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Notes

Asymmetric auctions with resale: An experimental study ☆

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Abstract

We study auctions with resale based on Hafalir and Krishna's (2008) [6] model. As predicted, weak bidders bid more with resale than without, so that average auction prices tend to increase. 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. In other treatments outcomes are much closer to the risk neutral Nash model's predictions. Bid distributions for weak and strong types are more similar with resale than without, in line with the theory.
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1. Introduction

Auctions with resale have been the subject of considerable theoretical interest lately. Haile [8–10] studies auctions where bidders have noisy signals about their values, as well as potential new buyers arriving after the auction. Garratt and Troeger [2] study the impact of speculators with zero value for the item, who compete with bidders who buy for their own use. Hafalir and

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Krishna [6] study auctions with asymmetric valuations so that a lower value bidders may obtain the item but can profitably resell to a higher value bidder.

The present paper focuses on the HK [6] model: A weak and a strong bidder compete for a single item in a first-price sealed bid (FPSB) private value auction. The auction winner makes a take it or leave it offer to the loser. Key comparative static predictions of the model are that the weak players bid higher with resale, and in some cases even bid above their value for the item. The response of strong bidders is not nearly as uniform, sometimes bidding a bit higher or a bit lower than without resale. The net result is that resale always raises auction prices, but has a mixed effect on (ex ante) efficiency compared to no resale, increasing it in some cases and decreasing it in others (HK [7]).

We report results for three treatments. In treatment one the risk neutral Nash equilibrium (RNNE) calls for weak bidders to bid above their private value when resale opportunities are present, winning half the auctions and making small positive average profits. Although weak bidders consistently bid above their private value they bid well below the RNNE, resulting in much less resale than predicted. Weak bidders consistently lose money conditional on winning the auction as a result of the small profits in equilibrium in conjunction with strong types bidding above the RNNE. The latter results in an adverse selection effect so that weak bidders win far more often than predicted with bids above the strong players' value.

In treatment two weak players 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 which has the advantage of being able to directly investigate the key comparative static predictions of the model. With resale weak bidders consistently make positive profits conditional on winning, bidding higher than absent resale and nearly equal to their private value throughout. Auction prices are significantly higher with resale opportunities, and the distribution of bids becomes more symmetric than absent resale opportunities. Ex ante efficiency is predicted to *decrease* modestly, but it increases by a small amount instead.

Treatment three 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 type bids are the same. However, average auction prices decrease modestly as opposed to the modest increase predicted.

To our knowledge there exist only three other experimental studies of auctions with resale. Georganas [4] looks at symmetric English auctions where resale opportunities arise out of small deviations from equilibrium bidding. A recent paper by Jabs-Saral [11] also looks at symmetric English auctions and studies speculation and remand reduction. Lange et al. [13] study symmetric FPSB auctions where resale results from bidder uncertainty regarding the value of the item. Neither study's results are directly applicable to our environment. More relevant is the literature on asymmetric private value auctions, in particular Goeree and Offerman [3] and Gueth et al. [5], both of which employ supports similar to ours.

The HK model, is restricted to two bidders, and cannot be readily generalized to more bidders. However, the key comparative static predictions of the model regarding the impact of resale on prices, the distribution of bids and efficiency must almost certainly generalize, at least qualitatively, to much broader environments. As such these predictions are interesting to investigate in a controlled laboratory environment that closely matches the theory, thereby having a clear benchmark against which to evaluate auction outcomes.

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Section 2 characterizes the theoretical implications of auctions with resale as it relates to our parameterization. Section 3 covers the experimental design and procedures. Results are reported in Section 4. Section 5 summarizes the outcomes.

2. Theoretical implications

Bidders compete in a FPSB auction where, following the auction, the winner offers to sell the item at a take it or leave it price, absent any information about the loser's bid. There is one weak and one strong bidder with a single item for sale. Strong bidders values are iid from a uniform distribution with support U$[0, a_s]$ where $a_s = 100$ in all treatments. Weak bidders private values are iid from support U$[0, a_w]$ where a_w takes on values of 10, 34 and 60 in the three treatments (referred to as W10, W34 and W60, respectively).

The RNNE bid function for bidder i in auctions with resale is (see HK [6])[1]

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

Absent resale, bidders employ the following bid functions (see Plum [14])

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

$$b_w(v_i) = v_i \big/ \left(1 + \sqrt{1 - \gamma v_i^2}\right), \quad \text{with } \gamma = 1/a_w^2 - 1/a_s^2.$$

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. In contrast, the response of strong bidders is mixed both within and across treatments, increasing in some cases and decreasing in others compared to the no resale case. With resale, the bid distributions for the weak and strong types are the same in the sense that a third party, only observing bids but not knowing 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: 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 resale always improves efficiency compared to the auction outcome, since weak types bid higher, this generates a more inefficient allocation to begin with, which is only partially offset with resale, as weak bidders may price the item above the strong bidder's (unobserved) value (HK [7]). 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.

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 $[0, b_j^{-1}(b_i)]$, $r^* = 1/2(b_j^{-1}(b_i) + v_i)$.

[1] HK 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.

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Table 1
Summary of sessions.

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

3. Experimental design and procedures

W10 sessions involved only auctions with resale. The first three W34 sessions also involved resale only, after which three sessions were conducted using dual markets. With dual markets subjects first bid with no opportunity for resale. But before these results are reported, they bid in a second auction, with exactly the same valuations, with resale permitted. After that both outcomes are reported, with subjects paid randomly on the basis of one of the two markets. W60 sessions employed dual markets throughout. Dual markets were introduced in order to directly examine the comparative static predictions of the model. As will become apparent, given the W10 results, we saw no need to conduct dual market sessions for this case.

Each session began with instructions distributed to subjects which were read aloud by the experimenter. A short quiz followed covering payoff calculations as well as general auction procedures.[2] All but one session began with two dry runs followed by 40 auctions for cash (see Table 1 which summarizes the parameters, and reports the number of subjects, in each session).

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, with roles held constant for the first half of the paid periods. After this, roles for weak and strong types were switched, and remained the same until the session ended. Dual market sessions began with ten auctions with resale only, after which dual markets were employed throughout. In resale auctions, sellers did not have any choice whether to put the item up for sale, but were advised that if they did not want to sell they could set $r = 101$. Feedback after the final allocation consisted of biders net profits, both players bids and their corresponding valuations, along with their type, with information from past periods available on subjects' computer screens.

Subjects received an initial capital balance of 250 experimental currency units (ECUs) in W10 and 100 ECUs in W34 and W60. Profits and losses were added to these starting capital balances with end-of-session balances paid in cash at the exchange rate of \$1 = 17 ECUs in W10 and \$1 = 15 ECUs in W34 and W60. There was no show up fee. Different starting capital balances

2 Instructions are available in the web appendix.

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and conversion rates were adopted in view of the lower expected profits for weak players in W10 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 was developed using zTree [1].

4. Experimental results

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. However, we discuss significant changes in bid patterns over time in cases where they are most pronounced.[4]

4.1. Markets with resale only: W10 and W34 treatments

Fig. 1 reports bids for strong and weak bidders pooled across experimental sessions in the form of box plots. Strong bidders consistently overbid relative to the RNNE for low values in both treatments, but not at higher values, particularly in W10. Overbidding relative to the RNNE in FPSB auction experiments is a well established pattern (Kagel [12], reviews the literature). In both treatments, strong type bids at, or a bit below, the RNNE for higher values still leaves their bids above the upper bound of the interquartile range of weak types' bids.

With W10, most weak type bids are above the 45 degree line, as predicted. However weak types underbid relative to the RNNE, and do so to a much greater extent than strong types overbid: The upper end of the IQR for weak types is just a little above 10 except at the highest resale value, with the median bid below 10 throughout. This compares to the RNNE bid which is 11 for $v_i = 4$ and 27.5 for $v_i = 10$. The result is that weak types won only about half of the auctions they were predicted to win (27% actual versus 50%). Profits of weak bidders are consistently negative conditional on winning the auction, averaging -3.5 per period which, as will be argued below, goes a long way to explaining why they underbid so much relative to the RNNE.

Weak types bid much closer to their predicted values with W34, and win substantially more often than with W10, 37% versus 27%. This is still significantly less than the 50% predicted in equilibrium, largely as a result of strong types bidding more than predicted. Weak types bidding their equilibrium value with W34 eliminates the possibility for losses, so that in practice losses occurred much less often compared to W10.

Reserve prices are shown in Fig. 2. Observed reserve prices tend to be a bit below the Nash prediction (r^*_{Nash}) and well below the best response reserve price (r^*_{BR}).[5] Strong bidders rarely

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[3] After a bankruptcy, with an uneven number of subjects, a bidder was randomly chosen to sit out in each period. There was one W60 session with three bankruptcies early on, resulting in only 11 subjects after auction period 9, at which point the session was terminated. Data from this session are not reported.

[4] Session 1 had only 30 periods. To be consistent we only consider periods 10–20 from this session.

[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. r^*_{BR} rests on the rather heroic assumption that bidders have observed the whole distribution of bids.

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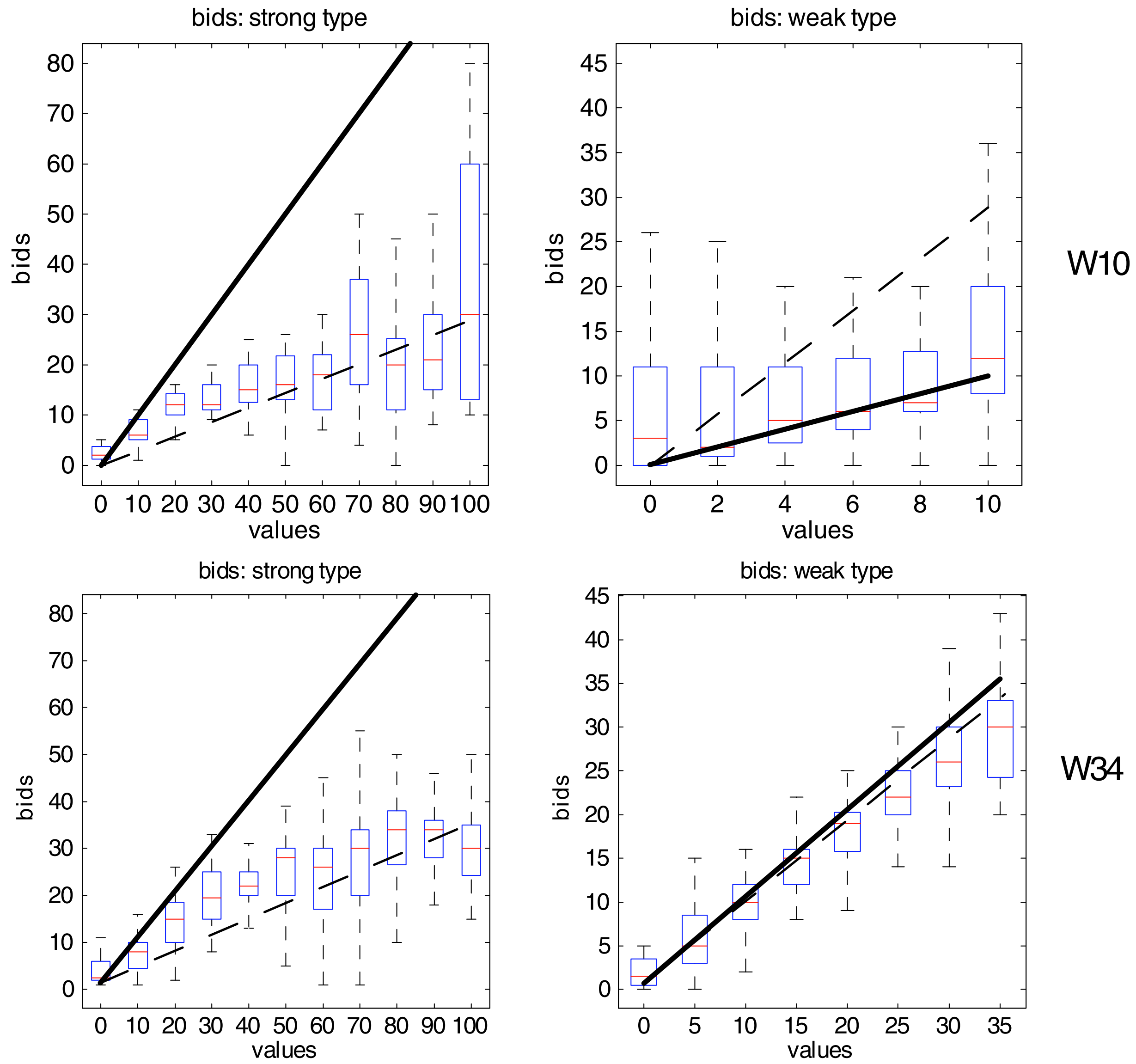

Fig. 1. Series of boxplots of private values vs bids for the low and high types in treatment 10. Each box drawn represents the distribution of the bids for a block of values. The length of the box represents the interquartile range (IQR, which covers 75% of all bids). The whisker extends from the box 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.

rejected a resale offer that would have given them a positive profit.[6] There were a handful of cases where weak bidders set very high reserve prices, 100 or very close to it, that would preclude any opportunity for resale. Apart from these outliers, reserve prices tend to increase monotonically with increases in r^*_{Nash}. For lower valuations r^*_{BR} is significantly higher than r^*_{Nash} as it is sensitive to the fact that there are some strong types who underbid a lot which skews the best response upward. However, at higher valuations the two lines converge.

Profits for weak types conditional on winning the auction were consistently negative with W10, averaging −3.5 per period. These negative profits can be accounted for by two factors.

[6] With W10 (W34) profitable offers were rejected about 15% (11%) of the time in the first 10 auctions, but none (6%) after that.

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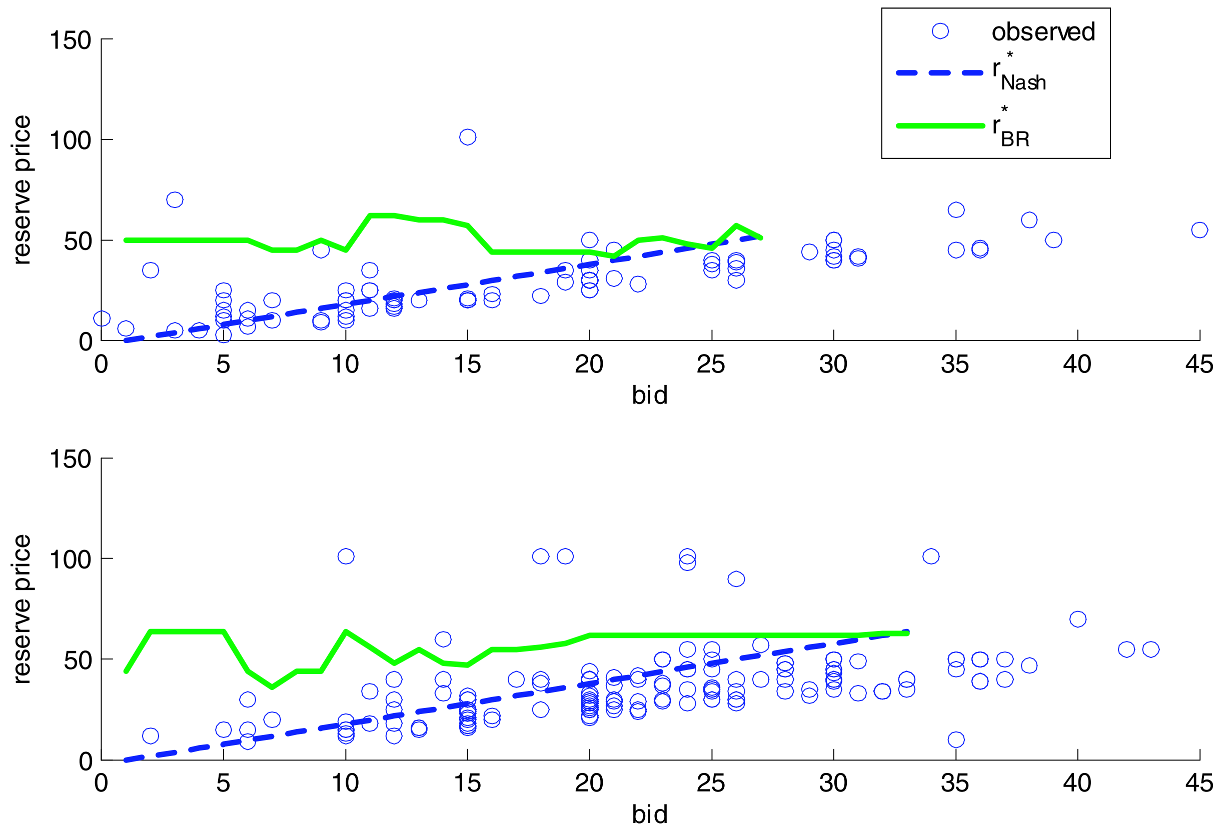

Fig. 2. Reserve prices in W10 and W34 along with predicted (r^*_{Nash}) and best response (r^*_{BR}) reserve prices.

First, there are very little profits for weak types in equilibrium, averaging around 1 ECU per period (unconditional expected profit). Second, deviations from the RNNE were sufficient to tip these small positive profits into negative earnings. In equilibrium weak players win 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, thereby generating a much higher frequency of winning and losing money. This resulted primarily from strong types bidding above the RNNE. In other words, strong types bidding above the RNNE (even by a modest amount) substantially reduces weak players opportunities to earn positive profits. These negative profits are sufficient to explain why weak players tended to bid below the RNNE.

In contrast, with W34 profits for weak types conditional on winning averaged 2.9 per period, close to the what they would earn had they used the Nash reserve prices (4.8 per period), or had they used best response reserve prices (6.4 per period).[7] The positive realized profits, in conjunction with the fact that bidding one's value is a perfectly safe strategy, helps to explain why weak types are bidding closer to equilibrium with W34.

Strong bidders profits averaged quite close to the level predicted: 28.9 per period versus 30.2 predicted with W10 and 20.8 versus 21.5 predicted with W34. In both cases the somewhat lower than predicted profits can be fully accounted for by the fact that strong types consistently bid above the RNNE.

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[7] Profits are calculated using actual bids of both types in the first stage assuming that they chose r^*_{Nash} or r^*_{BR} in the resale stage. Assuming that both bids and reserves follow the RNNE predictions, profits for winning weak players would be 6.8 per period.

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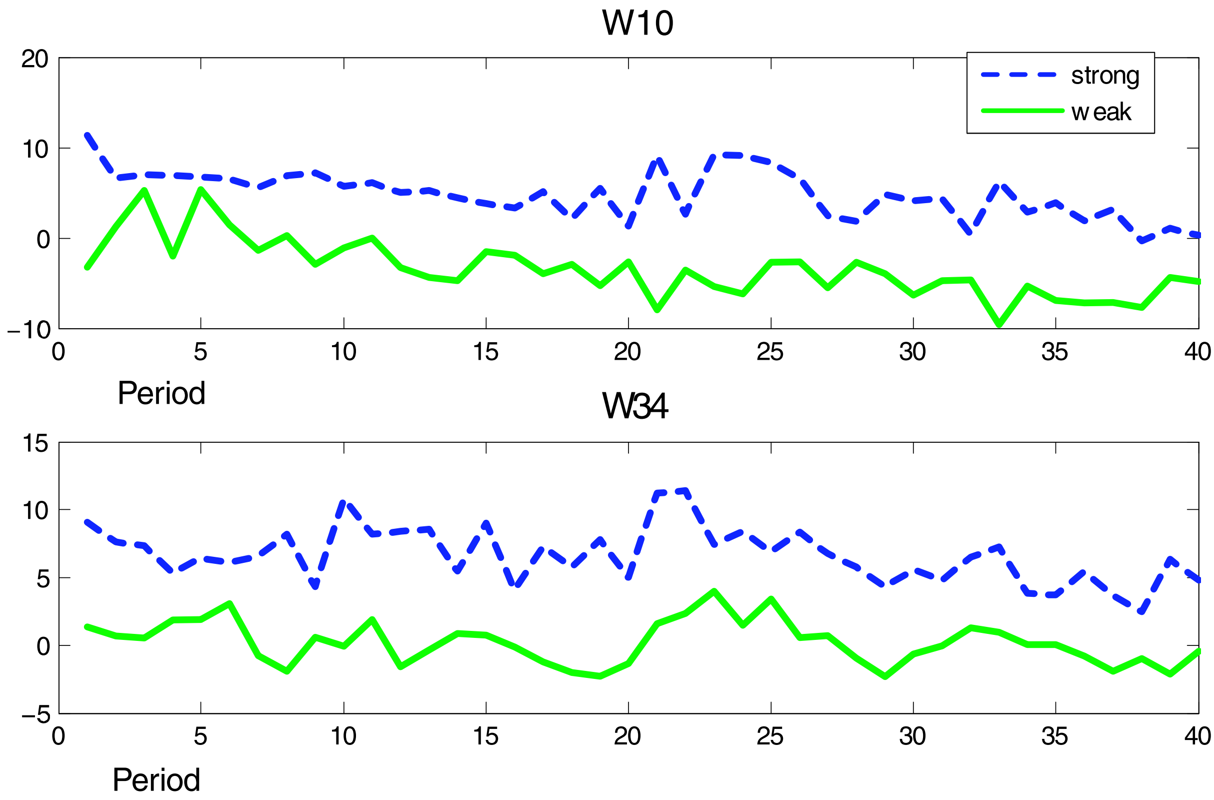

Fig. 3. Bid deviation (actual – theoretical) over time for both types in treatments W10 and W34.

Fig. 3 shows average bids over time. With W10, initial bids of weak types hovered around the RNNE reference point, after which they were consistently below the RNNE, most likely as a result of the negative average profits realized. Strong types started out bidding above the RNNE to begin, and continue to do so, on average, throughout. Note the small spike in bids for both types relative to the RNNE after period 20 when roles were switched, only to revert back to the decreasing time trend fro weak types after 5 or 10 rounds of bidding. There is much less learning/adjustment in bids over time with W34, with strong types bidding above the RNNE throughout, and weak types bidding close to the RNNE. However, here too there was a small spike in bids after roles switched.

First stage auction prices averaged 20 (0.5) per period with W10 compared to predicted prices of 18.8 (0.2) (standard error of the mean in parentheses). Although there is no data for bidding without resale in this treatment, weak types would not be expected to bid above value, with strong types not bidding much above 10 in anticipation (see, for example, the results reported in [5] and in the no resale markets reported on below).[8] Using this as an upper bound for what prices would have been absent resale suggests that resale resulted in at least a doubling of auction prices compared to no resale. Discussion of auction prices with W34 are reported in the next section where we can directly measure the impact of resale on auction prices.

Efficiency predictions in [7] are reported in terms of the average value of final holdings, which is the convention adopted here.[9] Realized efficiency is quite close to predicted efficiency with

[8] Gueth et al. [5] 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.

[9] This is different from the way efficiency is usually measured in experimental auction papers – the average of $(x_H/x_M) \times 100$, where x_H is the value of the ultimate holder of the item and x_M is the maximum value. Large scale

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Table 2
Summary of results for W34 and W60.

			First stage			Second stage	
W34			Prices	Efficiency	% Weak wins	Prices	Efficiency
	resale	predicted	22.6	45.8	47	26.1	51.2
		actual	30.3	46.7	36	31.9	51.7
	no resale	predicted	18.5	51.6	24.4	–	–
		actual	26.9	50.7	25.3	–	–
W60	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	–	–

W10, 48.1 (1.8) predicted versus actual of 49.9 (1.7) (standard errors of the mean in parentheses). Absent directly comparable measures of efficiency for auctions without resale it is not possible to determine if efficiency would have decreased, as predicted with W10. On the one hand bidding above the RNNE by strong types, and below the RNNE by weak types, would have reduced efficiency distortions relative to what would have been predicted with resale. On the other hand, the typical pattern of bidding above the RNNE, means that efficiency would more than likely have been higher than predicted without resale. Efficiency changes for W34 are measured directly in the next section.

5. Dual markets: W34 and W60

The dual market technique allows us to directly evaluate the impact of moving from auctions with no resale to those with resale, all else equal.

Fig. 4 compares bids with and without resale W34 (top panel) and W60 (bottom panel). In both cases there is not much difference in predicted bids for strong types with and without resale, which the box plots confirm for actual bids. But for weak types bids are predicted to increase uniformly with resale. This is clearly true at the aggregate level for all valuations with W34, and at lower valuations ($v_i < 40$ or so) with W60. Individual subjects generally bid more with resale than without it: For W34, using individual subject data as the unit of observation, 79.6% ($n = 49$) of weak types bid higher on average with resale than without.[10] Of these, 89.8% bid significantly higher with resale (based on a one tailed t-test, $p \leqslant 0.05$). Of the remaining bidders, 17.6% bid exactly the same on average and 8.2% bid less, but none significantly less. Data for W60 are comparable: 75.4% ($n = 69$) of weak types bid higher on average with resale than without. Of these, 75% bid significantly higher on average, 5.8% bid the same and 18.8% bid less, but none significantly less.

Table 2 compares prices and efficiency with and without resale under both treatments. For W34, average auction prices 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

simulations indicate that for small predicted increases or decreases in efficiency, the standard experimental measure does not reliably track the predicted changes based on HK's measure.

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

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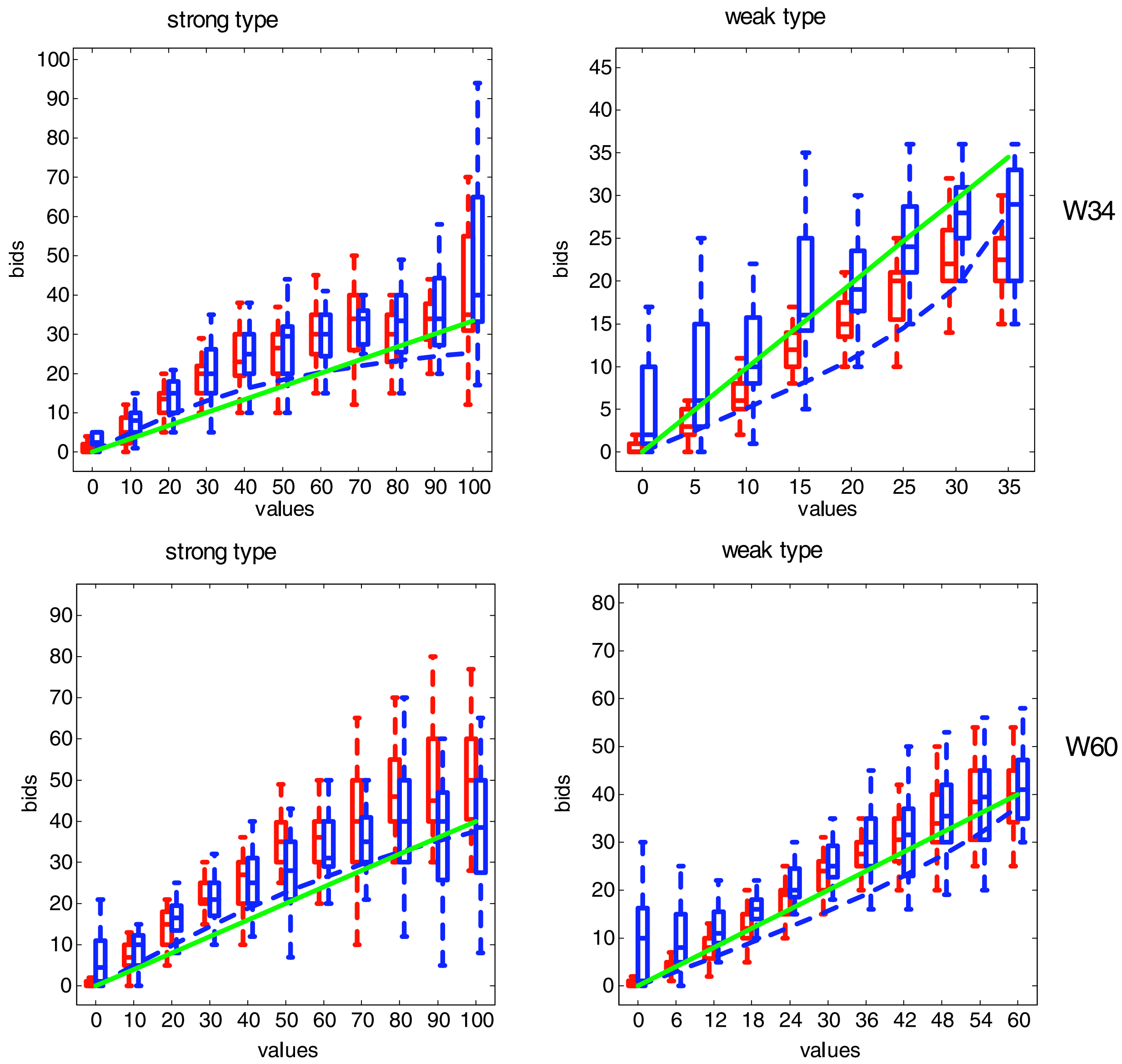

Fig. 4. Boxplots of actual bids for both types with dual markets in treatments W34 and W60. For every block of values on the left, lighter shaded boxplot represents the no resale case, while the darker shaded boxplot is with resale. The solid lines represent the Nash equilibrium with resale, the dotted lines represent the no resale case.

($p < 0.01$, one-tailed t-test), a slightly smaller absolute increase and a much smaller percentage increase (12.6%) based on the higher than predicted no resale prices.

With W60, average auction prices are predicted to increase from 25.4 with no resale to 26.7 with resale. Actual prices *decreased* from 34.7 with no resale to 33.6 with resale ($p < 0.01$, two-tailed t-test). The decrease in average auction prices here can be accounted for by the small increase predicted, in conjunction with the fact that strong types bid considerably more on average without resale than with resale at higher valuations (when they were most likely to win).

Ex ante efficiency is predicted to decrease with resale with W34 and to increase with W60. Large scale simulations show that efficiency decreases from 50.7 with no resale to 50.1 with resale, and increases from 55.2 to 55.4 with W60.[11] Both differences are quite small by any

[11] The simulations employed three million replications in each case.

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standard. The predictions in Table 2 are based on the sample of draws from the experimental data which predict a slightly smaller decrease with W34 (51.6 versus 51.2) as well as a small *decrease* with W60 (54.9 versus 54.3).

For W34, 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 2 show that weak types are winning with about 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%).[12] So the small increase in efficiency in this case can largely be attributed to weak types winning the auction less often than predicted with resale.

For W60, 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 often than predicted without resale which lowers efficiency, and win less often than predicted with resale, which increases efficiency.

One of the key predictions of the model is that with resale the bid distribution for strong and weak types will be the same, but will be readily distinguishable without resale. Fig. 5 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.

For W34 (top panels), with resale the pdfs for weak and strong bidders fail to completely overlap as weak types have a substantially higher frequency of low bids than strong types, 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 although the point prediction of the model is not satisfied here, as rarely occurs in the experimental auction literature, the qualitative implication of the model is satisfied as the differences in pdfs have narrowed considerably. For W34, also note the lower overall frequency of low bids relative to the theory, particularly for strong bidders, compared to what is predicted with resale, along with the tail of high bids not predicted. Both of these effects result from bidding above the RNNE, the typical pattern reported in FPSB action experiments.

For W60 (bottom panels), the differences in pdfs for strong and weak bidders without resale are much smaller than with W34. But still a Kolmogorov–Smirnov test for equality between the two distributions rejects a null hypothesis that they are the same at better than the 1% level. With resale these differences have essentially disappeared, and cannot be detected with a Kolmogorov–Smirnov test ($p = 0.56$).

[12] Strong bidders, after winning the auction also had the opportunity to offer the item for resale. Although the theory predicts no 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 bid patterns.

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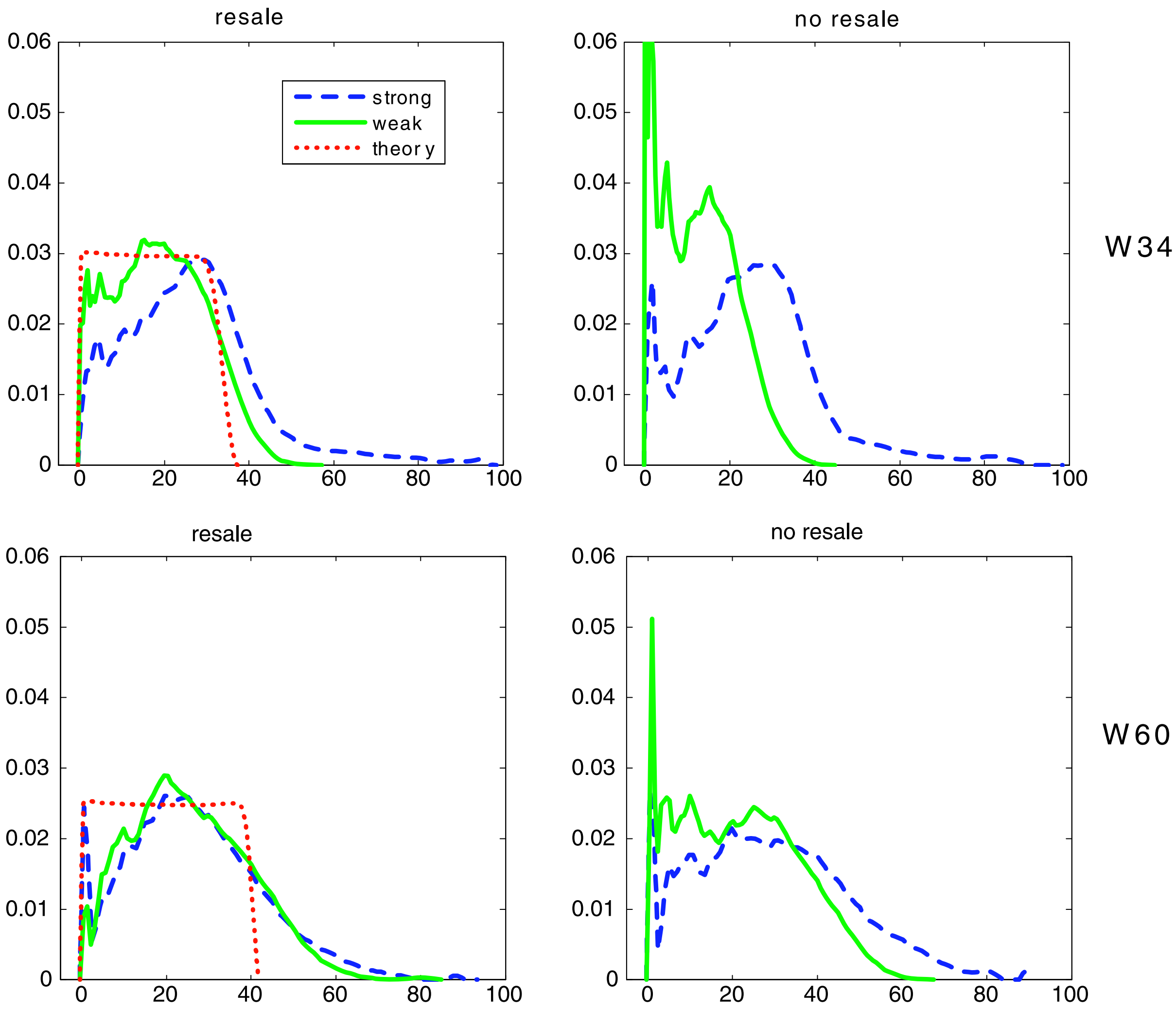

Fig. 5. Kernel density estimates of probability density functions of bids of weak and strong types with resale (left panel) and without resale (right panel) in treatments W34 and W60.

6. Conclusions

HK's [6] model of auctions with resale generate three strong predictions: (1) bidding by weak types should become more aggressive with resale than without, (2) average auction prices increase with resale, and (3) the distribution of bids becomes symmetric so that one cannot distinguish between types on the basis of their bids. Our results show that weak type bids increase in all three treatments. Auction prices increase substantially in the W10 and W34 treatments where the predicted increases are relatively large. But contrary to the theory prices decrease modestly with W60 where the predicted 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 test is not able to distinguish between the two types with resale under the W60 treatment.

Auction 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. The problem with the W10 treatment is that there is little scope for profits for weak types, and a rather unappealing distribution of earnings conditional on winning even if everyone follows equilibrium play perfectly. As such one area for future research will be

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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.

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