and 0.4 euros for sellers.[17] Average earnings were 15.68 euros and subjects spent approximately two hours in the lab. Table 3 summarizes the structure of our experimental design.

Table 3: Overview of experimental design

Treatment	**Independent Groups**	**Markets/ Group**	**Subjects/ Market**	**Number of Subjects**	**Number of Periods**
Baseline	6	2	5	60	20
T1 (& Info)	6	2	5	60	20
T2 (& No Info)	6	2	5	60	20
Total Number of Subjects	180				

3 Experimental Results

The experimental results of our study are presented in this section. We start by analyzing the effects of shill bidding on prices, payoffs and efficiency in Section 3.1. Then, we continue by exploring buyer and seller final bid behavior in Section 3.2. Finally, we analyze buyers' and sellers' dynamic behavior in Section 3.3. We sometimes refer to the Baseline as B, Treatment 1 as T1 and Treatment 2 as T2. To test for differences in means across the treatments, we use the Mann-Whitney U rank sum test on the independent Group averages. The p-values for this test is denoted by p_{MWU}. We also test for mean differences within treatments, then we use the Wilcoxon matched-pairs signed-ranks test on the independent Group averages. The p-values for this test is denoted by p_{SR}. Finally, complementary regression analysis can be found in Appendix B.[18]

3.1 Prices, payoffs and efficiency

We present results on prices, payoffs and efficiency in this section. Figure 1 shows, by treatment, the average final prices, seller payoffs and buyer payoffs in the FA and the SA, as well as SA without sellers' participation as shill bidders (SA & No sellers participated), as well as average efficiency in the FA, SA and both auctions together.[19]

Final Prices: By looking at Figure 1a, we can conclude that shill bidding affects the final prices in both the FA and the SA. The FA final prices are significantly higher in the shill bidding treatments than in the Baseline (B vs T1, $p_{MWU} = 0.0374$ and B vs T2, $p_{MWU} = 0.0782$). The same is true for the SA final prices (B vs T1, $p_{MWU} = 0.0303$ and B vs T2, $p_{MWU} = 0.0547$). The price increase in the shill bidding treatments is around 17% in the FA and 27% in the SA. However, we find no difference in prices between the two shill bidding treatments. This is particularly

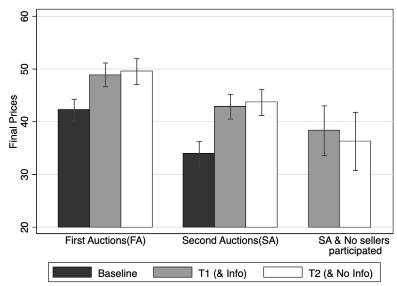
[17] This was done for two purposes: Firstly, in order to try to keep the average earnings of both roles relatively close to each other. Secondly, to decrease the wealth effect of sellers as this may affect the incentive to shill bid in the SA.

[18] A complete description of all variables that have been used in the regression analysis can be found in Table 8 and Table 9 of Appendix A.3.

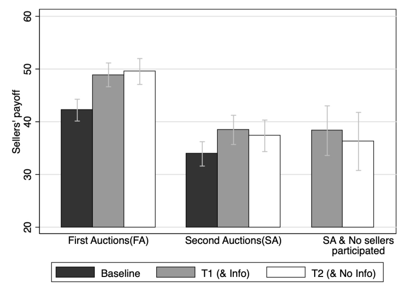
[19] Table 10 in Appendix B shows the summary statistics and expected outcomes for these variables.

interesting in the SA, as having access to previous bidding histories does not increase the ability of shill bidding sellers to increase the final price. It also suggests that the bidding history information has no effect on the FA final prices, which it could have if buyers would hide their private value by bidding lower in T1 compared to T2. Consequently, we find support for Hypothesis 1 that prices are higher in both the FA and SA when the sellers are allowed to shill bid, but are not given any bidding history information.

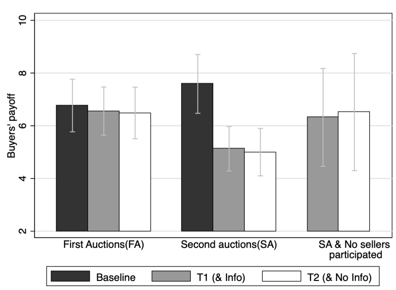
Figure 1: Overview of treatment effects



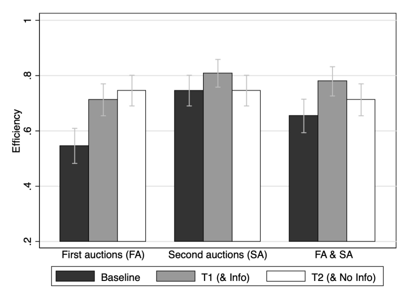
(a) Final prices



(b) Seller payoff



(c) Buyer payoff



(d) Efficiency

Notes: *Figure 1a, 1b and 1c display the average final prices, seller payoff and buyer payoff in the FA and SA. We also present the SA without the actual participation of sellers in Treatment 1 and Treatment 2. Figure 1d shows the average efficiency in the FA, SA and for both auctions together. The FA (SA) is efficient if the bidder with the highest (second highest) private value in that Market wins the item and both the FA and SA are efficient together in a Market if the two previous conditions hold simultaneously. The lines show 95% confidence intervals.*

SA final prices are also higher in both shill bidding treatments when the seller shill bids compared to the Baseline (B vs T1, $p_{MWU} = 0.025$ and B vs T2, $p_{MWU} = 0.0104$).[20] However, there are no statistically significant differences in SA final prices between the Baseline and the shill bidding treatments when the seller did not choose to particpate as a shill bidder. This implies that the participation of shill bidding sellers in the SA affects final prices. Finally, the final prices are higher in the FA than in the SA for each independent Group. Thus, as Ashenfelter (1989);

[20]The sellers submitted at least one shill bid in 71.7% of the SAs in T1 and 76.7% in T2.

Preston and Daniel (1993) and others, we find evidence of decreasing prices within sequences of auctions in all three treatments.[21]

Result 1. *Prices:* ***(i)*** *Shill bidding in the second auction increases prices in both the first and the second auctions.* ***(ii)*** *In the second auction, prices are higher when the sellers shill bid compared to when they do not.* ***(iii)*** *Prices are higher in the first auction than in the second auction in all three treatments.*

Seller Payoff: As a seller's payoff in the FA equals the FA price, the seller earns more from the FA in the two shill bidding treatments than in the Baseline.[22] In spite of higher SA auction prices in the two shill bidding treatments, the sellers' SA payoff is not different across any of the three treatments. This can be seen in Figure 1b that displays average seller payoff. The reason for this may be that the sellers won the item in 14.6% of the cases in T1 and 17.4% in T2, in which case the payoff is 0.[23] Thus, we partly find support for Hypothesis 2 since the sellers only earn more in the FA. Finally, shill bidding raises the SA payoff when the seller does not win the item in the SA in both shill bidding treatments (B vs T1, $p_{MWU} = 0.025$ and B vs T2, $p_{MWU} = 0.0104$).[24]

Buyer Payoff: Surprisingly, Figure 1c displays no treatment differences in buyers' FA payoffs, even though FA prices are higher in the shill bidding treatments. As expected, however, the buyers' SA payoffs are lower in the shill bidding treatments compared to the Baseline (B vs T1, $p_{MWU} = 0.025$ and B vs T2, $p_{MWU} = 0.0104$). Hence, we do not find full support for Hypothesis 3 as the buyers' payoff is only lower in the SA of T2 compared to the Baseline. Moreover, SA payoffs are lower in the shill bidding treatments when the sellers shill bid compared to the Baseline (B vs T1, $p_{MWU} = 0.0163$ and B vs T2, $p_{MWU} = 0.0104$). However, there are no differences when the sellers do not shill bid.[25]

Finally, sellers earn more in the FA than in the SA, but only buyers in T1 earn more in the FA than in the SA ($p_{SR} = 0.0277$). In sum, we can conclude that the sellers are the winners from shill bidding:

Result 2. *Payoffs: Due to shill bidding in the second auction,* ***(i)*** *sellers' payoffs are increased in the first auction and are unaffected in the second auction; and* ***(ii)*** *buyers' payoffs are not affected in the first auction, but their second auction payoffs are lower.*

Efficiency: The somewhat surprising result that buyers' FA payoffs are not lower in the shill bidding treatments compared to the Baseline can be explained by differences in efficiency across

[21] In Table 11 of Appendix B, we provide the results from OLS regressions, which confirm these results.

[22] In the analysis of seller's payoff we include the payoff of the sellers from both auctions and thus disregard that the sellers were only paid one of the two prices, which was chosen by a lottery at the end of the round.

[23] In the experiment, there was a cost of 1 ECU for sellers participating as a shill bidder. This cost is disregarded in this analysis.

[24] GLS random effects regressions confirming these results are shown in Table 12 of Appendix B.

[25] Table 13 in Appendix B presents the GLS random effects regressions results regarding buyer payoffs.The GLS random effects regressions confirm the results. However, in models (4) and (6), with buyer SA payoff as a dependent variable, the coefficients of the shill bidding treatments are negative but not statistically significant.

treatments. We define the FA (SA) to be efficient if the buyer with the highest (second highest) private value wins the item. Moreover, the FA and SA are both efficient if the two previous requirements are fulfilled.

Figure 1d shows that efficiency is higher in the FA for the shill bidding treatments compared to the Baseline (B vs T1, $p_{MWU} = 0.0159$ and B vs T2, $p_{MWU} = 0.0127$).[26] The difference is sizable as average FA efficiency is 54.2% in the Baseline, 69.6% in T1 and 70.8% in T2. Since buyers with the highest private value win the FA to a larger extent in the shill bidding treatments than in the Baseline, this counteracts the increase of final prices in the shill bidding treatments on the buyers' FA earnings. In FA & SA, the efficiency in Treatment 1 (& Info) is significantly higher than that in baseline (B vs T1 $p_{MWU} = 0.0526$). Finally, there are no statistically significant differences in SA efficiency across treatments.[27]

Result 3. *Efficiency: The possibility of Shill bidding in the second auction, **(i)** increases efficiency in the first auction; but does not lower efficiency in the second auction. **(ii)** When shill bidding is possible and the bidding history from the past auctions is disclosed, the overall efficiency in both FA and SA auctions together is higher than that in baseline when shill bidding is not possible.*

3.2 Final bid behavior

We now turn our attention to buyers' and sellers' final bid behavior. We analyze buyers in Section 3.2.1 and sellers in Section 3.2.2.

3.2.1 Buyer behavior

In this section we analyze buyers' final bid behavior.

Treatment Differences: We start by noting that there are no significant differences in the average FA bids across treatments. Thus, we do not find support for either Hypothesis 4 or Conjecture 1 on average. One reason for this might be that buyers with a low private value may be unable to submit their desired final bid since other buyers may push the current price above this bid before it was submitted. Therefore, we display the buyers' average final FA and SA bids conditional on their private value in Figure 2. Figure 2a and Figure 2b show FA bids for the Baseline and T2 as well as T1 and T2 respectively, while Figure 2c displays SA bids for all treatments. Looking at Figure 2a, we can see that a shill bidding effect exists for buyers with a private value above 50 since their final FA bids are higher in T2 than in the Baseline. Moreover, the buyers with a private value of 50 and above are less likely to be unable to submit their desired final bid.[28] Consequently, we partly find support for a shill bidding effect in line with Hypothesis

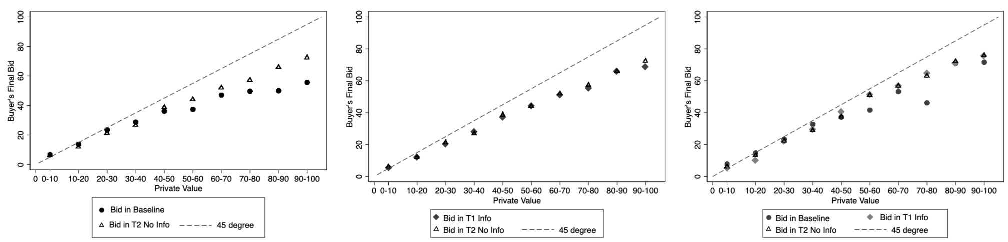
[26]The averages shown in Figure 1d include all SAs in which the sellers win the item and efficiency is never lower in any of the two shill bidding treatments compared to the Baseline.

[27]We also tried an alternative measure of efficiency. As you can see from Figure 9 in Appendix B, we also measured efficiency by the ratio of the winner's private value to the current highest private value in that auction. We still find a similar result that when shill bidding is possible, the efficiency of the first auctions is significantly increased, so is the overall efficiency.

[28]A crude measure of this is to count the number of buyers for whom the FA final price is higher than or equal to their private value and who do not submit the highest or second highest bid. By doing this, only

Figure 2: Buyers' average final bids by private value

(a) Shill bidding effect - FA (b) Information effect - FA (c) Final bids - SA



Notes: *We divided buyers into 10 groups based on their private value. The data in each figure is the average of the final bids for all buyers in the same private value group. Figure 2a compares the average final bid in the FA between Baseline and T2 (with shill bid and No info). Figure 2b shows the average final bid in the FA between T1(with shill bid and Info) and T2. Figure 2c shows the average SA bid for all treatments.*

4. By inspecting Figure 2b, we can see that providing the shill bidding sellers with the FA bidding history does not have an effect on the buyers' final FA bids for any private value group. Contrary to previous studies, we do not find an information effect on buyers FA bids nor support for Conjecture 1.[29] We believe we do not find an information effect because we only informed the buyers about the information condition in the instructions and since the information was given to a different kind of player (a seller). This was intentional in order to replicate the eBay environment since there is nothing reminding the buyers that the sellers can use their information during a real eBay auction. In previous studies, such as (Cason et al., 2011), a buyer sees and uses other buyers' bidding information to form her bids after each auction. This in turn reminds the buyer that other buyers' can use her bidding information. In Table 14 of Appendix B, we provide results from GLS regressions that confirm these two results.

Turning to the final SA bids, Figure 2c paints a somewhat similar picture since it looks as if buyers with a higher private value bid higher in the shill bidding treatments compared to the Baseline. However, the results from GLS regressions, displayed in Table 15 in Appendix B, suggest that this effect is much weaker and non-existent. This is to be expected as the buyers have the same dominant strategy in all three treatments in the SA.

Estimating bidding functions: Now we estimate the derived bidding functions from Section 2.3 using Maximum Likelihood and assuming normally distributed errors. The results are shown in Table 4.

We report the estimate of the coefficient β_1 when $Bid_{FA} = \beta_1 * v_i + \epsilon$ for the Baseline. The estimate equals 0.674, and we accept the null hypothesis that this is equal to the theoretically expected value of $\frac{2}{3}$ using a Wald test ($p = 0.8303$). For Treatment 2 we estimate the buyers'

9.5% of the buyers with a private value above 50 are unable to submit their desired bid. For the buyers with a private value of 50 or less, this number is 73.5%.

[29] We do find that buyers overbid less in the FA in T1 than in T2. Table 20 and Figure 10 in Appendix B shows the Probit regression on buyers' probability of submitting an overbid and the graph for comparing the overbidding behavior across treatments, which confirms this result.

Table 4: MLE of buyers' bidding functions.

	Baseline			T1 Info			T2 No Info		
	Expected	Observed	p-value	Expected	Observed	p-value	Expected	Observed	p-value
FA	$\beta_1 : 0.678$	0.674	.	-	41.157	***	$S : 33.33$	45.697	***
		[0.036]			[1.947]	***	$S : 50$	[3.326]	.
SA	$\beta_2 : 1$	0.785	***	$\beta_2 : 1$	0.863	***	$\beta_2 : 1$	0.868	***
		[0.068]			[0.029]			[0.031]	

Notes: Parameters of buyer bids are estimated using maximum likelihood.

Stars (*) are reported from Wald tests between the expected and observed parameter values.

The test in Treatment 1 is compared with the expected values from Treatment 2.

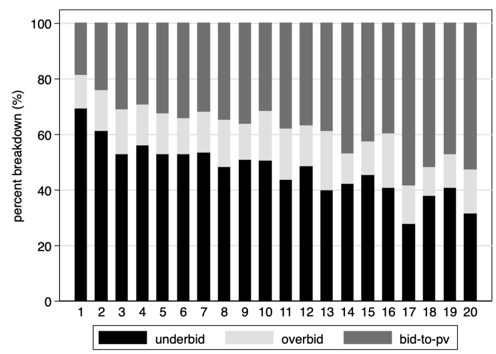
*Standard errors clustered on Group level in brackets.*** p<0.01, ** p<0.05, * p<0.1.

expectation of the SA shill bid, which we denote S. Specifically, we estimate $Bid_{FA} = \frac{2}{3} * v_i + \frac{S^3}{v_i^2 * 3} + \epsilon$ for $v_i > S$ and $Bid_{FA} = v_i + \epsilon$ for $v_i \leq S$. Hence, S determines the shape of the bidding functions for the buyers with a private value larger than S and which buyers who bid their private value. The estimate equals 45.7, and we accept the null hypothesis ($p = 0.1957$) that it is equal to the theoretically conjectured shill bid when the sellers take both auctions into account, which is 50. However, it is significantly greater ($p < 0.001$) than the conjectured value of 33.33 that would occur if the buyers believe that the sellers do not consider the effect the SA shill bid has on the buyers' FA bids, which the sellers should not since it is not possible to affect the buyers' FA bids once shill bidding in the SA. Furthermore, the average shill bid is 27.0 in T2 when averaging over participating and non-participating sellers. Consequently, buyers overreact to the threat of shill bidding in the SA both with respect to theory and the empirical estimate. Sellers, thus, enjoy high FA payoffs without having to submit high SA shill bids. For the sake of comparison, we estimate S for T1 as well, and we find that it is significantly different from 50 and 33.33 ($p < 0.01$). In summary, we find support for Hypothesis 4, at least for the buyers with a private value above average, but not for Conjecture 1. Furthermore, while the buyers in the Baseline bid as expected in the FA, they overreact to the threat of shill bidding in Treatment 2.

Result 4. *Buyers' first auction final bid:* ***(i)*** *Partly in line with the prediction of Hypothesis 4, shill bidding in the second auction increases the first auction final bid, at least for buyers with a private value greater than average.* ***(ii)*** *Contrary to Conjecture 1, providing the seller with the complete bidding history from the first auction does not lower the buyers' first auction final bid.* ***(iii)*** *Buyers overreact to the threat of shill bidding by submitting FA bids that are higher than expected.*

Turning to the SA final bids, we estimate β_2 in $Bid_{SA} = \beta_2 * v_i + \epsilon$ assuming normally distributed errors. While the estimated parameters are not significantly different between treatments, we find that β_2 is significantly lower than the conjectured value of 1 in all treatments when using Wald tests ($p < 0.01$). However, buyers seem to learn to use the optimal strategy, which is to submit a bid equal to their private value. While only 18.7% of the buyers used the optimal strategy in the first period, 52.8% did so in the last period.[30] In order to deeper analyze learning effects, we divide the buyers in the SA into three categories depending on how they bid: bid-to-pv (bid equal to private value), underbid (bid lower than private value) and overbid (bid higher than private value). Figure 3 displays the percentage of buyers in each category across the 20 periods.

Figure 3: Learning effect in the SA



Notes: *Bid-to-pv refers to the subjects who submit a bid equal to their private value, overbid to the subjects who bid higher than their private value and underbid to the subjects who bid lower than their private value in the SA. The percentage of buyers in each category is plotted over the 20 periods.*

Figure 3 shows that there is a considerable amount of underbidding in the SA that decreases over periods, while the number of overbidders are relatively few and stable over time. This may suggest that under-biding buyers learn to bid equal to their private value as the number of periods increase.[31] This is in fact the largest group of buyers who switch strategy from one period to the next. The regression results presented in Table 24 in Appendix B show that buyers are more likely to submit a bid equal to their private value if they have done so in the previous round. The probability to bid equal to private value is not affected by earnings or winning in the previous round, regardless of which strategy was previously used. Underbidders, however, are not more likely to underbid if they have done so in the previous round. Furthermore, the probability of submitting an underbid is decreasing if the buyer used any of the other two strategies in the previous round. So, why do some underbidders change strategy to bid equal to their private value? Interestingly, this group of underbidders is not different from underbidders who underbid in the next round, when looking at the probability of winning or earnings in the previous round (the period prior to the change of strategy. See Table 25 in Appendix B). Table 24 in Appendix B shows that the probability of bidding equal to your private value is positively correlated with the previous period price. In fact, the group of underbidders who switch to this strategy face higher previous period prices than the other buyers who underbid, which can be seen in Table 25 in Appendix B. Thus,

[30] In the FA, buyers submit a bid equal to their private value more often in the later auctions in T1 and T2, but not in the Baseline. This could be interpreted as the buyers learning about the threat of shill bidding in the SA and, therefore, bid high in the FA in order to avoid participating in the SA.

[31] The learning effect across periods is not significant different across treatments except a weak effect by comparing Treatment 1 (Shill bidding & Info) to the Baseline (No shill bidding).

it seems that underbidders learn to bid equal to their private value from high past prices. This makes sense if buyers expect high prices in the future auctions, in which case a higher bid will be needed to win. Or perhaps they realize from past high prices that increasing their bid would have increased their expected earnings. Moreover, as more buyers submit bids equal to their private values, prices on average increase, which in addition may partly explain why many buyers continue to bid equal to their private value.

The effects of learning suggests that the previously presented results may change if we disaggregate the data into early and late periods. However, the only major difference we find is an information effect in the last five rounds; buyers submit lower FA final bids in T1 compared to T2. This effect is absent in the first five rounds. The regression results are presented in Table 26 in Appendix B.

Result 5. *Buyers' second auction final bid:* ***(i)*** *In line with what is expected, there are no treatment differences in buyers' SA final bids.* ***(ii)*** *Buyers who previously underbid seem to learn to use the optimal strategy, which is to submit a final bid equal to their private value, more over time. These buyers seem to learn from experiencing high SA prices.*

3.2.2 Seller behavior

The sellers choose to participate as bidders and bid fairly often in the SA. They submit at least one shill bid in 71.7% of the SAs in T1 and 76.7% in T2.[32] Table 5 presents mean percentages of SAs in which the seller shill bid, won the SA and successfully raised the SA price, by the two shill bidding treatments. We do not find any significant differences between the two treatments. Consequently, giving the sellers the complete bidding history from FA in Treatment 1 does not increase their performance.[33]

Table 5: Means of descriptive statistics for sellers by the two shill bidding treatments

Variables	Treatment 1	Treatment 2
Seller shill bids SA (%)	71.67	76.67
	[45.16]	[42.38]
Seller wins SA (%)	14.53	17.39
	[35.35]	[38.01]
Successful shill bid (%)	30.23	25
	[46.06]	[43.42]

Notes: The percentage of Seller wins SA and Successful shill bid are calculated conditional on the seller shill bidding

Sellers' final bid behavior: Turning to the sellers' final bid behavior, Table 6 shows the average seller SA final bid conditional on participating in an auction and the correlation between

[32]This is lower than expected, at least in T2, where we expect 100% participation in theory since shill bidding is profitable even when there is a risk of winning the auction.

[33] Table 21, in Appendix B, shows results from a Probit regression that the sellers' probability of participating as a shill bidder does not differ by treatments.

the FA price and the sellers' SA final bids. While there are no treatment differences in the magnitude of final bids, sellers bid lower than 50 in T2, which is the theoretical prediction if they would take the effect of the shill bid on both auctions' payoff into account ($p_{SR} = 0.028$). However, we cannot reject the null-hypothesis that the bids are equal to 33.33, which is the prediction if they only consider the effect on the SA payoff. This is optimal to do since the FA has finished once the sellers submit shill bids, which implies that the SA shill bids cannot affect the buyers' FA bids nor the sellers' FA payoff. Moreover, from the Spearman rank-order correlation coefficients between the sellers' SA bid and the price in the FA, we can conclude that sellers in T1 react to the information they are shown. The correlation is significantly stronger in T1 than in T2.

Table 6: Sellers' bidding strategy

	Average seller bids		Correlation ρ (info vs bids)	
	Treatment 1	Treatment 2	Treatment 1	Treatment 2
SA	37.81 [18.80]	35.19 [21.92]	0.469***	0.103
Signed-ranks test if $s = 50$	**	**	T1 > T2***	
Signed-ranks test if $s = 33.33$	Accept	Accept		

Notes: The test for Treatment 1 is compared with the theory of Treatment 2.
Standard deviation in brackets. *** p<0.01, ** p<0.05, * p<0.1.

Consequently, we find support for Conjecture 2:

Result 6. *Sellers' final bid behvaior:* ***(i)*** *Sellers submit final shill bids equal to the theoretically expected when they are not shown the first auction bidding history.* ***(ii)*** *Sellers react to the information since by providing the sellers with the complete bidding history from the first auction there is a positive correlation between the FA price and the sellers' SA bid.*

3.3 Dynamic bidding behavior

The behavioral analysis has only considered final bids so far. However, the fact that we used eBay auctions in the experiment allows buyers and sellers to submit multiple upward bids at different stages of the auctions. This makes it possible to analyze dynamic bidding strtategies and conditional responses of buyers and sellers. We analyze buyers in Section 3.3.1 and compare buyers and sellers in Section 3.3.2

3.3.1 Buyer behavior

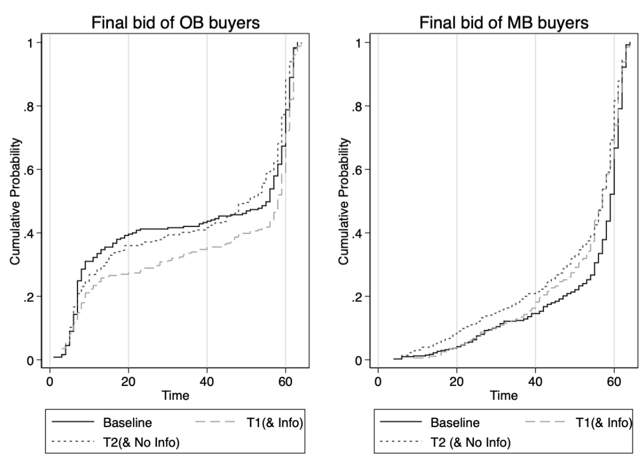
Ockenfels and Roth (2006) study buyers' dynamic bidding strategies in single eBay auctions without shill bidding. While bidding (your private value) once and early in the auction is one equilibrium, bidding late may also be optimal. If incremental bidders, who always bid an amount slightly above the current price, participate in the auction, bidding early might induce a bidding war. Bidding once and late, on the other hand, gives incremental bidders no time to push up the final prices and can thus be optimal. Furthermore, the authors show that a bidding-late-equilibrium may exist even as bidders gain experience. Thus, we have three conjectured predictions for buyer's dynamic bidding strategies: 1) Bid once and either 2) Bid early, or 3) Bid late.

Table 7: One Bid and Multiple Bids buyers in the SA

	All Treatments	Baseline	T1 (&Info)	T2 (&No Info)
Percentage of OB buyers across all buyers(%)	27.2	26.1	27.1	28.4
Percentage of buyers who bid late among OB buyers(%)	53.2	54.2	60.7	51.6
Percentage of buyers who bid early among OB buyers(%)	26	30.3	21.9	26

To check the three conjectured predictions, we categorize buyers into two types: One Bid (OB) buyers who only submit one bid and Multiple Bid (MB) buyers who bid more than once during the auction. Table 7 presents percentages of OB buyers and MB buyers in the second auctions (SA) across treatments.[34] If a bid is submitted within the last 10 seconds of an auction, we treat it as a late bid. Meanwhile, if a bid is submitted within the first 10 seconds, we treat it as an early bid.

Figure 4: CDF for final bids of One Bid (OB) and Multiple Bids (MB) buyers in SA



We do not find much support for buyers bidding once as only 27.2% do so in our experiment. However, a majority of OB buyers (79.2%), bid either early or late. This can clearly be seen in Figure 4, which plots the CDFs of OB and MB buyers' final bid in the SAs across treatments.

[34]We also present the results of FA auctions across treatments in Table 18 and Figure 12 in Appendix B. Simliar results are observed.

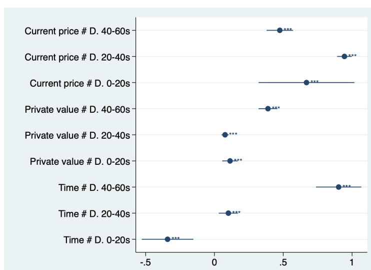
Compared to OB buyers, MB buyers submit more late final bids.[35] From Table 7, we also find that more OB buyers bid late in Treatment 1 (Shill bidding & Info) than in Treatment 2 (Shill bidding & No info) ($p_{MWU} = 0.0547$) in SA. This suggests that disclosing buyers' bidding history information from past auctions to sellers may affect OB buyers to bid late.

Result 7. ***(i)*** *Few buyers (27.2%) bid only once.* ***(ii)*** *For buyers who only bid once, most of them bid either early or late, where bidding late is more common.* ***(iii)*** *Once the bidding history information is disclosed to shill bidding sellers, One Bid buyers are more likely to bid late.*

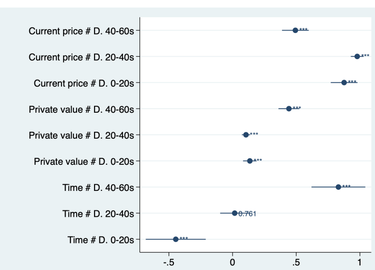
Based on our results above, more than 70% of buyers submitted multiple bids during an auction. To study multiple bidding in more depth, we analyze how different types of buyers behaved in different states of play by looking at how the FA and SA bids are affected by: 1) The current price they observed before submitting the bids; 2) The timing of submitted bids and 3) The buyer's private value. Using these variables, we analyze buyers' dynamic bidding behavior across time within an auction, treatment and private value. Figure 5 shows buyers' conditional responses in the FA (5a) and SA (5b) depending on whether they are in seconds 0 - 20, 20 - 40 or 40 - 60, when submitting their bids.

Figure 5: Dynamic buyer behavior across time

(a) FA across time



(b) SA across time



(c) Post estimation coefficient tests

Null Hypothesis	FA auction P-value	SA auction P-value
Current price # D. 40-60s = Current price # D. 20-40s	(***)	(***)
Current price # D. 40-60s = Current price # D. 0-20s	(.)	(***)
Current price # D. 20-40s = Current price # D. 0-20s	(.)	(**)
Private value # D. 40-60s = Private value # D. 20-40s	(***)	(***)
Private value # D. 40-60s = Private value # D. 0-20s	(***)	(***)
Private value # D. 20-40s = Private value # D. 0-20s	(.)	(.)
Time # D. 40-60s = Time # D. 20-40s	(***)	(***)
Time # D. 40-60s = Time # D. 0-20s	(***)	(***)
Time # D. 20-40s = Time # D. 0-20s	(***)	(***)

Notes: *p-values from regressions are marked alongside the markers in Figure 5a and 5b: * p < 0.1, ** p< 0.05, *** p<0.01.Current price is the observed current price at the time of the bid. Private value refers to the buyer's private value in the auction. Time measures the number of seconds that had passed in the auction when the bid was submitted. Each of the three variables are interacted (#) with one of the following three dummy variables: D. 0-20s is a dummy variable indicating whether or not the bid is submitted in seconds 0 - 20. D. 20-40s is a dummy variable indicating whether or not the bid is submitted in seconds 20 - 40. D. 40-60s is a dummy variable indicating whether or not the bid is submitted in seconds 40 - 60.*

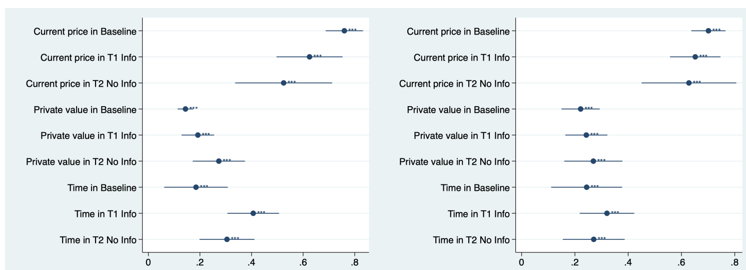
[35] The related regression results are presented in Table 19 = in Appendix B.

We interact the variables of the current price, timing of the bid and the buyers' private value with three dummy variables based on these time intervals and use them as independent variables. The figures display coefficient estimates from OLS regressions with FA and SA bid as the dependent variable. The outputs from the regressions can be found in Table 27 of Appendix B. Figure 5c shows significance levels from Wald tests between the different coefficient estimates.

The first thing we note is that buyers' behavior is almost identical in the FA and the SA: Buyers bid higher in the first 40 seconds of the auction than in the last 20 seconds when they observe a high current price, especially in the SA. We also find that private value has a greater effect in the last 20 seconds of the auctions. This might be expected since the current price will typically be higher in the last 20 seconds in which case the buyers with the highest private values are the only ones who can bid and win without making a loss. Furthermore, buyers bid a lot higher in the end of the last 20 seconds than they do in the early 40 seconds. In fact, timing has the smallest effect in seconds 20 - 40 and buyers tend to start the auctions with higher bids relative to the end of the first 20 seconds.

Figure 6: Dynamic buyer behavior across treatments

(a) FA by treatment (b) SA by treatment



Null Hypothesis	FA auction P-value	SA auction P-value
Current price in T2 No Info = Current price in T1 Info	(.)	(.)
Current price in T2 No Info = Current price in Baseline	(**)	(.)
Current price in T1 Info = Current price in Baseline	(*)	(.)
Private value in T2 No Info = Private value in T1 Info	(.)	(.)
Private value in T2 No Info = Private value in Baseline	(**)	(.)
Private value in T1 Info = Private value in Baseline	(.)	(.)
Time in T2 No Info = Time in T1 Info	(.)	(.)
Time in T2 No Info = Time in Baseline	(.)	(.)
Time in T1 Info = Time in Baseline	(***)	(.)

(c) Post estimation coefficient tests

Notes: *p-values from regression are marked alongside the markers in Figure 6a and 6b: * p < 0.1, ** p< 0.05, *** p<0.01. Current price is the observed current price at the time of the bid. Private value refers to the buyer's private value in the auction. Time measures the number of seconds that had passed in the auction when the bid was submitted. Each of the three variables are interacted with one of the three treatment dummies: Baseline, T1 Info or T2 No Info.*

We now turn our attention to treatment differences and present a similar analysis,[36] but across the three treatments. Even though the figures paint a similar picture, behavior is statistically

[36]The regression outputs are given in Table 29 of Appendix B.

different between the shill bidding treatments and the baseline in the FA, while there are no differences in the SA. In the FA, the current price has a smaller effect, while private value has a greater effect in Treatment 2 compared to the Baseline. The timing stands out for Treatment 1 as more buyers submit higher bids towards the end of the auction relative the Baseline.

The greater effect of the current price in the FA of the Baseline than in Treatment 2 could stem from that information from buyers is more important than in Treatment 2 since the SA price is solely determined by buyers in the Baseline. Therefore, as buyers take the expected payment in the SA into account when submitting their FA bids, the FA current prices in the Baseline give a better idea of what the SA price will be. Moreover, we can see that there is a stronger effect of private value in Treatment 2 than in the Baseline. However, there is no difference between Treatment 1 and the Baseline. This could suggest that buyers with high private values in Treatment 1 try to hide some information from the seller by letting their non-final bids be closer to other buyers' bids. Moreover, that buyers bid higher in the end of the auction in Treatment 1 relative to the Baseline could be interpreted as an attempt to hide some information from the seller.

Finally, we also investigate how buyers behave as a function of their private values. Therefore, we divide the buyers into three groups based on their private value: 1) High private value (High pv) if private value is greater than 66; 2) Middle private value (Mid pv) if private value is smaller than 67 and greater than 33; 3) Low private value (Low pv) if private value is lower than 34. However, we did not find any new significant results by this analysis and the effects are not very robust (see Figure 14 and Table 28 in Appendix B). Therefore, we can conclude that there is more difference in buyers' dynamic behavior across time than private value. Consequently, we conclude:

Result 8. ***(i)*** *Buyers' dynamic bidding behavior differs more across time than private value.* ***(ii)*** *Buyers update with higher bids in the beginning as well as in the end of the auctions relative to the middle of the auctions. They also bid higher when they observe a high current price in the first 40 seconds compared to the last 20 seconds.* ***(iii)*** *Buyers' dynamic behavior is different in the shill bidding treatments compared to the baseline in the FA, but not in the SA.* ***(iv)*** *Comparing to the no shill bidding treatment, there is a smaller effect of current price on buyers' bids when shill bidding is possible. Moreover, buyers' bids are affected more by their private values when sellers can shill bid with no bidding history information and timing when sellers can shill bid with bidding history information.*

We find that buyers bid higher as a response to a high current price. This could be explained by the effects of anchoring (Gillian Ku and Murnighan, 2006). If buyers treat the current price as an anchor, then every time the price changes so does the anchor. In response to a higher current price, buyers react by updating with a higher bid. In spite of our prediction that buyers will only submit one bid in the SA, we find many MB buyers. These buyers may have a preference for actively playing the game and derive utility from outbidding their opponents (spite) and of being the temporary winner in the spirit of having a joy of winning as studied by, e.g., (Cooper and Fang, 2008).The dynamic analysis also shows that a majority of buyers bid late and submits higher bids towards the end of an auction. This could be explained by buyers having beliefs that other buyers are incremental MB buyers, as suggested by (Ockenfels and Roth, 2006).

The facts that buyers tend to bid late and submit higher bids towards the end of an auction have important welfare implications. By doing this, a buyer faces the risk of losing the bid since it may be submitted after the auction has ended. While lost bids may affect a winning buyer positively since she may pay a lower price, it also introduces a possible loss of not winning the item. More importantly, if the buyer with the highest private value does not win the auction due to a lost bid, it generates a loss in efficiency. Moreover, both sellers and auction houses may earn less since lost bids can generate lower prices. To alleviate such negative effects, it is important that auction houses and policy makers urge buyers to bid their final bid early in the auction. However, with the presence of shill bidding, bidding early gives the seller more time to calibrate her shill bid, which may hurt the buyers. Therefore, auction houses should keep identifying and penalizing shill bidding to further encourage early bidding. In addition, auction houses may consider using a softer ending rule to decrease last-minute bidding (Ariely et al., 2005).

3.3.2 Do buyers and sellers behave differently during the auctions?

Since shill bidding may hurt buyers, it is interesting to know if it is possible for buyers, and auction houses, to detect when a seller is shill bidding. Therefore, we compare the behavior of buyers and sellers in different respects in this section. First of all, Figure 7 shows statistics of different behavior that we observed between buyers and sellers in our experimental data. We test the differences by using the Wilcoxon matched-pairs signed-ranks test on the independent Group averages with a hypothesis of no difference between their behaviors. All data presented in this section is from the SA since sellers can only submit bids in this auction.[37]

Final bids: In Figure 7a, we ranked the three buyers who participated in a SA into three levels based on their private value (PV). As we can see from the graph, the sellers' final bids are smaller than those from the highest PV buyer, close to those from the 2nd highest PV buyer and greater than those from the 3rd highest PV buyer. We found acceptance between the bids submitted by the 2nd highest PV buyer and the sellers ($p_{SR} = 0.735$ in T1 and $p_{SR} = 0.600$ in T2). For the other comparisons, we reject equality and the difference goes in the direction that we observe in Figure 7a ($p_{SR} = 0.028$ in each of the four tests). It, thus, seems that sellers final bids are essentially equal to the bids submitted by the second highest PV bidders.

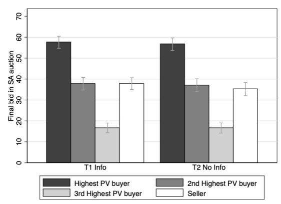
Sniping: Following Ariely et al. (2005) and Roth and Ockenfels (2002), we plot the CDFs of the timing of the final bid for buyers and sellers in Figure 7b and Figure 7c. There is a significant difference between the share of buyers and sellers who submit their final bid in the last 5 seconds of the SA ($p_{SR} = 0.075$ in T1 and $p_{SR} = 0.035$ in T2) in both shill bidding treatments. We observe that 65.2% of buyers submitted their last bid within the last 5 seconds of the SA, while 43.7% of the sellers did the same.[38] Consequently, we conclude that buyers snipe more than sellers.

[37] The treatment differences for these variables, for both buyers and sellers in the SA using GLS regressions, are shown in Table 22 and Table 23 in Appendix B. They confirm the different bidding behavior between buyers and sellers, and also imply that they are affected differently by shill bidding and information.

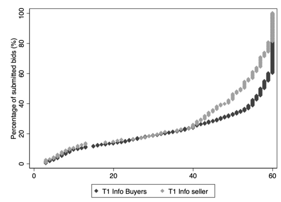
[38] In Figure 11 in Appendix B, we also show the CDFs of the timing of the last submitted bid for buyers and compare these between treatments. It suggests that there are no treatment differences, which means that buyers snipe a lot even when there is no threat of shill bidding.

Figure 7: Behavior between buyers and sellers

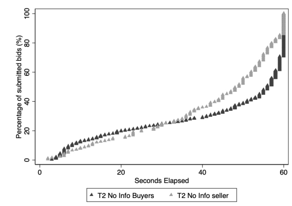
(a) Final bids



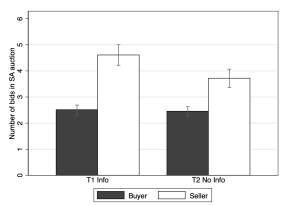
(b) Sniping in T1 Info



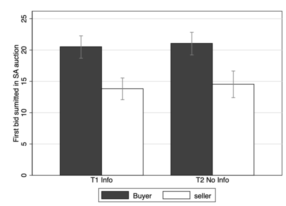
(c) Sniping in T2 No Info



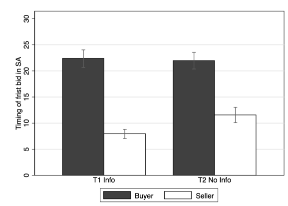
(d) Number of bids



(e) First bids



(f) Timing of first bids



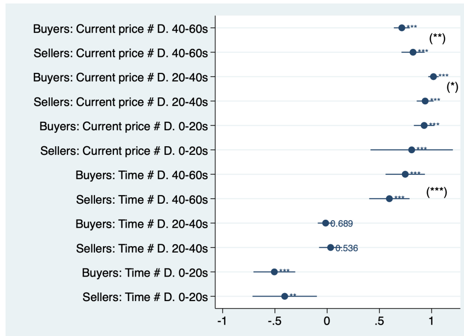
Notes: In Figure 7a (final bids), we rank the three buyers who participated in a SA by their private value into highest, second highest and third highest private value (PV) buyer. We only include the sellers who chose to participate in the SA auction. In Figure 7b and 7c, the CDFs of the timing of the final SA bid for both buyers and sellers in each shill bidding treatment are plotted. Figure 7d, 7e and 7f show the average for each variable divided by seller and buyer. The lines show 95% confidence intervals.

Number of bids: With the purpose of seeing how active sellers and buyers are in the auctions, we display Figure 7d to see how many bids that they submit during the SA. Figure 7d suggests that sellers are much more active as they submit more bids ($p_{SR} = 0.028$ in both T1 and T2) than buyers.

First bids: In Figure 7e and 7f, which show the average of the size and timing of the first bids, we can see that sellers submit their first bids earlier and that they are lower than buyers' first bids ($p_{SR} = 0.028$ in all four tests).

Now we deepen the analysis by looking at conditional responses of buyers compared to sellers. Figure 8 displays coefficient estimates from a regression with SA bid as the dependent variable. The regression output can be found in Table 30 of Appendix B. For this regression we have interacted the effects of current price and timing with dummy variables indicating when in the auctions the bids are submitted: In seconds 0 - 20, 20 - 40 or 40 - 60. By applying Wald tests for the estimated coefficients between buyers and sellers in each interacted variable, we find that sellers and buyers start out with similar behavior, but in the last 40 seconds they have significantly different behaviors: Sellers bid higher when they observe a high current price, while buyers bid higher towards the end of the auction. These results are reasonable since a high current price could indicate that a seller can shill bid higher to earn more and buyers may bid higher at the end of the auction to protect themselves from shill bidding. Based on these results it, thus, seems possible for buyers and auction houses to detect a shill bidding seller. However, we also checked if buyers

Figure 8: Dynamic bidding strategies: Seller vs Buyers



Notes: *p-values from regressions shown alongside markers; p-values testing for coefficient differences between buyers and sellers in each variable shown in parentheses. No stars means no significant difference in this variable.*p < 0.1, ** p < 0.05, *** p < 0.01.Current price is the observed current price at the time of the bid. Private value refers to the buyer's private value in the auction. Time is when in seconds the bid was submitted. Each of the three variables are interacted (#) with a dummy variable indicating if the bidder is a buyer or a seller.*

react differently depending on if another buyer or a seller submitted the current price (See Table 30 in Appendix B) and we find in general that they do not. We conclude this section with the following results:

Result 9. ***(i)*** *Buyers and sellers behave differently during the auctions.* ***(ii)*** *Sellers submit more bids, lower and earlier first bids and react more to the current price at the end of the auctions. Buyers bid more often and higher at the end of the auctions.* ***(iii)*** *However, buyers do not react differently depending on if a seller or another buyer submitted the bid that became the current price.*

4 Conclusion

We conducted a laboratory experiment to test the effects of shill bidding in sequential eBay auctions. Our experiment replicates this real-world issue in online auctions that has been observed by previous researchers. Using two sequential eBay auctions, we investigate the effects of shill bidding in ongoing and future auctions, and the impact of disclosing past buyer bidding histories to sellers, on prices, earnings as well as buyers' and sellers' bidding behavior.

We find that shill bidding in the second auction affects outcomes in both auctions. Shill bidding causes prices to be higher in both auctions, and sellers are the winners of shill bidding as they earn more in the first auction, while buyers earn less in the second auction. The behavioral data show that buyers with a private value above average overreact to the threat of future shill bidding by bidding higher in the first auction than expected from theory and the observed level of shill bidding. As a consequence of this, sellers increase their first auction earnings without having to submit high second auction shill bids. Consequently, these results provide further evidence that shill bidding does hurt buyers with a higher willingness to pay and benefit sellers in the end, so online auction platforms should figure out how to protect their buyers from shill bidding to increase their trust in the auction house. However, since the prices in auctions are higher due to shill bidding, and eBay charges a percentage of the final selling price[39], it also implies a conflict between protecting buyers by preventing shill bidding or getting higher profits by implicitly allowing shill bidding. This suggests that even though preventing shill bidding is what online auction platforms should do, they may not have a strong incentive to do so. We also find that the threat introduced by shill bidding increases the efficiency of auctions because more high private value buyers win the early auctions. However, providing the seller with the bidding history from the previous auctions has very little effect on behavior and outcomes. This suggests that such information disclosure may not be an issue for auction houses as long as buyers have private values for the items. Information effects and their interactions with shill bidding are still important in common value auctions as shown by (Chakraborty and Kosmopoulou, 2004; Kosmopoulou and De Silva, 2007). Through our analysis of buyers' dynamic bidding, we find that more than 70% of buyers did not behave in accordance with our conjecture to submit only one bid in the auction. By analysing of how buyers update their bids, we find that timing and the current price information are key elements for their dynamic bidding decisions during the auctions. Importantly, we find that buyers and sellers behave quite differently when acting as bidders. If the difference between buyers and sellers also carries over to the real world, then it makes it possible for buyers and auction houses to detect and prevent shill bidding sellers.

Our experiment suggests a few open questions for future research. A natural extension to our experimental design is to compare shill bidding to the case in which the seller chooses a reservation price before the start of the second auction. In this case, we hypothesize that buyers' behavior will be less affected compared to shill bidding since the sellers only act before the auctions start. We also believe that giving the seller the bidding history from the first auction will, at least, have more impact on the behavior and outcomes of the sellers when setting reservation prices. Another path would be to compare the effects of seller participation in sequential auctions using different auction formats such as sealed-bid, and English auctions. In reality, shill bidding sellers who win their own items can resell them. Accommodating this into an experimental design would lower the cost of shill bidding, and we would, consequently, expect more shill bidding. Moreover, there exist other online auction platforms such as Amazon, eBid, which have a similar environment with sequential auctions and where shill bidding is possible. However, sometimes such auction houses use different rules regarding, e.g., pricing, ending and housing fees. Testing how different rules affect shill bidding could be another direction for future research. Finally, insights from our behavioral analysis could help in improving theories of dynamic bidding behavior in English out-cry auctions for both buyers and sellers.

[39]For details, see this eBay web page.

References

Alzahrani, A., Sadaoui, S., 2020. Clustering and labeling auction fraud data. In: Data Management, Analytics and Innovation. Springer, pp. 269–283.

Ariely, D., Ockenfels, A., Roth, A. E., 2005. An experimental analysis of ending rules in internet auctions. RAND Journal of Economics 36 (4), 890–907.

Ashenfelter, O., 1989. How Auctions Work for Wine and Art. Journal of Economic Perspectives 3 (3), 23–36.

Barbaro, S., Bracht, B., 2021. Shilling, squeezing, sniping. a further explanation for late bidding in online second-price auctions. Journal of Behavioral and Experimental Finance 31, 100553.

Bose, S., Daripa, A., 2017. Shills and snipes. Games and Economic Behavior 104, 507–516.

Cason, T. N., Kannan, K. N., Siebert, R., 2011. An Experimental Study of Information Revelation Policies in Sequential Auctions. Management Science 57 (4), 667–688.

Chakraborty, I., Kosmopoulou, G., 2004. Auctions with shill bidding. Economic Theory 24 (2), 271–287.

Cooper, D. J., Fang, H., 2008. Understanding overbidding in second price auctions: An experimental study. The Economic Journal 118 (532), 1572–1595.

Denker, U., Schwartz, S., Ward, C., Young, R., 2014. Voluntary disclosure in a bargaining setting: A research note". Management Accounting Research 25 (3), 223 – 229.

Dong, F., Shatz, S. M., Xu, H., Majumdar, D., 2012. Price comparison: A reliable approach to identifying shill bidding in online auctions? Electronic Commerce Research and Applications 11 (2), 171–179.

Dufwenberg, M., Gneezy, U., 2000. Price Competition and Market Concentration: An Experimental Study. International Journal of Industrial Organization 18, 7–22.

Dufwenberg, M., Gneezy, U., 2002. Information disclosure in auctions: An experiment. Journal of Economic Behavior and Organization 48 (4), 431–444.

Dye, R. A., 1985. Disclosure of nonproprietary information. Journal of Accounting Research 23 (1), 123–145.

Einav, L., Kuchler, T., Levin, J., Sundaresan, N., 2015. Assessing sale strategies in online markets using matched listings. American Economic Journal: Microeconomics 7 (2), 215–47.

Elmaghraby, W. J., Katok, E., Santamaría, N., 2012. A Laboratory Investigation of Rank Feedback in Procurement Auctions. Manufacturing & Service Operations Management 14 (1), 128–144.

Engelberg, J., Williams, J., 2009. eBay's proxy bidding: A license to shill. Journal of Economic Behavior and Organization 72 (1), 509–526.

Ertac, S., Gumren, M., Kockesen, L., Sep 2017. Strategic feedback in teams: Theory and experimental evidence. Tech. Rep. 1714, Koc University-TUSIAD Economic Research Forum,Working Paper.

Février, P., Linnemer, L., Visser, M., 2007. Buy or wait, that is the option: the buyer's option in sequential laboratory auctions. The RAND Journal of Economics 38 (1), 98–118.

Fischbacher, U., Jun 2007. z-tree: Zurich toolbox for ready-made economic experiments. Experimental Economics 10 (2), 171–178.

Ganguly, S., Sadaoui, S., 2018. Online detection of shill bidding fraud based on machine learning techniques. In: International Conference on Industrial, Engineering and Other Applications of Applied Intelligent Systems. Springer, pp. 303–314.

Gillian Ku, A. D. G., Murnighan, J. K., 2006. Starting low but ending high: a reversal of the anchoring effect in auctions. Journal of Personality and Social Psychology 90 (6), 975–986.

Gonçalves, R., Hey, J., 2011. Experimental evidence on English auctions: Oral outcry versus clock. Bulletin of Economic Research 63 (4), 313–352.

Gong, Q., Tan, X., Xing, Y., 2014. Ordering sellers in sequential auctions. Review of Economic Design 18 (1), 11–35.

Graham, D. A., Marshall, R. C., Richard, J. F., 1990. Phantom bidding against heterogeneous bidders. Economics Letters 32 (1), 13–17.

Grebe, T., Ivanova-Stenzel, R., KrÃ¶ger, S., 2021. How do sellers benefit from buy-it-now prices in ebay auctions? – an experimental investigation. Tech. Rep. 1.

Grether, D., Porter, D., Shum, M., 2015. Cyber-shilling in automobile auctions: Evidence from a field experiment. American Economic Journal: Microeconomics 7 (3), 85–103.

Guttman, I., Kremer, I., Skrzypacz, A., 2014. Not only what but also when: A theory of dynamic voluntary disclosure. The American Economic Review 104 (8), 2400–2420.

Izmalkov, S., 2004. Shill bidding and optimal auctions. International Conference on Game Theory, 1–21.

Jansen, J., Pollak, A., Sep 2014. Strategic disclosure of demand information by duopolists: Theory and experiment. Working Paper Series in Economics 75, University of Cologne, Working Paper Series in Economics.

Jin, G. Z., Luca, M., Martin, D., November 2017. Is no news (perceived as) bad news? an experimental investigation of information disclosure. Harvard Business School NOM Unit Working Paper No.15-078.

Kannan, K. N., 2010. Declining prices in sequential auctions with complete revelation of bids. Economics Letters 108 (1), 49–51.

Katsenos, G., 2010. Optimal Reserve Prices in Sequential Auctions with Imperfect Commitment. Leibniz Universitat Hannover. Working paper.

Katuščák, P., Michelucci, F., Zajíček, M., 2015. Does feedback really matter in one-shot first-price auctions? Journal of Economic Behavior and Organization 119, 139–152.

Kauffman, R. J., Wood, C. A., 2005. The effects of shilling on final bid prices in online auctions. Electronic Commerce Research and Applications 4 (1), 21–34.

Kosmopoulou, G., De Silva, D. G., 2007. The effect of shill bidding upon prices: Experimental evidence. International Journal of Industrial Organization 25 (2), 291–313.

Kwasnica, A. M., Katok, E., 2007. The effect of timing on jump bidding in ascending auctions. Production and Operations Management 16 (4), 483–494.

Lamy, L., 2009. The shill bidding effect versus the linkage principle. Journal of Economic Theory 144 (1), 390–413.

Leufkens, K., Peeters, R., Vorsatz, M., 2012. An experimental comparison of sequential first-and second-price auctions with synergies. The BE Journal of Theoretical Economics 12 (1).

McCannon, B. C., Minuci, E., 2020. Shill bidding and trust. Journal of Behavioral and Experimental Finance 26, 100279.

Milgrom, P. R., Weber, R. J., 1982. A theory of auctions and competitive bidding. Econometrica 50, 1089–1122.

Milgrom, P. R., Weber, R. J., 2000. A Theory of Auctions and Competitive Bidding, II. In: P.Klemperer (Ed.), The Economic Theory of Auctions. Edward Elgar Publishing Ltd.

Neugebauer, T., Pezanis-Christou, P., 2007. Bidding behavior at sequential first-price auctions with(out) supply uncertainty: A laboratory analysis. Journal of Economic Behavior and Organization 63 (1), 55–72.

Ockenfels, A., Reiley, D., Sadrieh, A., Dec. 2006. Online Auctions. NBER Working Papers 12785, National Bureau of Economic Research, Inc.

Ockenfels, A., Roth, A. E., 2006. Late and multiple bidding in second price Internet auctions: Theory and evidence concerning different rules for ending an auction. Games and Economic Behavior 55 (2), 297–320.

Preston, M. R., Daniel, V., 1993. The Declining Price Anomaly. Journal of Economic Theory 60 (1), 191–212.

Riley, J. G., Samuelson, W. F., 1981. Optimal auctions. The American Economic Review 71 (3), 381–392.

Roth, A. E., Ockenfels, A., 2002. Last-minute bidding and the rules for ending second-price auctions: Evidence from eBay and Amazon auctions on the internet. American Economic Review 92 (4), 1093–1103.

Sherstyuk, K., Dulatre, J., 2008. Market performance and collusion in sequential and simultaneous multi-object auctions: Evidence from an ascending auctions experiment. International Journal of Industrial Organization 26 (2), 557–572.

Strecker, S., 2010. Information revelation in multiattribute English auctions: A laboratory study. Decision Support Systems 49 (3), 272–280.

Teoh, S. H., 1997. Information disclosure and voluntary contributions to public goods. The RAND Journal of Economics 28 (3), 385–406.

Wang, J. T.-y., 2006. The eBay Market as Sequential Second Price Auctions - Theory and Experiments. National Taiwan University . Working paper.

Online Appendix

A Theoretical model

We make the simplifying assumption that each auction is conducted as a sealed-bid second-price auction. In each round two items are sold by a seller who uses two sequential sealed-bid auctions with $n \geq 3$ bidders. The bidders have unit demand and the winner of the FA will therefore not participate in the SA. Each bidder i has a private value, v_i, which is the same for both items. The private value is drawn from a uniform distribution on (0,1). For any bidder i, let $Y_1, \ldots, Y_{n-1}$ denote the private values of the other $n-1$ bidders, where $Y_1 > Y_2 > \ldots > Y_{n-1}$. Let $\beta_1(v_i)$ be a bidding function determining how much a bidder with private value v_i bids in the FA. Similarly, $\beta_2(v_i)$ is a bidding function for the SA. We assume that $\beta_1(v_i)$ and $\beta_2(v_i)$ are symmetric and strictly increasing. This implies that the bidder with the highest private value wins the FA and the bidder with the second highest private value wins the SA. The seller's private value for the items is assumed to be 0.

A.1 Buyer behavior

We start by considering the case in which the seller cannot shill bid. This is equal to the standard model of Milgrom and Weber (2000). As the SA is equal to a standard sealed-bid second-price auction, the bidders have a dominant strategy of submitting a bid equal to their private value. Thus, $\beta_2(v_i) = v_i$. Turning to the FA, the bidder is trading off the possibility of winning an item now or waiting to possibly acquire an item in the SA. We will consider what happens if a bidder bids $\beta_1(w)$,where $w \neq v_i$ and then assume truthful bidding to drive the optimal bidding function $\beta_1(v_i)$. Then we will return to the cases where the bidder deviates and show that this makes him strictly worse off. Assume that the bidder bids $w \geq v_i$, then the expected payoff, $U_i(w, v_i)$ for a bidder in the FA is:

$$U_i(w, v_i) = w^{n-1} \left(v_i - E[\beta_1(Y_1)|Y_1 < w]\right) \tag{3}$$

$$+(n-1)(1-w)\, v_i^{n-2} \left(v_i - E[\beta_2(Y_2)|Y_2 < v_i < Y_1\right),$$

where the first term results from the event that $Y_1 < w$ and the second from $Y_2 < v_i < w < Y_1$ and since the bidders valuations are independently drawn from a uniform distribution on (0,1), v_i^{n-1} is the probability that bidder i wins the FA.[40] With uniformly distributed private values and since $\beta_2(v_i) = v_i$ 3 becomes:

$$U_i(w, v_i) = w^{n-1} \left(v_i - \frac{n-1}{n}\beta_1(w)\right) \tag{4}$$

[40] $(n-1)(1-w)\, v_i^{n-2}$ is the probability that bidder i loses the FA and wins the SA.

$$+(n-1)\,(1-w)\,v_i^{n-2}\left(v_i - \tfrac{n-2}{n-1}v_i\right),$$

Taking the derivate of Equation 4 w.r.t w and setting it to 0 yields:

$$\begin{aligned}\frac{\partial}{\partial w}U_i(w,v_i) =&(n-1)w^{n-2}\left(v_i - \frac{n-1}{n}\beta_1(w)\right) - w^{n-1}\frac{n-1}{n}\beta_1'(w)\\ &-(n-1)v_i^{n-2}\left(v_i - \frac{n-2}{n-1}v_i\right) = 0,\end{aligned} \tag{5}$$

In equilibrium $w = v_i$, which gives:

$$\beta_1'(v_i) = \frac{(n-2)n}{n-1} - \beta_1(v_i)\frac{n-1}{v_i} \tag{6}$$

The solution to the differential equation 6 is:

$$\beta_1(v_i) = \frac{n-2}{n-1} \times v_i \tag{7}$$

Now assume that the bidder bids $w < v_i$, then the expected payoff, $U_i(w,v_i)$ for a bidder in the FA is:

$$\begin{aligned}U_i(w,v_i) =&w^{n-1}\left(v_i - \frac{n-1}{n}\beta_1(w)\right)\\ &+(n-1)(1-v_i)\int_0^{v_i}(v_i-p)p^{n-3}f(p)\partial p\\ &+(n-1)\int_w^{v}(n-2)\int_0^{y_1}(v_i-p)p^{n-3}f(p)\partial p f(y_1)\partial y_1\end{aligned} \tag{8}$$

where the first term results from the event that $Y_1 < w$, the second from $Y_2 < v_i < Y_1$and the third from $w < Y_1 < v_i$. By taking the derivative of Equation 8 and setting it to 0 we get:

$$\begin{aligned}\frac{\partial}{\partial w}U_i(w,v_i) =&(n-1)w^{n-2}\left(v_i - \frac{n-1}{n}\beta_1(w)\right)\\ &-w^{n-1}\frac{n-1}{n}\beta_1'(w) - (n-1)w^{n-2}\left(v_i - \frac{n-2}{n}w\right)\\ &+w^{n-1}\frac{n-2}{n} = 0,\end{aligned} \tag{9}$$

Equation 9 together with the equilibrium requirement that $w = v_i$,gives Equation 6 and, thus, the optimal strategy given in Equation 7.

Now we will check that the bidders have no incentive to deviate from the optimal strategy by bidding $\beta_1(w)$, where $w \neq v_i$. To do this we will check that Equation 5 and 9 are maximized at $w = v_i$and that $\frac{\partial}{\partial w}U_i(w,v_i) \leq 0$ when $w > v_i$and $\frac{\partial}{\partial w}U_i(w,v_i) \geq 0$ when $w < v_i$for $\beta_1(w) = \frac{n-2}{n-1} \times w$. Using the optimal strategy, and after some manipulations, Equation 5 becomes:

$$v_i - \frac{n-2}{n-1}w - \left(\frac{v_i}{w}\right)^{n-2}\frac{v_i}{n-1} = 0, \tag{10}$$

which holds true for $w = v_i$ and is less than equal to 0 for any $w > v_i$,which is what we need.

Similarly, by replacing $\beta_1(w) = \frac{n-2}{n-1} \times w$in Equation 9 and performing some manipulations we get $0 = 0$, which concludes the proof.

Now we introduce the possibility for the seller to submit a shill bid in the SA. We let $s \in [0, 1]$ denote the shill bid submitted by the seller in the SA. However, for now, the seller does not have any information regarding the bids submitted in the FA. The bidders' dominant strategy in the SA does not change due to the sellers' ability to shill bid. Regardless of whatever shill bid the seller submits, it is still optimal for the bidders to bid their private value in SA .

We will consider what happens if a bidder bids $\beta_1(w)$,where $w \neq v_i$ and then assume truthful bidding to drive the optimal bidding function $\beta_1(v_i)$. Then we will return to the cases where the bidder deviates and show that this makes him strictly worse off. For the bidders whose private value is less than s, they view the FA as the last auction they participate in and hence submit a bid of v_i. For any bidder for whom $v_i \geq s$, assume that the bidder bids $w \geq v_i$, then the expected payoff, $U_i(w, v_i)$ in the FA is:

$$\begin{aligned} U_i(w, v_i) =& w^{n-1} \left(v_i - \frac{n-1}{n} \beta_1(w) \right) \\ &+ (n-1)(1-w) \left[\int_s^v (n-2)(v_i - p) p^{n-3} \partial p + (v_i - s) s^{n-2} \right], \end{aligned} \tag{11}$$

which is equal to:

$$\begin{aligned} U_i(w, v_i) &= w^{n-1} \left(v_i - \frac{n-1}{n} \beta_1(w) \right) \\ &+ (n-1)(1-w) \left[v_i^{n-1} - \left(\frac{v_i^{n-1}(n-2) + s^{n-1}}{(n-1)} \right) \right], \end{aligned} \tag{12}$$

Taking the derivate of Equation 12 w.r.t w and setting it to 0 yields:

$$\begin{aligned} \frac{\partial}{\partial w} U_i(w, v_i) =& (n-1) w^{n-2} \left(v_i - \frac{n-1}{n} \beta_1(w) \right) \\ &- w^{n-1} \frac{n-1}{n} \beta_1'(w) \\ &- (n-1) \left[v_i^{n-1} - \left(\frac{v_i^{n-1}(n-2) + s^{n-1}}{(n-1)} \right) \right] = 0, \end{aligned} \tag{13}$$

In equilibrium $w = v_i$, which gives:

$$\beta_1'(v_i) = \frac{(v_i^{n-1}(n-2) + s^{n-1}) n}{v_i^{n-1}(n-1)} - \beta_1(v_i) \frac{n-1}{v_i} \tag{14}$$

The solution to this differential equation is:

$$\beta_1(v_i) = \frac{v_i^{n-1}(n-2) + s^{n-1}}{v_i^{n-2}(n-1)} \tag{15}$$

Now assume that the bidder bids $w < v_i$, then the expected payoff, $U_i(w, v_i)$ for a bidder in the FA is:

$$\begin{aligned} U_i(w, v_i) =& w^{n-1}\left(v_i - \frac{n-1}{n}\beta_1(w)\right) \\ &+ (n-1)(1-v_i)\left(\int_s^v (n-2)(v_i-p)p^{n-3}\partial p + (v_i - s)s^{n-2}\right) \\ &+ (n-1)\int_w^v (n-2)\int_s^{y_1}(v_i-p)p^{n-3}f(p)\partial p + (v_i-s)s^{n-2}f(y_1)\partial y_1, \end{aligned} \tag{16}$$

which is equal to:

$$\begin{aligned} U_i(w, v_i) =& w^{n-1}\left(v_i - \frac{n-1}{n}\beta_1(w)\right) \\ &+ (n-1)(1-v_i)\left(\int_s^v (n-2)(v_i-p)p^{n-3}\partial p + (v_i - s)s^{n-2}\right) \\ &+ v^{n-1}(v_i - \frac{n-2}{n}v_i) - s^{n-1}v_i - w^{n-1}(v_i - \frac{n-2}{n}w) + s^{n-1}w, \end{aligned} \tag{17}$$

By taking the derivative of Equation 16 and setting it to 0 we get:

$$\begin{aligned} \frac{\partial}{\partial w}U_i(w, v_i) =& (n-1)w^{n-2}\left(v_i - \frac{n-1}{n}\beta_1(w)\right) - w^{n-1}\frac{n-1}{n}\beta_1'(w) \\ &- (n-1)w_i^{n-2}(v_i - \frac{n-2}{n}w) + w^{n-1}\frac{n-2}{n} + s^{n-1} = 0, \end{aligned} \tag{18}$$

Equation 18 together with the equilibrium requirement that $w = v_i$,gives Equation 14 and, thus, the optimal strategy given in Equation 15.

Now we will check that the bidders have no incentive to deviate from the optimal strategy by bidding $\beta_1(w)$, where $w \neq v_i$. To do this we will check that Equation 13 and 18 are maximized at $w = v_i$and that $\frac{\partial}{\partial w}U_i(w, v_i) \leq 0$ when $w > v_i$and $\frac{\partial}{\partial w}U_i(w, v_i) \geq 0$ when $w < v_i$for $\beta_1(w) = \frac{w^{n-1}(n-2)+s^{n-1}}{w^{n-2}(n-1)}$. Using the optimal strategy, and after some manipulations, Equation 13 becomes:

$$v_i - \left(\frac{v_i}{w}\right)^{n-2} v_i + \frac{(v_i^{n-1} - w^{n-1})(n-2)}{w^{n-2}(n-1)} = 0, \tag{19}$$

which holds true for $w = v_i$ and is less than 0 for any $w > v_i$.

Similarly, by replacing $\beta_1(w) = \frac{n-2}{n-1} \times w$ in Equation 18 and performing some manipulations we get that $0 = 0$, which concludes the proof.

Now we turn to the situation in which, before submitting a shill bid in the SA, the seller can observe all except the winning bid from the FA. Since the bidders are assumed to use $\beta_1(\cdot)$, the seller can perfectly infer the private values of the bidders who will participate in the SA from the bids they submitted in the FA by inverting $\beta_1(\cdot)$. Therefore, it is optimal for the seller to submit a shill bid equal to the private value of the bidder who submitted the second highest bid in the SA and then the payment to the bidder who wins the SA is equal to this bidder's private value. While leaving the dominant strategy in the SA unchanged, this gives the bidders incentives to report a low private value in the FA. Consequently, $\beta_1(\cdot)$ does not exist in this scenario:

Proposition 2. *If the seller shill bids and is informed of the losing bidders' bids in the FA, then there does not exist a strictly increasing symmetric bidding function $\beta_1(v_i)$ for any bidder i.*

Therefore, we expect that giving the seller the complete anonymous bidding history from the FA, as in Treatment 1, will decrease the bidders' bids in the FA compared to Treatment 2. The proof of 2 is similar to the proofs of Proposition 9 and Proposition 10 in Katsenos (2010). The proof is mainly given here for completeness. The proof builds on the idea that since the seller is informed of the bidders' bids in the FA and the bidders follow a symmetric strategy, the seller can extract all surplus from the bidders in the SA. This gives incentives for the bidders to report a lower private value as this makes it possible to expect a positive surplus also from the SA.

Proof. If a bidder i follows the symmetric strategy $\beta_1(v_i)$ and misrepresents his private value by $w \geq v_i$ in the FA, then his expected payoff is:

$$U(w, v_i) = w^{n-1}\left(v_i - \frac{n-1}{n}\beta_1(w)\right) \tag{20}$$

Note that if the bidder wins the SA, then he gets zero. This is because the bidder has reported a higher private value, which leads the seller to submit a shill bid that is higher than the bidder's private value and the seller will therefore win the item in the SA.

For a deviation to not be profitable, it must be that $\partial \Delta U(w, v_i)/\partial w \leq 0$.

$$\frac{\partial}{\partial w}U_i(w, v_i) = (n-1)w^{n-2}\left(v_i - \frac{n-1}{n}\beta_1(w)\right) - w^{n-1}\frac{n-1}{n}\beta_1'(w) \leq 0 \tag{21}$$

If the bidder instead reports a lower private value $w \leq v_i$, then the expected payoff of the bidder is:

$$\begin{aligned} U_i(w, v_i) =& w^{n-1}\left(v_i - \frac{n-1}{n}\beta_1(w)\right) + (n-1)(1-v_i)\int_0^{v_i}(v_i - p)p^{n-3}f(p)\partial p \\ &+ (n-1)(1-w)w^{n-2}(v_i - w) \\ &+ (n-1)\int_w^{v}(n-2)\int_0^{y_1}(v_i - p)p^{n-3}f(p)\partial p f(y_1)\partial y_1, \end{aligned} \tag{22}$$

where the first term results from the event $Y_1 < w$, the second from $w < Y_2 < v_i < Y_1$, the third from $Y_2 < w < Y_1$and the fourth from $w < Y_2 < Y_1 < v_i$ For a deviation not to be profitable, it must be that $\partial \Delta U(w, v_i)/\partial w \geq 0$.

$$\begin{aligned} \frac{\partial}{\partial w}U_i(w, v_i) =& (n-1)w^{n-2}\left(v_i - \frac{n-1}{n}\beta_1(w)\right) - w^{n-1}\frac{n-1}{n}\beta_1'(w) \\ &+ (n-1)(n-2)w^{n-3}(v_i - w) - (n-1)^2 w^{n-2}(v_i - w) \\ &- (n-1)(w^{n-2} - w^{n-1}) - (n-1)(v_i - \frac{n-2}{n}w) + w^{n-1}\frac{n-2}{n} \geq 0 \end{aligned} \tag{23}$$

Combining Equation (21) and (23) we get:

$$(n-2)w^{n-3}(v_i-w)-(n-1)w^{n-2}(v_i-w)-w^{n-2} \quad (24)$$

$+w^{n-1}-(v_i-\frac{n-2}{n}w)+w^{n-1}\frac{n-2}{(n-1)n}\geq 0,$

which equals:

$$\left[v_i\left[(n-2)w^{n-3}-(n-1)w^{n-2}-1\right]+w\left[\frac{n-2}{n}\right]\right] \quad (25)$$

$+\left[\frac{n^2+n-2}{(n-1)n}w^{n-1}-\frac{n^3-2n^2+2n}{(n-1)n}w^{n-2}\right]\geq 0$

Equation (25) can never be true as both terms are less than 0 for any $w<v_i$ and $n\geq 3$. □

A.2 Seller behavior

We start by considering the setting in which the seller can submit shill bids, but have no information about the FA bids. In order to derive the optimal shill bid we consider the expected payment of a bidder in the SA in this scenario, which is:

$$(n-1)(1-v_i)\left(\int_s^{v_i}(n-2)pp^{n-3}\partial p+ss^{n-2}\right). \quad (26)$$

The seller knows that the bidders' private values are uniformly distributed between 0 and 1. Therefore, the seller's expected revenue in the SA is:

$$n\left[\int_s^1(n-1)(1-v_i)\int_s^{v_i}(n-2)pp^{n-3}f(p)\partial pf(v_i)\partial dv_i+\int_s^1(n-1)(1-v_i)ss^{n-2}f(v_i)\partial dv_i\right], \quad (27)$$

which is equal to:

$$\frac{n-2}{n+1}+\frac{n}{2}s^{n-1}-2(n-1)s^n+\frac{3(n-1)n}{2(n+1)}s^{n+1} \quad (28)$$

Taking the F.O.C of 28 w.r.t to s and solving for s gives: $s=\frac{1}{3}$

However, the seller may also take into account the effect of the shill bid on the bidders' FA bids. When the bidders use the optimal strategy in Equation 15, then the expected payment of a bidder for whom $v_i\geq s$ in the FA is:

$$(n-1)\int_s^{v_i}\left(\frac{n-2}{n-1}+\frac{s^{n-1}}{p^{n-1}(n-1)}\right)pp^{n-2}f(p)\partial p+(n-1)\int_0^s pp^{n-2}f(p)\partial p, \quad (29)$$

which equals:

$$\frac{n-2}{n}v_i^n+s^{n-1}v_i-\frac{n-1}{n}s^n \quad (30)$$

For any bidder for whom $v_i<s$, the expected payment in the FA is:

$$(n-1)\int_0^{v_i}pp^{n-2}f(p)\partial p=\frac{n-1}{n}v_i^n \quad (31)$$

The seller's expected revenue in the FA becomes:

$$n\left[\int_{s}^{1}\frac{n-2}{n}v_i^n+s^{n-1}v_i-\frac{n-1}{n}s^n f(v_i)\partial v_i+\int_{0}^{s}\frac{n-1}{n}v_i^n f(v_i)\partial v_i\right], \tag{32}$$

which equals:

$$\frac{n-2}{(n+1)}+\frac{n}{2}s^{n-1}-(n-1)s^n+\frac{n(n-1)}{2(n+1)}s^{n+1} \tag{33}$$

To derive the optimal s,we combine Equation 28 and Equation 33, which is the expected payment from the FA and SA, and take the derivative of this w.r.t s and setting it equal to 0. This gives us:

$$s^2-\frac{3}{2}s+\frac{1}{2}=0. \tag{34}$$

From Equation 34 it follows that the seller's revenue is maximized when $s=\frac{1}{2}$.

A.3 Description and construction of variables used in regressions

Table 8: Description of variables used in regression analysis

Variable	Description and construction of the variables
Ave private value	Ave private value is the average private value among the participating bidders in an auction.
Buyer	A dummy variable that takes the value 1 if the subject is a buyer and 0 otherwise.
FA (SA) payoff (bidders)	Bidder's payoff is their private value minus the final price if they are the winner of an auction and it is 0 if they lose the auction. There is one payoff for the first auction (FA payoff) and one for the second auction (SA payoff).
FA (SA) payoff (sellers)	A seller's payoff in an auction equals the final price of that auction. There is one payoff for the first auction (FA payoff) and one for the second auction (SA payoff)
FA (SA) price	The FA (SA) price is the final price that the winning bidder pays to the seller, which is determined by the second highest bid submitted before the end of that auction. There is one price for the first auction (FA price) and one price for the second auction (SA price).
FA (SA) 50 and FA (SA) 55	These variables measure late bidding by subjects and are divided by if the last submitted bid was submitted in the last 10 seconds (FA50 and SA50) or last 5 seconds (FA55 and SA55) in each auction. FA and SA refers to the first auction and the second auction.
Final FA (SA) bid	Final bid takes the value of the last bid that bidders and sellers successfully submitted before the end of each auction. Final bid is divided by first (Final FA bid) and second auction (Final SA bid).
First bid SA	This variable measures the magnitude of bidders' and sellers' first bid in the second auction.
Last period balance	This is the experimental currency balance of the last period. This is showed to the subjects at the end of each auction for bidders and each round for sellers.
Last period shill bid	This is a dummy variable that takes the value of 1 if the seller submitted at least one shill bid in the second auction of the previous round and zero otherwise.
Nr bids FA (SA)	The Nr bids variables summarize the number of bids that a bidder or a seller submitted in each auction. This variable is divided by the first (Nr bids FA) and second auction (Nr bids SA).

Table 9: Description of variables used in regression analysis continued

Variable	Description and construction of the variables
Nr of previous shill bidding SA	This variable represents the number of previous rounds in which the sellers submitted at least one shill bid in the second auction.
Period	Period takes the value of the current round that subjects are participating in. There are 20 periods in total.
Pr first bid SA	The probability that a subject submits the first bid in the second auction.
Private value	The private value is assigned randomly to each bidder at the beginning of each round from a uniform distribution of 0 to 100.
Seller	A dummy variable that takes the value of 1 if the subject is a seller and 0 otherwise.
Seller shill bids	Is a dummy variable that takes the value of 1 if the seller submits at least one shill bid in the second auction of that round and 0 otherwise.
Seller wins SA	This is a dummy variable that takes the value of 1 if the seller shill bids and wins the item and zero otherwise.
T. first bid	This variable records the timing, in seconds, that subjects submit their first bid in the second auction.
T1	A dummy variable that takes the value of 1 if the subject is in Treatment 1 in which the seller can shill bid and is given the complete bidding history from the first auction.
T2	A dummy variable that takes the value of 1 if the subject is in Treatment 2 in which the seller can shill bid, but is not given the complete bidding history from the first auction.
% of earlier wins FA (SA)	This is defined as the percentage of the auctions that a bidder or seller won in the previous rounds. There is one variable for the first auction (% of earlier wins FA) and one for the second auction (% of earlier wins SA).

B Additional analysis and regression tables

Table 10 shows the theory driven variables and the data observed statistics. Here in the following, we will explain how we compute those theory driven numbers in details. The derived bidding functions in Equation 1 and 2 give rise to hypotheses regarding prices, efficiency and earnings 10. With buyer private values uniformly distributed between $(0, 1)$ it follows that the expected first, second and third order statistics of this distribution equals 0.8, 0.6 and 0.4 respectively. In the Baseline, it follows that the expected FA price is $\frac{2}{3} * 0.6 = 0.4$, which is equal to the expected SA price of 0.4. These are also the seller's expected earnings. As the bidders are assumed to follow $\beta_1(v_i)$ and $\beta_2(v_i)$ we expect full efficiency in the baseline in the sense that the buyer with the highest private value wins the FA and the buyer with the second highest private value wins the SA. From this it follows that we expect the winning buyer's earnings to be 0.4 in the FA and 0.2 in the SA. Therefore, the average buyer earnings are 0.1 and 0.05 in the FA and SA respectively

In Treatment 2 it turns out that the seller submits a shill bid that makes her forego some profit from the SA. By submitting a shill bid of 0.5, Equation 33 and 28 in Appendix A give that the seller expects to earn 0.5 in the FA and 0.3875 in the SA. The expected price in the FA is 0.5, but the expected SA price is 0.5125. The reason for this is that the seller sometimes wins the SA and the expected price for this event is 0.125. We expect full efficiency in the FA of Treatment 2, but since there is a 12.5% probability that the seller wins the SA when submitting a shill bid of 0.5 we expect SA efficiency to be 87.5%. Finally, the winning buyer's earnings are expected to be 0.3 in the FA and 0.1375 in the SA, so average buyer earnings are predicted to be 0.075 in the FA and 0.0344 in the SA.

Table 10: Other theory driven variables andobserved statistics

	Theory Driven			Data Observed		
	Baseline	Treatment 2: $s = 50$	Treatment 2: - $s = 33.33$	Baseline	Treatment 1	Treatment 2
FA price	40	50	44.2	42.20	48.89	49.53
				[17.77]	[16.26]	[19.32]
SA price	40	45	42.7	33.90	43.02	43.65
				[18.19]	[18.06]	[19.42]
Ave buyer FA earnings	10	7.5	9	6.72	6.54	6.23
				[15.62]	[14.44]	[14.8]
Ave buyer SA earnings	5	2.5	4	7.46	5.08	4.77
				[17.3]	[13.29]	[13.32]
FA seller earnings	40	50	44.2	42.20	48.89	49.53
				[16.26]	[17.77]	[19.32]
SA seller earnings	40	38.75	41.5	33.90	38.64	37.33
				[18.19]	[21.64]	[23.55]
FA efficiency	100%	100%	100%	54.17%	69.58%	70.83%
				[49.93]	[46.10]	[45.55]
SA efficiency	100%	87.5%	96.3%	44.58%	51.67%	50.00%
				[49.81]	[50.08]	[50.10]

Notes: Entries are multiplied by 100 to match the outcomes in the experiment.

Buyer earnings refer to winning buyer's earnings.

We don't have theory for Treatment 1, so there is no theory driven for this.

Table 11: OLS regressions with FA and SA final prices as dependent variables

	(1)	(2)	(3)	(4)	(5)
	FA price	FA price	SA price	SA price	SA price
T1	6.688**	6.031**	9.117**	4.864	4.484
	[2.982]	[2.589]	[3.447]	[4.129]	[3.683]
T2	7.325**	7.430**	9.750***	2.364	4.140
	[3.443]	[3.115]	[3.282]	[4.517]	[3.068]
Seller shill bids * T1				5.969**	7.437***
				[2.684]	[1.791]
Seller shill bids * T2				9.634**	9.328***
				[3.662]	[1.177]
Period		0.239**			0.257**
		[0.0990]			[0.103]
Ave private value		0.821***			0.799***
		[0.0353]			[0.0446]
Constant	42.20***	-1.610	33.90***	33.90***	-3.955
	[2.096]	[3.012]	[2.669]	[2.673]	[2.608]
Observations	720	720	720	720	720
R^2	0.034	0.472	0.055	0.077	0.549
Clusters	18	18	18	18	18

Notes: Robust standard errors clustered on Group level in brackets

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 12: GLS random effects models with sellers' FA and SA payoff as dependent variable

	(1)	(2)	(3)	(4)	(5)	(6)
	FA payoff	FA payoff	SA payoff	SA payoff	SA payoff	SA payoff
T1	6.688**	4.790*	4.733	5.680	4.429	3.339
	[2.982]	[2.628]	[2.903]	[4.501]	[3.574]	[3.639]
T2	7.325**	6.156*	3.429	2.017	4.032	3.770
	[3.443]	[3.421]	[3.221]	[4.354]	[3.021]	[2.749]
Seller shill bids * T1				-1.329	0.203	4.588*
				[4.618]	[3.321]	[2.545]
Seller shill bids * T2				1.841	0.531	4.695***
				[3.031]	[2.002]	[1.528]
Ave private value		0.820***			0.892***	0.774***
		[0.0347]			[0.0444]	[0.0382]
Last period balance		0.0220**			0.0124	0.0159
		[0.00979]			[0.0138]	[0.0103]
Last period shill bid		-0.794			-0.0302	-0.321
		[1.988]			[2.434]	[1.286]
Nr bids SA					0.139	0.444
					[0.409]	[0.290]
% of earlier wins SA		8.642			-0.808	6.612
		[5.900]			[6.512]	[4.241]
Period		-0.637			-0.188	-0.361
		[0.406]			[0.546]	[0.426]
Seller wins SA						-36.50***
						[2.342]
Constant	42.20***	-2.197	33.90***	33.90***	-8.942***	-3.460*
	[2.096]	[2.911]	[2.669]	[2.673]	[2.294]	[2.066]
Observations	720	720	720	720	720	720
Number of Subject	36	36	36	36	36	36
Clusters	18	18	18	18	18	18

Notes: Robust standard errors clustered at Group level in brackets

*** p<0.01, ** p<0.05, * p<0.1

Table 13: GLS random effects models with buyers' FA and SA payoff as dependent variable

	(1)	(2)	(3)	(4)	(5)	(6)
	FA payoff	FA payoff	SA payoff	SA payoff	SA payoff	SA payoff
T1	-0.175	0.596	-2.386***	-1.186	-1.130	-0.624
	[0.443]	[0.836]	[0.780]	[1.160]	[0.784]	[1.218]
T2	-0.491	0.608	-2.690***	-1.232	-1.614*	-0.583
	[0.708]	[1.239]	[0.746]	[1.095]	[0.891]	[1.058]
Seller shill bids * T1					-1.764***	-0.966
					[0.537]	[0.735]
Seller shill bids * T2					-1.404*	-1.024
					[0.739]	[0.795]
Nr of previous shill bidding SA		-0.175		-0.133		-0.114
		[0.124]		[0.0983]		[0.104]
Private value		0.250***		0.191***		0.191***
		[0.0126]		[0.0150]		[0.0149]
Nr bids FA		-0.236**				
		[0.111]				
% of earlier wins FA		4.436***		-0.304		-0.319
		[1.468]		[1.753]		[1.755]
% of earlier wins SA		0.345		0.389		0.390
		[1.951]		[1.740]		[1.748]
Last period balance		-0.00772**		0.0137***		0.0136***
		[0.00311]		[0.00421]		[0.00429]
Period		0.188**		-0.146*		-0.151*
		[0.0943]		[0.0827]		[0.0828]
Nr bids SA				1.037***		1.031***
				[0.134]		[0.135]
Constant	6.717***	-6.445***	7.461***	-5.931***	7.461***	-5.817***
	[0.353]	[1.093]	[0.680]	[1.668]	[0.681]	[1.706]
Observations	2,880	2,880	2,880	2,880	2,880	2,880
Number of Subject	144	144	144	144	144	144
Clusters	18	18	18	18	18	18

Notes: Robust standard errors clustered at Group level in brackets

*** p<0.01, ** p<0.05, * p<0.1

Table 14: GLS random effects regressions with buyers' FA final bids as dependent variable

	(1)	(2)	(3)	(4)
	Final FA bid	Final FA bid	Final FA bid	Final FA bid
T1	4.148*	1.625	-5.552**	-7.555**
	[2.294]	[2.179]	[2.630]	[3.386]
T2	4.144*	2.453	-5.123**	-7.436**
	[2.511]	[2.633]	[2.119]	[3.092]
Private value * T1			0.181***	0.184***
			[0.0612]	[0.0576]
Private value * T2			0.186***	0.199***
			[0.0528]	[0.0512]
Private value		0.662***	0.567***	0.533***
		[0.0328]	[0.0426]	[0.0378]
Nr of previous shill bidding SA		0.290		0.272
		[0.199]		[0.202]
Nr bids FA		1.288***		1.324***
		[0.188]		[0.198]
% of earlier wins FA		3.887*		4.160*
		[2.129]		[2.325]
% of earlier wins SA		3.258		2.848
		[2.054]		[2.043]
Last period balance		-0.0123		-0.0127
		[0.00863]		[0.00901]
Period		0.235		0.252
		[0.218]		[0.225]
Constant	35.72***	-2.849	7.223***	3.505
	[1.695]	[2.644]	[2.035]	[2.933]
Observations	2,880	2,880	2,880	2,880
Number of Subject	144	144	144	144
Clusters	18	18	18	18

Notes: Robust standard errors clustered at Group level in brackets

*** p<0.01, ** p<0.05, * p<0.1

Table 15: GLS random effects regressions with buyers' SA final bid as dependent variable

	(1)	(2)	(3)	(4)	(5)
	Final SA bid	Final SA bid	Final SA bid	Final SA bid	Final SA bid
T1	1.334	3.838	-4.433**	-2.247	-0.350
	[2.725]	[3.152]	[1.917]	[2.024]	[2.464]
T2	0.702	4.124	-3.893**	-1.675	2.299
	[3.038]	[3.368]	[1.693]	[1.964]	[2.131]
Seller shill bids * T1					-2.870
					[2.706]
Seller shill bids * T2					-5.519**
					[2.215]
Seller shill bids * Private value * T1					0.0856
					[0.0698]
Seller shill bids * Private value * T2					0.142***
					[0.0507]
Private value * T1			0.147*	0.138*	0.0789
			[0.0859]	[0.0820]	[0.0956]
Private value * T2			0.138	0.132	0.0259
			[0.0886]	[0.0879]	[0.0958]
Private value		0.784***	0.711***	0.697***	0.697***
		[0.0375]	[0.0778]	[0.0765]	[0.0767]
Nr of previous shill bidding SA		-0.167		-0.154	-0.137
		[0.168]		[0.161]	[0.159]
Nr bids SA		1.198***		1.172***	1.164***
		[0.238]		[0.228]	[0.228]
% of earlier wins FA		-0.205		-0.0454	0.129
		[2.253]		[2.294]	[2.268]
% of earlier wins SA		0.495		0.391	0.303
		[2.631]		[2.563]	[2.526]
Last period balance		0.0214***		0.0214***	0.0214***
		[0.00535]		[0.00561]	[0.00551]
Period		0.0969		0.0896	0.0761
		[0.123]		[0.121]	[0.119]
Constant	36.10***	-7.536***	5.112***	-3.584*	-3.459*
	[2.348]	[2.578]	[1.503]	[1.967]	[1.957]
Observations	2,164	2,164	2,164	2,164	2,164
Number of Subject	144	144	144	144	144
Clusters	18	18	18	18	18

Notes: Robust standard errors clustered at Group level in brackets

*** p<0.01, ** p<0.05, * p<0.1

Table 16: Probit regressions with the buyer's probability of submitting a late final SA bid in the last 10 and 5 seconds as dependent variable

	(1)	(2)	(3)	(4)
	SA 50	SA 50	SA 55	SA 55
T1	-0.220	-0.0232	-0.249	-0.0317
	[0.191]	[0.284]	[0.153]	[0.251]
T2	-0.352*	-0.245	-0.372**	-0.179
	[0.206]	[0.302]	[0.169]	[0.304]
Seller shill bids * T1		-0.360**		-0.313***
		[0.162]		[0.111]
Seller shill bids * T2		-0.213		-0.242
		[0.137]		[0.171]
Nr of previous shill bidding SA		0.0141		0.00346
		[0.0196]		[0.0216]
Private value		0.0190***		0.0142***
		[0.00170]		[0.00143]
Nr bids SA		0.145***		0.0958***
		[0.0237]		[0.0198]
% of earlier wins FA		-0.150		-0.0558
		[0.270]		[0.264]
% of earlier wins SA		-0.0128		0.0199
		[0.199]		[0.221]
Last period balance		0.00162**		0.00118*
		[0.000667]		[0.000665]
Period		-0.00929		0.00255
		[0.0170]		[0.0174]
Constant	0.383**	-1.009***	0.0853	-1.083***
	[0.179]	[0.225]	[0.137]	[0.183]
Observations	2,164	2,164	2,164	2,164
Clusters	18	18	18	18

Notes: Robust standard errors clustered at Group level in brackets

*** p<0.01, ** p<0.05, * p<0.1

Table 17: Probit regressions on the probability of submitting a late final FA bid in the last 10 and 5 seconds as dependent variable for buyers

	(1)	(2)	(3)	(4)
	FA 50	FA 50	FA 55	FA 55
T1	0.169	0.0700	0.126	-0.000638
	[0.170]	[0.221]	[0.173]	[0.216]
T2	-0.0316	-0.134	-0.0555	-0.181
	[0.174]	[0.225]	[0.185]	[0.224]
Nr of previous shill bidding SA		0.0197		0.0208
		[0.0158]		[0.0167]
Private value		0.0165***		0.0143***
		[0.00130]		[0.00123]
Nr bids FA		0.136***		0.0772***
		[0.0350]		[0.0226]
% of earlier wins FA		-0.131		0.0666
		[0.219]		[0.196]
% of earlier wins SA		-0.0833		-0.00911
		[0.243]		[0.224]
Last period balance		-0.000166		8.76e-05
		[0.000939]		[0.000880]
Period		-0.00171		-0.00971
		[0.0170]		[0.0167]
Constant	0.152	-0.962***	-0.131	-1.039***
	[0.162]	[0.182]	[0.166]	[0.206]
Observations	2,880	2,880	2,880	2,880
Clusters	18	18	18	18

Notes: Robust standard errors clustered at Group level in brackets

*** p<0.01, ** p<0.05, * p<0.1

Table 18: One Bid and Multiple Bids buyers in the FA

	All Treatments	Baseline	T1 (&Info)	T2 (&No Info)
Percentage of OB buyers across all buyers(%)	30.6	26.4	29.3	36.4
Percentage of buyers who bid late among OB buyers(%)	53.8	44.3	67.2	50
Percentage of buyers who bid early among OB buyers(%)	26.3	35.9	16.3	27.4

Table 19: Buyer's bid once and bid late strategy

	Probit Regression		OLS Regression			
	Buyers		One Bid buyers		Multiple Bids buyers	
Dependent Variables	FA bid once	SA bid once	FA time	SA time	FA time (Final bid)	SA time (Final bid)
D. Baseline	Ref	Ref	Ref	Ref	Ref	Ref
D. Treatment 1	-0.398*	-0.103	-6.268	--5.242	0.347	--7.529*
	(-2.25)	(-0.51)	(-0.69)	(-0.58)	(0.11)	(-2.59)
D. Treatment 2	-0.257	-0.0861	-3.871	-3.539	-0.343	-8.076
	(-1.82)	(-0.42)	(-0.42)	(-0.34)	(-0.11)	(-2.11)
Private value	-0.00608*	-0.00730***	0.217***	0.281***	0.171***	0.127***
	(-2.55)	(-26.31)	(7.04)	(7.56)	(4.76)	(5.68)
D. Baseline * Private value	Ref	Ref	Ref	Ref	Ref	Ref
D. Treatment 1 * Private value	0.00436	-0.00312***	0.158***	0.0839	-0.0265	0.0749*
	(1.41)	(-4.98)	(4.07)	(1.77)	(-0.67)	(2.14)
D. Treatment 2 * Private value	0.00559*	-0.000883	-0.0146	-0.0321	0.0112	0.0722
	(2.19)	(-0.43)	(-0.19)	(-0.44)	(0.26)	(1.74)
Period	-0.00296	0.00881	-0.107	0.0817	-0.163	0.0506
	(-0.43)	(1.51)	(-0.36)	(0.20)	(-1.26)	(0.45)
D. Baseline * Period	Ref	Ref	Ref	Ref	Ref	Ref
D. Treatment 1 * Period	0.0258**	0.0259**	0.801	0.583	0.263	0.134
	(2.59)	(2.98)	(1.91)	(1.30)	(1.39)	(0.79)
D. Treatment 2 * Period	0.0256**	0.0181	0.629	0.491	0.00645	0.0736
	(2.58)	(1.78)	(1.95)	(1.03)	(0.04)	(0.49)
Constant	-0.305**	-0.378**	25.14**	25.31*	44.11***	47.50***
	(-2.92)	(-2.68)	(3.07)	(2.87)	(17.74)	(22.69)
N	57600	57600	880	783	1687	1160

Notes: Robust standard errors clustered at Group level in brackets

*** p<0.01, ** p<0.05, * p<0.1

Table 20: Probit regression on share of overbid in FA and SA auction for buyers

	(1)	(2)
	overbidFA	overbidSA
T1	-0.324***	-0.191*
	(-3.84)	(-2.31)
T2	0.0178	0.0419
	(0.23)	(0.54)
Private value	-0.0104***	-0.0130***
	(-8.69)	(-10.51)
Nr bids FA	0.0399***	
	(3.43)	
Nr bids SA		0.100***
		(8.22)
% of wins FA in the past	0.0124	-0.0200
	(0.07)	(-0.12)
Last period balance	-0.000439	0.000354
	(-1.30)	(1.09)
constant	-0.737***	-0.905***
	(-6.70)	(-8.14)
Observations	2879	2879

Notes: t statistics in parentheses

*** p<0.001, ** p<0.01, * p<0.05

Table 21: Probit regression on sellers' shill bid

	(1)	(2)	(3)	(4)
	P. Shill bid (Within T1)			P. Shill bid (T1 vs T2)
FA final price	-0.00377	-0.00454	-0.00438	
	[-0.79]	[-0.95]	[-0.90]	
Accumulated Earning		0.000449	0.000474	0.000369
		[1.36]	[1.25]	[1.26]
P.Won Past Rounds			-0.321	0.641
			[-0.26]	[0.94]
T1				-0.147
				[-0.58]
Constant	0.759***	0.562**	0.571***	0.466
	[3.40]	[3.24]	[2.78]	[1.71]
Observation N	240	240	240	240

Notes: Robust standard errors clustered at Group level in brackets

*** p<0.01, ** p<0.05, * p<0.1

Table 22: Probit regressions with probability of submitting a late bid and of submitting the first bid as dependent variables for both buyers and sellers

	(1)	(2)	(3)	(4)	(5)	(6)
	SA 50	SA 50	SA 55	SA 55	Pr first bid SA	Pr first bid SA
Buyer * T1	0.132	0.119	0.124	0.116	-0.145**	-0.165**
	[0.125]	[0.148]	[0.123]	[0.144]	[0.0706]	[0.0797]
Seller * T1	-0.163	-0.693**	-0.388*	-0.691***	0.951***	0.471**
	[0.228]	[0.303]	[0.216]	[0.258]	[0.201]	[0.202]
Seller * T2	-0.293	-0.688***	-0.551***	-0.768***	0.513**	0.143
	[0.200]	[0.226]	[0.163]	[0.220]	[0.239]	[0.242]
Ave private value		0.00942***		0.00519*		-0.000915
		[0.00207]		[0.00270]		[0.00131]
Period		0.0115		0.0124		-0.0275**
		[0.00792]		[0.0127]		[0.0117]
Last period balance		0.000493		0.000264		0.000714
		[0.000329]		[0.000519]		[0.000521]
Nr bids SA		0.177***		0.0971***		0.155***
		[0.0283]		[0.0182]		[0.0232]
Constant	0.0311	-1.006***	-0.287***	-0.938***	-0.540***	-0.763***
	[0.104]	[0.162]	[0.101]	[0.144]	[0.0399]	[0.0565]
Observations	1,799	1,799	1,799	1,799	1,424	1,424
Clusters	12	12	12	12	12	12

Notes: Robust standard errors clustered at Group level in brackets

*** p<0.01, ** p<0.05, * p<0.1

Table 23: GLS random effects models with Number of bids, Final bid, magnitude of first bid and timing of first bid for both buyers and sellers in SA

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Nr bids	Nr bids	Final bid	Final bid	First bid	First bid	T.first bid	T. first bid
Buyer * T1	0.0855	0.0686	0.630	-0.328	-0.728	-1.040	0.333	0.315
	[0.316]	[0.314]	[2.411]	[2.158]	[2.810]	[2.359]	[2.290]	[1.946]
Seller * T1	1.915***	1.522***	-0.151	-4.306	-6.560***	0.0514	-16.56***	-14.09***
	[0.196]	[0.129]	[3.446]	[2.999]	[2.261]	[2.154]	[1.412]	[1.233]
Seller * T2	1.245***	0.835**	-2.709	-5.542	-7.738***	-3.323	-14.41***	-12.85***
	[0.416]	[0.375]	[4.105]	[4.495]	[2.144]	[2.728]	[1.433]	[2.142]
Ave private value		0.0148***		0.680***		0.435***		0.111***
		[0.00480]		[0.0269]		[0.0443]		[0.0368]
Period		-0.0336***	0.116	0.230		0.415***		0.515***
		[0.0123]	[0.102]	[0.184]		[0.0992]		[0.109]
Last period balance		0.00150***		-0.00290		-0.00619		0.000743
		[0.000559]		[0.00967]		[0.00473]		[0.00459]
Nr bids SA				2.723***		-2.245***		-1.505***
				[0.330]		[0.344]		[0.268]
Constant	2.397***	1.805***	35.58***	-0.168	21.22***	5.297***	22.04***	15.41***
	[0.220]	[0.220]	[2.237]	[2.328]	[2.668]	[1.790]	[1.803]	[2.689]
Observations	1,799	1,799	1,799	1,799	1,637	1,637	1,637	1,637
Nr.Subject	120	120	120	120	120	120	120	120
Clusters	12	12	12	12	12	12	12	12

Notes: Robust standard errors clustered at Group level in brackets

*** p<0.01, ** p<0.05, * p<0.1

Table 24: Marginal effects from probit regressions of the probabilities of bidding equal to private value, underbid, or overbid in the second auction

	(1)	(2)	(3)
	Bid = pv	Underbid	Overbid
Win previous Period with underbid	-0.0483	0.0830	-0.0305
	[0.0696]	[0.0707]	[0.0328]
Win previous Period with overbid	-0.109	0.0210	0.00690
	[0.103]	[0.106]	[0.0437]
Win previous Period with bid = pv	0.0222	-0.0126	0.000236
	[0.0577]	[0.0734]	[0.0425]
Payoff previous Period with underbid	0.00227	-0.00145	-0.00125
	[0.00180]	[0.00167]	[0.000995]
Payoff previous Period with overbid	-0.00403	-0.00397	0.00259*
	[0.00248]	[0.00319]	[0.00146]
Payoff last Period with bid = pv	0.000517	-0.00161	0.000172
	[0.00190]	[0.00233]	[0.00120]
Previous Period with bid = pv	0.308***	-0.284***	-0.0323
	[0.0860]	[0.0951]	[0.0412]
Previous Period with underbid	-0.0912	0.0897	0.00558
	[0.0606]	[0.0617]	[0.0291]
Previous Period with overbid	-0.120	-0.214**	0.191***
	[0.0815]	[0.0927]	[0.0377]
Accumulated payoff with overbid	-6.28e-05	-0.000549	0.000471***
	[0.000285]	[0.000345]	[0.000155]
Accumulated payoff with underbid	-0.000540**	0.000485**	6.02e-05
	[0.000245]	[0.000243]	[0.000137]
Acummulated payoff with bid = pv	0.000510**	-0.00113***	0.000220*
	[0.000232]	[0.000280]	[0.000113]
Private value	0.000877	0.00204**	-0.00273***
	[0.000702]	[0.000874]	[0.000362]
Period	0.00765**	-0.00373	-0.00331**
	[0.00325]	[0.00357]	[0.00154]
Previous Period price	0.00174***	-0.00136*	-0.000349
	[0.000618]	[0.000764]	[0.000440]
Current Period price	0.000232	-0.00336***	0.00283***
	[0.000850]	[0.00107]	[0.000487]
Constant	0.150***	0.720***	0.131***
	[0.0421]	[0.0597]	[0.0276]
Observations	1,665	1,665	1,665
Clusters	18	18	18

Standard errors clustered on Group level in brackets

**** p<0.01, ** p<0.05, * p<0.1*

Table 25: Regression results of previous period payoff and price as well as marginal effects from probit regression of probability of winning in previous period

	(1)	(2)	(3)
	Previous Period payoff	Previous Period price	Previous Period win
			SA
P-1: overbid; P: overbid	-2.750**	6.855**	0.0840*
	[1.239]	[2.447]	[0.0459]
P-1: overbid; P: undrbid	-8.729***	4.084*	0.0257
	[1.617]	[2.247]	[0.0590]
P-1: overbid; P: bid = pv	-8.413***	2.182	-0.0871
	[1.691]	[3.722]	[0.0841]
P-1: underbid; P: overbid	-4.503**	0.830	-0.145**
	[1.555]	[2.527]	[0.0605]
P-1: underbid; P: bid = pv	-0.772	6.251***	-0.0381
	[1.925]	[2.018]	[0.0546]
P-1: bid = pv; P: underbid	-3.278***	3.712	0.00952
	[1.106]	[2.696]	[0.0441]
P-1: bid = pv; P: bid = pv	2.320	3.914**	0.141***
	[1.569]	[1.756]	[0.0271]
P-1: bid = pv; P: overbid	2.501	1.687	0.131***
	[2.640]	[2.208]	[0.0510]
Constant	8.462***	37.18***	0.271***
	[0.709]	[2.247]	[0.0140]
Observations	1,558	1,558	1,558
Clusters	18	18	18

*Notes: Robust standard errors clustered on Group level in brackets *** $p<0.01$, ** $p<0.05$, * $p<0.1$*

Constant is previous Period underbid Period underbid.

P-1 indicates previous period stragey and P indicates the bidding strategy in current period.

Table 26: GLS regressions with Final FA bid and Final SA bid as dependent variables for periods 1-5 and 16-20

	(1)	(2)	(3)	(4)
	Final FA bid	Final FA bid	Final SA bid	Final SA bid
T1: Period 16 - 20	-4.893**	-4.684**	0.234	0.156
	[2.338]	[2.387]	[1.753]	[1.916]
B: Period 16 - 20	-8.894***	-6.637	-1.477	-5.673
	[2.259]	[4.073]	[3.043]	[3.684]
T1: Period 1 - 5	5.377	1.819	1.656	1.039
	[5.813]	[5.925]	[5.291]	[5.452]
T2: Period 1 - 5	4.070	0.393	3.191	2.349
	[5.493]	[5.512]	[3.649]	[3.410]
B: Period 1 - 5	1.562	-1.926	-0.792	-2.627
	[6.898]	[6.785]	[5.445]	[5.645]
Private value	0.688***	0.663***	0.789***	0.771***
	[0.0297]	[0.0321]	[0.0375]	[0.0396]
Period	0.754**	0.514	0.348	0.249
	[0.372]	[0.515]	[0.266]	[0.270]
Nr of previous shill bidding SA		0.184		
		[0.292]		
Nr bids FA		1.227***		
		[0.309]		
% of earlier wins FA		5.568**		-0.291
		[2.378]		[2.581]
% of earlier wins SA		3.660*		0.801
		[2.181]		[2.950]
Last period balance		-0.0121		0.0205***
		[0.00983]		[0.00591]
Nr of previous shill bidding SA				-0.217
				[0.171]
Nr bids SA				1.125***
				[0.374]
Constant	-3.619	-2.185	-1.094	-4.404
	[6.894]	[6.692]	[5.326]	[5.188]
Observations	1,440	1,440	1,082	1,082
Number of Subjects	144	144	144	144
Clusters	18	18	18	18

*Notes: Robust standard errors clustered on Group level in brackets. *** p<0.01, ** p<0.05, * p<0.1*

Table 27: Buyers' dynamic bidding behavior across time: OLS regression with buyers' FA and SA bid as dependent variables

	(1)	(2)
	FA Bid	SA Bid
Current price # D. 40- 60s	0.475***	0.493***
	(0.0456)	(0.0497)
Current price # D. 20- 40s	0.945***	0.979***
	(0.0253)	(0.0239)
Current price # D. 0- 20s	0.669***	0.876***
	(0.165)	(0.0497)
Private value # D. 40- 60s	0.389***	0.443***
	(0.0324)	(0.0389)
Private value # D. 40- 60s	0.0774***	0.105***
	(0.0120)	(0.0151)
Private value # D. 40- 60s	0.113***	0.136***
	(0.0269)	(0.0252)
Time # D. 40- 60s	0.902***	0.831***
	(0.0782)	(0.100)
Time # D. 20- 40s	0.101***	0.0167
	(0.0330)	(0.0541)
Time # D. 0- 20s	-0.340***	-0.446***
	(0.0889)	(0.112)
D. 20-40s	-8.492***	-7.069***
	(1.590)	(1.616)
D. 40-60s	-51.88***	-49.37***
	(3.885)	(6.013)
Constant	7.842***	8.647***
	(1.147)	(1.266)
N	8257	5438
R^2	0.6130	0.6586
Cluster	18	18

Notes: Standard errors clustered on Group level in parentheses

** p< 0.1 ** p<0.05 ***p < 0.01*

Table 28: OLS regression on buyers' dynamic bidding across private value

	FA Bid	SA Bid
Current price # D. High pv	0.596***	0.678***
	(0.0574)	(0.0468)
Current price # D. Mid pv	0.575***	0.568***
	(0.0469)	(0.0395)
Current price # D. Low pv	0.673***	0.636***
	(0.0615)	(0.0504)
Private value # D. High pv	0.311***	0.410***
	(0.0614)	(0.0843)
Private value # D. Mid pv	0.211***	0.288***
	(0.0284)	(0.0399)
Private value # D. Low pv	0.204***	0.270***
	(0.0343)	(0.0358)
Time # D. High pv	0.478***	-27.42***
	(0.0567)	(5.865)
Time # D. Mid pv	0.318***	-9.482***
	(0.0393)	(1.729)
Time in # D. Low pv	0.0223	0.469***
	(0.0374)	(0.0625)
D. High pv	-22.65***	0.347***
	(3.888)	(0.0366)
D. Mid pv	-8.769***	0.0704***
	(1.398)	(0.0224)
Constant	3.013***	1.542**
	(1.018)	(0.711)
N	8257	5438
R^2	0.5721	0.6196
Cluster	18	18

*Notes: Standard errors clustered at Group level in parentheses: * p< 0.1 ** p<0.05 ***p < 0.01*

Table 29: OLS regression on buyers' dynamic bidding across treatments

	FA Bid	SA Bid
Current price in Baseline	0.760***	0.701***
	(0.0343)	(0.0304)
Current price in T1 Info	0.625***	0.652***
	(0.0607)	(0.0449)
Current price in T2 No Info	0.524***	0.628***
	(0.0891)	(0.0843)
Private value in Baseline	0.144***	0.222***
	(0.0146)	(0.0341)
Private value in T1 Info	0.192***	0.243***
	(0.0299)	(0.0374)
Private value in T2 No Info	0.273***	0.269***
	(0.0480)	(0.0517)
Time in Baseline	0.185***	0.244***
	(0.0584)	(0.0631)
Time in T1 Info	0.407***	0.320***
	(0.0474)	(0.0485)
Time in T2 No Info	0.305***	0.271***
	(0.0505)	(0.0550)
T2 No Info	-4.526	-0.636
	(3.098)	(2.139)
T1 Info	-7.011**	-1.504
	(3.234)	(2.690)
Constant	-1.350	-3.991**
	(2.653)	(1.796)
N	8257	5438
R^2	0.5636	0.5985
Cluster	18	18

Notes: Robust standard errors clustered on Group level in brackets in parentheses: * p< 0.1 ** p<0.05 ***p < 0.01

Table 30: OLS regression on bidding stratgies between buyers and sellers

	SA bid (who they are)	SA Bid (Who submitted current price)
Buyers:Current price # D. 40- 60s	0.715***	0.718***
	(0.0362)	(0.0609)
Sellers: Current price # D. 40- 60s	0.822***	0.726***
	(0.0525)	(0.0409)
Buyers: Current price # D. 20- 40s	1.018***	0.925***
	(0.0238)	(0.0570)
Sellers: Current price # D. 20- 40s	0.938***	1.060***
	(0.0383)	(0.0269)
Buyers: Current price # D. 0- 20s	0.929***	1.223***
	(0.0468)	(0.159)
Sellers: Current price # D. 0- 20s	0.809***	0.979***
	(0.187)	(0.0752)
Buyers: Time # D. 40- 60s	0.747***	0.856***
	(0.0892)	(0.0897)
Sellers: Time # D. 40- 60s	0.596***	0.805***
	(0.0915)	(0.112)
Buyers: Time # D. 20- 40s	-0.0145	0.123
	(0.0357)	(0.0847)
Sellers: Time # D. 20- 40s	0.0331	-0.00675
	(0.0524)	(0.0520)
Buyers: Time # D. 0- 20s	-0.505***	-0.523**
	(0.0948)	(0.209)
Sellers: Time # D. 0- 20s	-0.406**	-0.402*
	(0.146)	(0.191)
D. Time in 2040	-8.173***	-6.604*
	(1.617)	(3.140)
D. Time in 4060	-33.49***	-34.75***
	(4.654)	(6.247)
Constant	15.19***	8.647***
	(1.576)	(1.266)
N	6899	4250
R^2	0.5760	0.5776
Cluster	18	18

Notes: Robust standard errors clustered on Group level in brackets in parentheses: * p< 0.1 ** p<0.05 ***p < 0.01

Figure 9: Alternative measurement of Efficiency

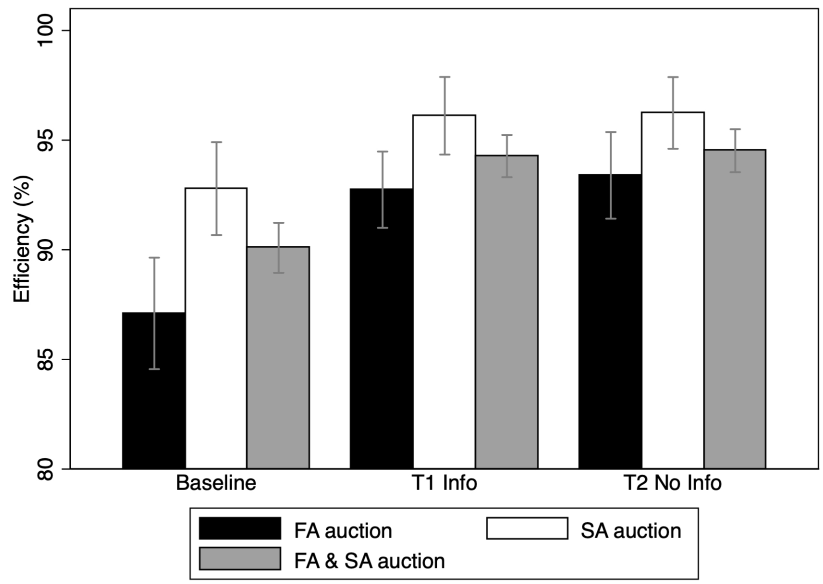


Figure 10: Buyers' overbidding behavior across treatments

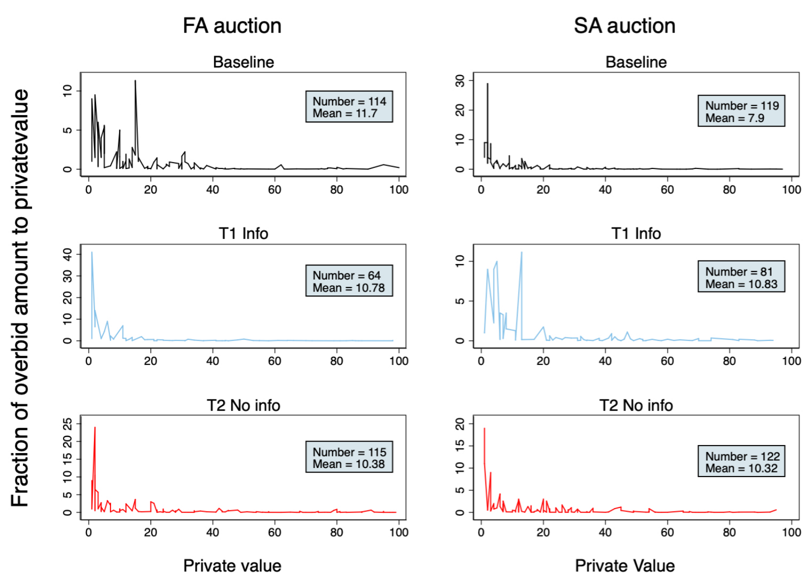


Figure 11: Cumulative distributions of buyers' submitted final bids over time in first and second auctions

(a) First auction (b) Second auction

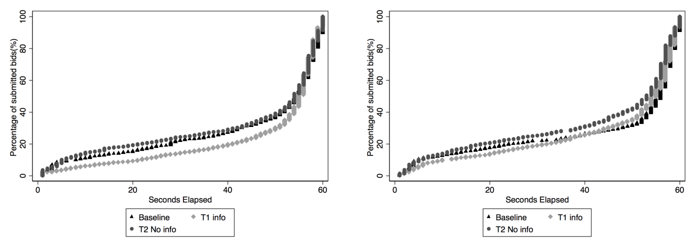


Figure 12: CDF for final bids of One Bid (OB) and Multiple Bids (MB) buyers in FA

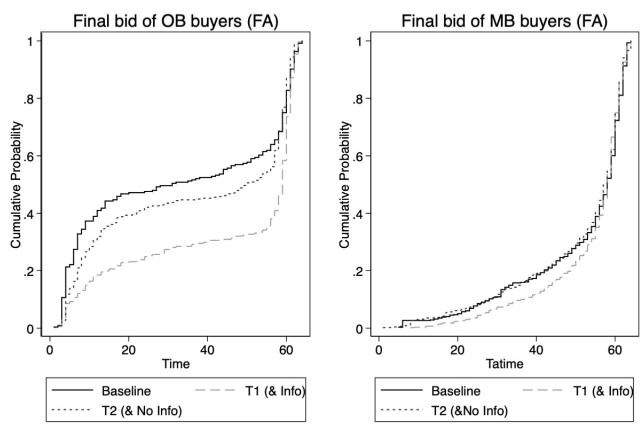


Figure 13: Buyers and sellers behavior comparing (including baseline)

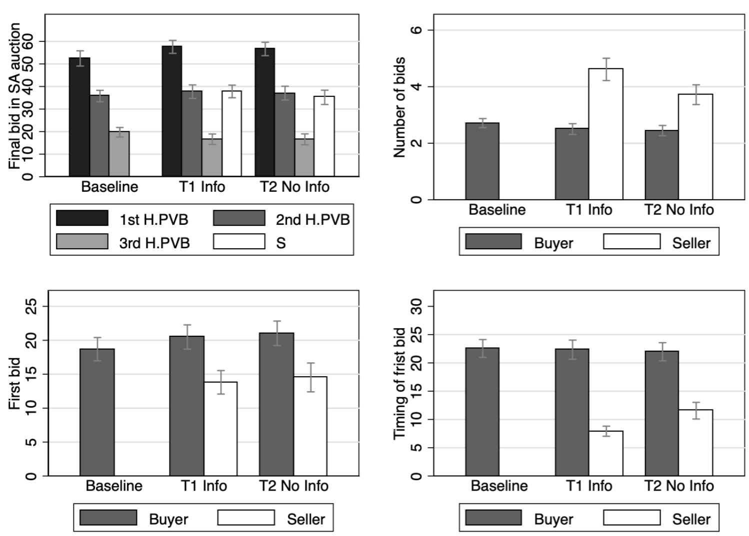
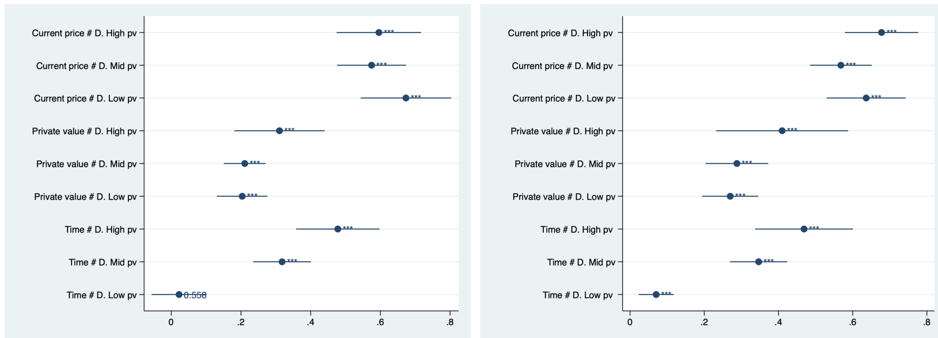


Figure 14: Dynamic buyer behavior across private value

(a) FA by private value (b) SA by private value



Null Hypothesis	FA auction P-value	SA auction P-value
Current price # D. High pv = Current price # D. Mid pv	(.)	(**)
Current price # D. High pv = Current price # D. Low pv	(.)	(.)
Current price # D. Mid pv = Current price # D. Low pv	(*)	(.)
Private value # D. High pv = Private value # D. Mid pv	(.)	(.)
Private value # D. High pv = Private value # D. Low pv	(*)	(.)
Private value # D. Mid pv = Private value # D. Low pv	(.)	(.)
Time # D. High pv = Time # D. Mid pv	(***)	(***)
Time # D. High pv = Time # D. Low pv	(***)	(***)
Time # D. Mid pv = Time # D. Low pv	(***)	(***)

(c) Post estimation coefficient tests

Notes: *p-values from regressions are marked alongside the markers in Figure 14a and 14b: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Current price is the observed current price at the time of the bid. Private value refers to the buyer's private value in the auction. Time measures the number of seconds that had passed in the auction when the bid was submitted. Each of the three variables are interacted (#) with one of the following three dummy variables: D. High pv is a dummy variable indicating if the buyer has a private value that is greater than 66 or not. D. Mid pv is a dummy variable indicating if the buyer has a private value that is lower than 67 and greater than 33 or not. D. Low pv is a dummy variable indicating if the buyer has a private value that is lower than 34 or not.*

C Instructions for the experiment

These instructions are for the all the treatments together and have been translated from Spanish.

I N S T R U C T I O N S

Welcome to the experiment! The purpose of this experiment is to study how individuals make decisions in a certain context. The experiment consists of several rounds of auctions. The instructions are simple and if you follow them carefully you will at the end of the session earn money. The amount of money you earn depends on the decisions you and others make in the experiment. If you have any questions, please do not hesitate to ask us by raising your hand. Apart from these questions, any kind of communication is prohibited and may lead to your immediate exclusion from the experiment.

Overview:

In this experiment you will make decisions in a number of auctions. At the beginning of the experiment you will be randomly assigned a role as either a bidder or a seller. You will keep the same role throughout the whole experiment.

The experiment consists of 20 rounds and in each round you will participate in two auctions. At the beginning of each round, you are randomly matched in a group of five participants including one seller and four bidders. In each round, the seller has two identical items which will be sold in two separated auctions. The two auctions will be conducted sequentially meaning that the second auction starts when the first auction is finished. Bidders are only allowed to buy one item in each round. Therefore, the bidder who wins the first auction will not participate in the second auction of that round. However, once a new round starts they can bid again.

At the beginning of every round, each bidder will be given a private value which is how much the bidder values the two items that are to be sold in this round. This private value will be an integer between 0 and 100 which is randomly picked by a computer. Any integer in this interval is equally likely to be given to a bidder. A bidder's private value is always displayed on the bidder's screen. Furthermore, a bidder's private value is not known by any other participants in the experiment.

Once a round is completed and before the start of a new round, you will be randomly rematched into a new group of one seller and four bidders, while maintaining your role. Moreover, the bidders will be given a new private value. Given that no participant will be given any identity number, all the actions that you take during the experiment will be absolutely anonymous.

Each participant receives a €5 show up fee. The additional payment depends on the outcome of the auctions. All participants start with a balance of 100 Experimental Currency Unit (ECU) to which gains and losses will be added and subtracted during the course of the experiment.

The auction environment:

To Bidders:

Each round consists of two auctions and before the start of the first auction, bidders will be shown their private value on the screen. In order to proceed to the first auction, all participants must press the "Continue" button.

In each auction one item is to be sold by the seller. An auction lasts 60 seconds during which it is possible for you to submit bids for the item. A bid is submitted by writing an integer number in the "Your bid" box followed by clicking the "Make bid" button.The winner of the item is the bidder who has submitted the highest bid before the auction ends. In case several bidders submit the same highest bid, the bidder who submitted the bid first will win the item. However, the winner only needs to pay the second highest bid which was submitted by one of the other bidders before the auction ended. The final second highest bid is thus the price of the item. A bidder who wins an auction will receive an amount of ECUs equal to his/her private value minus the price of the item. A bidder who does not win an auction gets 0 ECU.

You can start bidding and/or react to other bidders bids at any time during the 60 seconds.If you submit a bid which at that moment is the highest bid, the words "Winning" appears on the screen. Otherwise the words "Not winning" will be shown. Furthermore, the highest bid will never be shown on the screen of any participant. However, when some other bidder submits a higher bid, then the old highest bid becomes the second highest bid and is displayed on the screen as the current price. Furthermore, you are allowed to submit any number of bids. However, there are two restrictions:

1) Any submitted bid must be greater than the current price. At the beginning of the auction, the current price is set to 1 (ECU). During the auction, the current price will be updated in accordance with the submitted bids and it will always be shown on the screen. Remember, the final price of the item is determined by the final second highest bid.

2) Any submitted bid of yours must be greater than the your previously submitted bids.

During an auction the following information will be displayed on a bidder's screen: Your private value, the time left before the auction ends, if you are the current winner of the item or not, the current price and a history of all bids which were the current price at some point during the auction. In the history of prices, no information regarding the ID of the bidder who submitted the bid will be displayed. Furthermore, the history of current prices is updated as new second highest bids are submitted.

After the end of the first auction the bidders are informed of their payoff in ECUs and whether they will be able to bid in the second auction or not. Only the bidder who wins the item in the first auction will not be able to bid in the second auction. In order to proceed to the second auction, all participants must press the "Continue" button.

Payoff: After the second auction is finished, all participants will be displayed their payoff from the current round and their updated balance in ECUs. Note that a bidder may lose money by submitting a bid which is higher than his/her private value. If a bidder has lost money in a round, a message warning the bidders will appear. When all participants have pressed the "Continue" button, a new round starts unless you have completed all 20 rounds. When the 20 rounds are finished, the accumulated ECUs from all auctions will be converted into euros at a rate of 100 ECU = €2 for the bidders. If a bidder has a negative balance when the 20 rounds are finished, then the bidder will only earn the show up fee.

To Sellers:

Baseline: Sellers have no active part in the auction. During the first auction, the seller will be shown a blank screen. Between the first and the second auction, the seller will be shown the complete history of all the current prices from the recently finished first auction of the same round. During the second auction, the seller will be able to view the auction live. Specifically, the current price and the constantly updating history of current prices will be shown to the seller.

Payoff: The seller's payoff is only displayed once the second auction is finished. The seller gets a payoff in ECUs which is equal to the final price in one of the two auctions. A random draw from the computer, with 50 % probability assigned to each of the two auctions, determines which final price is paid out to the seller.

Treatment 1: During the first auction, the seller will be shown a blank screen. Between the first and the second auction, the seller will be shown the complete history of all the current prices from the recently finished first auction of the same round. Before the second auction starts, the seller can choose to join the second auction, which gives him/her the possibility to bid on his/her own item. Joining the auction costs 1 ECU and the seller will then be presented with the same screen as the bidders where the seller can submit bids. The rules for bidding are the same for the seller as for the bidders. If the seller does not join the second auction, the seller will be able to view the second auction live. This includes the information of the current price and the constantly updating history of current prices. The bidders are not told whether the seller decided to join the auction or not.

Payoff: The seller's payoff is only displayed once the second auction is finished. The seller gets a payoff in ECUs which is equal to the final price in one of the two auctions. A random draw from the computer, with 50 % probability assigned to each of the two auctions, determines which price is paid out to the seller. Hence, only one of the two prices is paid out to the seller in each round. Moreover, if the seller decided to join the second auction, 1 ECU is deducted from the payoff. Furthermore, if the seller wins the auction by bidding on his own item, he/she gets a payoff of -1 as the cost of joining the auction is paid.

Treatment 2: During the first auction the seller will be shown a blank screen. Between the first and the second auction, the seller will be shown a blank screen as well. Before the second auction starts, the seller can choose to join the second auction, which gives him/her the possibility to bid on his/her own item. Joining the auction costs 1 ECU and the seller will then be presented with the same screen as the bidders where the seller can submit bids. The rules for bidding are the same for the seller as for the bidders. If the seller does not join the second auction, the seller will be able to view the second auction live. This includes the information of the current price and the constantly updating history of prices. The bidders are not told whether the seller decided to join the auction or not.

Payoff: The seller's payoff is only displayed once the second auction is finished. The seller gets a payoff in ECUs which is equal to the final price in one of the two auctions. A random draw from the computer, with 50 % probability assigned to each of the two auctions, determines which final price is paid out to the seller. Hence, only one of the two prices is paid out to the seller in each round. Moreover, if the seller decided to join the second auction, 1 ECU is deducted from the payoff. Furthermore, if the seller wins the auction by bidding on his own item, he/she gets a payoff of -1 as the cost of joining the auction is paid.

After the second auction is finished, all participants will be displayed their payoff from the current round and their updated balance in ECUs. When the 20 rounds are finished, the accumulated ECUs from all auctions will be converted into euros at a rate of 100 ECU = €1 for the sellers. You need to fill the blank in the receipt paper on your table and sign it. An experiment assistant who has your payment information will give your earnings in cash after your filled out receipt has been turned in to him/her.

Good luck!

Example Before starting the experiment, please go over an example of one round to ensure that you understand how your payment is determined.Assume that the winner of the first auction has a private value 90. We will now consider three different final prices in order to illustrate how these affects the winner's payoff. Assume that the three different final second highest bids (prices) submitted are 20, 50 and 70. The earnings for the winning bidder in this round, by varying second highest bid (SHB), are as shown in the table below:

Private Vvalue	*SHB*	*First*	*Second*	*Earnings in this round*
90	20	$90 - 20 = 70$	0	70
90	50	$90 - 50 = 40$	0	40
90	70	$90 - 70 = 20$	0	20

Notice that the winning bidder in the first auction earns 0 in the second auction since he/she is not allowed to participate in it.

Then another bidder wins the second auction and assume that this bidder's private value is 84. Once again we consider the same three different second highest bids (prices) of 20, 50 and 70. So the earning for this bidder in this round by varying the second highest bid (SHB) are like the table below:

Private Vvalue	*SHB*	*First*	*Second*	*Earnings in this round*
84	20	0	$84 - 20 = 64$	64
84	50	0	$84 - 50 = 34$	34
84	70	0	$84 - 70 = 14$	14

Notice that since the bidder did not win the first auction, he/she gets 0 from first auction.

Now lets look at the earnings of the seller in this round. Since the computer will randomly pick a final price in one of the two auctions in this round to be paid out to the seller, the seller either get the final SHB of the First auction or the final SHB of the second auction. Hence, the seller earns on average more if the items in both auctions are sold by a high final price.

D Comprehension test and experimental screenshots and post-experiment questionnaire

Comprehension Test

Q1. Suppose that you are a bidder and that your private value is 60. Moreover, you bid 55 and win the second auction and the current second highest bid is 45. What is your earnings in this auction?

Q2. What is the seller's earnings if the outcome of the auction in question 1. is paid out?

Q3. Suppose that the seller joins the second auction in question 1 and submits a bid equal to 53 and that this bid becomes the final second highest bid. If this auction is paid out, how much does the seller earn?

Q4. Before starting the second auction, the seller will see the bidders' bidding history from the first auction of the same round. (True=1 or False=0)\

Q5. The seller can affect the final price of an item in the first auction by bidding. (True=1 or False =0)

Q6. The seller can affect the final price of an item in the second auction by bidding. (True=1 or False=0)

Q7. I will face the same bidders and sellers in all the rounds. (True=1 or False=0)

Q8. It is only possible to bid once in an auction. (True=1 or False=0)

Q9. How many bidders will participate in the first auction?

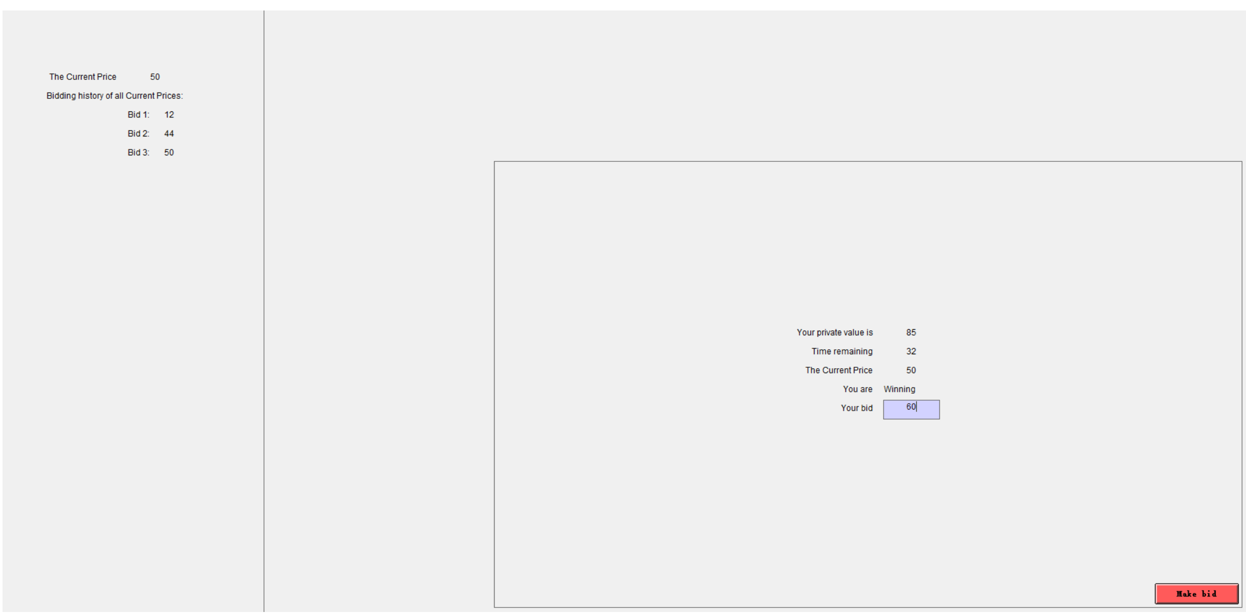
Q10. If the first item is sold, how many bidders will participate in the second auction?

Q11. How many auctions are there in each round?

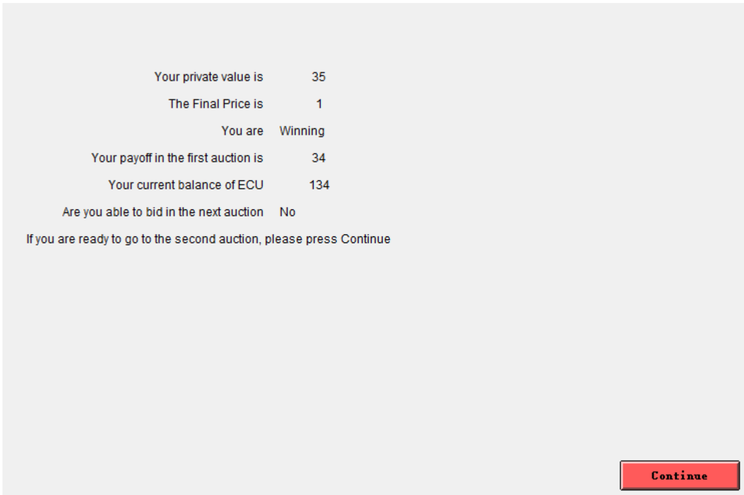
Q12. What is the total number of auctions that you will participate in during the entire experiment?

The second part of this appendix reports the main screenshots used during the experiment. The screen have been translated from Spanish to English.

Screen 1 : Bidding Screen

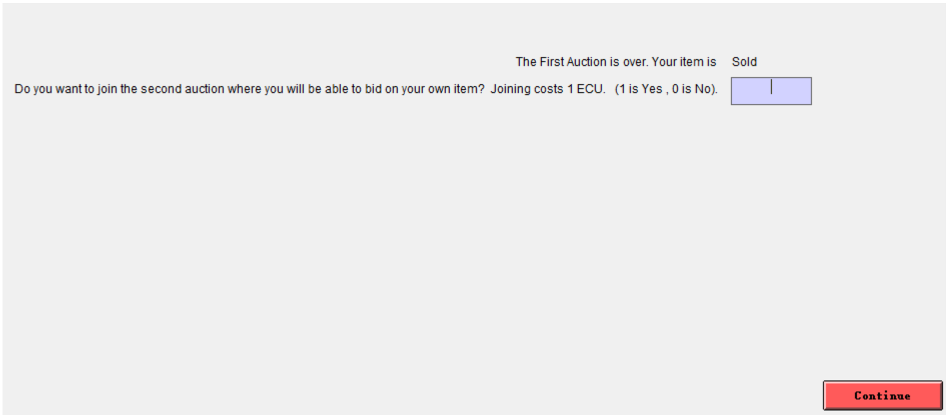


Screen 2 : Information stage for bidders



Screen 3: Information stage for sellers in Full information Treatment 1

Screen 4: Information stage for sellers in No Information Treatment 2



Screen 5 : Post-questionnaire stage