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Asymmetric Auctions with Resale: An Experimental Study*

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Abstract

We present results from an experiment based on Hafalir and Krishna's (2008) model of auctions with resale. As predicted weak bidders bid more with resale than without, so that resale raises average auction prices. When the equilibrium calls for weak types to bid higher than their values with resale they do, but not nearly as much as the theory predicts. When the equilibrium calls for weak bidders to bid at or below their value with resale, outcomes are much closer to the risk neutral Nash model's predictions.

Keywords: Auctions, resale, experiment.

JEL classification: D44, C90

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1 Introduction

Auctions with resale have been the subject of considerable theoretical interest lately. Haile (2000, 2001, 2003) studies auctions where bidders have noisy signals about their values, as well as potential new buyers arriving after the initial auction, to motivate interest in the subject. Garratt and Troeger's (2006) research is motivated by the role of speculators, bidders with zero value for the item, who buy with a view to resell and who compete with bidders who buy for their own use. Hafalir and Krishna (2008) study auctions where bidders have asymmetric valuations, a feature that is present to some degree or other in a number of auctions, so that a lower value bidder may obtain the item but can profitably resell it to a higher value bidder.

The present paper experimentally investigates the effect of resale in asymmetric auctions following the Hafalir and Krishna (2008) model. In their model a weak and a strong bidder first compete for the item in a first-price private value auction. The winner of the item then has the opportunity to sell it to the other bidder using a take it or leave it price.

Our experiment explores the case where the two value distributions are uniform, but with different supports (Plum, 1992). Key comparative static predictions of the model are that the weak player always bids higher with resale as they have the option of reselling the item, to the point that weak bidders may even bid above their value for the item. The response of strong bidders is not nearly as uniform or as strong as that of the weak bidder, sometimes bidding a bit higher or a bit lower than without resale. The net result is that resale raises auction prices in all cases, benefiting the seller. In contrast, resale has a mixed effect on efficiency compared to what it would have been without resale (ex ante efficiency), increasing it in some cases and decreasing it in others (Hafalir and Krishna, 2009).

We report results for three treatment conditions. In the first treatment the risk neutral Nash equilibrium (RNNE) calls for weak bidders to consistently bid above their private values when resale opportunities are present, winning half the auctions and making small positive average profits. Results show that weak bidders do, indeed, consistently bid above their private values, but not by nearly as much as the RNNE requires, so that there is not nearly as much resale as predicted. Weak bidders consistently lose money conditional on winning the item in the auction, which drives bidding down even further. These negative average profits have partly to do with the knife edge nature of the equilibrium in which weak bidders earn very small profits. Combining this with bidding above the RNNE on the part of strong bidders results in negative average profits as weak bidders win far more often than predicted with bids above the strong players' values, so that weak types are stuck with winning the item at a price that exceeds their value.

The second treatment is designed so that weak players will bid their value in equilibrium, thereby reducing the opportunity for losses to impact outcomes. We explore this treatment first in auctions with only resale opportunities present and then using a dual market procedure whereby subjects first bid in an auction without resale opportunities and then bid again, with exactly the same private values, in an auction with resale. The dual market procedure has the advantage that we can directly investigate the key comparative static predictions of the model regarding bids, revenue, and efficiency holding all other things equal. In this treatment, where with resale weak bidders consistently make positive profits conditional on winning the item, they bid higher than absent resale opportunities, bidding nearly equal to their private values throughout. Auction prices are significantly higher with resale opportunities than without, and the distribution of bids becomes more symmetric than absent resale opportunities, although not completely symmetric as the theory predicts. Ex ante efficiency is predicted to *decrease* modestly in this case, but the data show that it increases by a small amount instead.

The third treatment reduces the disparity in the support for the weak and strong bidders valuations so that efficiency is predicted to increase. Employing the dual market technique throughout, with resale, as predicted, weak bidders increase their bids, ex ante efficiency increases, and we are no longer able to reject a null hypothesis that the distribution of weak and strong types bids are the same. However, the average of auction prices decrease modestly as opposed to the modest increase predicted.

To our knowledge there exist only two other experimental studies of auctions with resale. Georganas (2003) looks at symmetric English auctions where resale opportunities arise out of small deviations from equilibrium bidding that become magnified once resale opportunities are present. Lange, List and Price (2004) study symmetric first price auctions where opportunities for resale result from bidder uncertainty regarding the value of the item. Neither study's results are directly applicable to our environment. More relevant is the growing literature on asymmetric private value auctions, in particular the Guth, Ivanova-Stenzel, and Wolfstetter (2005) experiment which employs supports similar to ours.

The outline of the paper is as follows. Section 2 characterizes the theoretical implications of auctions with resale following the Hafalir and Krishna model (2008, 2009) as it relates to our parameterization. Section 3 outlines our experimental design and procedures. Section 4 reports our results. Section 5 summarizes our results and conclusions.

2 Theoretical Implications

In auctions with resale, bidders first compete in a first-price sealed bid auction to buy the item. Following the auction, the winner has an opportunity to sell the item at a take it or leave it price to the losing bidder, absent any information about the losing player's bid. There is one weak and one strong bidder in each play of the game with a single item for sale. Strong bidders values are iid from a uniform distribution with support $[0, a_s]$ where $a_s = 100$ in all treatments. Private values for weak bidders are iid from a uniform distribution with support $[0, a_w]$ where a_w takes on values of 10, 34 and 60 in the three treatments, which we will refer to as W10,W34 and W60, respectively.

The risk neutral Nash equilibrium (RNNE) bid function for bidder i in auctions with resale is (see Hafalir and Krishna, 2008)[1]

$$b_i(v_i) = v_i \tfrac{(a_s+a_w)}{4a_i}$$

Absent resale bidders employ the following bid functions (see Plum, 1992)

$$b_s(v_i) = v_i/(1 + \sqrt{1 + \gamma v_i^2})$$

[1]Hafalir and Krishna (2008) note that the strong bidder's strategy does not constitute a strict best-response. Rather he is indifferent between his equilibrium bid and bidding 0 and attempting to buy in the resale market. As will be clear shortly, this alternative strategy is rarely observed in the data.

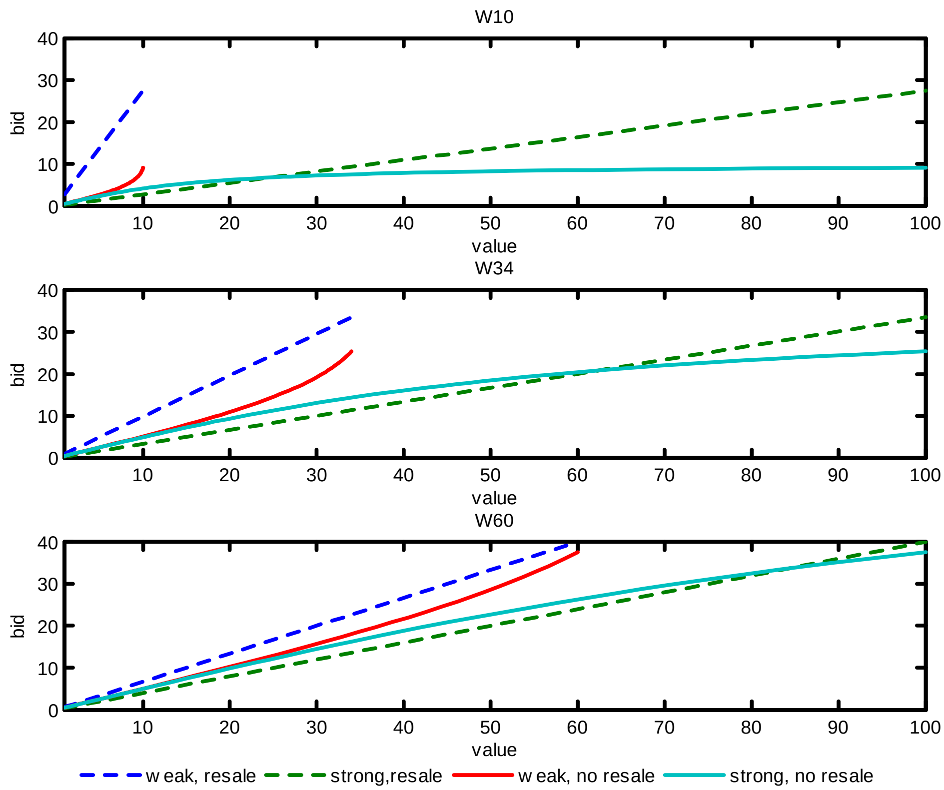

Figure 1: Equilibrium bid functions with and without resale.

$$b_w(v_i) = v_i/(1 + \sqrt{1 - \gamma v_i^2})$$

$$\text{with } \gamma = 1/a_w^2 - 1/a_s^2$$

The equilibrium bid functions with and without resale are shown in Figure 1 under all three treatments. Note that without resale weak bidders never bid above their value for the item and strong bidders never bid above the upper bound of the weak bidders support (a_w). Further, absent resale, for any given valuation weak bidders bid higher than strong bidders, which can generate inefficient allocations. With resale, weak bidders increase their bids for all valuations compared to the no resale case, even bidding above their value for the W10 case. In contrast, the response of strong bidders is mixed across treatments as well as within treatments compared to the no resale case.

With resale, the bid distributions for the weak and strong types are the same. Note, this does not mean that the bid functions for the two types are the same as the supports for their values are very different. Rather, with resale a third party only observing the bids, but not knowing the bidders values, would not be able to distinguish between strong and weak types.

A number of other comparative static predictions hold for auctions with resale. At the market level auction prices should be higher, on average, with resale than without in all cases. Efficiency is another matter. In the W10 and W34 treatments ex ante efficiency is predicted to decrease compared to auctions without resale, while it is predicted to increase with W60. Although in all three cases resale improves efficiency compared to the auction outcome, it also promotes higher bids on the part of weak bidders than absent resale. This generates a more inefficient auction allocation to begin with, which is only partially offset with resale, as weak bidders may price the item above the strong bidders (unobserved) value. The net result is reduced efficiency relative to the no resale case for the W10 and W34 treatments, but increased efficiency for the W60 case (Hafalir and Krishna, 2009). Note, however, that these predicted changes in efficiency are quite small, so that they can be easily undone with small deviations from the RNNE by either type of player.

In order to maximize profits in the second stage, the winner has to set an optimal reserve price. The optimal reserve price r^* given a winning bid b_i is calculated by first updating the support of the opponent's value. Given the belief that their opponent is using the RNNE bidding strategy $b_j(v_j)$ the updated support is $[0, b_j^{-1}(b_i)]$. The optimal reserve price is then $1/2(b_j^{-1}(b_i) + v_i)$.

3 Experimental Design and Procedures

The W10 sessions all involved auctions with only resale. The first three W34 sessions also involved resale only, after which three additional sessions were conducted using dual markets. With dual markets subjects first bid in an auction with no opportunity for resale. But before these results are reported, they bid in a second auction, with exactly the same induced valuations, in which resale is permitted. Once both sets of bids have been collected, outcomes are reported, with subjects paid randomly on the basis of either the no resale or the resale auction. The W60 sessions employed dual markets for all sessions. We switched to dual markets in order to directly examine the comparative static predictions of the model with respect to bids, prices and efficiency with and without resale. As will become apparent shortly, given the results of the W10 sessions, we saw no need to conduct dual market sessions for this case.

At the start of each session, instructions were distributed to subjects and were read aloud by the experimenter. The instructions explained the auction procedures in detail followed by a short quiz to make sure subjects understood the payoffs with resale opportunities, as well as the general auction procedures.[2] Each experimental session began with two dry runs followed by 40 auctions for cash (except for the first W10 session which had 30 cash auctions).

New valuations were drawn randomly at the start of each auction period with the matching between strong and weak bidders changed randomly prior to each auction. Bidder valuations were integer draws from their respective distributions. Half the subjects were randomly chosen to start as weak types and half as strong types, with these roles held constant for the first half of the paid periods. After this, roles for weak and strong types were switched, with these roles remaining the same throughout the second half of the paid periods. Dual market sessions began with ten auctions of resale only, after which dual markets were employed throughout. This was done to simplify procedures to begin with, after which subjects readily adapted to the dual market treatment.

In the auctions with resale, the highest bidder in each auction was awarded the item and paid a price, p_1, equal to what she bid. Following this the auction winner had the opportunity to sell the item to the losing bidder setting a reservation price r. The losing bidder, after observing the resale price, decided whether or not to buy the item. Sellers did not have any choice whether to put the item up for sale or not. However, sellers were advised that if they did not want to sell the item they could set $r = 101$. If the losing bidder chose not to buy the item, payoffs remained the same as in the auction. If the item was resold final payoffs were $r - p_1$ for the first stage winner and $v_i - r$ for the second stage winner.

[2] Instructions are available at http://www.econ.ohio-state.edu/kagel/Resale_Insts

Feedback after the final allocation consisted of reporting biders net profits, both players bids and their corresponding valuations, along with their type. Corresponding information from past periods was available on players' computer screens. In the dual market treatment feedback from the no resale market was only available after completion of the auction with resale.

Subjects received an initial capital balance of 250 experimental currency units (ECUs) in treatment W10 and 100 ECUs in the W34 and W60 treatments. Any profits or losses were added to these starting capital balances with subjects paid their end-of-session balances in cash at the exchange rate of $1 = 17 ECUs in W10 and $1 = 15 ECUs in the W34 and W60 treatments. There was no show up fee. These different starting capital balances and conversion rates were adopted in view of the lower expected profits for weak players in the W10 treatment along with the greater threat of bankruptcy. Bankrupt bidders, of which there were 6 were no longer permitted to bid and dismissed with a cash payment of $7.[3] Profits, excluding bankrupt subjects, averaged around $36 across all sessions.

Subjects were recruited from the undergraduate student population at Ohio State University. Software for conducting the auctions was developed using zTree (Fishbacher, 2007). Table 1 summarizes the parameters for each experimental session along with the number of subjects in each session.

4 Experimental Results

Results are presented separately for each of the three treatments. There are two learning phases to each session, once in the beginning and once after subjects switched roles. To focus on more experienced bidding we exclude data from periods 1-10 and 21-30.[4]

[3] After a bankruptcy a bidder was chosen at random each period to stay out, as the number of players left was not divisible by 2. There was one W60 session where there were three bankruptcies early on, which resulted in only 11 subjects after auction period 9, which was terminated at this point. Data from this session are not reported.

[4] Session 1 had only 30 periods in total, so to be consistent we only consider periods 10-20 from this session.

Session	Treatment	Exchange rate	Endowment	Paying periods	Number of Subjects
1	W10	17	250	30	12
2	W10	17	250	40	16
3	W10	17	250	40	16
4	W34	15	100	40	16
5	W34	15	100	40	14
6	W34	15	100	40	18
7	W34Dual	15	100	40	16
8	W34Dual	15	100	40	18
9	W34Dual	15	100	40	16
10	W60Dual	15	100	40	16
11	W60Dual	15	100	40	16
12	W60Dual	15	100	40	18
13	W60Dual	15	100	40	20

Table 1: Summary of sessions

	First Stage		**Second Stage**	
	Prices	**Frequency Weak type wins**	**Prices**	**Efficiency** (total surplus)
predicted	18.8	0.51	23.2	48.1
actual	20.0	0.27	20.1	49.9

Table 2: Summary of results in treatment W10.

4.1 Weak Bidders with Value Draws [0, 10]

Figure 3 reports bids for strong and weak bidders pooled across experimental sessions in the form of box plots where each box represents the interquartile range for the distribution of bids (IQR, which covers 75% of all bids) in the neighborhood of each the discrete values reported on the horizontal axis. The whiskers go from the end of the box to the most extreme value within 1.5 times the IQR, covering all but the most extreme outliers. The straight line within each box represents the median bid. In each case the thin dashed line through the origin represents the RNNE bid. The thick solid line is the 45 degree line, where bids are equal to values.

Strong bidders overbid relative to the RNNE for low values and underbid somewhat for values between 80 and 90. Weak bidders tended to bid above their values as the theory predicts, with most bids lying above the 45 degree line. However they underbid relative to the RNNE, and did so to a much greater extent than strong bidders overbid, with the upper end of the IQR just a little above 10 except at the highest value and the median bid below 10 throughout. This compares to the RNNE bid which is 11 for $v_i = 4$ for weak bidders and goes as high as 27.5 for $v_i = 10$. This underbidding by weak bidders resulted in them winning only about half of the auctions they were predicted to win (26% actual versus 50% predicted; see Table 2 above).

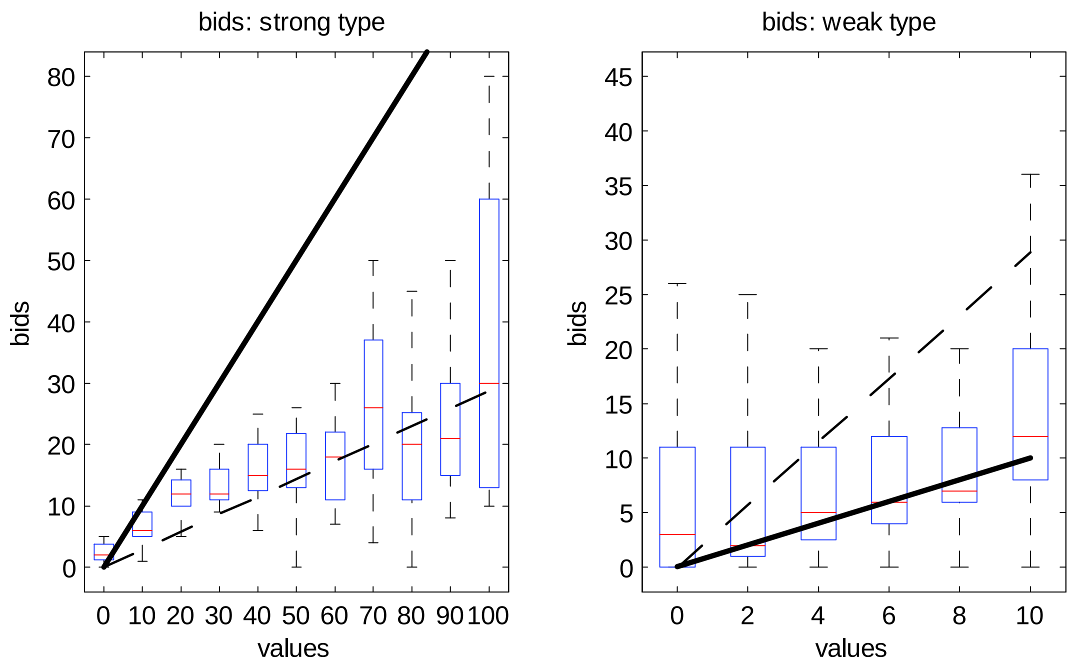

Figure 2: Series of boxplots of private values vs bids for the low and high types in treatment 10. Each box drawn represents the distribution of the bids for a block of values. The length of the box represents the interquartile range (IQR). The whisker extends from the box to the most extreme data value within 1.5 times the IQR. The dashed thin straight lines through the origin represent the equilibrium bids and the solid thick lines represent the 45 degree line.

Reserve prices for weak bidders when they did win are shown in Figure 3, along with predicted reserve prices (the straight line through the origin) (r^*_{Nash}) and the empirical best response line (the wavy, almost horizontal line) (r^*_{BR}) given the distribution of strong bidders' bids (in conjunction with the rather heroic assumption that bidders have observed the whole empirical distribution of bids).[5] The r^*_{BR} is high as it is sensitive to the fact that there are some strong types who underbid a lot which skews the best response upward. Observed reserve prices were almost always between the ones predicted by the Nash equilibrium (r^*_{Nash}) and the best response reserve prices (r^*_{BR}). Note, that strong bidders rarely rejected a resale offer that would have given them a positive profit.[6]

Profits of weak bidders were consistently negative conditional on winning the auction, averaging -3.5 per period on average. Average profits of weak players conditional on winning would have been -3.1 if they set reserve prices according to r^*_{Nash} versus -1.0 setting them according to r^*_{BR}. The negative profits weak bidders realized can be accounted for by several factors. First, there are very little profits to be made in the first place, as (unconditional) expected profits are around 1 ECU per period. Second, given the low profit margin to begin with, it only takes a little stochastic variation in bids around the RNNE on both agents part to generate negative profits for weak players: If both players bid according to the RNNE, weak players would have won with a bid above the strong player's value 26.6% of the time, thereby earning negative profits. In contrast, weak players won with bids above the strong players's value 41.0% of the time, substantially more often than predicted, thereby generating a much higher frequency of winning and losing money as a consequence. This results primarily from bidding above the RNNE on the part of strong bidders, so that weak bidders tend to win more often than predicted with a bid above the strong bidder's value. In other words, strong types bidding above the RNNE (even by a modest amount) substantially reduces weak players opportunities to earn positive profits. This, in conjunction with the low predicted profits to begin with, results in small negative profits for weak types.

These negative average profits are sufficient to explain why weak players tend to bid below the RNNE, as well as why average bids are decreasing over time relative to the

[5] To calculate r^*_{BR}, for every possible bid b_i we find the private values of the strong players who bid less than $(v_j|b_j < b_i)$ and search for the reserve price r that would yield the highest expected payoff. Also note that in the case of r^*_{Nash} a player's bid also implies a private value in equilibrium, which we use to calculate the optimal reserve.

[6] Profitable offers were rejected about 15% of the time in the first 10 auctions, but none after that.

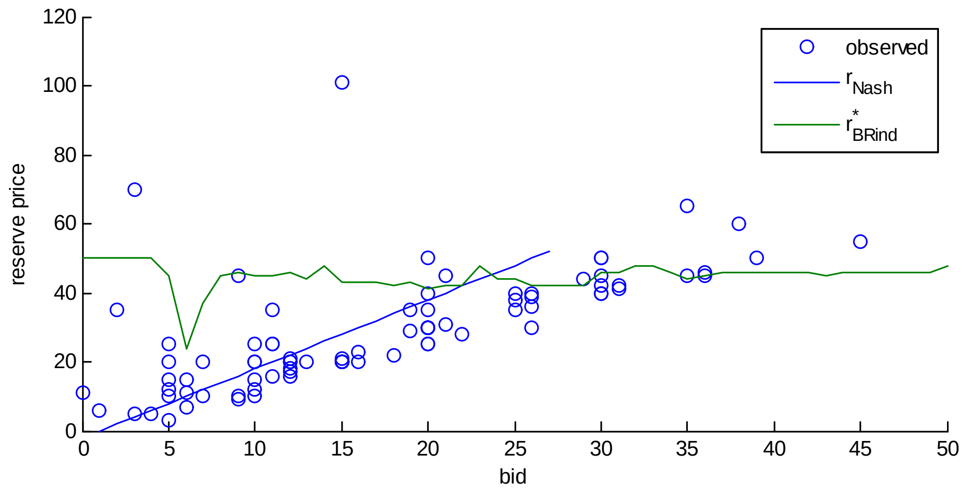

Figure 3: Reserve prices in W10 along with predicted and best response reserve prices.

RNNE. Indeed as Figure 4 shows, average bids of weak types varied around the RNNE reference point for the first several auctions, after which they were consistently below the RNNE. Also note the small spike in bids for both types relative to the RNNE after period 20 when roles were switched. However, after a few periods, strong types reduced their bids and weak players bids reverted back to continuing to decrease over time.

Looking at strong bidders, average profits were quite close to the level predicted under the RNNE - 28.9 per period versus 30.2. Given the underbidding of weak types, they could have done even better than predicted, earning 33.8 per period if they best responded to the weak bidders and bid less.

Despite the fact that subjects deviate from the RNNE, auction prices were close to the level predicted (see Table 2 above). This however should not be attributed to the theory predicting bids correctly, but to the fact that bids of both types deviate from the theory in such a way as to get close to predicted prices: Weak types underbid and win much less often than they should, resulting in strong bidders winning more often than predicted. The latter are bidding reasonably close to equilibrium or slightly above it, so that auction prices are slightly higher than predicted. Although we do not have any data for bidding without resale in this treatment, we would not expect weak types to bid above value and for strong types to bid much above 10 in anticipation of this, consistent with the results reported in Gueth et al. (2005) and in the no resale markets reported on below.[7] Using this as an upper bound for what prices would have been absent resale, the data suggest that resale would have resulted in essentially doubling prices compared to the no resale case.

Efficiency predictions in Hafalir and Krishna (2009) are reported in terms of the average value of final holdings (average total surplus associated with final holdings), which is the convention adopted here.[8] Realized efficiency is quite close to predicted efficiency in Table 2.

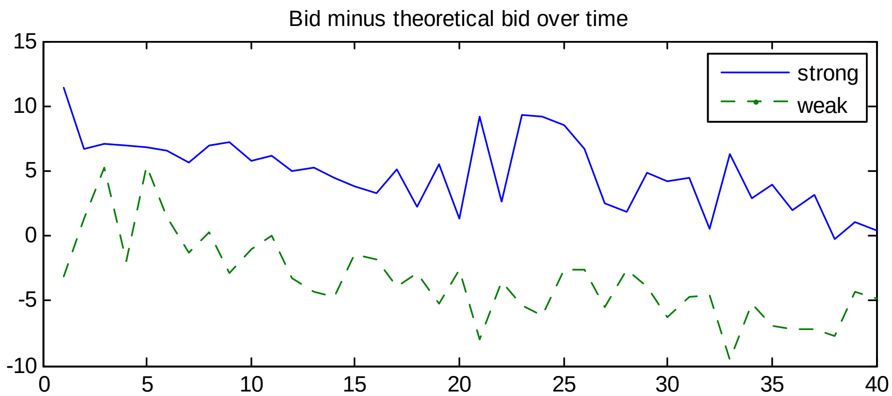

Figure 4: Bid deviation over time for both types in treatment 10.

4.2 Weak Bidders with Value Draws [0, 34]

The underbidding by weak types relative to the RNNE in the W10 treatment more than likely resulted from the losses they suffered in winning the auction. In contrast under the W34 treatment weak bidders bid their value in equilibrium which should eliminate, or

[7] Gueth et al (2005) employed asymmetric auctions without resale with supports similar to those employed here. They observe that strong bidders rarely bid more than the highest possible value in the support of the weak bidder.

[8] This is different from the way efficiency is usually measured in experimental auction papers - the average of (x_H/x_M)*100, where x_H is the value of the ultimate holder of the item and x_M is the maximum of the two bidders values. We eschew this measure because large scale simulations indicate that for small predicted increases or decreases in efficiency, the standard experimental measure does not reliably track the predicted changes based on the Hafalir and Krishna measure.

substantially reduce, the possibility for losses.

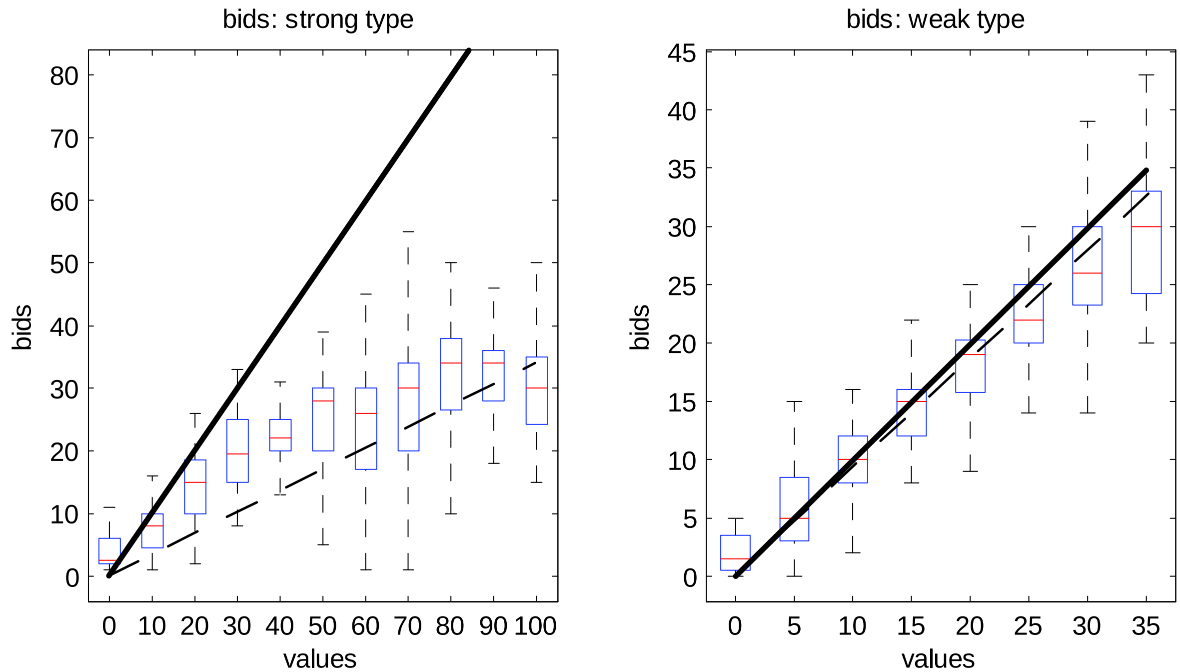

Figure 5: Series of boxplots of private values vs bids for the low and high types in treatment 34. Each box drawn represents the distribution of the bids for a block of values. The length of the box represents the interquartile range (IQR). The whisker extends from the box to the most extreme data value within 1.5 times the IQR. The dashed thin straight lines through the origin represent the equilibrium bids and the solid thick lines represent the 45 degree line.

Figure 6 reports bids for both strong and weak types under W34.[9] Here, except at the very highest values, strong bidders tend to overbid relative to the RNNE, and to overbid more than in the W10 treatment. There is larger variation in bids in the middle range as well. On the other hand weak types bid much closer to their predicted values throughout. The net result is that weak bidders win substantially more often than in the W10 treatment, 37% of the auctions compared to 27% with W10. This is still significantly less than the 50% predicted in equilibrium (see Table 3), largely as a result of strong types bidding more than predicted.

[9]Note that for the weak type the RNNE and the 45 degree line differ a bit. This is because the RNNE predicts exact value bidding only when the maximum private value of the weak type is 100/3. In the experiment we rounded this up to 34.

	First Stage		Second Stage	
	Prices	**Frequency Weak type wins**	**Prices**	**Efficiency**
predicted	22.0	0.5	25.3	48.5
actual	25.9	0.37	27.3	49.1

Table 3: Summary of results for treatment W34.

Resale prices for weak bidders are shown in Figure 6 along with the reserve prices predicted under the RNNE and with best response reserve prices. Except for a few outliers involving very high reserve prices, 100 or very close to it, that would preclude any opportunity for resale, reserve prices track the r^*_{Nash} reasonably closely.[10] Note, that once again $r^*_{BR} > r^*_{Nash}$, particularly when winning with relatively low bids, as weak bidders should take advantage of strong types' occasional very low bids.

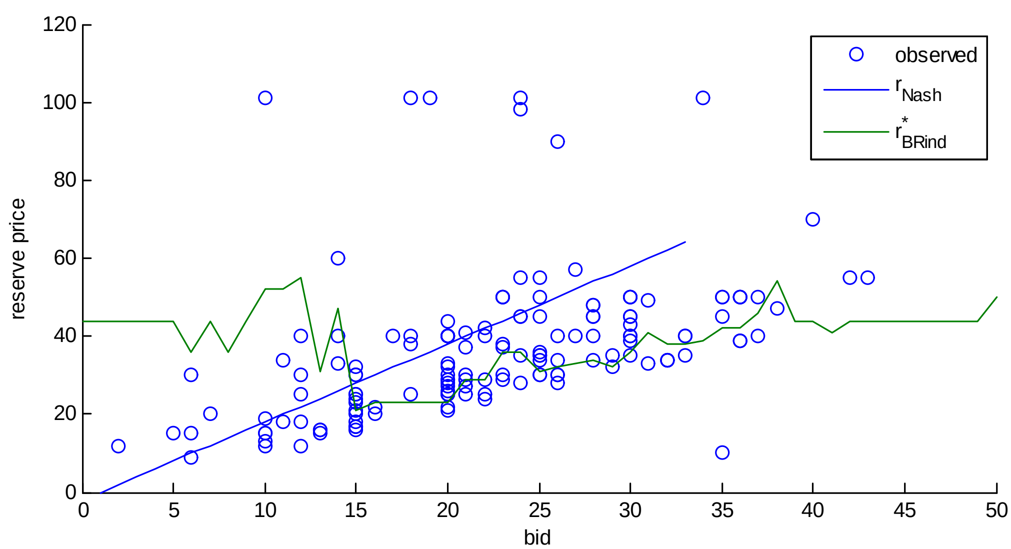

Figure 6: Reserve prices in treatment 34. We plot the observed ones, the ones that should be set according to theory and the ones that would be a best response to actual behavior.

Profits for weak types who won the first auction were 2.9 per period on average, very

[10]These seven very high reserve prices (80 or above) come from three subjects. In all cases these bidders had positive profits from bidding in the auction. There were occasional rejections of profitable resale proposals, 3.2% of all such offers.

close to the level predicted under the RNNE[11] (3.5 per period), or had they used best response reserve prices (3.8 per period). These positive profits are in marked contrast to weak types negative profits in the W10 treatment. The positive realized profits, in conjunction with the fact that bidding ones value is a perfectly safe strategy for weak bidders helps to explain why weak types are bidding closer to equilibrium under the W34 treatment. In other words, part of the explanation for weak types closer to equilibrium play results from the fact that the theory no longer requires them to continuously risk losses.

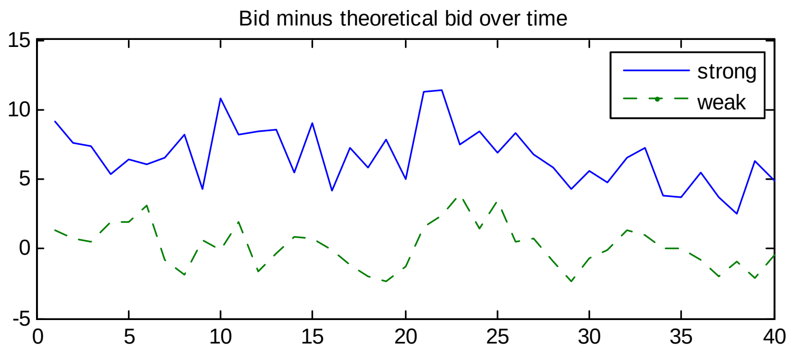

Figure 7: Bid deviation over time for both types in treatment W34.

Average profit per period for strong types was 20.8. This too is very close to the RNNE of 21.5 per period, and a little less than with best responding, 24.8. Note that these somewhat lower profits relative to best responding can be fully accounted for by the fact that strong types consistently bid above the RNNE, a common characteristic of bidding in standard (no resale) first-price sealed bid auction experiments (see Kagel, 1995 and Kagel and Levin, 2008, for survey results on this point). The higher than predicted bids for strong types resulted in auction prices that were higher than predicted (26.0 versus 22.0; see Table 3) and weak types winning less often than predicted (37% of the time versus 50%).

Figure 7 plots bids over time. There is much less learning/adjustment in bids over

[11] This is calculated given the actual bids of weak and strong types and assuming that they chose the Nash reserve prices in the resale stage.

time than in the W10 treatment. The absence of any systematic change in bids over time suggests that switching roles between the first half of the auctions to the second half by itself had minimal impact on how subjects bid. This is confirmed in comparing the average difference between actual and predicted bids in the last 10 auctions prior to the change in players' roles compared to the last 10 auctions after they had changed roles, which shows no difference at conventional significance levels.

5 Dual Markets

5.1 Dual 34

The dual market treatment is designed to establish a clear distinction between bidding with and without resale.

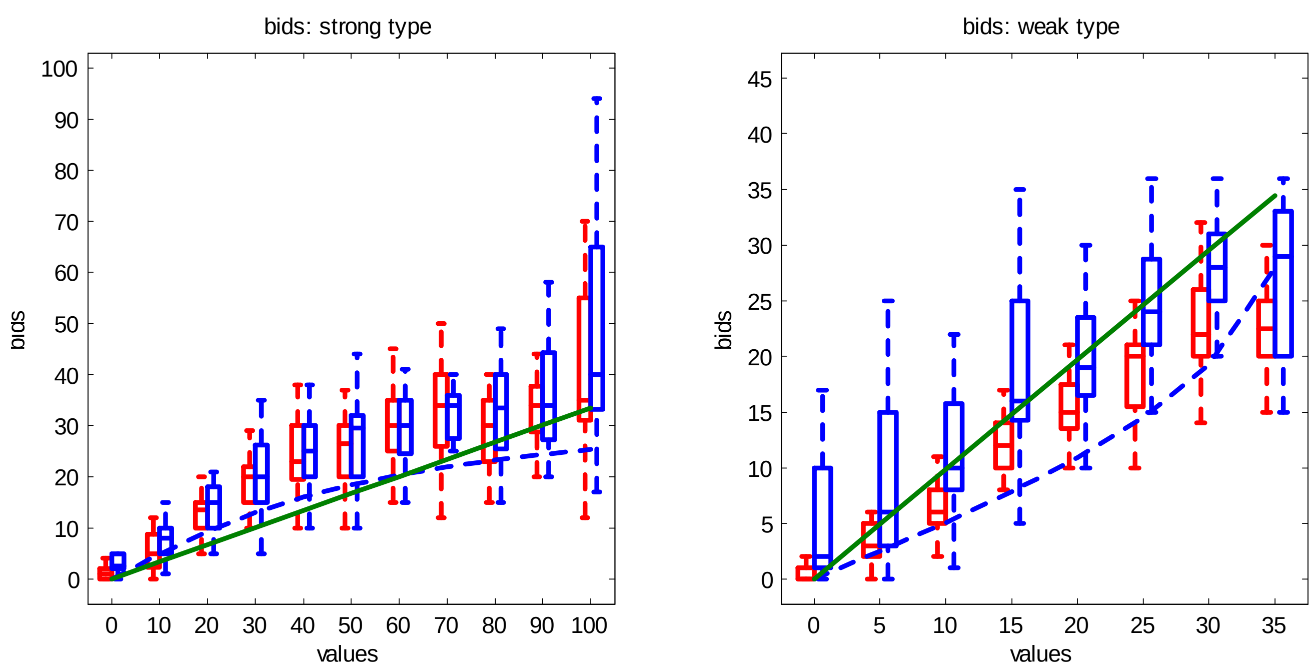

Figure 8: Boxplots of actual bids for the two types compared with theory with dual markets in the W34 treatment. For every block of values on the left, lighter shaded boxplot represents the no resale case, while the darker shaded boxplot is with resale. The solid lines represent the Nash equilibrium with resale, the dotted lines represent the no resale case.

In the W34 treatment, there is not much difference in predicted bids for strong types with and without resale, which the box plot confirms. But for weak types bids are predicted to increase uniformly with resale, which the box plot supports on the aggregate level. Further, using individual subject data as the unit of observation, 79.6% (39 out of 49) of weak bidders bid higher on average with resale than without.[12] Of these, 89.8% (35 out of 39) bid significantly higher with resale than without (based on a one tailed t-test, $p < 0.05$). Of the remaining bidders, 17.6% (6 out of 49) bid exactly the same with and without resale, and 8.2% (4 out of 49) bid less, but none significantly less (using a t-test).

Table 4 compares prices and efficiency with and without resale. Under the RNNE average prices in the first stage are predicted to increase from 18.5 with no resale to 22.6 with resale, an increase of 22.2%. Actual prices increased from 26.9 without resale to 30.3 with resale ($p < 0.01$, one-tailed t-test), a slightly smaller absolute increase in average auction prices and a much smaller percentage increase (12.6%) based on the higher than predicted no resale prices.

Ex ante efficiency is predicted to decrease with resale for the W34 treatment. Large scale simulations based on the W34 supports show that efficiency decreases from 50.7 with no resale to 50.1 with resale.[13] The predictions reported in Table 4 are based on the sample of draws from the experimental data which, in this case, predict an even smaller decrease in efficiency. The data show that contrary to the predicted decrease average efficiency increases a bit from 50.7 with no resale to 51.2 with resale. The proximate cause for this is that efficiency is a bit lower than predicted with no resale and a bit higher than predicted with resale. This suggests that weak types are winning more than predicted without resale thereby reducing surplus and/or less than predicted with resale thereby increasing surplus (or selling more often than predicted when they win). The data in Table 4 shows that weak types are winning with the same overall frequency predicted with no resale but less than predicted with resale. Further, conditional on winning, weak types sell a bit less often than predicted when they win (36.7% versus 38.6%).[14] So that the small increase in

[12] These calculations are based on averaging differences in bids with and without resale for each auction period for each subject.

[13] The simulation employed three million couples of values.

[14] Strong bidders, after winning the auction also had the opportunity to offer the item for resale. Al-

		First Stage			Second Stage	
		Prices	**Efficiency**	**Frequency Weak type wins**	**Prices**	**Efficiency**
resale	predicted	22.6	45.8	0.47	26.1	51.2
	actual	30.3	46.7	0.36	31.9	51.7
no resale	predicted	18.5	51.6	0.24	-	-
	actual	26.9	50.7	0.25	-	-

Table 4: Summary of results in W34 with dual markets.

average efficiency in this case can largely be attributed to weak types winning the auction less often than predicted with resale.

One of the key predictions of the model with asymmetric valuations and resale is that the bid distribution for strong and weak types will be the same with resale, but will be readily distinguishable without resale. Figure 9 reports kernel smoothing estimates for the probability density functions (pdf) of bids of weak and strong types with resale (left panel) and absent resale (right panel). Also shown for the resale case is the predicted pdf under the RNNE. First, the pdfs for weak and strong bidders fail to completely overlap with resale as weak types have a substantially higher frequency of low bids than strong types do, with strong types having a correspondingly higher frequency of high bids. However, comparing the differences between pdfs for bidder types with and without resale, the pdfs are clearly more similar with resale than without. So that on this dimension at least, although the point prediction of the model is not satisfied, as rarely occurs in the experimental auction literature, the qualitative implications of the model are satisfied as the differences in the pdfs for the types have narrowed considerably. Also not to be overlooked in these pdfs is the lower overall frequency of low bids relative to the theory (compare weak and strong pdfs with the predicted RNNE pdf with resale), along with the tail of high bids not predicted. Both of these effects result from the general pattern of bidding above the RNNE found in first-price sealed bid actions.

though the theory predicts no such sales, there were a few mutually profitable sales (1.4% of all the times strong bidders won). This is not unexpected given the inherent noise in bidder behavior and is substantially less than the frequency with which weak bidders resold.

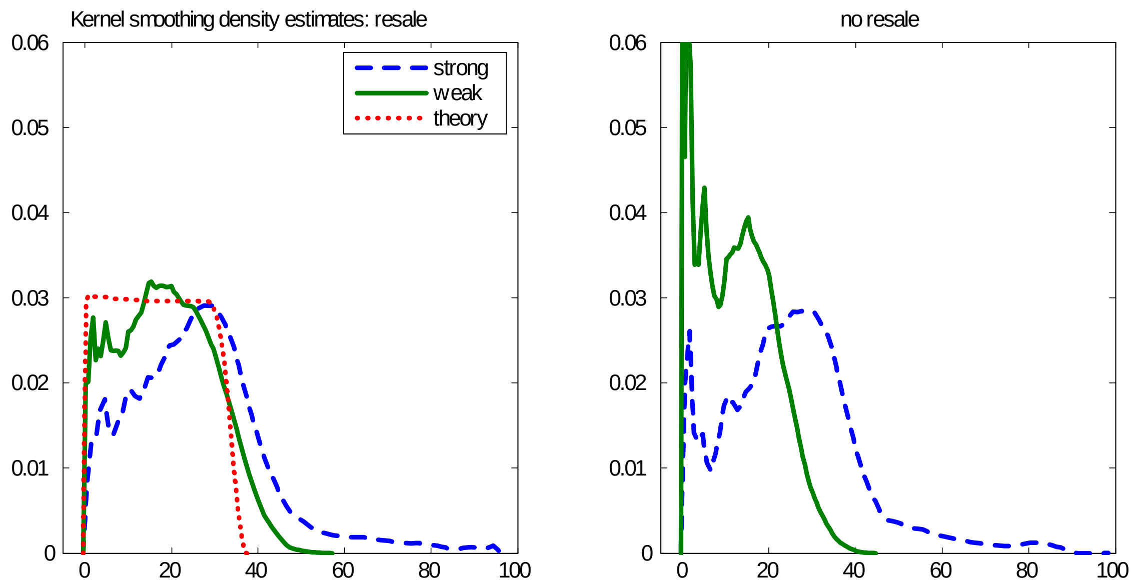

Figure 9: Kernel density estimates of probability density functions of bids of weak and strong types with resale (left panel) and without resale (right panel) in the W34 treatment.

5.2 Dual W60

Figure 10 provides box plots for bids with and without resale for strong and weak types along with the equilibrium bid functions under the RNNE for the W60 treatment. The predicted differences in equilibrium bid functions in this treatment are smaller than in the other treatments particularly for weak bidders where, although bids are predicted to increase with resale, they are not pedicted to increase as much as in the other two treatments. The box plots confirm essentially no change in average bids for strong types with and without resale except at higher valuations where there is a notable decrease in average bids with resale. Weak types do tend to bid more with resale than without, particularly at lower valuations (below 42 according to the box plots). This increase in average bids with resale for weak types is present using individual subject data as the unit of observation: 75.4% (52 out of 69) of weak bidders bid higher on average with resale than without. Of these, 75% (39 out of 52) bid significantly higher on average with resale than without (based on a one tailed t-test, $p < 0.05$). Of the remaining bidders, 5.8% (4 out of 69) bid exactly the same on average with and without resale, and 18.8% (13 out of

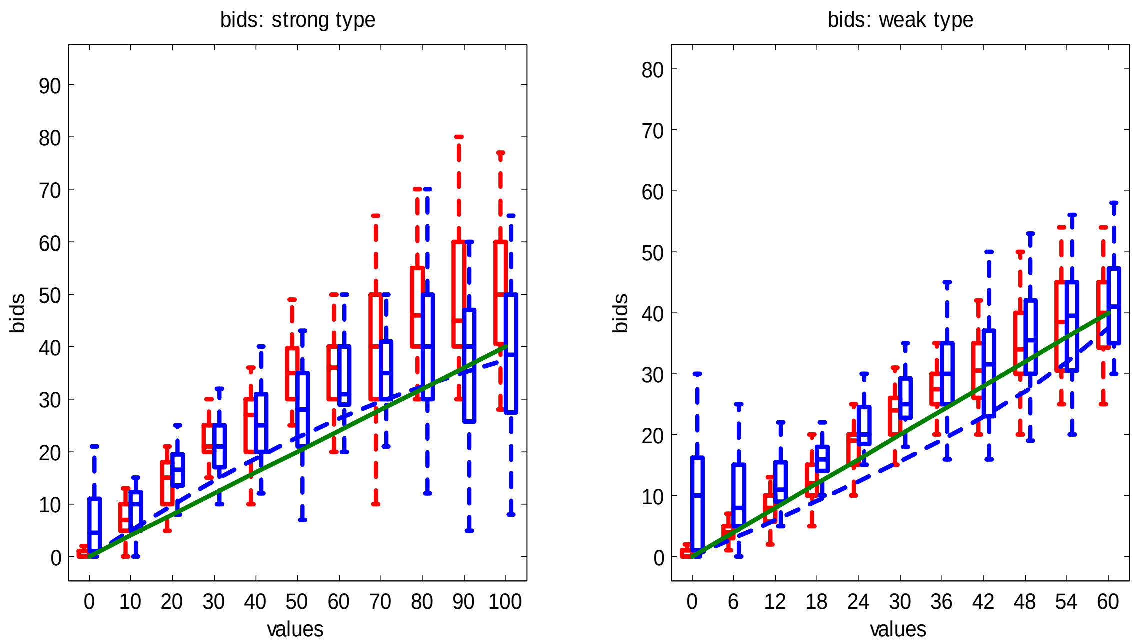

Figure 10: Boxplots of actual bids for the two types compared with theory with dual markets in the W60 treatment. For every block of values on the left, lighter shaded boxplot represents the no resale case, while the darker shaded boxplot is with resale. The solid lines represent the Nash equilibrium with resale, the dotted lines represent the no resale case.

69) bid less, but none significantly less (using a t-test).[15]

Table 5 compares prices and efficiency with and without resale. Under the RNNE average auction prices are predicted to increase from 25.4 with no resale to 26.7 with resale. Actual prices *decreased* from 34.7 without resale to 33.6 with resale, with this difference statistically significant at the 1% level using a two-tailed t-test. The fact that average auction prices decrease in this case can be accounted for by the small increase predicted, in conjunction with the fact that at higher valuations (when they were most likely to win) strong types bid considerably more on average without resale than with resale.

Efficiency is predicted to increase with resale in this treatment, but very modestly given our bidder supports according to large sample simulations (from 55.2 to 55.4). Table

[15]Here too there are no significant differences in average bids less predicted bids in comparing the last 10 auctions prior to subjects switching roles to the last 10 auctions after they had switched roles.

		First Stage			Second Stage	
		Prices	**Efficiency**	**Frequency Weak type wins**	**Prices**	**Efficiency**
resale	predicted	26.7	52.2	52.7	29.5	54.3
	actual	33.7	49.1	49.5	35.9	54.2
no resale	predicted	25.4	54.9	36.7	-	-
	actual	34.7	52.3	42.3	-	-

Table 5: Summary of results for W60.

5 shows that based on the sample of experimental draws, predicted efficiency is essentially the same with and without resale.[16] Actual efficiency increases from an average of 52.3 absent resale to 54.2 with resale. The proximate cause for this increase is that efficiency is lower than predicted absent resale and, although lower than predicted with resale, the absolute difference is smaller. In turn these differences can be accounted for by the fact that weak bidders win more than predicted without resale which, other thing equal, lowers efficiency and win less often than predicted with resale which increases efficiency.

Figure 11 reports kernel smoothing estimates for the pdfs of weak and strong types with resale (left panel) and absent resale (right panel). The differences between pdfs without resale are much smaller here than in the W34 treatment. But still a Kolmogorov-Smirnov test for equality between the two distributions rejects a null hypothesis that the two are the same at better than the 1% level. These differences in pdfs between weak and strong types bids have essentially disappeared with resale, and are not detected with a Kolmogorov-Smirnov test ($p = 0.56$)

6 Conclusions

We have investigated Hafalir and Krishna's (2008) model of auctions with resale where bidders have asymmetric valuations. Theory predicts two strong effects. First, bidding

[16] If we carry the average surplus calculations out to the second decimal place, efficiency is predicted to decrease from 55.09 to 55.05.

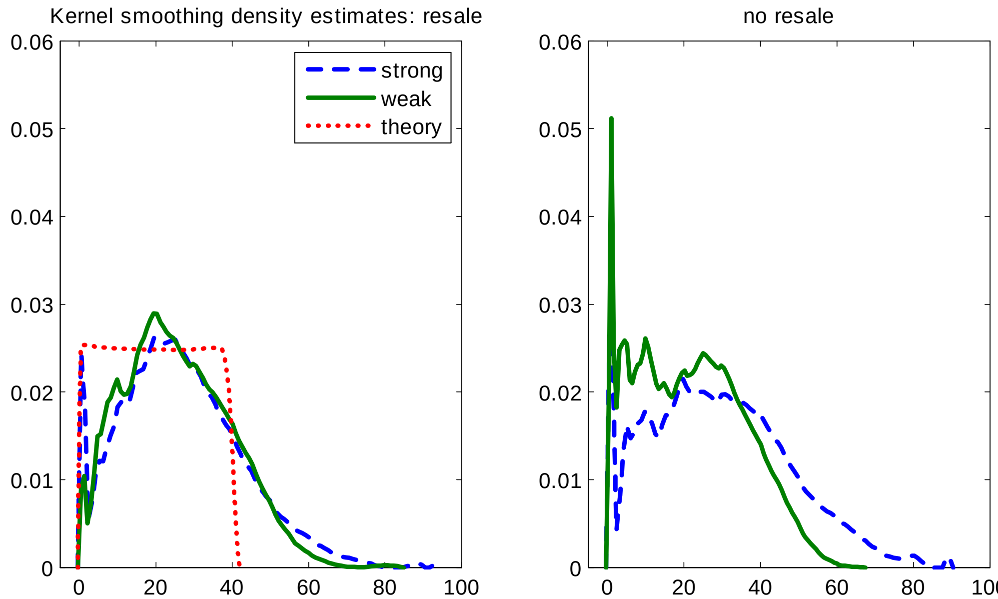

Figure 11: Kernel density estimates of probability density functions of bids of weak and strong types with resale (left panel) and without resale (right panel) in the W60 treatment.

by weak types should become more aggressive with resale than without, resulting in an increase in average auction prices and revenue. Second the distribution of bids becomes symmetric so that one cannot distinguish between weak and strong types on the basis of their bids. Our results show that auction prices increase substantially in the W34 treatment when they are predicted to increase the most under dual market procedures. But contrary to the theory average prices decrease modestly in the W60 treatment where the predicted price increase is much smaller. The distribution of bids is more symmetric in both dual market treatments with resale than without, to the point that a Kolmogorov-Smirnov tests is not able to distinguish between the two types with resale under the W60 treatment.

Auctions outcomes are much closer to the theoretical prediction when the equilibrium outcome for weak types does not require them to bid substantially above their private values with resale as in the W10 treatment. Although weak types bid above their private values when the theory calls for them to do so, they do not bid nearly as high as the RNNE predicts. The latter is associated with negative average profits for weak types when they win the auction and resell, which drives their bids down over time. The negative average profits result from the low profit opportunities available to begin with in conjunction with the fact that strong players tend to bid more than the RNNE predicts, which substantially reduces the scope for profitable resale on weak player's part. Moving to treatment conditions in which the equilibrium calls for weak bidders to essentially bid their value or less than their values, outcomes come much closer to the RNNE prediction.

As noted, one problem with the W10 treatment in which equilibrium play calls for weak types to bid substantially above their private values is that there is little scope for profits for weak types and the rather unappealing distribution of earnings conditional on winning even if everyone follows equilibrium play perfectly. As such one area for future research will be to explore bidding in auctions with resale that call for weak types to bid above their values but not in quite such a hostile environment; i.e., one that has higher expected profits conditional on winning and/or a substantially higher probability of positive as opposed to negative profits conditional on winning.

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