Multi-Object Auctions with Resale: An Experimental Analysis*

Marco Pagnozzi† Krista Jabs Saral‡

January 2014

Abstract

We analyze the effects of different resale mechanisms in multi-object uniform-price auctions with asymmetric bidders. The possibility of resale affects bidders' strategies, and hence the allocation of the objects on sale. Our experimental design consists of four treatments: one without resale and three resale treatments that vary the information available and the bargaining mechanism in the resale market. As predicted by theory: (*i*) without resale, asymmetry among bidders reduces demand reduction; (*ii*) the presence of a resale market, regardless of its structure, increases demand reduction by high-value bidders and speculation by low-value bidders, thus reducing auction efficiency. Low-value bidders always prefer resale to be allowed, but high-value bidders may not.

In contrast to what is usually argued, resale does not necessarily increase final efficiency and may not reduce the seller's revenue. Features of the resale market that tend to increase its efficiency also reduce auction efficiency and the seller's revenue.

JEL Classification: D44, C90.

Keywords: multi-object auctions, resale, asymmetric bidders, bargaining, economic experiments.

*We would like to thank Ciro Avitabile, Vincent Crawford, Dan Levin, Tim Salmon, and Anastasia Semykina for extremely helpful comments, as well as seminar participants at the University of Cambridge, the University of Padova, the University of Verona, the University of Milan Bicocca, the 2011 ASFEE Conference, the ESA conferences in Chicago, Luxembourg, and Zurich, the CSEF-IGIER Symposium on Economics and Institutions in Anacapri, the 2nd EIEF-UNIBO Workshop on Industrial Organization, the NERI Workshop in Naples, the Workshop on Economics of Conflict and Cooperation in Bergamo, and Swiss IO Day in Bern. We would also like to thank Svetlana Pevnitskaya and members of the xs/fs group for use of the laboratory at Florida State University, and Webster University Geneva for funding this project.

†Department of Economics and CSEF, Università di Napoli Federico II, Via Cintia (Monte S. Angelo), 80126 Napoli, Italy. Email: pagnozzi@unina.it.

‡George Herbert Walker School of Business and Technology, Webster University Geneva, Route de Collex 15, CH-1293 Bellevue, Switzerland. Email: jabs@webster.ch.

1. Introduction

Auctions are often characterized by the possibility of resale by winning bidders, which may dramatically alter the outcome from what would have been observed without resale. U.S. Treasury Bills and the Regional Greenhouse Gas Initiative (RGGI) program to sell CO_2 allowances are two economically relevant examples of auctions with an active resale market, and in the latter auction prices are in general lower than resale prices (Zhou, 2011) — a discrepancy that hints at the impact of resale. In spectrum auctions, bidders are typically allowed to trade the licenses acquired, and it is relatively common to observe small bidders winning and then reselling to larger ones.[1]

In this paper, we theoretically and experimentally examine the impact of various types of resale markets in multi-object auctions in order to address the following questions: How does the possibility of post-auction resale affect bidders' strategies, efficiency and the seller's revenue? Should resale be allowed after an auction? If so, how should the resale market be structured?

Post-auction resale may exist because of potential bidders unable to participate in the auction (Milgrom, 1987), valuations changing after the auction (Haile, 2001, 2003; Gupta and Lebrun, 1999), and asymmetry in bidders' valuations (Hafalir and Krishna, 2008; Zheng, 2002). We will focus on resale emerging because of bidders' strategic behavior in the auction — demand reduction and speculation (Garratt and Tröger, 2006; Garratt *et al.*, 2009; Pagnozzi, 2010).

In multi-object auctions bidders have an incentive to reduce demand — i.e., bid less than their valuations for marginal units, in order to reduce the auction price for inframarginal units (Wilson, 1979; Ausubel and Cramton, 1998) — and the presence of a resale market exacerbates this incentive since it provides bidders with a chance to purchase a unit that they do not acquire in the auction. Moreover, even bidders with low values have an incentive to speculate by bidding aggressively if they have a chance to resell the objects acquired. Both speculation and demand reduction make it more likely that the auction allocation is inefficient, so that bidders will be willing to trade in a post-auction resale market. Therefore, the possibility of resale is likely to affect both efficiency and the seller's revenue.

To explore these effects, we consider a uniform-price auction with two identical units on sale and two asymmetric bidders, one strong and one weak. The strong bidder has a higher valuation and demands both units; the weak bidder has a lower valuation and demands only one unit.[2] Considering bidders with different characteristics allows us to distinguish the different bidding strategies that they adopt in the auction, and the different effects that the presence of a

[1] For example, in the UK 3.4 GHz auction, two small bidders, Red Spectrum and Public Hub, won one license each and resold them to Pacific Century Cyberworks, a much larger company that was considered to have the highest valuation for the licenses on sale in the auction but chose not to outbid its competitors (Pagnozzi, 2010). In the 2000 UK auction, Orange won a 3G mobile-phone license and was later acquired by NTL (a consortium controlled by France Telecom) that participated in the same auction but did not win any license.

[2] For example, in an auction for geographically differentiated mobile phone licenses, a strong bidder can be interpreted as an incumbent operator who aims at acquiring a nationwide license, while a weak bidder can be interpreted as a new and smaller entrant, possibly interested only in a local license, or even as a pure speculator.

resale market has on these strategies. We assume that resale takes place through a post-auction bargaining procedure between bidders, so that bidders share the gains from trade in the resale market, if there are any.

In this context, without resale it is a dominant strategy for a weak bidder to bid up to his valuation for a unit. By contrast, when resale is allowed, a weak bidder speculates because winning the auction has the additional option value of providing a chance of reselling to the strong bidder (Haile, 2003; Garratt and Tröger, 2006; Pagnozzi, 2007).

Our theoretical analysis also shows that asymmetry among bidders' valuations makes demand reduction less attractive for strong bidders, because it is more costly to lose an object for a bidder with a higher valuation, and less costly to outbid a competitor with a lower valuation. Without resale, strong bidders with relatively high valuations outbid weak bidders and win both units; while strong bidders with relatively low valuations reduce demand for the second unit and allow the weak bidder to win one unit. The presence of resale, however, induces strong bidders to reduce demand regardless of their valuations, because it provides them with a second opportunity to purchase a unit lost in the auction (Pagnozzi, 2009, 2010).[3]

We conducted a series of controlled laboratory experiments with four treatments: *No Resale*, *Complete Information Resale*, *Incomplete Information Resale*, and *Bargain.* In the no resale treatment subjects participated in an ascending auction without resale. The complete information and the incomplete information resale treatments included a secondary market where one of the two bidders was randomly chosen to make a take-it-or-leave-it offer to the other.[4] In the first of these treatments, subjects were given complete information regarding the competitors' values in the resale market, while in the second, information was restricted to the distribution of the competitors' values. In the bargain treatment, both bidders were allowed to make multiple offers and to communicate through computerized chat in a resale stage.[5]

We analyze different resale mechanisms in order to investigate how the outcome of the resale market, and its effects on bidders' strategies in the auction, depend on the specific procedure adopted by bidders to trade after the auction. The complete and incomplete information resale treatments consider a static and more structured resale market, where each bidder expects to be given full bargaining power with equal probability. The bargain treatment extends this simple environment to replicate a more flexible, and arguably more realistic, post-auction bargaining procedure among bidders. To the best of our knowledge, we are the first to consider the impact of different types of resale markets on auction behavior, and the first to implement an unstructured bargaining game to experimentally analyze post-auction resale markets.

[3] See also Jehiel and Moldovanu (2000), Haile (2003), and Garratt and Tröger (2006) who analyze similar effects in single-object auctions.

[4] This resale mechanism was analyzed by Calzolari and Pavan (2006).

[5] Feltovich and Swierzbinski (2011) use a similar approach with computerized chat in an unstructured bargaining game experiment studying the role of cheap talk. See Roth and Malouf (1979) and Roth and Murnighan (1982) for earlier examples of experiments with bargaining proposals accompanied by messaging. For a survey on the role of communication in experiments see Crawford (1998) and for a survey of bargaining experiments see Roth (1995).

Consistent with the theoretical predictions, we show that in the no resale treatment weak bidders bid up to their value. This result parallels earlier work in single-unit ascending auctions (e.g., Coppinger *et al.*, 1980; Kagel *et al.*, 1987), and confirms the robustness of value bidding in a multi-object context.[6] We also find that the addition of a resale market significantly increases weak bidders' bids, indicating speculation, regardless of the specific structure of the resale market.

Also consistent with the theoretical predictions on demand reduction, in the no resale treatment strong bidders drop out at low prices with much higher frequency when their valuation is relatively low. This provides a novel contribution to the experimental literature that shows the prevalence of demand reduction in ascending auctions when bidders are symmetric (e.g., Alsemgeest *et al.*, 1998; Kagel and Levin, 2001, 2005; Engelmann and Grimm, 2009; Goeree *et al.*, 2013):[7] strong bidders do engage in demand reduction, but value asymmetry between bidders reduces demand reduction when resale is not allowed. By contrast, with resale strong bidders drop out at very low prices regardless of their valuations, and they do so significantly more than without resale, especially if they have high values.

Comparing the different resale treatments, the incomplete information treatment generated higher uncertainty of the resale outcome, because it involved a less flexible trading mechanism with lower information. As a result, strong bidders tended to reduce demand less than in the other resale treatments. Moreover, weak bidders tended to speculate more in the complete information resale treatment, because they correctly expected to obtain higher resale profit.

Beyond the results specifically related to bidding, our experiments also allow us to analyze the effect of post-auction resale on efficiency and the seller's revenue. It is often argued that resale after an auction should always be allowed, because it increases efficiency by allowing bidders to trade, if they are willing to do so, in the presence of gains from trade (e.g., Mankiw, 2007). But our analysis suggests that this is not necessarily the case. Although resale does increase efficiency after the auction, it also has a significant effect on bidders' strategies during the auction, and these tend to reduce auction efficiency. In fact, in all resale treatments auction efficiency is lower than without resale. Yet, the net effect is ambiguous: in the incomplete information resale treatment, final efficiency is not significantly different from final efficiency without resale; while in the two other resale treatments final efficiency is higher.

The net effect of resale on revenue is also ambiguous. In theory, allowing resale should always reduce the seller's revenue, because it should induce strong bidders to reduce demand. Our experimental results, however, indicate that allowing resale increases the seller's revenue when strong bidders do not reduce demand, since weak bidders bid more aggressively with

[6] McCabe *et al.*, (1990) also provide evidence of value bidding for bidders with single-unit demand in multi-unit ascending auctions. See Kagel (1995) for a comprehensive overview of experimental data on value bidding in single-unit auctions. Also see Kagel and Levin (2011) and Kwasnica and Sherstyuk (2012) for a broad survey of more recent experimental results in multi-object auctions.

[7] The literature shows that demand reduction, although present in various types of multi-object auctions, is more pronounced in open ascending than in sealed-bid auctions (Kagel and Levin, 2001). List and Lucking-Reiley (2000) also find evidence of demand reduction in field experiments.

resale, thereby increasing the auction price. On balance, the seller's revenue without resale is not significantly higher than in the complete information and the incomplete information resale treatments, but it is significantly higher than in either the bargain treatment.

We also analyze how the efficiency of the resale market depends on the resale mechanism adopted by bidders. A more flexible bargaining mechanism and more precise information about the size of the gains from trade increase the probability of successful resale and the resulting final efficiency. With take-it-or-leave-it offers in the resale market, the probability of successful resale is higher when weak bidders choose the resale price, since they tend to make less aggressive offers that are more likely accepted. However, all of these factors also reduce the seller's revenue and the auction efficiency because they increase strong bidders' incentive to reduce demand. So there is a trade-off between higher final post-resale efficiency and higher revenue and efficiency in the auction.

The resale price depends on the resale mechanism and is higher when bidders have more information in the resale market, because in this case the resale seller (weak bidder) manages to obtain higher profits. However, the resale profit of the resale seller is lower than that of the resale buyer (strong bidder) in all resale mechanisms. Considering also the auction profit, weak bidders always obtain higher total profits when resale is allowed, while strong bidders may obtain lower total profits with resale, depending on the actual resale mechanism. Finally, our analysis shows that resale prices tend to be higher than auction prices, since intra-bidder resale takes place when strong bidders reduce demand to allow weak bidders to win, thus reducing the auction price below the competitive level.[8]

Our paper contributes to the recent experimental literature on auctions with resale. Experiments on single-object auctions with resale include Georganas (2011), Georganas and Kagel (2011), Lange *et al.* (2011), and Saral (2012), which test how the presence of a resale market affects bidding behavior.[9] In these papers resale takes place either automatically, through another auction, or through a take-it-or-leave-it offer by the auction winner. Filiz-Ozbay *et al.* (2012) provide the only other experimental analysis of multi-object auctions with resale that we are aware of. They consider the effects of complementarities in comparing the efficiency of a Vickrey auction and independent second-price auctions and assume that, in the resale market, the auction winner makes take-it-or-leave-it offers to the losers, separately for each object acquired. Hence, the results of Filiz-Ozbay *et al.* (2012) complement ours, since they focus on the effects of a specific resale mechanism on different auction formats, in the presence of more complex bidders' valuations.

The rest of the paper is organized as follows. Section 2 presents a theoretical analysis of the model that we refer to for our experimental design, and its predictions in terms of bidding

[8] This is consistent with the evidence from various actual auction markets. For example, in the New Zealand auctions for import quota licenses held from 1981 to 1991, the prices at which licenses were traded in the secondary market were 26% higher on average than the auction prices (McAfee *et al.*, 1999).

[9] See also Harstad (2012) who shows how the presence of trading in an aftermarket may be used to evaluate the efficiency of an allocation mechanism.

strategies, efficiency and the seller's revenue. Section 3 discusses the design of our experiments, and Section 4 presents the experimental results. Specifically, Sections 4.1 and 4.2 shows bidding behavior by weak and strong bidders respectively, Section 4.3 discusses efficiency and the seller's revenue, and Section 4.4 analyzes subjects' behavior in the resale market. Finally, Section 5 concludes with a summary and discussion of our results. The Appendix contains sample instructions and screenshots from our experiments.[10]

2. Model and Theoretical Predictions

We construct the simplest possible model that will allow us to experimentally investigate the effects of resale on bidding strategies by asymmetric bidders, and on their incentives to reduce demand and speculate.

Auction. There is a (sealed-bid) uniform-price auction for 2 units of an identical good, with reserve price (footnote 21 discusses the effect of a positive reserve price): each player submits 2 non-negative bids, one for each of the units; the 2 highest bids are awarded the units; and the winner(s) pay a price equal to the 3rd-highest bid for each unit won. We consider a uniform-price auction because it is the auction mechanism in which the incentive to reduce demand arises more clearly and because it is widely used to allocate multiple objects.[11] The qualitative results of the analysis, however, also hold for any mechanism to allocate multiple units in which players face a trade-off between winning more units and paying lower prices. The auction may be followed by a resale market.

Bidders and Valuations. There are 2 risk-neutral asymmetric bidders. Bidders differ both in the number of units that they demand, and in their valuations for those units. Specifically, bidder S, the *strong* bidder, demands 2 units and has valuation $v_S \sim U\left[\underline{v_S}; \overline{v_S}\right]$ for each unit on sale (i.e., he has flat demand);[12] bidder W, the *weak* bidder, demands 1 unit only and has valuation $v_W \sim U\left[\underline{v_W}; \overline{v_W}\right]$ for that unit. Bidders are privately informed about their valuations, which are independent. We assume that $\underline{v_S} \geq \overline{v_W}$, implying that bidder S always has a higher valuation than bidder W, and that bidders know the ex-post efficient allocation of the units on sale before the auction. For simplicity, we also assume that bidder W cannot win more than 1 unit in the auction, even if resale is allowed.[13]

[10] All instructions are available on the authors' websites.

[11] Of course, the uniform-price auction is not an optimal mechanism in our context, neither with resale nor without resale.

[12] All our qualitative results also hold in the presence of complementarities, although bidder S's incentive to reduce demand is lower in this case, if there is a chance that he may not manage to acquire the second unit in the resale market.

[13] We chose to restrict bidder W to single-unit demand to create a simple experimental environment where subject confusion is unlikely, thus eliminating potential confounding effects. This also facilitates the comparison between the weak bidders' behavior with and without resale.

Even if bidder W can win 2 units when resale is allowed, it is an equilibrium for both bidders to reduce demand and bid for 1 unit only, as in our model. The reason is that, as it will become clear from the analysis, bidder S has an incentive to reduce demand only if he can win one unit in the auction.

Our assumption on bidders' valuations ensures that in our experiments bidders know the role they will have in the resale market when they bid in the auction — i.e., whether they will have a chance to buy or sell in the resale market — allowing us to focus on the different bidding strategies of the two types of bidders and on how these strategies are affected by the possibility of resale. The assumption also implies that bidders know there are gains from trade in the resale market if W wins a unit.

Resale Market. When resale is allowed after the auction, if bidder W wins a unit he can resell it to bidder S. In contrast to previous experiments on auctions with resale that assume a more restricted structure for the resale market,[14] we consider resale through a more general bargaining procedure between bidders. We believe that this is a more realistic representation of many real-life situations in which bidders attempt to trade after an auction but do not follow a formal trading mechanism (e.g., because no bidder has the bargaining power to impose his preferred trading mechanism) and may be unable to trade even if they know there are mutual gains from doing so (e.g., because of incomplete information).

Rather than analyzing all the specific bargaining mechanisms used in our experiments, we provide a simple framework that captures the main elements of various resale mechanisms in which both bidders in the auction expect to obtain some share of the (expected) gains from trade in the resale market. The actual gains from trade in the resale market are $v_S - v_W$, since W's outside option when he trades in the resale market is equal to his valuation, while S's outside option is zero. We assume that bargaining in the resale market results in S obtaining a share α of the gains from trade and W obtaining a share $1-\alpha$ of the gains from trade. This bargaining outcome follows from bidders trading at a resale price

$$r \equiv v_W + (1-\alpha)(v_S - v_W) = \alpha v_W + (1-\alpha) v_S,$$

and it can be interpreted as a reduced-form representation of the final outcome of various different trading mechanisms. Our qualitative results are robust to many alternative models of the resale market and hold for *any* sharing of the gains from trade in the resale market that is individually rational for bidder W (i.e., such that the resale price is not lower than W's valuation). Moreover, the results do not hinge on the resale market being fully efficient (see footnote 22).

In our experiments, we consider various bargaining mechanisms for the resale market. In one mechanism, if bidder W wins a unit in the auction, bidders are allowed to freely bargain over the resale price (see Section 3). In another mechanism, one of the two bidders, chosen randomly, is given the possibility of making a take-it-or-leave-it offer to the other bidder (Calzolari and Pavan, 2006).[15] In all of these mechanisms, both bidders expect to obtain some share of the

[14] Georganas (2011) and Harstad (2012) use a secondary auction for the resale market, while Georganas and Kagel (2011) and Filiz-Ozbay *et al.* (2012) utilize take-it-or-leave-it offers by the auction winner. Lange *et al.* (2011) and Saral (2012) assume automatic transfers to bidders with higher valuations.

[15] With complete information, this second resale mechanism, in which in expectation bidders obtain $\frac{1}{2}$ of the gains from trade in the resale market, is a special case of our class of bargaining mechanisms, when $\alpha = \frac{1}{2}$.

gains from trade in the resale market, which is the feature that drives all of our theoretical results.

Bidding Strategies. There is *demand reduction* if a bidder bids less than his valuation for a unit, while there is *speculation* if a bidder bids more than his valuation for a unit. In a uniform-price auction without resale, it is a weakly dominant strategy for a bidder to bid his valuation for the first unit, exactly as in a single-object second-price auction. Yet, bidder S may find it profitable to reduce demand and bid less than his valuation for the second unit in order to pay a lower price for the first unit in case he loses the second, thus obtaining a higher profit. The logic is the same as the standard textbook logic for a monopsonist withholding demand: buying an additional unit increases the price paid for the first, inframarginal, units. Moreover, when resale is allowed, bidder W may find it profitable to speculate and bid more than his valuation in the auction, if he expects to resell the item at a price higher than his valuation in the resale market. Of course, the auction allocation is inefficient when bidder W wins a unit in the auction (because he speculates or because bidder S reduces demand).

We will now describe the equilibrium bidding strategies with and without resale. Because our model has 2 units on sale and a total demand for 3 units, to characterize bidding strategies it will be sufficient to describe W's bid for one unit, and S's bid for the second unit. The lowest of these two bids will be the auction price, and either S will win both units on sale at a price equal to W's bid, or the two bidders will win one unit each at a price equal to S's bid.

2.1. Auction without Resale

Consider an auction without resale. Without resale, it is a weakly dominant strategy for bidder W to bid his valuation for a unit — i.e., v_W.[16] Given this strategy, bidder S has a choice between two alternatives. First, by outbidding W in the auction, S can win two units at an expected price equal to $\mathbb{E}[v_W]$, thus obtaining a profit equal to $2(v_S - \mathbb{E}[v_W])$. Second, S can reduce demand and bid 0 for the second unit, thus winning one unit at price 0 and letting W win the other unit.[17] In this case, S obtains a profit equal to $v_S - 0$. Therefore, bidder S prefers to reduce demand and win one unit only rather than outbid bidder W if and only if

$$v_S > 2(v_S - \mathbb{E}[v_W]) \quad \Leftrightarrow \quad v_S < 2\mathbb{E}[v_W].$$

When resale is not allowed, bidder S's incentive to reduce demand in the auction is lower when he has a relatively high valuation, because reducing demand and not winning the second unit is more costly when that unit is more valuable, or when he expects bidder W to have a low valuation and hence to bid less aggressively, because outbidding bidder W to win the second unit is less costly. Accordingly, without resale, if $v_S < 2\mathbb{E}[v_W]$ bidder S and bidder W win one

[16] If W wins the auction at price p, he earns $(v_W - p)$, while if W loses the auction, he earns 0. So he bids a price such that his profit from winning is equal to zero.

[17] Of course, reducing demand but bidding a strictly positive price is never an optimal strategy.

unit each and the auction price is equal to 0; if $v_S > 2\mathbb{E}[v_W]$ bidder S wins both units and the auction price is equal to v_W.

2.2. Auction with Resale

Consider an auction with resale. When resale is allowed, a player's "willingness to pay" for a unit in the auction — i.e., the highest auction price that a player is happy to pay for a unit — is represented by the price at which he expects to buy or sell a unit in the resale market (e.g., Milgrom, 1987).

By assumption, if bidder W wins a unit in the auction, he obtains an actual surplus equal to $(1-\alpha)(v_S - v_W)$ in the resale market. Therefore, bidder W bids

$$v_W + (1-\alpha)\,\mathbb{E}[v_S - v_W \,|\, v_W] = \alpha v_W + (1-\alpha)\,\mathbb{E}[v_S]$$

for a unit on sale in the auction.[18] Notice that this can be interpreted as $\mathbb{E}[r \,|\, v_W]$, the price at which bidder W expects to sell to bidder S in the resale market. Bidder W speculates because of the option to resell to bidder S and bids higher than his valuation for a unit, and hence higher than without resale (and this does not depend on the specific resale mechanism).

Since bidder W bids his expected resale price in the auction, bidder S has a choice between two alternatives. First, bidder S can outbid bidder W and win 2 units in the auction at an expected auction price equal to

$$\mathbb{E}[\mathbb{E}[r \,|\, v_W]] = \alpha\mathbb{E}[v_W] + (1-\alpha)\,\mathbb{E}[v_S],$$

thus obtaining an expected profit equal to

$$2\left(v_S - \alpha\mathbb{E}[v_W] - (1-\alpha)\,\mathbb{E}[v_S]\right). \tag{2.1}$$

Second, bidder S can reduce demand and bid zero for the second unit in the auction, thus winning one unit at price 0 in the auction and then buying the second unit from bidder W in resale market at an expected resale price equal to

$$\mathbb{E}[r \,|\, v_S] = \alpha\mathbb{E}[v_W] + (1-\alpha)\,v_S.$$

In this case, S obtains an expected total profit equal to[19]

$$\underbrace{v_S - 0}_{\text{auction profit}} + \underbrace{v_S - \mathbb{E}[r \,|\, v_S]}_{\text{resale profit}} = (1+\alpha)\,v_S - \alpha\mathbb{E}[v_W]. \tag{2.2}$$

[18] If W wins a unit in the auction at price p, he obtains an expected profit equal to $v_W - p + (1-\alpha)\,\mathbb{E}[v_S - v_W \,|\, v_W]$; while if W loses the auction, he obtains 0. So he bids a price such that his profit from winning is equal to zero.

[19] Notice that bidder S's expected profit from resale can also be interpreted as $\alpha\mathbb{E}[v_S - v_W \,|\, v_S]$, his share of the expected gains from trade in the resale market.

Comparing (2.1) and (2.2), bidder S prefers to reduce demand in the auction when resale is allowed if and only if

$$(1-\alpha)\left(2\mathbb{E}\left[v_S\right]-v_S\right)+\alpha\mathbb{E}\left[v_W\right]>0 \quad \Leftrightarrow \quad (1-\alpha)\left(\underline{v_S}+\overline{v_S}-v_S\right)+\alpha\mathbb{E}\left[v_W\right]>0.$$

Since this inequality is always satisfied, bidder S always prefers to reduce demand when resale is allowed.[20] Notice that this result holds for every α and for every v_S. Basically, bidder S is willing to bid a much lower price in the auction because of the option to buy in the resale market. And demand reduction allows bidder S to win 1 unit at price 0 in the auction and then purchase the other unit from bidder W at price r in the resale market, rather than pay bidder W's expected resale price for both units in the auction. The first option is more attractive than the second (unless bidder S expects the resale price to be much higher than bidder W, which can be the case when v_S is very high compared to its ex-ante expected value — see footnote 20 — but this never happens when bidder S's valuation is uniformly distributed).[21]

As a result, when resale is allowed, S and W win one unit each and then trade in the resale market. The auction price is equal to 0. (Of course, this can also be interpreted as tacit collusion among bidders, intended to reduce the seller's revenue.)[22]

Summing up, the theoretical predictions of the model that we test using experimental methodology are the following.

Result 1. *Without resale, bidder W bids v_W and bidder S reduces demand if and only if $v_S < 2\mathbb{E}\left[v_W\right]$.*

Result 2. *With resale, bidder W bids above v_W and bidder S always reduces demand.*

Result 3. *The allocation of the units on sale in the auction is always inefficient with resale, but not necessarily without resale. The final allocation of the units on sale is always efficient with resale, but not necessarily without resale.*

[20] More generally — i.e., when bidders' valuations are not necessarily uniformly distributed — a sufficient (but not necessary) condition for bidder S always preferring to reduce demand when resale is allowed is that $2\mathbb{E}\left[v_S\right] > v_S$.

[21] Our qualitative results do not hinge on the absence of a reserve price, since bidder S has an incentive to reduce demand even if he has to pay a strictly positive reserve price. For example, if the seller chooses the optimal reserve price without resale (which is equal to 30, a take-it-or-leave-it offer to bidder S), when $\alpha = \frac{1}{2}$ bidder W is willing to pay the reserve price and resell to bidder S if his value is higher than 20. Therefore, exactly as in our model, with resale bidder S prefers to reduce demand and win 1 unit at the reserve price, rather than outbid bidder W to win 2 units at the expected reserve price. (The reserve price may be so high that it is unprofitable for bidder W to win the auction, but sellers often lack the information and the commitment power to set high reserve prices.)

[22] All our qualitative results also hold if there is a positive probability q that bidders fail to trade in the resale market. (Our model is a special case: $q = 1$ in an auction without resale and $q = 0$ in an auction with resale.) If q is relatively low, S reduces demand and the seller's revenue is equal to zero, as in our model. In this case, the probability of an efficient final allocation is decreasing in q. By contrast, if q is higher than a threshold, S does not reduce demand when he has a high valuation (because of the risk of not being able to acquire in the resale market a unit lost in the auction), and the seller's revenue is positive but decreasing in q (since W's bid is increasing in q). In this case, the final allocation of the units is efficient when S outbids W. So changes in q have a non-monotonic effect on efficiency and the seller's revenue.

Result 4. *The seller's revenue is always equal to zero with resale, but not necessarily without resale.*

3. Experimental Design

The experiment was designed around three primary objectives: (*i*) analyze bidding behavior in uniform-price multi-object auctions with asymmetric bidders and no resale; (*ii*) analyze how post-auction resale between bidders affects their bidding strategies, efficiency, and the seller's revenue; (*iii*) investigate how bidders trade in the resale market, and how their strategies are affected by different resale mechanisms.

We implemented four treatments, one without resale, and three with different resale mechanisms. The resale mechanisms were designed to evaluate the effects of different levels of information and different trading procedures in the resale market. Each session of the experiment consisted of a single treatment, and the recruitment process restricted subjects' participation to a single session. At the beginning of a session subjects were randomly assigned to either the role of weak or strong bidder and that role assignment remained constant for the duration of the experiment.

In all treatments, each period began with an ascending clock uniform-price auction for two items of a hypothetical good.[23] Each auction always had 1 strong bidder and 1 weak bidder. The strong bidder was allowed to purchase up to 2 units of the hypothetical good, and randomly drew his private valuation for each unit from a uniform distribution on the range $[30, 50]$. The weak bidder could purchase 1 unit only, and randomly drew his private valuation from a uniform distribution on the range $[10, 30]$. Throughout the experiment, the strong bidder was referred to as a 2-unit bidder and the weak bidder as a 1-unit bidder to minimize labeling effects. During the auction each bidder was given information about the distribution of his competitor's valuation and the number of units the competitor demanded.

Bidders participated in the auction through a computer interface with a bid clock gradually increasing from 0 in increments of 1, which indicated the auction price for a unit. To bid in the auction, subjects chose to "drop out" when the clock reached a price at which they wanted to exit the auction. The auction ended as soon as one bidder dropped out, and the auction price paid for each unit was equal to the dropout bid. If neither subject dropped out, the auction ended when the bid clock hit the maximum possible value of the strong bidder, 50, and the units were awarded by random draw. If both subjects dropped out simultaneously, ties were again broken randomly. A bidder who won a unit earned the difference between his value and the price resulting from the auction.

In the treatment without a resale market, the auction determined the final outcome. In the three resale treatments, if the weak bidder won a unit, the resale market immediately started

[23] We use ascending auctions (rather than sealed-bid ones) because they are widely used in the field and, based on previous experimental evidence, easier to understand for bidders.

with the same participants from the auction. Two of the three resale treatments involved a take-it-or-leave-it offer where the proposer was determined with 50/50 probability. If the weak (strong) bidder was selected as the proposer, he had the opportunity to offer a buy (sell) price to the other bidder, who could then accept or reject the offer. Neither of these two treatments allowed communication between the participants and the sole difference involved the amount of information conveyed. In the first case, complete information of the competitor's valuation was provided to each participant after the auction while in the second, the information provided was limited to the distribution of the competitor's valuation.

The third and final resale treatment relaxed the no communication and one-shot offer constraints by implementing an unstructured bargaining game where both the weak and strong bidder could simultaneously make offers through a computerized offer board. Only one posted offer per participant was allowed at a time, but offers could always be changed prior to agreement. Either role could accept the offer made by their counterpart and the resale stage terminated once an offer was accepted. Bidders could also send each other messages and discuss the offers through an anonymous chat. There was a time limit of 3 minutes to reach agreement.[24]

In all resale treatments, either participant had a choice to exit the resale market without trading at any point of their choosing. If a resale offer was agreed upon, the unit was transferred from the weak bidder (seller) to the strong bidder (buyer). The weak bidder earned the difference between the resale price and his value, and the strong bidder earned the difference between his value and the resale price. If resale failed, both bidders earned 0. Any resale earnings were in addition to the earnings from the auction. The experimental treatments are summarized below.

1. **No Resale**: Subjects only participated in the auction.

2. **Complete Information Resale** (Comp Resale): After the auction, if the weak bidder won a unit, one of the bidders was randomly chosen to make a take-it-or-leave-it offer to the other and both bidders were given complete information regarding the valuation of the competitor.

3. **Incomplete Information Resale** (Incomp Resale): This treatment was identical to the complete information resale treatment, except that in the resale stage bidders' valuations were not revealed to the competitors and the offer proposer was given a calculator tool (slide bar of potential offers) to determine the probability that his offer led to negative resale earnings for the responder.

4. **Bargain**: After the auction, if the weak bidder won a unit, both bidders were allowed to make and accept offers and to communicate via anonymous computerized chat in an unstructured bargaining game. As in incomplete information resale treatment, bidders'

[24] This was not an overly binding constraint. In the bargain treatment we observe 351 resale markets with 44 (12.5%) timing out before agreement was reached. In a large number of the cases, bidders made their final offers with plenty of time remaining on the clock. We conjecture that this is evidence of resale failing because of a holdout strategy, rather than a binding time limit.

valuations were not revealed to the competitors in the resale stage. All participants were also given the calculator tool to facilitate decisions.

We conducted 3 sessions for each treatment yielding a total of 12 sessions with 16 participants in each session. The no resale, complete information resale, and incomplete information resale sessions each consisted of 30 periods. The bargain treatment required more time for each auction/resale round because of the nature of the resale stage, so each session of this treatment consisted of 20 periods. To ensure the least amount of changes possible we used the exact same value draws across all sessions. In the no resale, complete information resale, and incomplete information resale treatments, the 16 subjects were divided into 2 groups for random rematching of partners in each period, leading to two independent groups in each auction session for these three treatments. In the bargain treatment, subjects were rematched within the entire group of 16 subjects.[25] The subjects were students at Florida State University and were recruited using ORSEE (Greiner, 2004). All sessions were conducted at the xs/fs laboratory in March and June, 2011, and October, 2012.

The experiment was programmed using Z-tree software (Fischbacher, 2007), and prior to the beginning of the paid periods, all subjects were given instructions which included two examples of bidding behavior and, in the resale treatments, resale market outcomes. To ensure subjects' understanding, they were required to correctly complete a computerized quiz before continuing. Payoffs during the experiment were denominated in experimental currency units, ECUs, which transformed into US dollars at the rate of \$0.01 per ECU. Table 3.1 shows the earnings broken down by type and treatment.

	No Resale	Comp Resale	Incomp Resale	Bargain
Weak's Earnings	\$12.98	\$15.84	\$14.25	\$14.66
Strong's Earnings	\$23.09	\$23.14	\$22.52	\$20.42

Table 3.1: Average earnings.

4. Experimental Results

In this section, we describe the main results of our experiments. We begin in Sections 4.1 and 4.2 by describing the bidding behavior of weak and strong bidders, respectively, Section 4.3 discusses efficiency and the seller's revenue, while Section 4.4 concludes with subjects' behavior in the resale market. All data from all periods is included in the following analysis, unless explicitly noted.

[25] While we lose an independent group observation for each session of the bargain treatment for this choice, the decision was made to minimize the effect of rematching with the same partner under free-form communication. Examining the chat, we find no successful efforts towards collusion or reputation building.

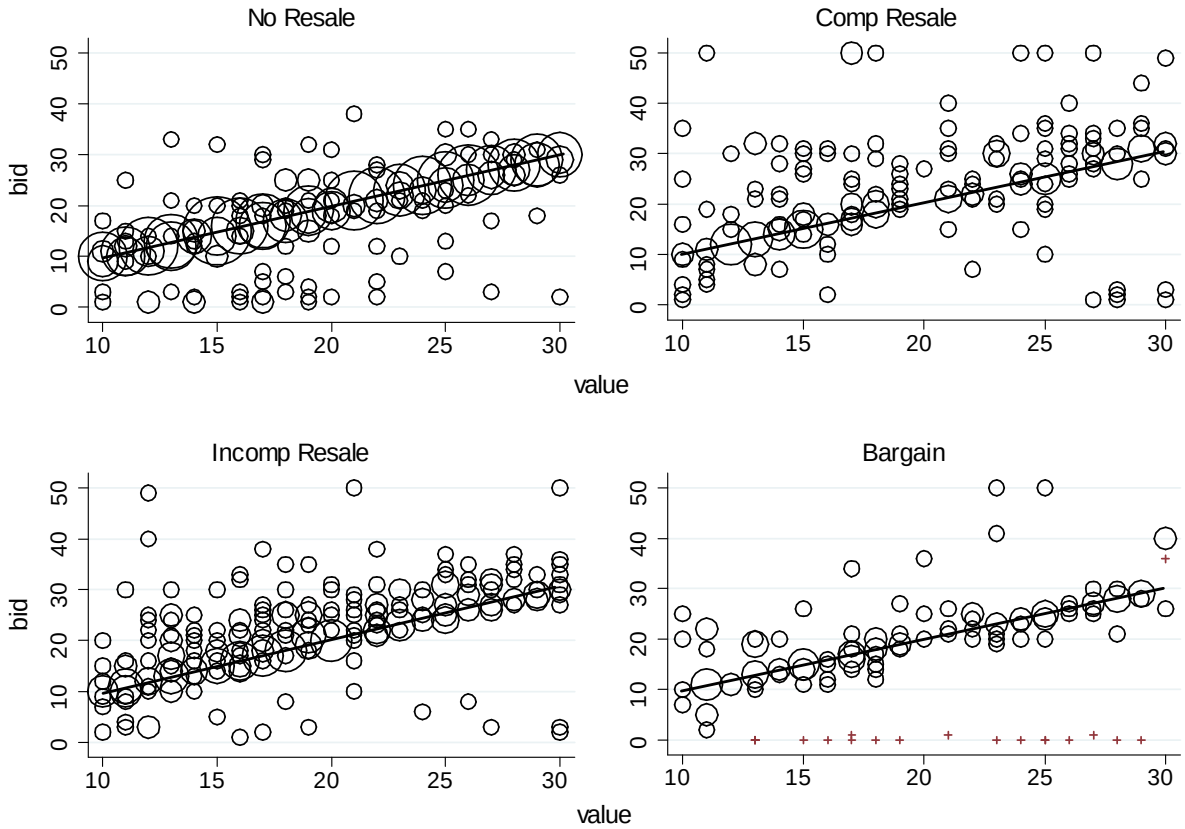

Figure 4.1: **Weak Bidding** – weighted scatterplot of observed bids (dropouts) by weak bidders versus valuations in the four treatments.

4.1. Weak Type Bidding

By Results 1 and 2 in Section 2, the weak bidder should bid up to his valuation in the auction when he cannot resell, while he should bid more than his valuation in all resale treatments. Figure 4.1 provides a weighted scatterplot of weak bidders' dropout bids against their values in the four treatments.[26] In all scatterplots, the markers are weighted by the frequency with which each value/bid combination was observed, so that larger markers indicate more frequent combinations. A line is included to indicate bids equal to values — i.e., the weak bidder's theoretical bidding function without resale.

It is clear from the scatterplot that in the no resale treatment (upper left graph of Figure 4.1) the majority of observed bids by weak bidders are equal to value. Quantifying this, we find that the mean absolute deviation of bid from value is 0.80 and 83% of observed bids fall within +/-2 of value. For a more accurate test of value bidding, Table 4.1 presents panel random

[26] The figure only represents observed bids. Because the experiments were based on ascending auctions, we do not observe the weak bidder's bid when he wins a unit in the auction.

effects bid regression results on observed bids for the no resale treatment with standard errors clustered at the individual level. Supporting the theoretical prediction of value bidding, a joint test on the estimated coefficients cannot reject the null that the constant is equal to zero and the coefficient on the value of the weak bidder is 1 ($p = 0.864$).

Weak Bid	Coefficient (robust std. error)	p-value
Constant	-0.172 (1.150)	0.881
v_w	0.982 (0.044)	< 0.001

Table 4.1: Random effects panel regression for weak's bids without resale.

The strong adherence of weak bidders' behavior to the theoretical prediction under no resale conditions parallels previous experimental results of value bidding in ascending auctions (see, for example, McCabe *et al.*, 1990, and Alsemgeest *et al.*, 1998).

Empirical Result 1: *Without resale, weak bidders bid up to their valuations.*

In the resale treatment with complete information (the upper right graph of Figure 4.1), it is also clear that the addition of a resale market dramatically changed bids in the upward direction. Using the 6 independent session averages per treatment, a Wilcoxon-Mann-Whitney (WMW) test confirms this difference in observed bids between the no resale and complete information resale treatments ($p = 0.037$), providing empirical support for Result 2.

Many of the observed bids, while certainly higher than value, still lie at or below 30 — the lowest possible value of the strong bidder. A plausible explanation is that since weak bidders only had information regarding the competitor's value distribution, they may not have wanted to risk paying more than strong bidders' valuations.[27]

In the resale treatment with incomplete information (the lower left graph of Figure 4.1), more weak bidders chose to bid value than under complete information, yet they also frequently bid above value. However, the above-value bids under incomplete information appear conservative as the majority fall below 30 and we observe more losing bids than under complete information. Arguably, higher uncertainty about the outcome of the resale market and the resale profit induced weak bidders to bid less aggressively with incomplete information. Despite this more conservative speculation, we still find moderately significant differences in session averages for the observed bids between the no resale treatment and the incomplete information resale treatment ($p = 0.078$).

The final resale treatment, bargain (lower right graph of Figure 4.1), resulted in the majority of observed bids at value or above.[28] There appears to be fewer aggressive bids in this treatment

[27] For experimental analysis on the role of expectations in bidders' deviations from equilibrium strategies see Reiss and Kirchkamp (2011) and Armantier and Treich (2009).

[28] We include the plus marker in the bargain treatment scatterplot to indicate the dropout bids placed by a single

than in the other resale treatments. However, these scatterplots only represent partial results, as they focus on auctions where the weak bidder did not win a unit. Notice, for example, that the graph for the incomplete information resale treatment contains more observations than the complete information resale treatment and fewer observations than the no resale treatment, because weak bidders won more often in the complete information resale treatment and less often in auctions without resale. As we will show in Section 4.2, this is a consequence of the strong bidders' strategic behavior. The graph for the bargaining treatment contains less observations both because of the strong bidders' strategy and because the treatment was run for fewer periods.

By Results 1 and 2, strong bidders should always let weak bidders win with resale, but not without resale. Table 4.2 provides the relative frequency of weak bidders winning a unit across treatments, both for all periods and omitting the first 10 periods to observe learning dynamics. Resale did result in weak bidders winning with higher frequency than without resale, with the highest frequency obtained in the complete information resale and bargain treatments. Later periods resulted in weak winning more often.

% auctions won by Weak	No Resale	Comp Resale	Incomp Resale	Bargain
all periods	38.89%	75%	63.19%	73.13%
omit first 10 periods	40.21%	83.13%	65.42%	80.00%

Table 4.2: Relative frequency of weak bidders winning 1 unit.

Formalizing the above results, table 4.3 presents random effects panel tobit regression results on bids for weak types. The use of a random effects tobit model is appropriate because of the large number of unobserved bids which are censored at the auction price whenever the weak bidder won a unit in the auction. We report marginal effects in addition to the model estimates and use bootstrapped standard errors.[29] The variable v_W represents the weak bidder's valuation, while Comp Resale, Incomp Resale, and Bargain are treatment dummies representing the resale treatments. The no resale treatment serves as our baseline group and the variable Period, which tracks the period of play, is included in Model 2 to test for learning effects over time.[30]

The results of Model 1 demonstrate a strong positive effect on weak bidders' bids when resale is possible, regardless of the form, confirming Result 2.[31] While all three resale treatments result in speculation by weak bidders, the strength of this effect is strongest in the complete information resale treatment. Interacting value with treatment provides evidence that in the bargain and

subject who consistently bid at 0 and 1 for the duration of the experiment. This bidding behavior is exceptional given the overall pattern of the data and is difficult to rationalize, so while this subject's data is included in all of our graphs and analysis, we mark them as outliers in the scatterplot.

[29] Our form of the model may also be referred to as a censored normal regression model as the censoring point may change in each observation (Wooldridge, 2001). Our reported marginal effect = $\frac{\partial E[bid|bid>price]}{\partial x_k}$, where x_k represents the kth independent variable.

[30] All regressions include 1023 uncensored bids and 1617 right-censored bids (at the auction price). The numbers reported in parentheses are bootstrapped standard errors. Three (***), two (**), and one (*) stars indicate statistical significance at the 1%, 5%, and 10% level, respectively.

[31] These experimental results are consistent with those found in single-object auctions with ex-ante symmetric bidders (Georganas, 2011; Saral, 2012).

	(1)		(2)	
Weak Bid	Coefficient	Marginal Effect	Coefficient	Marginal Effect
Constant	0.870 (1.037)		1.064 (1.047)	
v_w	0.993*** (0.043)	0.659	0.993*** (0.040)	0.659
Comp Resale (Comp)	13.248*** (2.643)	8.793	13.245*** (3.351)	8.788
Incomp Resale (Incomp)	6.951*** (2.349)	4.613	6.939*** (1.852)	4.604
Bargain	6.747*** (2.497)	4.478	6.665*** (2.028)	4.422
Period			−0.013 (0.032)	−0.008
$v_w \times$Comp	−0.316** (0.158)	−0.209	−0.318** (0.155)	−0.211
$v_w \times$Incomp	−0.117 (0.099)	−0.077	−0.117 (0.072)	−0.077
$v_w \times$Bargain	−0.236** (0.113)	−0.157	−0.236*** (0.090)	−0.157

Table 4.3: Random effects panel tobit - Weak bidding.

complete information resale treatments higher-value weak bidders bid slightly less aggressively than lower-valued ones.

Empirical Result 2: *Weak bidders bid higher with resale than without. Speculation by weak bidders is highest in the complete information resale treatment.*

Model 2 is included to test for any learning effects and as a robustness check. We find no significant learning effect for weak bidders.[32]

4.2. Strong Type Bidding

By Results 1 and 2 in Section 2, without resale the strong bidder should win both units if his value is higher than $2\mathbb{E}[v_W] = 40$ while he should reduce demand if his value is lower than 40. With resale the strong bidder should reduce demand across all values, regardless of the structure of the resale market or informational conditions.

Figure 4.2 plots weighted scatterplots of the observed strong bidders' dropout bids against per unit value. We again include a line to show where a bid would be equal to value. In the no resale treatment (upper left graph of Figure 4.2) it is apparent that strong bidders dropped out at low prices with higher frequency for values lower than 40. This is evidenced in two ways. First, we have larger clusters of zero bids for values below 40 and second, the number of observed bids is also much higher (showing that strong bidders dropped out first).

[32] We also find no significant learning effects in alternative model specifications that include interactions of period with treatments.

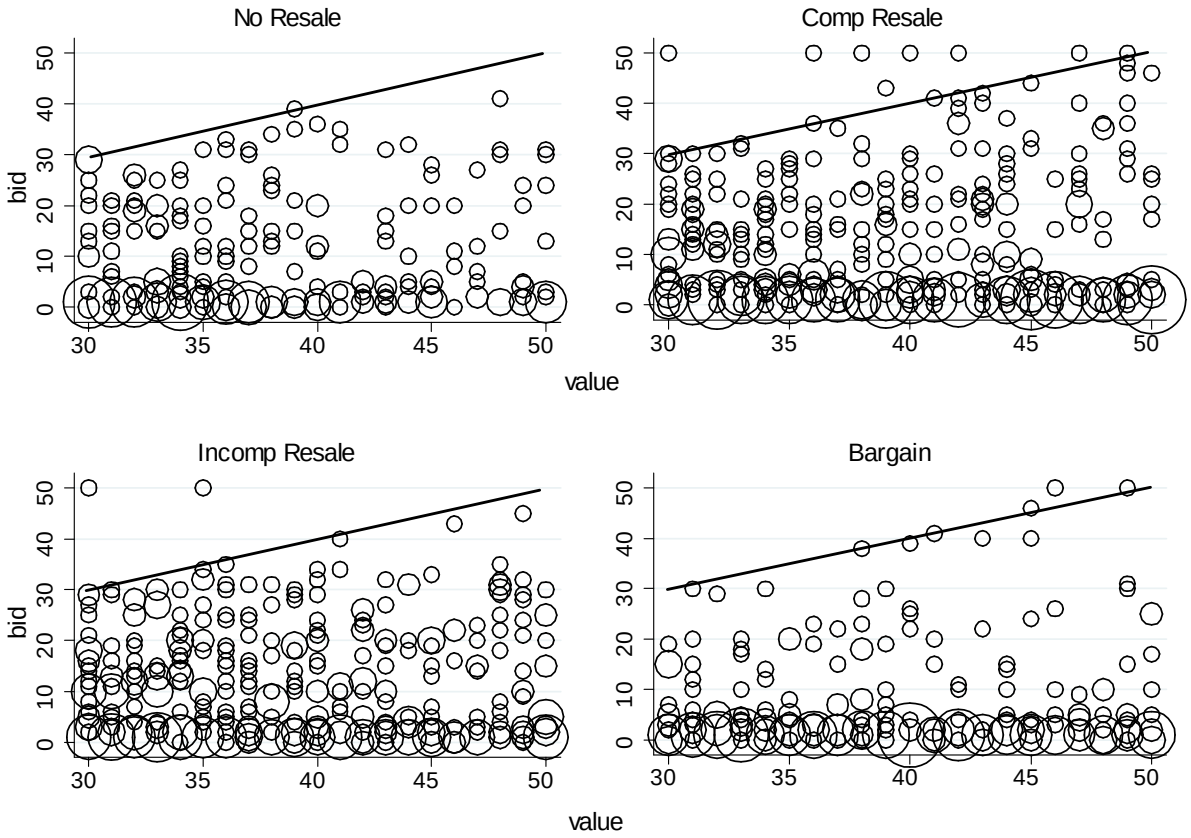

Figure 4.2: **Strong Bidding** – weighted scatterplot of observed bids (dropouts) by strong bidders versus valuations in the four treatments.

The remaining three graphs represent the resale treatments and provide visual evidence that strong bidders reduced demand much more often, responding as theoretically predicted in Result 2 to the presence of resale. Not only is the frequency of bids lower than values high throughout the resale treatments, but many of the bids are near the theoretical prediction of 0. The bargain treatment appears to adhere most accurately to the point predictions of the model, but similar to the weak bidder case, the observed bids only represent auctions where the strong bidder did not win both units.

To more accurately quantify the strong bidder's response to both value location and the presence of resale, Figure 4.3 graphs the relative frequency of the strong bidder winning both units, broken down by value for all treatments. If a strong bidder reduced demand by dropping out of the auction first, he won 1 unit and the auction allocation was inefficient, otherwise he won both units in the auction. In the no resale treatment (first graph of Figure 4.3), strong bidders won 2 units more often when their value was higher than 40. A Kolmogorov-Smirnov (K-S) test indicates that the observed difference between strong bidders winning when their value was above 40 and below 40 is statistically significant ($p < 0.001$).

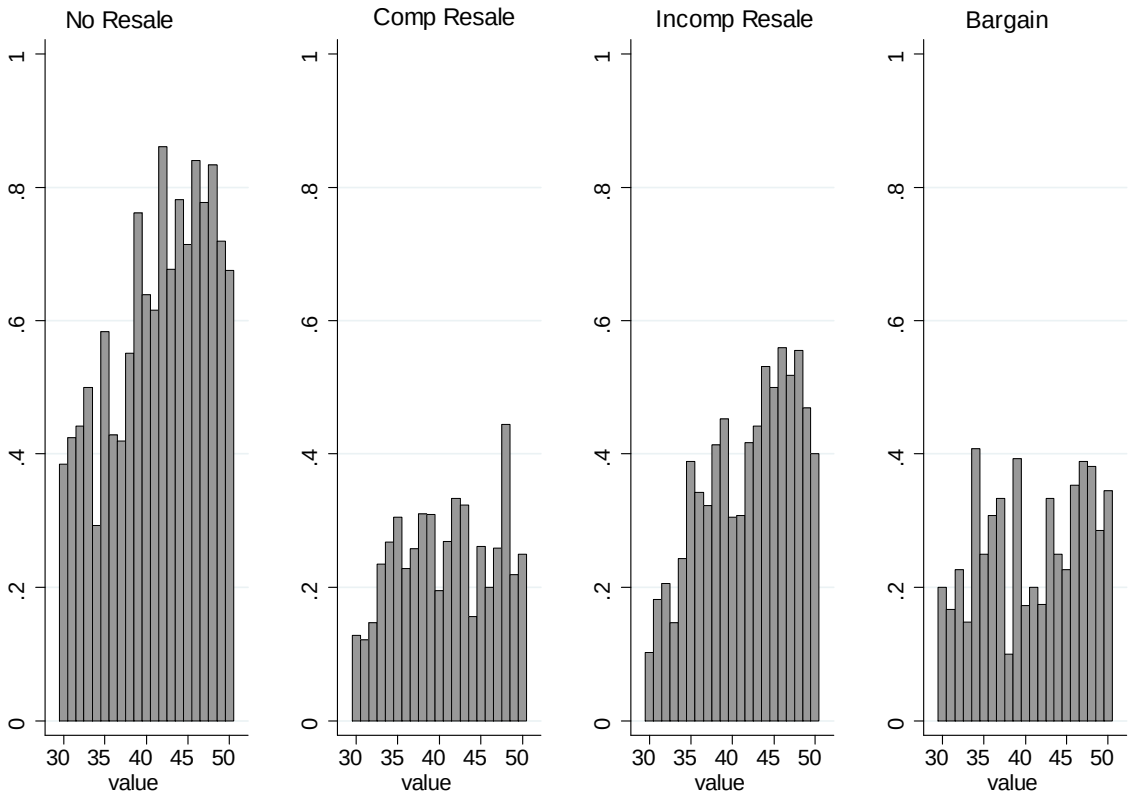

Figure 4.3: Relative frequency of strong bidders winning both units, by strong bidders' value, in the four treatments.

Turning to the resale treatments, it is immediately evident that the presence of resale resulted in much higher frequencies of demand reduction, although this effect is lessened under incomplete information. We find significant differences between the no resale treatment and all resale treatments for both high and low values (K-S, $v_S < 40$, $p \leq 0.007$; $v_S > 40$, $p < 0.001$). Complete information resale and bargain appear most similar and we find no significant differences between these treatments ($p = 0.264$). Between incomplete information resale and either complete information resale or bargain, significant differences exist when v_S was above 40 ($p \leq 0.001$), but not when v_S was below 40 ($p \geq 0.102$).

In theory, a strong bidder who reduces demand should drop out at zero. Yet bids below value or bids that allow the weak bidder to win a unit can be interpreted as demand reduction. Table 4.4 first summarizes demand reduction by strong bidders as bids lower than 3. In the no resale treatment, there is a larger percentage of near-zero bids when the strong bidder had a value less than 40. The resale treatments had the largest amount of near-zero bids. Table 4.4 also summarizes bids below the strong bidder's value. Again, there is more demand reduction in the resale treatments and a drop in demand reduction in the no resale treatment for values greater

than 40. There is also a similar drop for the incomplete information resale treatment. Bidding below value occurs more frequently in the complete information resale and bargain treatments.

Since without demand reduction the weak bidder should never win, Table 4.4 also reports the percentage of auctions where the weak bidder won a unit. In the no resale treatment, weak bidders won more often when strong bidders had low values. All resale treatments resulted in weak bidders winning more often than without resale. Restricting the data by omitting the first 10 periods to account for learning, we observe weak bidders winning even more often, particularly in the complete information resale and bargain treatments.

	% of Bids ≤ 2		% of Bids $< v_S$		% Weak Wins (all periods)		% Weak Wins (omit first 10 periods)	
	$v_S < 40$	$v_S > 40$	$v_S < 40$	$v_S > 40$	$v_S < 40$	$v_S > 40$	$v_S < 40$	$v_S > 40$
No Resale	30%	12%	53%	26%	52%	25%	56%	27%
Comp Resale	37%	43%	76%	72%	77%	72%	87%	79%
Incomp Resale	29%	22%	73%	54%	72%	53%	76%	55%
Bargain	48%	50%	74%	69%	74%	71%	80%	77%

Table 4.4: Relative frequency of demand reduction by strong bidders (out of all auctions).

To examine strong bidders' behavior in more depth, we again analyze random effects tobit models with bootstrapped standard errors in Table 4.5.[33] The strong bidder's unit valuation is represented by v_S, while $v_S > 40$ is a dummy variable indicating when the valuation was higher than 40. Comp Resale, Incomp Resale, and Bargain identify treatment dummies, with the no resale case serving as the baseline. Period represents the period of play.

In the no resale treatment, the positive significant coefficient on $v_S > 40$ confirms that strong bidders' bid higher when their values were above 40, implying less demand reduction when strong bidders had relatively high values. This provides empirical support for Result 1.

Empirical Result 3: *Without resale, strong bidders reduce demand less with high value asymmetry between bidders — i.e., when $v_S > 40$.*

Examining the effects of resale, the significant negative coefficients on Comp Resale, Bargain, and the interactions of Comp Resale and Bargain with $v_S > 40$ indicate that in these treatments there was more demand reduction than without resale across all values, and especially for high values. By contrast, the incomplete information resale treatment only resulted in more demand reduction than no resale for values greater than 40 and even this result only reaches significance at the 10% level. This is consistent with the fact that the resale market is less efficient in the incomplete information resale treatment, since bidders may fail to trade with incomplete information and take-it-or-leave-it offers, thus making it more risky for strong bidders to reduce demand.[34]

[33] All regressions include 1646 uncensored bids and 994 right-censored bids (at the auction price).

[34] Since strong bidders tended to bid higher in the incomplete information resale treatment than in the complete

Strong Bid	(1) Coefficient	(1) Marginal Effect	(2) Coefficient	(2) Marginal Effect
Constant	7.745* (4.444)		5.016 (4.407)	
v_s	0.516*** (0.100)	0.235	0.524*** (0.108)	0.239
Comp Resale (Comp)	−5.832* (3.385)	−2.664	−1.768 (3.481)	−0.806
Incomp Resale (Incomp)	−2.673 (3.558)	−1.221	−1.318 (3.984)	−0.601
Bargain	−10.454*** (3.140)	−4.775	−5.047 (3.946)	−2.302
v_s>40	7.287** (2.933)	3.328	6.576** (3.362)	3.000
Period	−0.420*** (0.052)	−0.192	−0.264*** (0.078)	−0.120
Comp×v_s>40	−8.684*** (3.204)	−3.966	−8.044** (3.777)	−3.669
Incomp×v_s>40	−6.546* (3.420)	−2.990	−6.254* (3.297)	−2.853
Bargain×v_s>40	−10.445*** (2.865)	−4.771	−9.873*** (3.640)	−4.504
Comp×Period			−0.263** (0.104)	−0.119
Incomp×Period			−0.084 (0.114)	−0.038
Bargain×Period			−0.434*** (0.163)	−0.198
v_s>40×Period	−0.078 (0.066)	−0.035	−0.067 (0.070)	−0.030

Table 4.5: Random effects panel tobit - Strong bidding.

Empirical Result 4: *With high value asymmetry between bidders, strong bidders reduce demand more with resale than without. With low value asymmetry between bidders, strong bidders reduce demand more with resale than without only in the bargain and complete information resale treatments. Demand reduction by strong bidders is highest in the bargain treatment.*

In contrast to the case of weak bidders, learning plays a significant role for strong bidders. Over time, the significant negative coefficient on Period indicates that strong bidders learned to reduce demand more. Model 2 decomposes this result by treatment. There is significant learning to reduce demand only in the complete information resale and bargain treatments, with a stronger effect in bargain. As we will show in Section 4.4, resale is most successful in these treatments, so efficient resale leads to reinforcement learning in the direction of the theoretical predictions.

resale treatment, there is no evidence that they tried to signal lower valuations to weak bidders when valuations were not revealed after the auction, in order to obtain higher profit in the resale market.

4.3. Efficiency and Seller's Revenue

Auction efficiency is measured as the ratio between the valuation of the auction winner and the valuation of the strong bidder, which is the highest valuation. Since one unit was always awarded to the strong bidder, we will focus on the efficiency results for the second unit. Auction efficiency is lower than 1 when the weak bidder won the second unit because of demand reduction or speculation.

When an auction is followed by a resale opportunity, the efficiency generated by the auction allocation can potentially change. We refer to the post-resale efficiency as final efficiency, which is measured as the ratio between the valuation of the final holder of the good and the valuation of the strong bidder. In our environment, final efficiency is 1 if the weak bidder resold to the strong bidder after the auction; while final efficiency is equal to auction efficiency if resale does not take place. By Result 3 in Section 2, auction efficiency should be lower with resale than without, while final efficiency should always be 1 in the bargain and complete information resale treatments, and higher than without resale. Final efficiency should be lower than 1 in the incomplete information resale treatments because bidders may fail to trade with take-it-or-leave-it offers and incomplete information.

Table 4.6 reports average efficiency, by treatment. No resale resulted in the highest auction efficiency, but not full efficiency because of demand reduction by strong bidders with lower values. Pairwise WMW tests on session averages find significant differences in auction efficiency between the no resale treatment and all resale treatments ($p \leq 0.025$). Among the resale treatments, incomplete information resale resulted in the highest auction efficiency.

Resale improved efficiency from the auction allocation to the final allocation, most strikingly when subjects were allowed to bargain or make take-it-or-leave it offers with complete information, consistent with Result 3.[35] Moreover, final efficiency in both the bargain and the complete information resale treatments is higher than without resale. However, it is not necessarily the case that resale always yielded higher final efficiency: no significant difference exists between final efficiency in the no resale and the incomplete information resale treatments ($p = 0.521$).

	No Resale	Comp Resale	Incomp Resale	Bargain
Auction Efficiency	0.82	0.64	0.71	0.65
	(0.241)	(0.256)	(0.258)	(0.261)
Final Efficiency	0.82	0.93	0.85	0.95
	(0.241)	(0.170)	(0.217)	(0.132)

Table 4.6: Average auction and final efficiency (standard deviations in parentheses).

Figure 4.4 examines efficiency through the relative frequency of the strong bidder holding 2 units after resale, depending on the strong bidders' value. To show how the allocation changed after the auction, we have overlaid the auction allocation seen previously in figure 4.3. Demand

[35] We find no significant differences in final efficiency between the complete information resale and bargain treatments ($p = 0.438$).

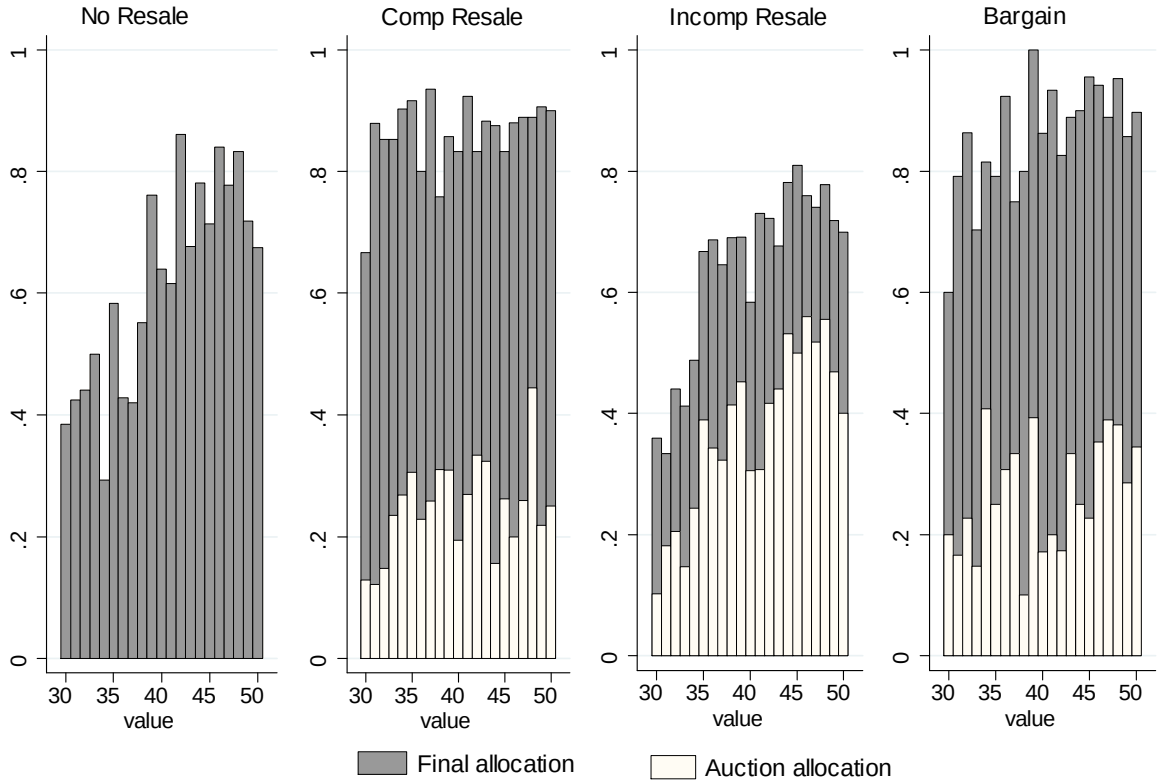

Figure 4.4: Relative frequency of final allocation and auction allocation of 2 units to strong bidder, by strong bidders' value.

reduction in all resale treatments resulted in low efficiency after the auction, but resale increased final efficiency. With complete information or bargaining, the second unit was almost always transferred to the strong bidder when the weak bidder won it in the auction, and there is no statistically significant difference between the final allocations in these two treatments (K-S, $p = 0.485$). Resale under take-it-or-leave-it offers with incomplete information also increased efficiency after the auction, but the final allocation for this treatment was similar to the no resale allocation. A K-S test confirms that there is no significant difference between the allocation in the no resale treatment and the final allocation in the incomplete information resale treatment ($p = 0.485$).

Empirical Result 5: *Auction efficiency is lower with resale than without. Final efficiency without resale is lower than in the bargain and complete information resale treatments, but is not significantly different from the incomplete information resale treatment.*

By Result 4 in Section 2, auction revenue should be higher without resale than with resale because resale induces demand reduction by strong bidders and hence reduces the auction price.

Table 4.7 reports average auction revenue per unit sold for each treatment, and by the type of the auction winner. The highest overall revenue was achieved in the no resale treatment, but revenue in the incomplete information resale treatment was almost as high as in the no resale treatment.[36] The reasoning behind the higher than expected revenue with resale is straightforward: weak bidders bid more aggressively with resale, and this increased the seller's revenue when strong bidders chose to win the auction rather than reduce demand.

	No Resale	Comp Resale	Incomp Resale	Bargain
Average Seller's Revenue	14.61 (10.062)	11.94 (12.448)	14.05 (11.099)	8.47 (10.567)
Average Revenue - Weak Wins	8.01 (10.117)	8.64 (11.339)	9.98 (10.387)	5.25 (8.873)
Average Revenue - Strong Wins	18.81 (7.440)	21.85 (10.181)	21.06 (8.493)	17.22 (9.849)

Table 4.7: Average seller's revenue per unit (standard deviation in parentheses).

Empirical Result 6: *The seller's revenue without resale is higher than in the bargain treatment, but it is not significantly higher than in the incomplete information or the complete information resale treatments.*

Table 4.7 also shows that, in all treatments, the seller obtained a lower revenue when weak bidders won a unit, so that the auction price was determined by strong bidders' bids (rather than weak bidders' bids), although strong bidders had a higher willingness to pay per unit. This is consistent with the fact that strong bidders tended to reduce demand and bid lower than weak bidders, with intentions to reduce the auction price.

4.4. Resale Market

In this section, we highlight key aspects of the resale market that underlie the empirical regularities described previously for the resale treatments. Recall that the resale market either involved a take-it-or-leave-it offer where the proposer was determined with 50/50 probability (complete information and incomplete information resale), or placed bidders into an unstructured bargaining game (bargain).

Table 4.8 provides the relative frequency of resale in all resale treatments, and breaks this down into successful and failed resale. Successful resale took place when both participants agreed to an offer while failed resale was either a result of one of the participants choosing to exit the resale stage or failed agreement before time expired.[37] Resale was more frequent and successful

[36] WMW tests on session averages for revenue find no significant differences between no resale and either complete ($p = 0.200$) or incomplete information resale ($p = 0.872$). By contrast, there are significant differences in revenue between either no resale or incomplete information resale and bargain ($p \leq 0.070$).

[37] In the bargain treatment, we observed 72 cases of failed resale (out of 351 resale markets). Of these, 41 were the result of time expiring while the remaining 31 failed because one of the two resale participants chose to exit the stage.

in the complete information resale and bargain treatments than in the incomplete information resale treatment because of the mix of incomplete information and a take-it-or-leave-it offer mechanism. An informal examination of the chat content from the bargain treatment makes it clear that communication facilitated trade between resale participants, in spite of the presence of incomplete information.[38]

	Resale Possible (weak won)	Successful Resale	Failed Resale
Comp Resale	75%	81.1%	18.9%
Incomp Resale	63.2%	42.2%	57.8%
Bargain	73.1%	79.5%	20.5%

Table 4.8: Relative frequency of possible resale (when the weak bidder won a unit the auction), successful resale, and failed resale (out of Resale Possible).

From an efficiency standpoint, it is important to understand which factors determined a higher probability of successful resale in each resale mechanism. Table 4.9 provides marginal effects from probit regressions with agreement to final resale as the dependent variable. Standard errors are clustered at the session level. Models 1 and 2 examine the complete and incomplete information resale treatments, respectively. The variable Offer represents the take-it-or-leave-it offers. Auction Price represents the dropout price from the auction, Auction Price$>v_W$ is a dummy variable indicating when the auction price was greater than the weak bidder's value (i.e., losses at the auction stage for the weak bidder), and $v_S - v_W$ represents the difference between the strong and weak values to capture the effect of varying asymmetry between bidders. Weak Proposer is a dummy variable which indicates whether the proposer was the weak bidder.

The results demonstrate that, as expected, an increase in the offer made by a strong proposer as well as a reduction in the offer made by a weak proposer significantly increased the probability of acceptance. We also find a significant and large positive effect of weak bidders assigned to the proposer role on the probability of agreement, arguably because weak bidders were less aggressive in the resale market than strong bidders, as we will show below.

Although in theory the profits from the auction should not affect the resale market, in the incomplete information treatment we find a strong positive effect when the auction price was higher than the weak bidder's value. Specifically, if the weak bidder paid an auction price higher than his value, incurring losses at the auction stage, the probability of resale agreement increased by 13%. The size of the gains from trade $v_S - v_W$ had little impact under complete information, but significantly increased the success rate of resale in the incomplete information treatment, likely because it increased the range of potential offers that led to positive profit in the resale market for both participants.

[38] While our categorization of chat is an admittedly subjective exercise, we have identified the most commonly discussed themes which include earnings based on the current offer, back-and-forth numeric offers, and declarations of final offer. This can be seen in the following examples: "I lose money at 33"; "Can you do 25? That way I can still earn a profit"; "My value is 30 so I can't really go lower." We have not formalized the analysis of communication because of limited data as we only have one treatment, bargain, with chat.

Final Resale Agreement	(1) Comp Resale	(2) Incomp Resale	(3) Bargain
Offer	0.019***	0.037***	
	(0.005)	(0.013)	
Initial Weak Offer – Initial Strong Offer			−0.011***
			(0.0005)
Auction Price	−0.003	−0.0003	0.0001
	(0.003)	(0.001)	(0.002)
Auction Price>v_w	0.060	0.134**	0.036
	(0.082)	(0.067)	(0.101)
v_s–v_w	0.004	0.022***	0.011***
	(0.004)	(0.006)	(0.001)
Weak Proposer	0.651***	0.705***	
	(0.037)	(0.193)	
Offer×Weak Proposer	−0.021***	−0.032**	
	(0.005)	(0.015)	
Auction Price×Weak Proposer	−0.003	−0.003	
	(0.002)	(0.001)	
# Offers Made			−0.009***
			(0.005)
Observations	534	445	344
Clusters (session level)	3	3	3

Table 4.9: Marginal effects from Probit regressions on resale of unit (final resale agreement), conditional on weak winning.

For the bargain treatment in Model 3, we restructured the estimated model to account for the unstructured process of this mechanism, where we typically observe a series of alternating offers rather than a single offer. To determine the role of offers under bargaining, we difference the first two offers made by strong and weak bidders, respectively. If agreement was reached with a single initial offer, this difference is defined as zero. We also include a variable, # Offers Made, which tracks the total number of offers made by a bargaining pair. We find that the distance between the weak and strong initial offers negatively impacted the probability of final agreement: every 1 unit increase in distance is associated with a 1.1% decrease in the probability of acceptance. We also find a significant, but relatively weak negative effect for the number of offers made. As in the incomplete information resale treatment, higher value asymmetry increased the probability of successful resale.

Empirical Result 7: *Resale is more likely to succeed when the weak bidder has more bargaining power, with more information in the resale market, larger gains from trade, and more flexibility in the bargaining mechanism. Bidders trade most often (when it is efficient to do so) in the bargain and complete information resale treatments.*

Table 4.10 summarizes average resale prices, earnings (measured as the distance between the resale price and the bidder's value), and proposed offers by type of bidder. Resale prices were higher in the complete information resale treatment than either the bargain or the incomplete information resale treatments. WMW tests on the independent session averages for resale prices

show significant differences between complete information and incomplete information resale ($p = 0.054$) and between complete information resale and bargain ($p = 0.020$). There is no significant difference between incomplete information resale and bargain ($p = 0.796$).

There are also differences in earnings between strong and weak bidders. Weak bidders obtained a lower profit than strong bidders in the resale market, but managed to obtain relatively higher profits with complete information, where profits were closer to equal splits of the resale surplus.[39] Differences in earnings were mainly driven by strong bidders making more aggressive offers in the resale market, especially with incomplete information. Comparing the average offers for the take-it-or-leave-it treatments, strong proposers made significantly lower offers under incomplete information ($p = 0.006$), while there is no significant difference between offers made by the weak proposers ($p = 0.872$).

	Resale Price	Weak Earnings	Strong Earnings	Resale Offer Weak / Strong
Comp Resale	29.56 (5.619)	9.45 (5.527)	10.20 (5.749)	32.47/25.45 (4.664) (6.240)
Incomp Resale	27.38 (7.686)	8.74 (7.964)	12.59 (7.635)	32.45/17.93 (6.911) (7.035)
Bargain	27.44 (4.474)	8.35 (5.866)	12.43 (6.559)	-

Table 4.10: Average resale prices, resale earnings, and offers by type (standard deviations in parentheses).

Comparing average resale prices from Table 4.10 to average auction prices (which are equivalent to the seller's revenue) from Table 4.7 it is clear that, in all treatments with resale, auction prices are lower than resale prices on average. This difference is particularly large in auctions where the weak bidder wins and there is pronounced demand reduction by strong bidders; but resale prices are higher than auction prices even when the strong bidder wins and the auction is not followed by a resale market.

Since resale tends to reduce the seller's revenue, it may be expected that bidders always prefer auctions with resale. This is not necessarily the case, however, as shown in Table 4.11, which reports average total bidders' profits — i.e., auction earnings plus resale earnings in each period — by types and treatments. Pairwise WMW tests on session averages find significant earnings differences for weak bidders across all treatments ($p \leq 0.077$) except between the complete information resale and bargain treatments. Weak bidders obtain higher profits when resale is allowed, because of the option value of selling the unit acquired after the auction. By contrast, strong bidders' profits without resale are significantly lower than in the bargain treatment ($p = 0.070$), but are not significantly different than in the complete information and

[39] In the resale treatments with take-it-or-leave-it offers, the bidder who is chosen as the proposer should make an offer that makes (actually or in expectation) the other bidder just indifferent between accepting or rejecting it, and hence obtain the whole resale surplus. So, in expectation, a bidder should obtain half of the gains from trade in the resale market.

incomplete information resale treatments ($p \leq 0.631$).[40] Therefore, strong bidders obtain higher profits when resale is allowed only when the resale market is sufficiently flexible and efficient, so that they manage to trade with high probability after the auction.

	No Resale	Comp Resale	Incomp Resale	Bargain
Weak's Profit	4.95	14.47	9.18	15.83
	(8.838)	(14.279)	(11.709)	(12.620)
Strong's Profit	38.64	38.82	36.76	44.62
	(16.911)	(17.979)	(18.028)	(17.147)

Table 4.11: Average bidders' total profits (standard deviations in parentheses).

Despite the option value of resale, there are two reasons why the presence of a resale market may reduce strong bidders' profit: (i) resale induces strong bidders to give up a unit in the auction much more often, even though they may not manage to buy that unit in the resale market; (ii) buying a unit in the auction is more costly with resale, because weak bidders bid more aggressively.

5. Conclusion

It is often argued that resale should always be allowed after an auction, because it favors a more efficient allocation of the objects on sale (see, e.g., Mankiw, 2007). The possibility of resale, however, also affects bidders' strategies in the auction and the seller's revenue. We have used controlled laboratory experiments to analyze the effects of post-auction resale and asymmetries among bidders in multi-object auctions, with varying information conditions and resale mechanisms.

Our experimental results provide strong qualitative support for the bidding strategies predicted by theory in multi-object uniform-price auctions. First, without resale, bidders reduce demand less when they have a relatively higher valuation than competitors. Second, with resale, bidders who expect to sell in the resale market (weak bidders) tend to speculate by bidding at prices that are higher than their valuations, while bidders who expect to buy in the resale market (strong bidders) reduce demand much more often than without resale, especially when they have high valuations. So the possibility of resale motivates both strong and weak bidders to bid further away from their values. These results are robust to different resale mechanisms, but the magnitude of the response to resale depends on the properties of the resale market. Specifically, higher uncertainty about the resale market's outcome (due to a less flexible resale mechanism and the availability of less information) induces weak bidders to speculate less and strong bidders to reduce demand less.

As commonly argued, resale does increase efficiency ex-post, once the auction is terminated,[41]

[40] The only other significant difference in the pairwise comparison of overall profits for strong bidders is between incomplete information resale and bargain ($p = 0.038$).

[41] The possibility of resale has an even stronger positive effect on final efficiency when potential buyers may not participate in the auction or when the order of bidders' valuations may change after the auction.

but our analysis shows that resale also affects bidders' strategies during the auction in ways that tend to reduce auction efficiency, and ultimately final efficiency as resale may fail even in the presence of gains from trade (for example due to frictions created by asymmetric information or the actual resale mechanism). Arguably, in our experiments resale was likely to succeed because subjects knew there were mutual gains from trade whenever they had a chance to trade in the resale market. In a more realistic environment where bidders may be unsure about the presence of gains from trade, post-auction resale would be less efficient than in our experiments. So, we conjecture that final efficiency with resale may be even lower. Resale transactions themselves may be costly and require significant delays in the efficient allocations of the objects.

Moreover, as predicted by theory, the possibility of resale tends to reduce the seller's revenue because it provides a chance to exploit mutual gains from trade among bidders after the auction.[42] However, resale induces weak bidders to speculate, which actually increases the seller's revenue when strong bidders do not reduce demand. In our experiments, revenue is highest both without resale and with incomplete information resale, and is lowest with bargaining.

When interpreting the effect of resale on the seller's revenue, it must be noted that our analysis assumes a fixed number of bidders while the possibility of resale is likely to affect participation in the auction.[43] In fact, in the presence of entry costs, weak bidders may be more willing to participate when they are allowed to resell since, as we have shown, they obtain higher profit in this case. Resale may even attract pure speculators who have no use value for the objects on sale. This tends to increase competition and hence the seller's revenue. By contrast, whether strong bidders prefer an auction with or without resale depends on the actual resale mechanism adopted by bidders.

In sum, our experimental results suggest that allowing resale in multi-object auctions is not guaranteed to increase efficiency nor does it necessarily reduce the seller's revenue.

Similar to what has been observed in many real-world auctions followed by active resale markets, in our experiments resale prices are significantly higher than auction prices, precisely because players who are willing to acquire multiple objects choose to trade in the resale market rather than compete aggressively in the auction in order to pay lower auction prices. So the presence of a resale market may stimulate costly rent-seeking activity to obtain underpriced objects in the auction (Leslie and Sorensen, 2013).

The outcome of the resale market depends on the actual mechanism adopted by bidders to trade and on the information available to bidders. Specifically, more information, a dynamic and more flexible bargaining mechanism, more bargaining power for the resale seller, and larger gains from trade all tend to increase the probability of successful resale. More information also tends to increase the resale price and the resulting resale profit obtained by the resale seller, although the resale seller always obtains lower profits than the resale buyer. A more efficient resale

[42] Demand reduction leading to low auction prices can be interpreted as implicit collusion among bidders and the resale market as a device through which bidders implement side payments, thus facilitating collusion.

[43] For an analysis of the effects of resale on entry in single-object auctions see Xu *et al.* (2013).

market, however, also tends to reduce the seller's revenue and efficiency in the auction, since it makes strong bidders more willing to reduce demand and trade after the auction. Consequently, a market designer may face a trade-off between higher post-resale efficiency and higher auction efficiency and seller's revenue.

References

[1] Alsemgeest, P., C. Noussair and M. Olson (1998), "Experimental Comparisons of Auctions under Single- and Multi-Unit Demand." *Economic Inquiry*, 36, 87-97.

[2] Armantier, O., and N. Treich (2009), "Subjective Probabilities in Games: An Application to the Overbidding Puzzle." *International Economic Review*, 50(4), 1079-1102.

[3] Ausubel, L., and P. Cramton (1998), "Demand Reductions and Inefficiency in Multi-Unit Auctions." Mimeo, University of Maryland.

[4] Calzolari, G., and A. Pavan (2006), "Monopoly with Resale." *RAND Journal of Economics*, 73(2), 362-375.

[5] Coppinger, V., V. Smith and J. Titus (1980), "Incentives and Behavior in English, Dutch and Sealed-bid Auctions." *Economic Inquiry,* 43, 1-22.

[6] Crawford, V. (1998), "A Survey of Experiments on Communication via Cheap Talk." *Journal of Economic Theory,* 78(2), 286-298.

[7] Engelmann, D., and V. Grimm (2009), "Bidding Behavior in Multi-Unit Auctions – An Experimental Investigation." *Economic Journal,* 119, 855-882.

[8] Feltovich, N., and J. Swierzbinski (2011), "The Role of Strategic Uncertainty in Games: An Experimental Study of Cheap Talk and Unstructured Bargaining in the Nash Demand Game." *European Economic Review,* 55(4), 554-574.

[9] Filiz-Ozbay, E., K. Lopez-Vargas and E. Ozbay (2012), "Multi-Object Auctions with Resale: Theory and Experiment." Mimeo, University of Maryland.

[10] Fischbacher, U. (2007) "Z-Tree: Zurich Toolbox For Readymade Economic Experiments." *Experimental Economics*, 10(2), 171-178.

[11] Garratt, R., and T. Tröger (2006), "Speculation in Standard Auctions with Resale." *Econometrica*, 74(3), 753-769.

[12] Garratt, R., T. Tröger and C. Zheng (2009), "Collusion via Resale." *Econometrica*, 77(4), 1095-1136.

[13] Georganas, S. (2011), "English Auctions with Resale: An Experimental Study." *Games and Economic Behavior*, 73(1), 147-166

[14] Georganas, S., and J. Kagel (2011), "Asymmetric Auctions with Resale: An Experimental Study." *Journal of Economic Theory*, 146, 359-371.

[15] Goeree, J., T. Offerman and R. Sloof (2013), "Demand Reduction and Preemptive Bidding in Multi-Unit License Auctions." *Experimental Economics*, 16, 52-87.

[16] Greiner, B. (2004), "The Online Recruitment System ORSEE 2.0 — A Guide for the Organization of Experiments in Economics." University of Cologne, Working Paper n. 10.

[17] Gupta, M., and B. Lebrun (1999), "First Price Auctions with Resale." *Economic Letters*, 64, 181-185.

[18] Hafalir, I., and V. Krishna (2008), "Asymmetric Auctions with Resale." *American Economic Review*, 98(1), 87-112.

[19] Haile, P. (2001), "Auctions with Resale Markets: An Application to U.S. Forest Service Timber Sales." *American Economic Review*, 91(3), 399-427.

[20] Haile, P. (2003), "Auctions with Private Uncertainty and Resale Opportunities." *Journal of Economic Theory*, 108(1), 72-110.

[21] Harstad, R. (2012),"Behavioral Efficiency: Definition, Methodology, Demonstrations." Mimeo, University of Missouri.

[22] Jehiel, P., and B. Moldovanu (2000), "Auctions with Downstream Interaction among Buyers." *RAND Journal of Economics*, 31, 768-791.

[23] Kagel, J. (1995), "Auctions: a survey of experimental research," in *The Handbook of Experimental Economics*, ed. by A.Roth and J. Kagel, Princeton University Press.

[24] Kagel, J., R. Harstad and D. Levin (1987), "Information Impact and Allocation Rules in Auctions with Affiliated Private Values: A Laboratory Study" *Econometrica*, 55, 1275-1304.

[25] Kagel, J., and D. Levin (2001), "Behavior in Multi-Unit Demand Auctions: Experiments with Uniform Price and Dynamic Vickrey Auctions." *Econometrica*, 69, 413-454.

[26] Kagel, J., and D. Levin (2005), "Multi-Unit Demand Auctions with Synergies: Behavior in Sealed-Bid versus Ascending-Bid Uniform-Price Auctions." *Games and Economic Behavior*, 53, 170- 207.

[27] Kagel, J., and D. Levin (2011), "Auctions: A Survey of Experimental Research, 1995-2010." forthcoming in *The Handbook of Experimental Economics*, Vol. 2, ed. by A.Roth and J. Kagel, Princeton: Princeton University Press.

[28] Kwasnica, A., and K.Sherstyuk (2012), "Multi-Unit Auctions." Mimeo, University of Hawaii.

[29] Lange, A., J. List and M. Price (2011), "Auctions with Resale when Private Values Are Uncertain: Theory and Empirical Evidence." *International Journal of Industrial Organization*, 29, 54-64.

[30] Leslie, P., and A. Sorensen (2013), "Resale and Rent-Seeking: An Application to Ticket Markets." *Review of Economic Studies*, forthcoming.

[31] List, J., and D. Lucking-Reiley (2000), "Demand Reduction in Multi-Unit Auctions: Evidence from a Sportscard Field Experiment." *American Economic Review*, 90(4), 961-972.

[32] Mankiw, G. (2007). *Principles of Microeconomics*. Thoms South-Western.

[33] McAfee, P., W. Takacs and D. Vincent (1999), "Tariffying Auctions." *RAND Journal of Economics*, 30, 158-179.

[34] McCabe, K., S. Rassenti and V. Smith (1990), "Auction Institutional Design: Theory and Behavior of Simultaneous Multiple-Unit Generalizations of the Dutch and English Auctions." *American Economic Revie*w, 80 (5), 1276-1283.

[35] Milgrom, P. (1987), "Auction Theory," in *Advances in Economic Theory: Fifth World Congress of the Econometric Society*, ed. by T. Bewley, Cambridge University Press, 1-32.

[36] Pagnozzi, M. (2007), "Bidding to Lose? Auctions with Resale." *RAND Journal of Economics*, 38(4), 1090-1112.

[37] Pagnozzi, M. (2009), "Resale and Bundling in Auctions." *International Journal of Industrial Organization*, 27(6), 667-678.

[38] Pagnozzi, M. (2010), "Are Speculators Unwelcome in Multi-Object Auctions?" *American Economic Journal: Microeconomics*, 2(2), 97-131.

[39] Reiss, P., and O. Kirchkamp (2011), "Out-of-Equilibrium Bids in Auctions — Wrong Expectations or Wrong Bids?" *Economic Journal*, 121, 1361-1397.

[40] Roth, A., and M. Malouf (1979), "Game-Theoretic Models and the Role of Information in Bargaining." *Psychological Review*, 86(6), 574-594.

[41] Roth, A., and J. Murnighan (1982), "The Role of Information in Bargaining: An Experimental Study." *Econometrica*, 50 (5), 1123–1142.

[42] Roth, A. (1995), "Bargaining experiments," in *Handbook of Experimental Economics*, ed. by A.Roth and J. Kagel, Princeton University Press.

[43] Saral, K. J. (2012), "Speculation and Demand Reduction in English Clock Auctions with Resale." *Journal of Economic Behavior and Organization*, 84(1), 416-431.

[44] Wilson, R. (1979), "Auctions of Shares." *Quarterly Journal of Economics*, 94, 675-689.

[45] Wooldridge, J. (2001). *Econometric Analysis of Cross Section and Panel Data.* Cambridge, MA: MIT Press.

[46] Xu, X., D. Levin and L. Ye (2013), "Auctions with Entry and Resale." *Games and Economic Behavior,* forthcoming.

[47] Zheng, C. (2002), "Optimal Auction with Resale." *Econometrica*, 70(6), 2197-2224.

[48] Zhou, X. C. (2012), "Structural Analyses of Emission Permit Auctions Under Cap-And-Trade Programs In the United States." Ph.D. Thesis, Stanford University.

A. Appendix

A.1. Sample Instructions - Bargain Treatment

Thank you for participating in today's experiment. I will read through a script to explain to you the nature of today's experiment as well as how to work the computer interface you will be using. I will be using this script to make sure that all sessions of this experiment receive the same information, but please feel free to ask questions as they arise. We ask that everyone please refrain from talking or looking at the monitors of other subjects during the experiment. If you have a question or problem please raise your hand and one of us will come to you. I also ask that you please turn off your cell phones.

General information: The purpose of this experiment is to study how people make decisions in a particular situation. You will receive $10 for showing up on time for the experiment. You will also make additional money during today's experiment. Upon completion of the experiment the amount that you make will be paid to you in cash. Payments are confidential; no other participant will be told the amount you make. All amounts in this phase of the experiment are denominated in experimental currency units, ECUs. ECUs will transform into real dollars at the rate of $0.01 per ECU. These earnings are in addition to the show-up fee. In this experiment, you will be a bidder in a series of auctions. Please hit continue for general instructions. Please do not hit continue again until after I have finished with all instructions for this screen.

In this experiment, we will create a market in which you will act as a bidder in a sequence of auctions. Each auction has two identical units of a hypothetical item for sale. You will be bidding in the auction against one other person. At the end of each auction there will be the possibility of the winner reselling the item to the other person. The person you are matched with to bid against will be randomly chosen at the start of each auction and will therefore be different across auctions. Each auction will always have two bidders: a 1-unit bidder and a 2-unit bidder. The 1-unit bidder can purchase only 1 unit of the item and will be assigned a single value for one (1) unit. The 2-unit bidder can purchase up to 2 units of the item and will be assigned a single value for each of the two (2) units. For both types of bidders, these values represent the value of the good to you - what we will pay you for any items purchased. Please hit continue for information on roles, values, and resale. Again, please do not hit continue until I have finished with all instructions for this screen.

You were randomly assigned a role of 1-unit bidder or 2-unit bidder, which is listed at the top of your screen. The possible values for the 2-unit bidder are the integers between 30 and 50, with all values being equally likely, and the possible values for the 1-unit bidder are the integers between 10 and 30, again all values are equally likely. If you are a 1-unit bidder, you will be bidding against a 2-unit bidder and vice versa. If the 1-unit bidder purchases a unit, they will have the opportunity to resell it to the 2-unit bidder. If the 2-unit bidder purchases a unit, they will not resell it because they have a higher value than the 1-unit bidder. Please press continue again to work with the auction interface. What you should see is a flat example screen. Please do not hit continue until I have finished with all instructions for this screen.

What you should see in front of you is a sample of the screen you will see for this auction. The left side of the screen contains boxes that have instructions and payoffs. On the right side of the screen you will see the primary auction interface. Beside the word "Auction" in the top line, you will see the number of units you can win (called "Units Demanded"). Below that you will see what your value is for a unit in ECUs for this auction (remember your value is what we will pay you for each unit won). Underneath your value, you will see a bid clock. This clock

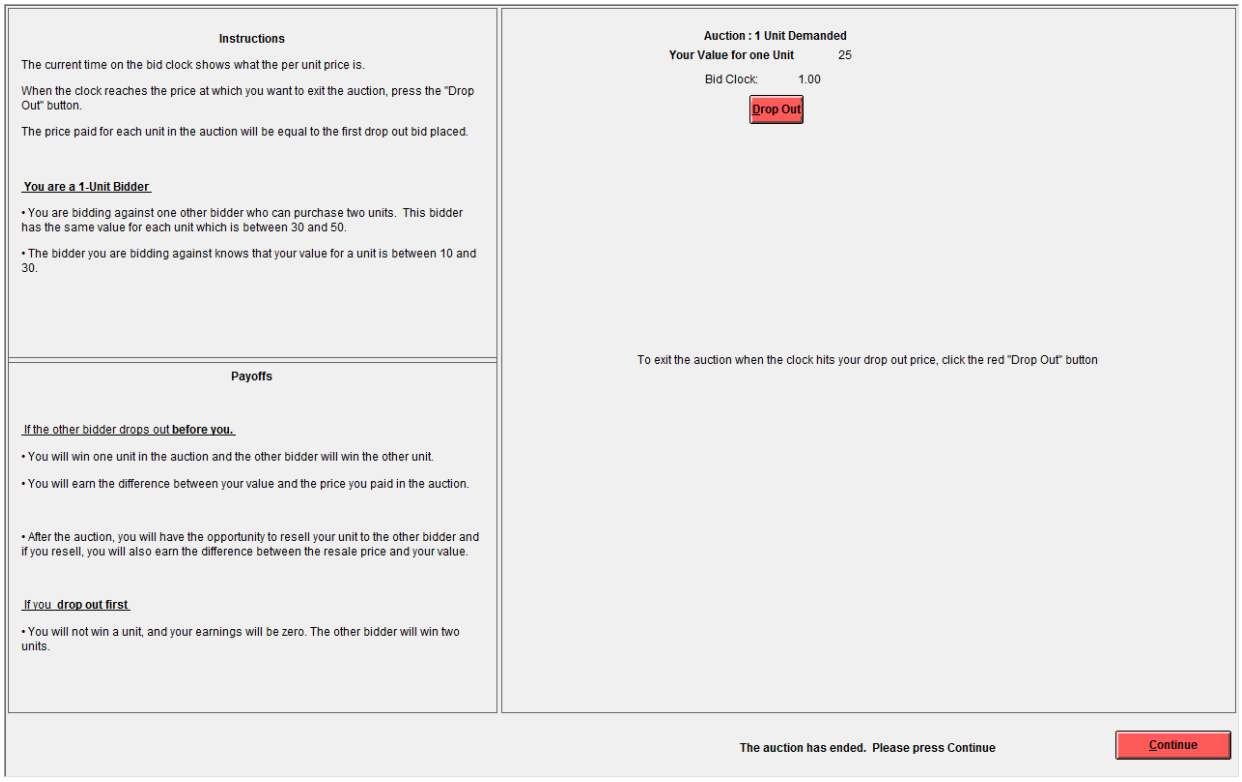

Figure A.1: Sample auction screen (weak bidder).

shows the current price in the auction and will steadily count up. The clock is not increasing now, because this is just an example screen. If this were the actual auction, the clock would be ticking up by 1 ECU per second. Both bidders begin the round "in" the auction. As the price increases on the bid clock, you can click on the "Drop Out" button to drop out of the auction at any point of your choosing. Note that drop out choices are irreversible so as soon as any bidder presses the drop out button, the auction will end and the time on the clock will be the auction price. After the auction, there may be an opportunity for reselling the object.

Payoffs: If the 1-unit bidder drops out first, the 2-unit bidder wins both units in the auction and there is no resale because the 2-unit bidder has the highest value. In this case, the 2-unit bidder will earn the difference between their value and the auction price, for each unit. The 1-unit bidder will earn zero. If the 2-unit bidder drops out first, the 1-unit bidder wins one unit, and the 2-unit bidder also wins 1 unit. In this case, each bidder will earn the difference between their value and the auction price for the unit they won. In addition, because the 2-unit bidder has the highest value, the 1-unit bidder will have the opportunity to resell the unit they won in the auction to the 2-unit bidder. Please press continue again to work with the resale interface.

Resale: If resale is possible because the 1-unit bidder won 1 unit, both bidders automatically enter the resale stage. What you should see in front of you is a sample of the screen you will see in resale. If you were a 1-unit bidder in the auction, you will always be the seller in the resale stage. If you were a 2-unit bidder in the auction, you will always be the buyer in the resale stage. These roles are now defined by the bolded sentence at the top left of the screen. If you are the buyer, you have the opportunity to purchase the 2nd unit from the seller and if you are the seller, you have the opportunity to sell the unit you won in the auction to the

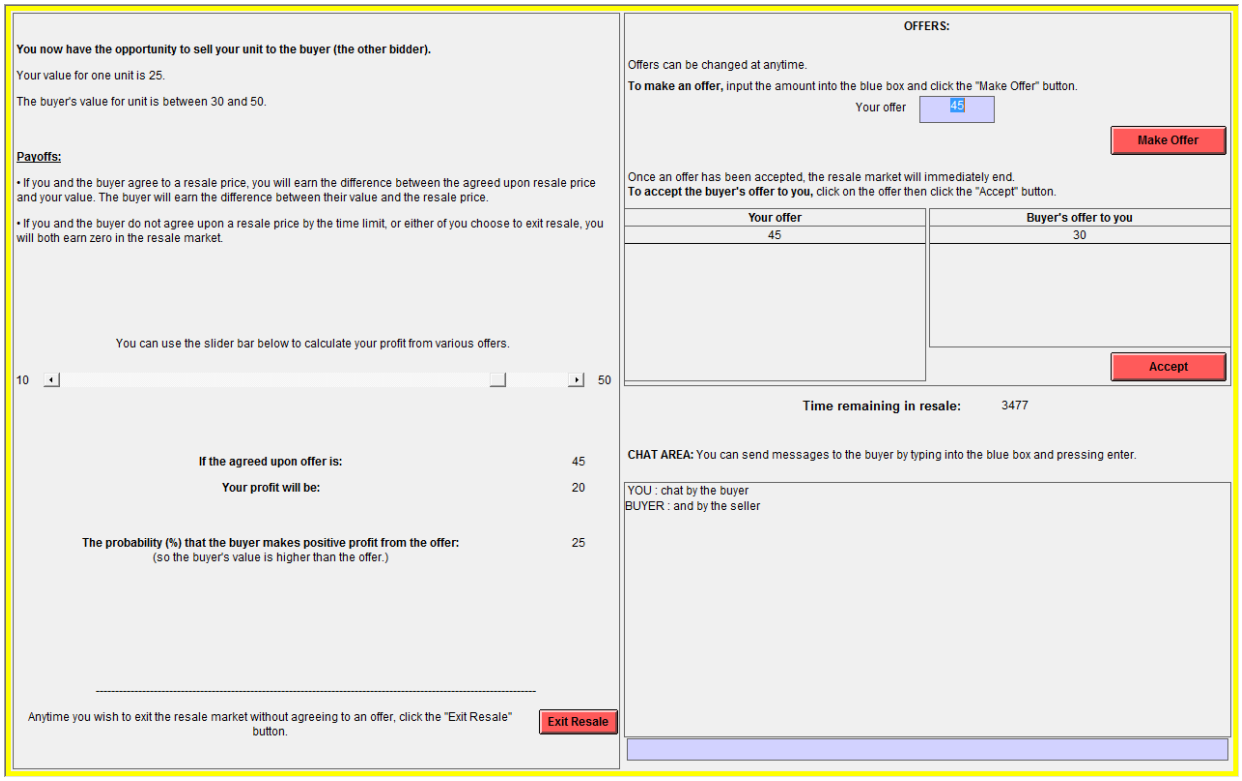

Figure A.2: Sample resale screen (weak seller).

buyer. Immediately below this, you will see a reminder of your value for the unit and the range of potential values for the other resale participant you are bargaining with. Your value and the other participant's value remain identical to the values you both had in the auction stage. Immediately below this, still on the left side of the screen is the resale payoff information. For resale to occur, both the buyer and seller must agree to a resale offer. If they agree to a resale offer, the seller will earn the difference between the resale price and their value. The buyer will earn the difference between their value and the resale price. If no resale offer is agreed to, both the buyer and seller earn 0 in this stage. Any earnings from the resale stage are in addition to the earnings from the auction.

Resale offers are made at the top right of the screen. To make an offer, type in the price you would like to offer into the blue box and click "Make Offer." Once you make this offer, it will immediately appear in the box below under the label, "Your Offer." Any offers made by the other resale participant to you will also appear in this box on the right hand side. Please input any offer amount into the blue box and press "Make Offer." You should see that your offer box has updated with the offer you input. You should also see the other participant's offer to you once they have made their offer. Please now input another offer and click "Make Offer" to see that your offer has changed. To accept the offer of the other participant, click on their offer, which will highlight in blue and then click "Accept." You can only accept offers made by the other participant. Currently, the Accept button is disabled because this is an example screen, but when either the buyer or seller agree to an offer by pressing this button, the resale stage will immediately terminate. Prior to agreement, offers can be changed at anytime.

You have two tools to facilitate your resale decisions. The first is chat, located at the bottom

right hand side of the screen. Messages can be sent to the other participant in this box. Please type a message now, for example, "hello" and press enter. You will see that your message has popped up and is identifiable by the label, "YOU." If your practice partner has also sent a message, that message should have popped-up in the box and is identifiable by their role of either BUYER or SELLER. Make sure that you hit enter after you have typed a message for it to be sent. We also ask that throughout the experiment you do not provide identifiable information about yourself to the other participant. In addition to chat, you will also have access to the scrollbar seen on the left side of the screen. You can use the scrollbar to determine your payoff for a given offer. The minimum possible resale offer is 10, and the maximum is 50. You can choose any resale price between these two values by sliding the scrollbar, or clicking on the right and left arrows, which will increase and decrease the resale price. Please move the scrollbar now. You should now see that information has appeared below the scrollbar, which will be automatically updated as you move the scrollbar. The resale offer is given directly below the scrollbar. Below the offer, you are given your resale profit for that given offer. Directly below your profit, you are given the probability that the other participant's resale profit will be positive for that particular offer. If you would like to exit resale, there is a button at the bottom left of the screen that you can click to choose to exit the resale stage at any time. You will have 180 seconds (3 minutes) to agree to an offer with the other participant. The time will be indicated in the middle of the right side of the screen, above chat. If an offer is not accepted either by you or the other participant before time expires, no resale will occur. Please press Exit Resale to continue.

Please follow along with example 1, as we go through a sample auction. Please note that this example is for explanatory purposes only and is not intended to suggest how you should make decisions. If you are a 1-unit bidder, your value is 25 and if you are the 2-unit bidder, your value is 35. In this example, the 1-unit bidder will drop out first at a price of 20, so the 2-unit bidder (who doesn't drop out) will win both units in the auction. We will now play this auction out. When you click continue, you will immediately be taken into the auction with the live bid clock. On the next screen, the 1-unit bidder should drop out when the auction price hits 20. The 2-unit bidder should not click the drop out button. Please click continue to enter the practice auction.

(Once in auction screen) You will now see the bid clock ticking up. The 1-unit bidder should press the drop out button once the bid clock has reached a price of 20. The 2-unit bidder should not click the drop out button.

(After 20 seconds and bidder has dropped out.) If you dropped out at a price other than 20, the computer assumed the drop out price was 20 for example purposes. You should now see that the auction has ended because the drop-out button disappeared. You will also be told of the auction price. Please click continue to be taken to the results summary.

You should now see the results screen for this practice auction. The 2-unit bidder won both units in the auction because the 1-unit bidder dropped out first. The 1-unit bidder did not win a unit. Since the 2-unit bidder won both units and has a higher value, there is no resale. Earnings for example 1: Notice that the auction price of the item is equal to the drop out price of 20 made by the 1-unit bidder. The 2-unit bidder won two units. For each unit, the 2-unit bidder's earnings are the difference between their value, 35, and the auction price, 20, so the 2-unit bidder earns 15 for each unit and the total payoff for both units won is 30. The 1-unit bidder earns zero because they did not win a unit. Please click continue as we will now go through an example where the 2-unit bidder drops out first.

Example 2: Recall, if you are a 1-unit bidder your value for this example is 25 and if you

are a 2-unit bidder your value is 35. In this example, the 2-unit bidder will drop out first at a price of 20, so the 1-unit bidder (who doesn't drop out) will win one unit in the auction and the 2-unit bidder will win the other unit. We will now play this auction out. When you click continue, you will be immediately taken into the auction with the live bid clock. On the next screen, the 2-unit bidder should drop out when the auction price hits 20. The 1-unit bidder should not click the drop out button. Please click continue to enter the next practice auction.

(Once in auction screen) Remember, the 2-unit bidder should try to drop out at a price of 20. The 1-unit bidder should not click the drop out button.

(After 20 seconds and bidder has dropped out) Again, if the 2-unit bidder dropped out at a price different from 20, the computer assumed a drop out of 20 for example purposes. The auction is now over, and since the 2-unit bidder dropped out first, the 2-unit bidder won one unit and the 1-unit bidder won one unit. Because the 2-unit bidder has the highest value, there will be a resale stage where the 1-unit bidder will have the opportunity to resell the item to the 2-unit bidder, but first you will be taken to an auction summary screen. Please click continue to be taken to the pre-resale auction results summary.

Both bidders won a unit in the auction and paid a price equal to the 2-unit bidder's drop out price of 20. The 1-unit bidder earned the difference between their value, 25 and the price 20, for auction profit equal to 5. The 2-unit bidder earned the difference between their value 35 and the price paid in the auction, 20, for auction profit equal to 15. This pre-resale results screen will also remind you of your role in resale. The 1-unit bidder is always the seller in the resale market, while the 2-unit bidder is always the buyer. Please click continue to be taken to resale stage.

Assume in the resale stage that both resale participants agree to a resale price of 32. To see how accepting an offer works, please input an offer of 32 and click "Make Offer." Once the other participant has input a price of 32, you will see that update as well. To agree to the offer made by the other participant, click on the offer given. You will know you have selected the offer once it highlights in blue. During the actual paid resale games, you do not have to both input the same offer for resale agreement; this is only for practice purposes. Please note that either role can accept and make offers, and it is only necessary for 1 offer to be made and accepted for resale to take place. After selecting the offer, click the "Accept" button. Once an accept decision is made, resale ends and you should be now taken to the results screen.

You should now see the results screen which summarizes your auction profit at the top and your resale profit at the bottom. The seller's resale profit is 7, which is the difference between the resale price, 32, and their value, 25. The buyer's resale profit is 3, which is the difference between their value, 35, and the resale price, 32. Total earnings are equal to auction profit plus resale profit.

Last informational points: Note that it is possible to lose money in the auction or in resale. The 2-unit bidder loses money if they purchase a unit at a price that is higher than their value. The 1-unit bidder loses money if they purchase a unit in the auction but the resale price is lower than the auction price. You will all begin this phase of the experiment with a balance of 150 ECUs. This balance will increase as you make profits and decrease when you make losses. Should you lose enough money that this balance becomes negative; you will be reset with your initial balance once, and continue participating. If you go bankrupt a second time, you will be removed from the experiment and paid your show-up fee only. Ties: If both bidders dropped out at the exact same time, the computer will randomly select a winner to break the tie. Random Groups: You will be randomly re-assigned to a new group each period. There will always be two people in your group, and the other bidder will be the opposite role. At some point, because of

the software, we may have a group finish before another. This does not imply any advantage in payments and we ask that you please wait patiently for the others to finish. Please press Continue.

We are now about to take a short quiz to ensure you understand the instructions. When you have finished the quiz, please press continue again to check your answers. If you have an incorrect answer for one of the questions, a pop-up will notify you which question was answered incorrectly. Please correct your incorrect answer and hit continue again until all questions have been answered correctly. Once everyone has completed this quiz, the experiment will continue.

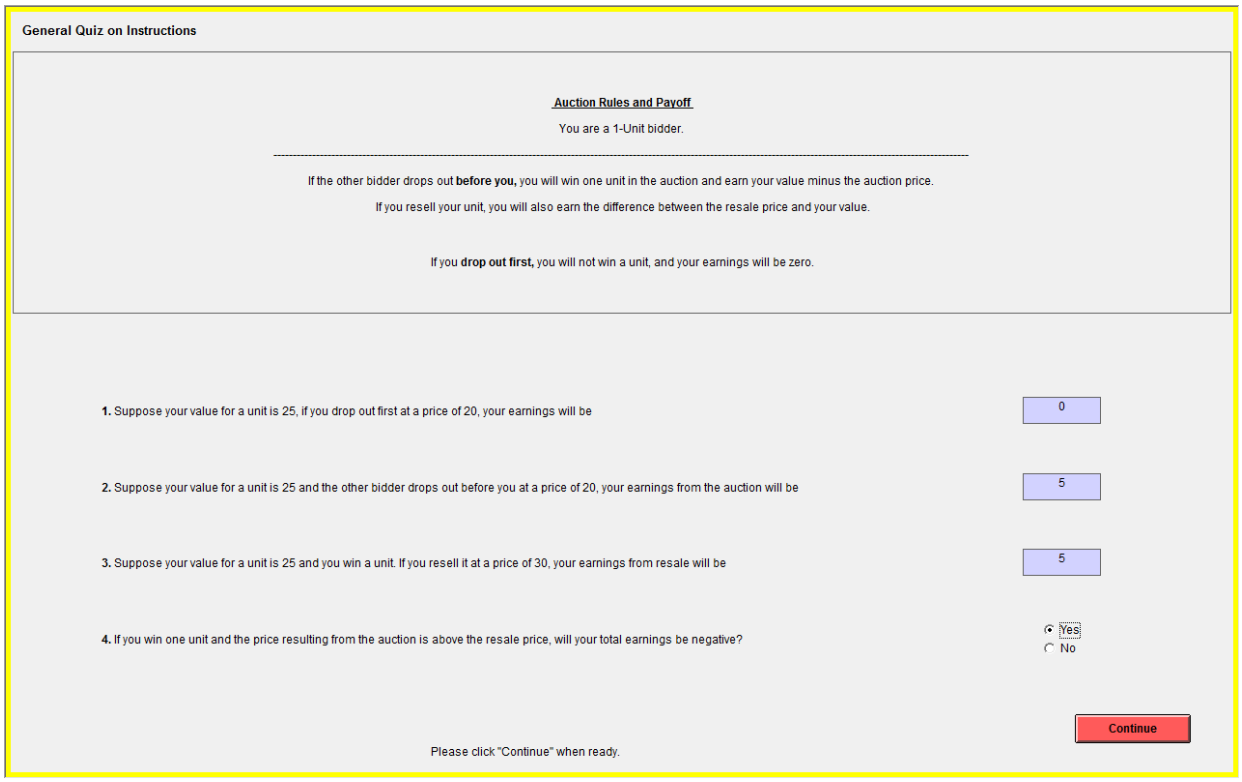

Figure A.3: Weak quiz.

(After Quiz) Are there any questions? We are about to begin the actual auctions that you will be paid for. Before each auction round, you will see this pause screen which will inform you of your value for the next round. You will now begin the paid rounds. You are participating at your own pace. Please follow the on-screen instructions. Please also make sure that when a continue button is available, you click it whenever you are ready so the experiment can continue.

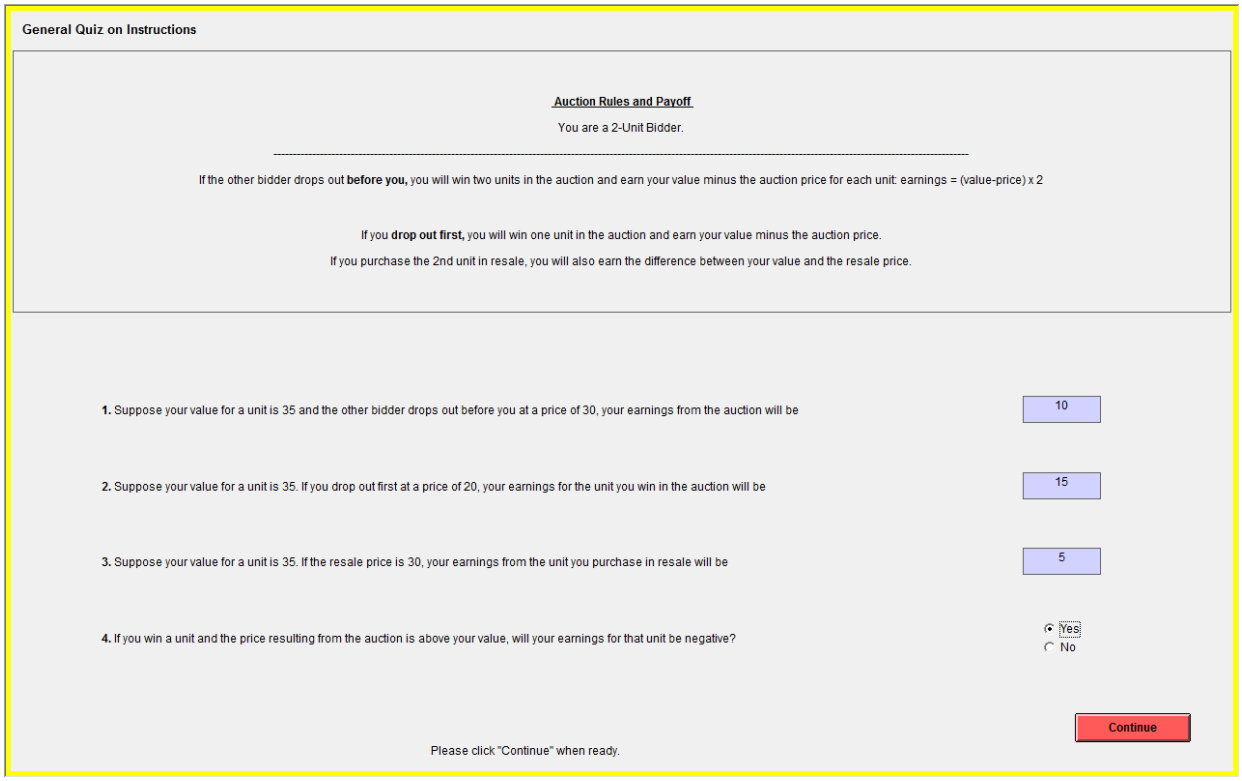

Figure A.4: Strong quiz.

A.2. Additional Screenshots

The following figures are sample screenshots for No Resale, Complete Information Resale, and Incomplete Information Resale.

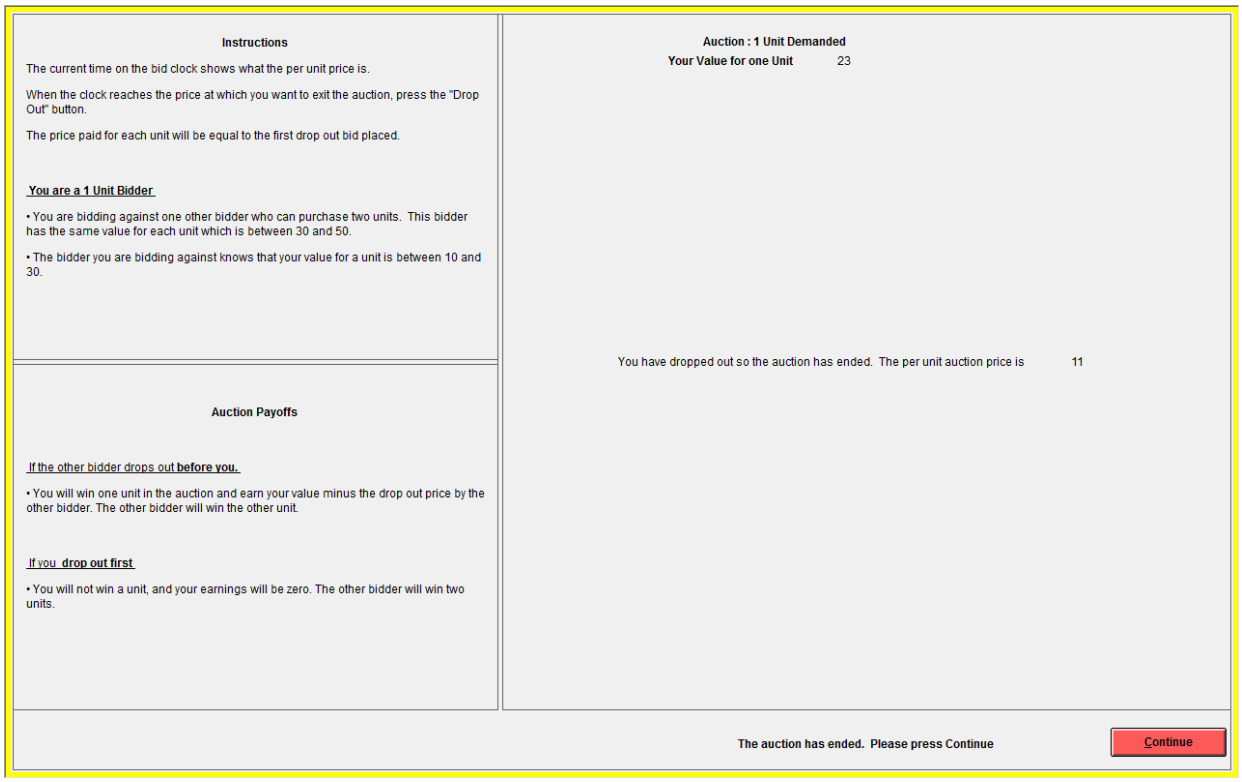

Figure A.5: Auction screenshot, no resale treatment — weak bidder.

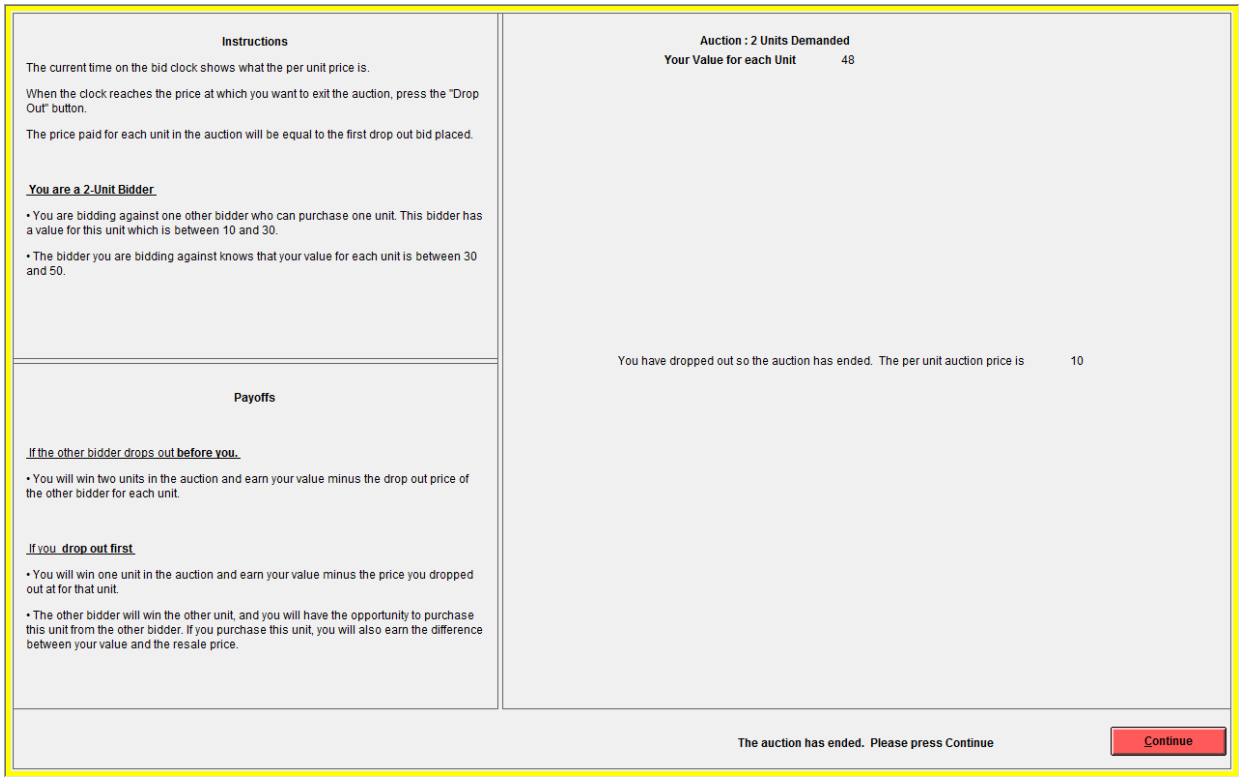

Figure A.6: Auction screenshot, comp resale and incomp resale — strong bidder.

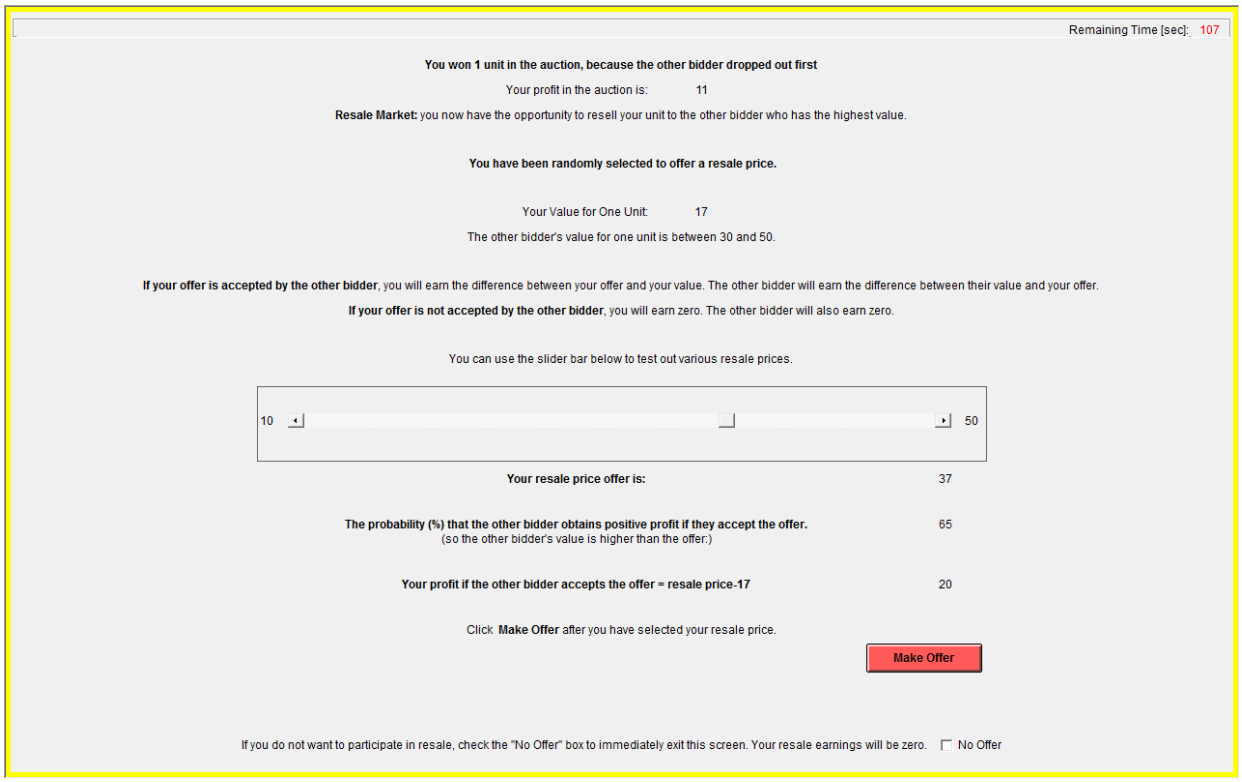

Figure A.7: Resale screenshot, incomp resale — weak proposer.

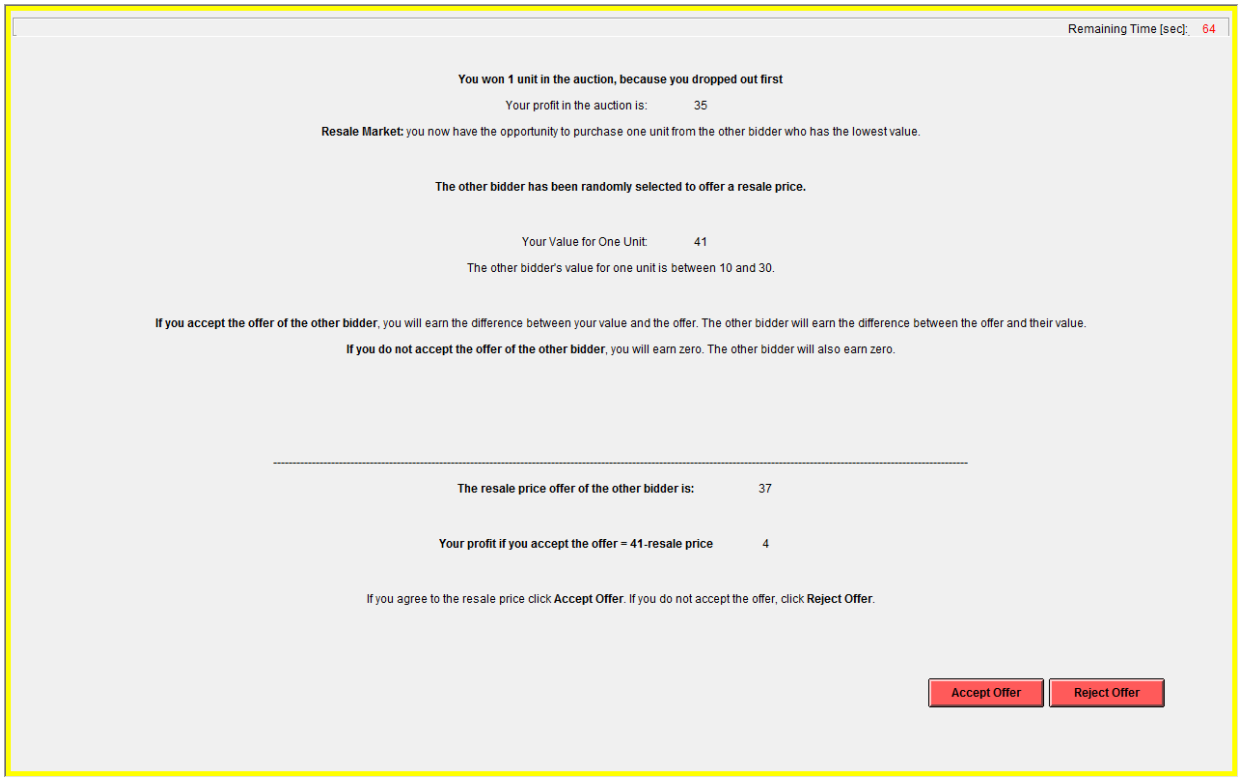

Figure A.8: Resale screenshot, incomp resale — strong responder.