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### ***Multi-Object Auctions with Resale: An Experimental Analysis***

**Marco Pagnozzi and Krista Jabs Saral**

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# ***Multi-Object Auctions with Resale: An Experimental Analysis***

**Marco Pagnozzi\* and Krista Jabs Saral\*\***

### **Abstract**

We analyze the effects of resale through bargaining 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 and the seller's revenue. Our experimental design consists of four treatments: one without resale and three resale treatments that vary both the bargaining mechanism and the amount of information available in the resale market. As predicted by theory: (i) without resale, asymmetry among bidders reduces demand reduction; (ii) resale increases demand reduction by high-value bidders; (iii) low-value bidders speculate by bidding more aggressively with resale. Therefore, resale induces speculation and demand reduction which reduce auction efficiency. 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 the seller's revenue.

**JEL Classification:** D44, C90.

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

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## 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<sub>2</sub> 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.<sup>1</sup>

In this paper, we theoretically and experimentally examine the impact of resale in multi-object auctions in order to address the following questions: How does the possibility of post-auction resale affect bidders' strategy, 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 the strategic choices of bidders in the auction (Garraat and Tröger, 2006; 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.<sup>2</sup> 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

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<sup>1</sup>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.

<sup>2</sup>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).

In order to both test and inform the theory of multi-object auctions with resale, we conducted a series of controlled laboratory experiments with four treatments: *No Resale*, *Complete Information Resale*, *Incomplete Information Resale*, and *Bargain*. The no resale treatment consisted of subjects only participating in an ascending auction. 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.<sup>3</sup> 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 during the resale stage.<sup>4</sup>

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 auction bidders. To the best of our knowledge, we are the first to consider an unstructured bargaining game to experimentally analyze post-auction resale markets.

Consistent with the theoretical predictions, we show that in the no resale treatment weak

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<sup>3</sup>This resale mechanism was analyzed by Calzolari and Pavan (2006).

<sup>4</sup>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).



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.<sup>5</sup> 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 complements previous experimental results that have shown 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.*, 2012):<sup>6</sup> 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.

In summary, as predicted by theory, our experimental analysis shows that asymmetry and resale affect bidders' strategy in an auction: (i) without resale strong bidders reduce demand much less often when they have high valuations; (ii) the possibility of resale increases demand reduction by strong bidders; (iii) weak bidders bid more aggressively when they have a chance to resell.

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 always increases efficiency by allowing bidders to trade, if they are willing to do so, in the presence of gains from trade. 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.

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<sup>5</sup>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.

<sup>6</sup>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.

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 resale, thereby increasing the auction price. On balance, the seller's revenue without resale is not significantly higher than in the incomplete information resale treatment, but it is significantly higher than in either the bargain or the complete information resale 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.<sup>7</sup>

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), Saral (2012) — that test how the presence of a resale market affects bidding behavior — and Harstad (2012) — that analyzes the effects of aftermarkets on efficiency. 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

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<sup>7</sup>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).

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 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.

## 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, where the reserve price is normalized to zero: 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 3<sup>rd</sup>-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.<sup>8</sup> 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  $v_S \sim U[\underline{v}_S; \overline{v}_S]$  for each unit on sale (i.e., he has flat demand);<sup>9</sup> bidder  $W$ , the *weak* bidder, demands 1 unit only and has valuation  $v_W \sim U[\underline{v}_W; \overline{v}_W]$  for that unit. Bidders are privately informed about their valuations, which are independent. We assume that  $\underline{v}_S \geq \overline{v}_W$ , so that bidder  $S$  always has a higher valuation than bidder  $W$ , and 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.

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

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<sup>8</sup>Of course, the uniform-price auction is not an optimal mechanism in our context, neither with resale nor without resale.

<sup>9</sup>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.

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,<sup>10</sup> we assume that resale takes place through bargaining 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).

When they bid in the auction, both bidders expect to obtain some share of the 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). In order to capture different bargaining mechanisms, we assume that bargaining in the resale market results in  $S$  obtaining a share  $\alpha$  of the gains from trade and  $W$  obtaining a share  $1 - \alpha$  of the gains from trade. This can be interpreted as bidders trading at a resale price

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

Our 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 16).

In our experiments, we consider different 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). 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  $\alpha = \frac{1}{2}$ .

*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

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<sup>10</sup>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.

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.,  $v_W$ .<sup>11</sup> 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.<sup>12</sup> 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 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 —

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<sup>11</sup>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.

<sup>12</sup>Of course, reducing demand but bidding a strictly positive price is never an optimal strategy.

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.<sup>13</sup> 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.

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

$$2(v_S - \alpha \mathbb{E}[v_W] - (1 - \alpha) \mathbb{E}[v_S]). \quad (2.1)$$

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<sup>14</sup>

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

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

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

Since this inequality is always satisfied, bidder  $S$  always prefers to reduce demand when resale

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<sup>13</sup>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.

<sup>14</sup>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.

is allowed.<sup>15</sup> Notice that this result holds for every  $\alpha$  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 15 — but this never happens when bidder  $S$ 's valuation is uniformly distributed).

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.)<sup>16</sup>

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  $v_S < 2\mathbb{E}[v_W]$ .*

**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 (after resale) is always efficient with resale, but not necessarily without resale.*

**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 auction bidders trade in the resale market, and how their strategies are affected by different resale mechanisms.

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<sup>15</sup>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  $2\mathbb{E}[v_S] > v_S$ .

<sup>16</sup>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.

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.<sup>17</sup> 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 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 about the number of units he 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 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

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<sup>17</sup>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.



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.<sup>18</sup>

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.

We conducted 3 sessions for each treatment yielding a total of 12 sessions. 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. We had 16 participants in each session, which were randomly assigned to the roles of weak and strong bidder (8 subjects per role). 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.

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<sup>18</sup>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.

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.

### 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.<sup>19</sup> 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  $\pm 2$  of value. For a more accurate test of value bidding, Table 4.1 presents panel random effects bid regression results on observed bids for the no resale treatment.<sup>20</sup> Supporting the theoretical prediction of value bidding, in the regression model the estimated coefficient on the value of the

<sup>19</sup>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.

<sup>20</sup>The regression contains 440 observations, with standard errors clustered at the individual level.

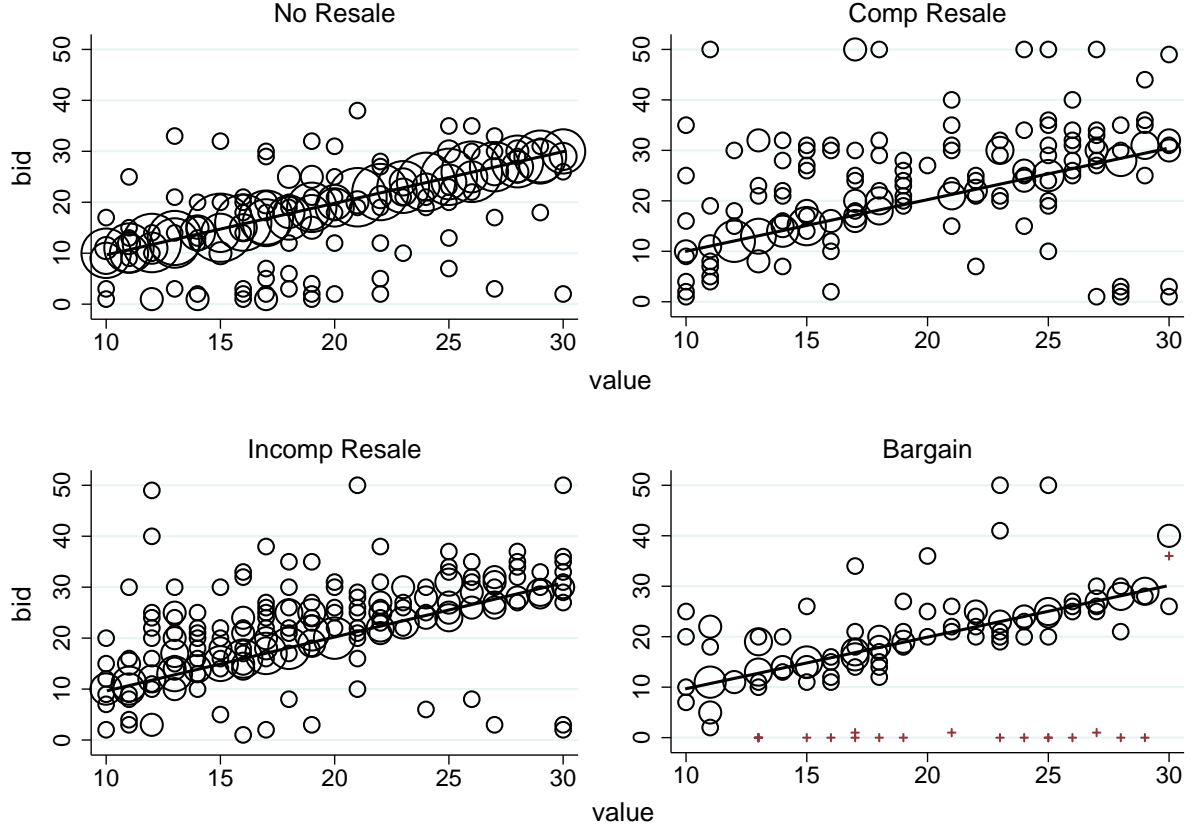


Figure 4.1: **Weak Bidding** – weighted scatterplot of observed bids (dropouts) by weak bidders versus valuations in the four treatments.

weak bidder, 0.982, is not significantly different from 1 ( $p = 0.689$ ), while the constant is not significantly different from 0.

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. A Wilcoxon-Mann-Whitney (WMW) test confirms this difference in observed bids between the no resale and complete information resale treatments ( $p < 0.001$ ), 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.<sup>21</sup>

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 significant differences in observed bids between the no resale treatment and the incomplete information resale treatment ( $p < 0.001$ ) and fail to find a significant difference between the incomplete and complete information resale treatments ( $p = 0.240$ ).

The final resale treatment, bargain (lower right graph of Figure 4.1), resulted in the majority of observed bids at value or above.<sup>22</sup> But there appears to be fewer aggressive bids in this treatment than in the other resale treatments. This is confirmed by a WMW test that shows no significant difference between bargain and no resale ( $p = 0.221$ ), and significant differences between bargain and either incomplete information resale or complete information resale ( $p \leq 0.001$ ).<sup>23</sup>

These are only partial results, however, as they only 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

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<sup>21</sup>For experimental analysis on the role of expectations in bidders’ deviations from equilibrium strategies see Reiss and Kirchkamp (2012) and Armantier and Treich (2009).

<sup>22</sup>We include the plus marker in the bargain treatment scatterplot to indicate the dropout bids placed by a single 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.

<sup>23</sup>As the bargain treatment was run with fewer periods than the other three treatments (20 vs. 30 periods per session), in all comparisons with the bargain treatment we have run identical tests for the full sample (which is reported) and a restricted sample of 20 periods per session (unreported). In all cases, our reported results are unchanged, except for one test of total earnings for the weak bidder in Section 4.4 where we report both unrestricted and restricted results.

treatment contains even less observations because the treatment was run for fewer periods. 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 without resale they should only let weak bidders win if their unit value is less than  $2\mathbb{E}[v_W] = 40$ . Table 4.2 provides the relative frequency of weak bidders winning a unit, overall and broken down by the strong competitor's value. Resale did result in the weak bidder winning a unit with higher frequency than without resale, with the highest frequency obtained in the complete information resale and bargain treatments. Even with resale, especially in the incomplete information resale treatment, the weak bidder won a unit more often when the strong bidder had a value lower than 40.

	No Resale	Comp Resale	Incomp Resale	Bargain
% auctions won by Weak	38.89%	75.00%	63.19%	73.13%
% auctions won when $v_S < 40$	51.98%	76.84%	72.03%	74.09%
% auctions won when $v_S > 40$	25.15%	72.42%	53.03%	70.59%

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

Formalizing the above results, table 4.3 presents random effects tobit regression results on bids for weak types. The use of a 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 tobit model estimates.<sup>24</sup> 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.<sup>25</sup>

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. 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 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.*

<sup>24</sup>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  $k^{th}$  independent variable.

<sup>25</sup>All regressions include 1023 uncensored observations and 1617 right-censored observations (at the auction price). The numbers reported in parentheses are standard errors. Three (\*\*\*) , two (\*\*), and one (\*) stars indicate statistical significance at the 1%, 5%, and 10% level, respectively.

	(1)		(2)	
Weak Bid	Coefficient	Marginal Effect	Coefficient	Marginal Effect
Constant	0.870 (1.444)		1.064 (1.484)	
$v_w$	0.993*** (0.053)	0.659	0.993*** (0.053)	0.659
Comp Resale (Comp)	13.248*** (2.285)	8.793	13.245*** (2.282)	8.788
Incomp Resale (Incomp)	6.951*** (2.162)	4.613	6.939*** (2.160)	4.604
Bargain	6.747*** (2.545)	4.478	6.665*** (2.547)	4.422
Period			-0.013 (0.023)	-0.008
$v_w \times \text{Comp}$	-0.316*** (0.092)	-0.209	-0.318*** (0.092)	-0.211
$v_w \times \text{Incomp}$	-0.117 (0.084)	-0.077	-0.117 (0.084)	-0.077
$v_w \times \text{Bargain}$	-0.236** (0.108)	-0.157	-0.236** (0.108)	-0.157

Table 4.3: Random effects panel tobit - Weak bidding.

Model 2 is included to test for any learning effects and as a robustness check. We find no significant learning effect for weak bidders.<sup>26</sup>

## 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).

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. Despite these similarities, pairwise WMW tests find significant differences between all three resale treatments ( $p < 0.001$ ).

<sup>26</sup>We also find no significant learning effects in alternative model specifications that include interactions of period with treatments.

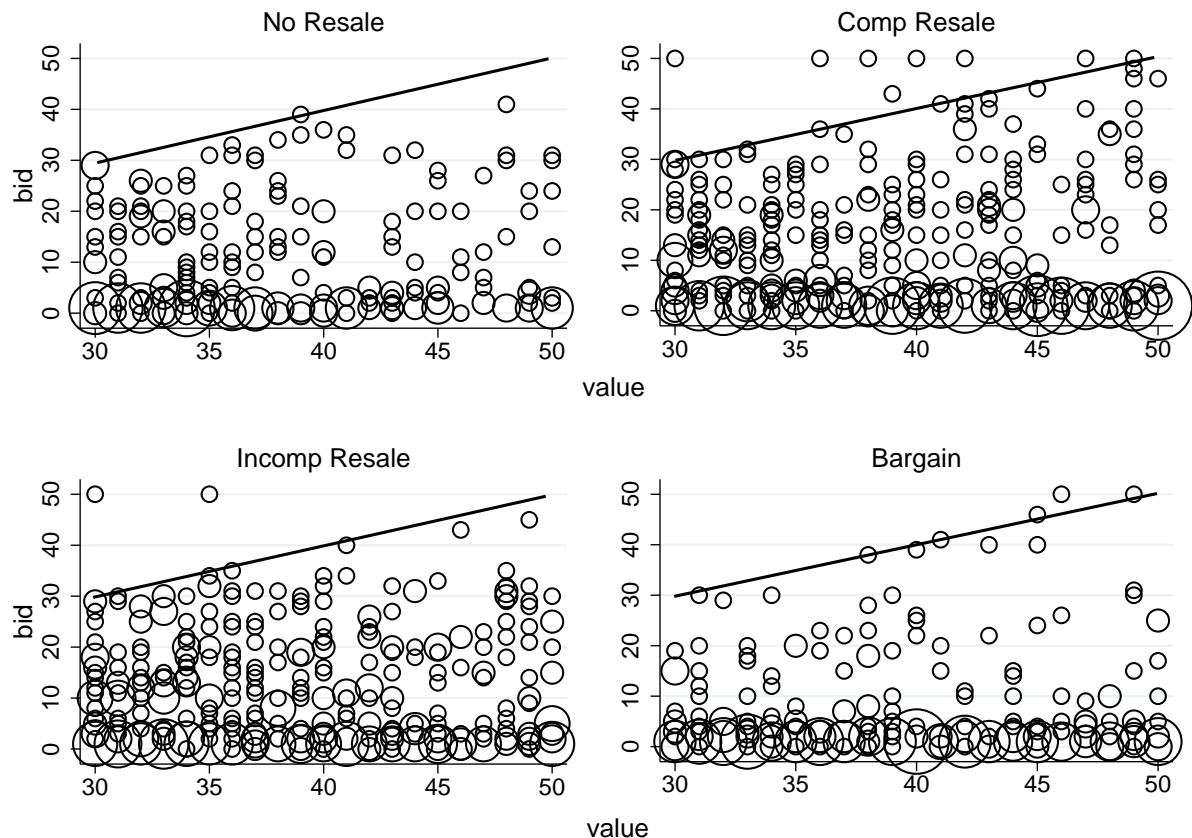


Figure 4.2: **Strong Bidding** – weighted scatterplot of observed bids (dropouts) by strong bidders versus valuations in the four treatments.

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 ( $p < 0.001$ ).

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

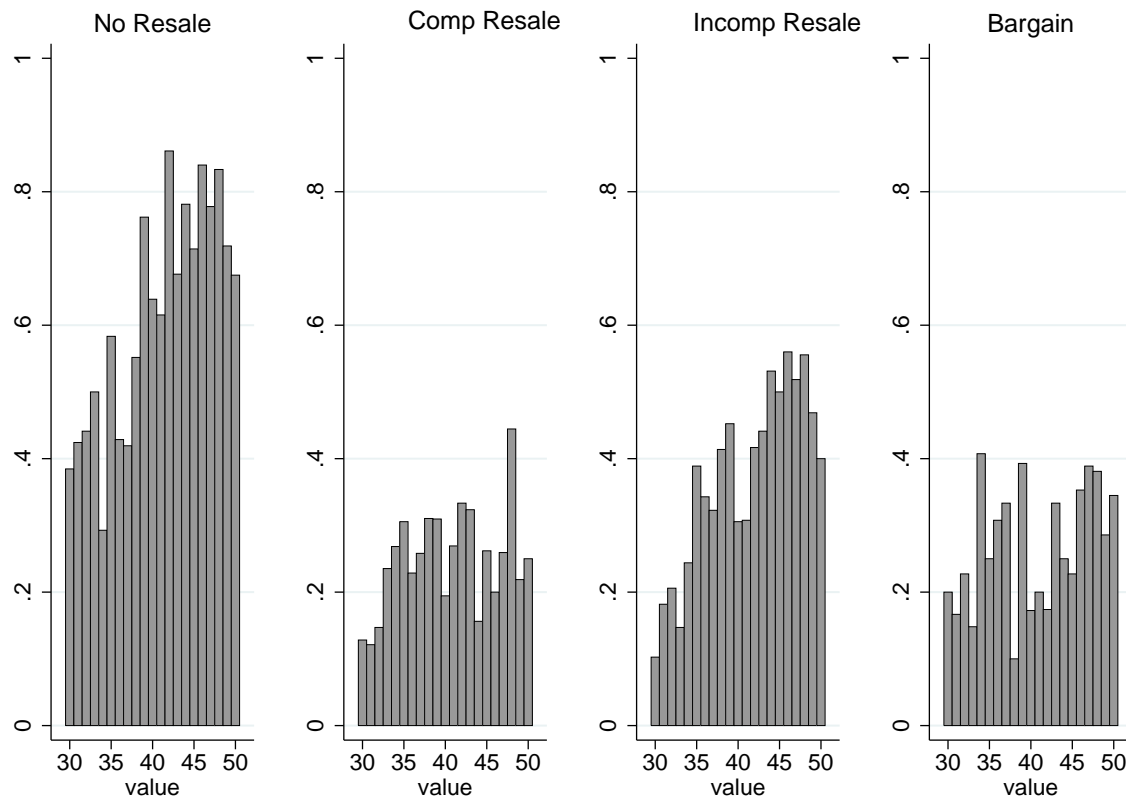


Figure 4.3: Relative frequency of strong bidders winning both units, by strong bidders' value, in the four treatments.

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 any bid below 10, the lowest possible value of the weak bidder, can also be interpreted as strong demand reduction, since weak bidders should never drop out at a price lower than their value. Table 4.4 summarizes low-bidding behavior by strong bidders which is consistent with theory (conservatively defined as bids lower than 3). In the no resale treatment, 30% of all bids were near-zero dropouts when the strong bidder had a value less than 40. This percentage decreased substantially when the strong bidder had a value greater than 40. There is no comparable decrease in the resale treatments, but resale did result in the largest amount of near-zero bids, for both high and low values, particularly in the bargain treatment.

To examine strong bidders' behavior in more depth, we analyze random effects tobit models in Table 4.5.<sup>27</sup> Model 1 is our primary model of treatment and value location effects. Models

<sup>27</sup>All regressions include 1646 uncensored observations and 994 right-censored observations (at the auction price).



Percentage of Bids $\leq 2$	No Resale	Comp Resale	Incomp Resale	Bargain
$v_S < 40$	30%	37%	29%	48%
$v_S > 40$	12%	40%	21%	41%

Table 4.4: Relative frequency of near-zero bids by strong bidders.

2 and 3 explore learning effects. 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.

Strong Bid	(1)		(2)		(3)	
	Coefficient	Marginal Effect	Coefficient	Marginal Effect	Coefficient	Marginal Effect
Constant	0.078 (3.705)		7.745** (3.634)		5.016 (3.706)	
$v_S$	0.560*** (0.086)	0.254	0.516*** (0.082)	0.235	0.524*** (0.082)	0.239
Comp Resale (Comp)	-5.894** (3.031)	-2.681	-5.832** (3.007)	-2.664	-1.768 (3.240)	-0.806
Incomp Resale (Incomp)	-2.635 (3.034)	-1.198	-2.673 (3.010)	-1.221	-1.318 (3.248)	-0.601
Bargain	-8.615*** (3.065)	-3.918	-10.454*** (3.045)	-4.775	-5.047 (3.334)	-2.302
$v_S > 40$	4.721*** (1.497)	2.147	7.287*** (1.785)	3.328	6.576*** (1.774)	3.000
Period			-0.420*** (0.041)	-0.192	-0.264*** (0.066)	-0.120
Comp $\times v_S > 40$	-8.621*** (1.505)	-3.921	-8.684*** (1.433)	-3.966	-8.044*** (1.435)	-3.669
Incomp $\times v_S > 40$	-6.410*** (1.538)	-2.915	-6.546*** (1.464)	-2.990	-6.254*** (1.465)	-2.853
Bargain $\times v_S > 40$	-9.257*** (1.682)	-4.211	-10.445*** (1.646)	-4.771	-9.873*** (1.639)	-4.504
Comp $\times$ Period					-0.263*** (0.081)	-0.119
Incomp $\times$ Period					-0.084 (0.082)	-0.038
Bargain $\times$ Period					-0.434*** (0.114)	-0.198
$v_S > 40 \times$ Period			-0.078 (0.063)	-0.035	-0.067 (0.062)	-0.030

Table 4.5: Random effects panel tobit - Strong bidding.

In the no resale treatment, the positive significant coefficient on  $v_S > 40$  in Model 1 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 significantly more demand reduction than no resale for values greater than 40. 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.

**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.*

Model 2 tests for learning effects. As opposed to the results for 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 3 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.

### 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 find significant differences in auction efficiency between all treatments, except complete information resale and bargain ( $p = 0.519$ ). 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 Result 3.<sup>28</sup> 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 (WMW,  $p = 0.103$ ).

	No Resale	Comp Resale	Incomp Resale	Bargain
Auction Efficiency	0.82 (0.241)	0.64 (0.256)	0.71 (0.258)	0.65 (0.261)
Final Efficiency	0.82 (0.241)	0.93 (0.170)	0.85 (0.217)	0.95 (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 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 there is no significant difference between that revenue and the revenue in the incomplete information

<sup>28</sup>We find no significant differences in final efficiency between the complete information resale and bargain treatments (WMW,  $p = 0.970$ ).

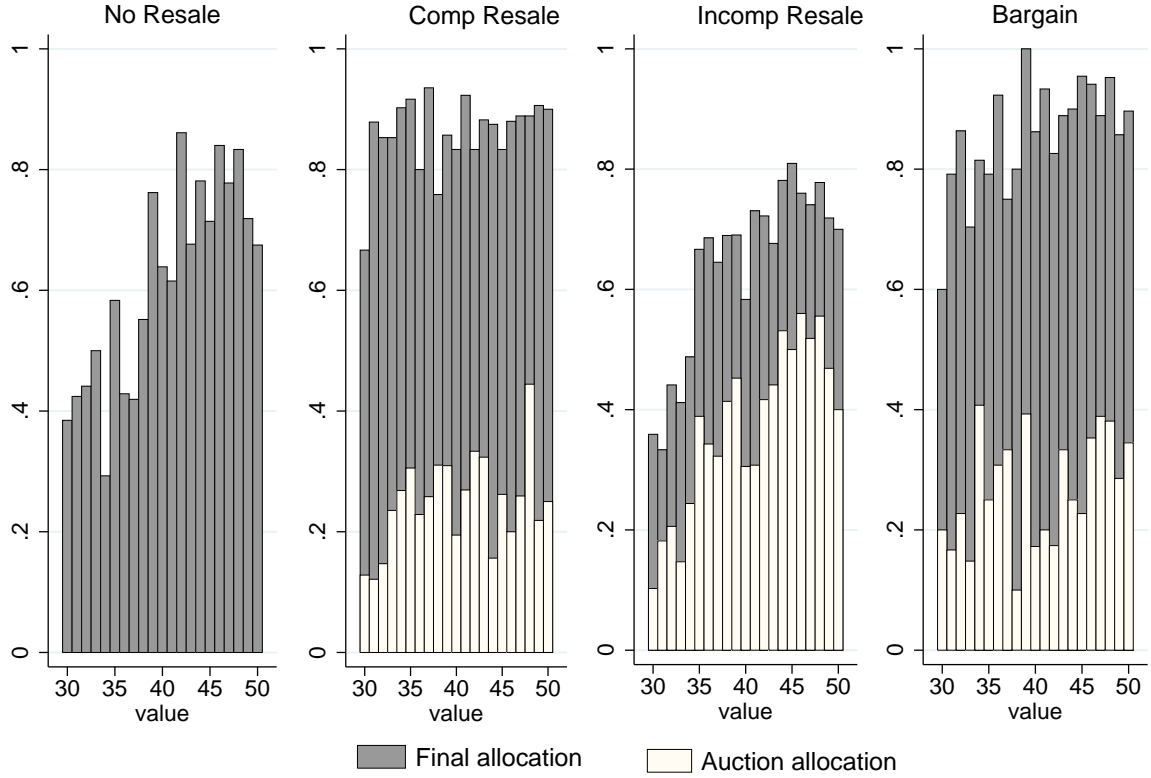


Figure 4.4: Relative frequency of final allocation and auction allocation of 2 units to strong bidder, by strong bidders' value.

resale treatment (WMW,  $p = 0.319$ ). 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. By contrast, consistent with Result 4, we do find significant differences between revenue in the no resale treatment and revenues in the complete information resale treatment ( $p < 0.001$ ) and the bargain treatment ( $p < 0.001$ ).

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

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' ones), 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

	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 deviations in parentheses).

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.<sup>29</sup> Resale was more frequent and successful in the complete information resale and bargain treatments than in the incomplete information resale treatment; there is no significant difference between the first two treatments in the frequencies of possible resale ( $\chi^2$ ,  $p = 0.467$ ) or success in resale ( $p = 0.550$ ). Incomplete information resale resulted in both a significantly lower frequency of possible resale ( $p < 0.001$ ) and a significantly higher rate of failed resale ( $p < 0.001$ ), arguably because of the mix of incomplete information and a take-it-or-leave-it offer mechanism.

	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. Models

<sup>29</sup>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.

1 and 2 examine the complete and incomplete information resale treatments, respectively. The variable Offer represents the observed 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.

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

Table 4.9: Marginal effects from Probit regressions on resale of unit (final resale agreement), conditional on weak winning. Standard errors clustered at the session level.

The results indicate that, as expected, an increase in the offer made by a strong proposer significantly increased the probability of final agreement by 2% in the complete information resale treatment and by almost 4% in the incomplete information resale treatment. Similarly, the interaction of offer with weak proposer shows that a reduction in the offer made by a weak proposer increased the probability of acceptance by a strong responder. 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 shown 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.

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 one. To determine the role of offers under bargaining, we difference the first two offers made by both strong and weak bidders. 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 implied 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 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 significantly higher in complete information resale than either bargain (WMW,  $p < 0.001$ ) or incomplete information resale ( $p < 0.001$ ). For bargain and incomplete information resale, the difference is not significant ( $p = 0.437$ ). There are also significant differences in earnings between strong and weak bidders in all treatments, but the relationship is statistically weaker for the complete information resale treatment ( $p = 0.065$ ) than the incomplete information resale and bargain treatments ( $p < 0.001$ ). Hence, 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.<sup>30</sup> Differences in earnings were mainly driven by strong bidders making more aggressive offers in the resale market, especially with incomplete information. Comparing the offers for the take-it-or-leave-it treatments, strong proposers made significantly lower offers under incomplete information ( $p < 0.001$ ), while we find no significant difference between offers made by the weak proposers (WMW,  $p = 0.345$ ).

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, on

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<sup>30</sup>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.

	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).

average, auction prices are lower than resale prices. 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. Signed rank sum tests by treatment confirm significant differences between the auction and resale prices for all resale treatments ( $p < 0.001$ ).

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 auction round — by types and treatments. Pairwise WMW tests, using a restricted sample of 20 periods, find significant earnings differences for both weak ( $p < 0.001$ ) and strong bidders ( $p \leq 0.003$ ) across all treatments.<sup>31</sup> Weak bidders obtain higher profits when resale is allowed, because of the option value of selling the units acquired after the auction. By contrast, strong bidders obtain higher profits when resale is allowed only when the resale market is sufficiently 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 (8.838)	14.47 (14.279)	9.18 (11.709)	15.83 (12.620)
Strong’s Profit	38.64 (16.911)	38.82 (17.979)	36.76 (18.028)	44.62 (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.

<sup>31</sup>Using the unrestricted sample (bargain with 20 periods versus 30 periods in other treatments), there is no significant difference for weak bidders between the complete information resale and bargain treatments ( $p = 0.225$ ). This is the only case where statistical results change with different samples.



## 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. The possibility of resale, however, also affects bidders' strategies in the auction and the seller's revenue. We use 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,<sup>32</sup> 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 more 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.

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.<sup>33</sup> 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, while bargaining or complete information resale lead to lower revenue.

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

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<sup>32</sup>Of course, 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.

<sup>33</sup>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.

participation in the auction. 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.

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 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.

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## 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

Instructions	Auction : 1 Unit Demanded
<p>The current time on the bid clock shows what the per unit price is.</p> <p>When the clock reaches the price at which you want to exit the auction, press the "Drop Out" button.</p> <p>The price paid for each unit in the auction will be equal to the first drop out bid placed.</p>	<p>Your Value for one Unit      25</p> <p>Bid Clock:      1.00</p> <div style="border: 2px solid red; padding: 5px; display: inline-block; color: red; font-weight: bold;">Drop Out</div>
<p><u>You are a 1-Unit Bidder</u></p> <ul style="list-style-type: none"> <li>You are bidding against one other bidder who can purchase two units. This bidder has the same value for each unit which is between 30 and 50.</li> <li>The bidder you are bidding against knows that your value for a unit is between 10 and 30.</li> </ul>	
<p><b>Payoffs</b></p>	
<p><u>If the other bidder drops out before you.</u></p> <ul style="list-style-type: none"> <li>You will win one unit in the auction and the other bidder will win the other unit.</li> <li>You will earn the difference between your value and the price you paid in the auction.</li> </ul> <p>• After the auction, you will have the opportunity to resell your unit to the other bidder and if you resell, you will also earn the difference between the resale price and your value.</p>	<p>To exit the auction when the clock hits your drop out price, click the red "Drop Out" button</p>
<p><u>If you drop out first</u></p> <ul style="list-style-type: none"> <li>You will not win a unit, and your earnings will be zero. The other bidder will win two units.</li> </ul>	

The auction has ended. Please press Continue

Continue

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

**You now have the opportunity to sell your unit to the buyer (the other bidder).**

Your value for one unit is 25.

The buyer's value for unit is between 30 and 50.

**Payoffs:**

- If you and the buyer agree to a resale price, you will earn the difference between the agreed upon resale price and your value. The buyer will earn the difference between their value and the resale price.
- If you and the buyer do not agree upon a resale price by the time limit, or either of you choose to exit resale, you will both earn zero in the resale market.

You can use the slider bar below to calculate your profit from various offers.

10

50

**If the agreed upon offer is:**

**Your profit will be:**

**The probability (%) that the buyer makes positive profit from the offer:**  
(so the buyer's value is higher than the offer.)

45

20

25

Anytime you wish to exit the resale market without agreeing to an offer, click the "Exit Resale" button.

Exit Resale

**OFFERS:**

Offers can be changed at anytime.

To make an offer, input the amount into the blue box and click the "Make Offer" button.

Your offer 

45

Make Offer

Once an offer has been accepted, the resale market will immediately end.

To accept the buyer's offer to you, click on the offer then click the "Accept" button.

Your offer	Buyer's offer to you
45	30

Accept

**Time remaining in resale:** 3477

**CHAT AREA:** You can send messages to the buyer by typing into the blue box and pressing enter.

YOU : chat by the buyer

BUYER : and by the seller

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

if you are the seller, you have the opportunity to sell the unit you won in the auction to the 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.

**General Quiz on Instructions**

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**Auction Rules and Payoff**  
You are a 1-Unit bidder.

---

If the other bidder drops out **before you**, you will win one unit in the auction and earn your value minus the auction price.  
If you resell your unit, you will also earn the difference between the resale price and your value.

If you **drop out first**, you will not win a unit, and your earnings will be zero.

---

1. Suppose your value for a unit is 25, if you drop out first at a price of 20, your earnings will be 0

2. Suppose your value for a unit is 25 and the other bidder drops out before you at a price of 20, your earnings from the auction will be 5

3. Suppose your value for a unit is 25 and you win a unit. If you resell it at a price of 30, your earnings from resale will be 5

4. If you win one unit and the price resulting from the auction is above the resale price, will your total earnings be negative? ☒ Yes  
☐ No

Continue

Please click "Continue" when ready.

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.

General Quiz on Instructions

Auction Rules and Payoff

You are a 2-Unit Bidder.

---

If the other bidder drops out **before you**, you will win two units in the auction and earn your value minus the auction price for each unit:  $\text{earnings} = (\text{value} - \text{price}) \times 2$

If you **drop out first**, you will win one unit in the auction and earn your value minus the auction price.

If you purchase the 2nd unit in resale, you will also earn the difference between your value and the resale price.

1. Suppose your value for a unit is 35 and the other bidder drops out before you at a price of 30, your earnings from the auction will be

10

2. Suppose your value for a unit is 35. If you drop out first at a price of 20, your earnings for the unit you win in the auction will be

15

3. Suppose your value for a unit is 35. If the resale price is 30, your earnings from the unit you purchase in resale will be

5

4. If you win a unit and the price resulting from the auction is above your value, will your earnings for that unit be negative?

☒ Yes ☐ No

Please click "Continue" when ready.

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.

<p><b>Instructions</b></p> <p>The current time on the bid clock shows what the per unit price is.</p> <p>When the clock reaches the price at which you want to exit the auction, press the "Drop Out" button.</p> <p>The price paid for each unit will be equal to the first drop out bid placed.</p> <p><u>You are a 1 Unit Bidder.</u></p> <ul style="list-style-type: none"> <li>• You are bidding against one other bidder who can purchase two units. This bidder has the same value for each unit which is between 30 and 50.</li> <li>• The bidder you are bidding against knows that your value for a unit is between 10 and 30.</li> </ul>	<p><b>Auction : 1 Unit Demanded</b></p> <p>Your Value for one Unit      23</p>
<p><b>Auction Payoffs</b></p> <p><u>If the other bidder drops out before you.</u></p> <ul style="list-style-type: none"> <li>• You will win one unit in the auction and earn your value minus the drop out price by the other bidder. The other bidder will win the other unit.</li> </ul> <p><u>If you drop out first</u></p> <ul style="list-style-type: none"> <li>• You will not win a unit, and your earnings will be zero. The other bidder will win two units.</li> </ul>	<p>You have dropped out so the auction has ended. The per unit auction price is      11</p>
<p>The auction has ended. Please press Continue</p> <p style="text-align: right;"><b>Continue</b></p>	

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

Instructions	Auction : 2 Units Demanded
<p>The current time on the bid clock shows what the per unit price is.</p> <p>When the clock reaches the price at which you want to exit the auction, press the "Drop Out" button.</p> <p>The price paid for each unit in the auction will be equal to the first drop out bid placed.</p>	<p>Your Value for each Unit      48</p>
<p><u>You are a 2-Unit Bidder</u></p> <ul style="list-style-type: none"> <li>You are bidding against one other bidder who can purchase one unit. This bidder has a value for this unit which is between 10 and 30.</li> <li>The bidder you are bidding against knows that your value for each unit is between 30 and 50.</li> </ul>	
<p style="text-align: center;"><b>Payoffs</b></p>	
<p><u>If the other bidder drops out before you.</u></p> <ul style="list-style-type: none"> <li>You will win two units in the auction and earn your value minus the drop out price of the other bidder for each unit.</li> </ul>	
<p><u>If you drop out first</u></p> <ul style="list-style-type: none"> <li>You will win one unit in the auction and earn your value minus the price you dropped out at for that unit.</li> <li>The other bidder will win the other unit, and you will have the opportunity to purchase this unit from the other bidder. If you purchase this unit, you will also earn the difference between your value and the resale price.</li> </ul>	
	<p>You have dropped out so the auction has ended. The per unit auction price is      10</p>
<p>The auction has ended. Please press Continue</p> <div style="display: flex; justify-content: flex-end; margin-top: 10px;"> <div style="border: 2px solid red; padding: 5px 15px; background-color: #f0f0f0; cursor: pointer;">Continue</div> </div>	

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

Remaining Time [sec]: 107

You won 1 unit in the auction, because the other bidder dropped out first

Your profit in the auction is: 11

**Resale Market:** you now have the opportunity to resell your unit to the other bidder who has the highest value.

You have been randomly selected to offer a resale price.

Your Value for One Unit: 17

The other bidder's value for one unit is between 30 and 50.

If your offer is accepted by the other bidder, you will earn the difference between your offer and your value. The other bidder will earn the difference between their value and your offer.

If your offer is not accepted by the other bidder, you will earn zero. The other bidder will also earn zero.

You can use the slider bar below to test out various resale prices.

10

50

Your resale price offer is:	37
The probability (%) that the other bidder obtains positive profit if they accept the offer. (so the other bidder's value is higher than the offer.)	65
Your profit if the other bidder accepts the offer = resale price - 17	20

Click **Make Offer** after you have selected your resale price.

Make Offer

If you do not want to participate in resale, check the "No Offer" box to immediately exit this screen. Your resale earnings will be zero. ☐ No Offer

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

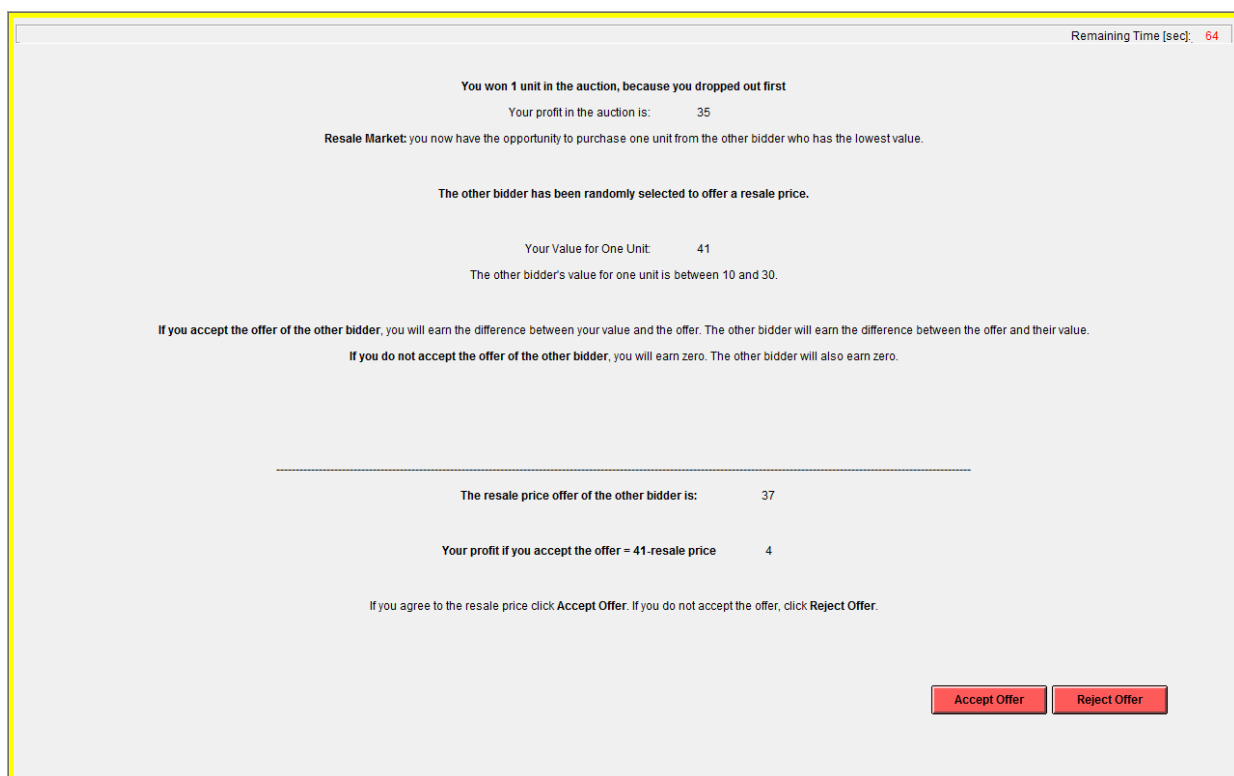


Figure A.8: Resale screenshot, incomp resale — strong responder.