Implementing Efficient Multi-Object Auction Institutions:
An Experimental Study of the Performance of Boundedly Rational Agents*

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Abstract

We study three alternative implementations of the Vickrey (1961) multi-unit demand auction: Vickrey's original static sealed-bid auction and two dynamic alternatives, with and without public dropout information reported during the auction (Ausubel, 2004). Although implemented by a weaker solution concept, behavior in the dynamic Vickrey auction with the public dropout information comes significantly closer to the theoretical prediction of sincere bidding, bidding one's valuations, than either the static Vickrey auction or the dynamic auction without dropout information. This suggests a possible tradeoff between the simplicity and transparency of a mechanism and the strength of its solution concept when agents are still learning and/or when players are not fully rational. Drawing on results from related single unit and multi-unit demand auctions, and the results of a new single unit demand auction experiment, we provide important insights into the behavioral mechanism underlying the superior performance of the Ausubel auction.

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In a seminal paper, Vickrey (1961) characterized procedures that provide bidders with incentives to truthfully reveal their values for objects in both single and multi-unit demand auctions. Unlike the well-known and often used single-unit demand version, the multi-unit version is relatively obscure, more complex and rarely used. For example, in their comments to the Federal Communications Commission describing the multi-unit Vickrey auction Nalebuff and Bulow (1993) write (p. 29): "However, experience has shown that even Ph. D. students have trouble understanding the above description. ... The problem is that if people do not understand the payment rules of the auction then we do not have confidence that the end result will be efficient." Indeed, experiments show that bidders often do not use the dominant strategy even in the simpler single-unit demand (second-price) Vickrey auction. In contrast, the same bidders quickly adopt the dominant strategy in the strategically equivalent single-unit, ascending-bid, "English clock" auction (Kagel, Harstad and Levin, 1987).[1]

Mainly in response to these concerns Ausubel (2004) proposed a dynamic implementation of Vickrey's multi-unit auction designed to mimic the success of the English clock auction in the single-unit case.[2] In this auction, at the clock-starting price, each bidder is actively competing for the number of units s/he would demand at that price. As the price rises, a bidder chooses, *unit by unit*, the price at which s/he will cease competing for that unit (possibly reducing demand for multiple units at the same price). Prices paid by winning bidders satisfy the Vickrey price rules. There are two variants to the clock auction. In the first, denoted by *Ausubel** from here on, winners and prices paid are not announced until the auction

[1]This auction has been called a "Japanese clock" auction (see Milgrom and Weber, 1982 and Cassady, 1967).

[2]Also see Perry and Reny (2005) for similar developments, out of similar concerns, in this case for multi-unit demand auctions with interdependencies between units.

has ended. In the second, denoted by *Ausubel* from here on, dropout prices are announced as the auction proceeds, along with announcements of units earned (or "clinched") and prices paid.

With private values and (weakly) diminishing marginal valuations, sincere bidding, where bidders bid their valuations in the static version or reduce their demand for units at prices equal to the value of these units in the dynamic version, is a weakly-dominant strategy in the static Vickrey auction and the Ausubel* (clock) auction. In contrast, and perhaps somewhat surprisingly, sincere bidding is no longer a dominant strategy in the Ausubel auction, although it remains an equilibrium in iterated deletion of (weakly-) dominated strategies (Ausubel, 2004, Theorem 2).

This paper reports an experiment comparing Vickrey's static, multi-object auction and the Ausubel* auction to the Ausubel auction. The experiment employs an *independent-private-value* (IPV) framework in which bidders have weakly diminishing marginal valuations. The Ausubel auction generates behavior closer to sincere bidding, and significantly higher efficiency, than either the static Vickrey auction or the Ausubel* auction. Drawing on results from related single unit and multi-unit demand auctions, and the results of a new single unit demand experiment, we provide important insights into the behavioral mechanism underlying the superior performance of the Ausubel auction.

Our results contribute to the debate concerning the question of which type of auction, static or dynamic, would better perform in multi-unit auctions. They also have important implications for the mechanism design literature. They demonstrate that focusing solely on equilibrium properties and strength of the solution concept in choosing which mechanism to implement may omit important and relevant considerations when learning is still taking place and/or agents are not fully rational. No doubt, with fully rational agents who are able to behave optimally instantaneously, a mechanism that is implemented by a dominant strategy is the most preferred, as it is the most robust and overcomes any strategic uncertainty. In fact, it is the only game theoretic solution concept that assumes individual rationality on the part of players without also requiring common-knowledge of rationality. The latter is a demanding (and quite restrictive) additional assumption needed even for *dominance solvability* (where a unique profile of strategies remains after iterated deletion of dominated strategies) and/or Nash equilibrium. But, if agents are still learning and/or are not fully rational they may benefit from the additional information and transparency embedded in a dynamic format, in spite of possible strategic uncertainty that it may introduce, and thereby come closer to the predicted allocation, even if such implementation employs a weaker solution concept.[3]

We are familiar with six other experimental studies of Vickrey type auctions with bidders demanding multiple units. In four of these - Brenner and Morgan (1997), Isaac and James (2000), List and Lucking-Reiley (2000), and Porter and Vragov (in press) - comparisons are made between the sealed-bid Vickrey auction and some other auction mechanism (e.g., a uniform-price auction).[4] The other two papers are closer in spirit to the present paper. Manelli, Sefton, and Wilner (in press) study multi-unit demand auctions in which there is a significant *common value* component. They focus on the ability of the Ausubel auction to provide bidders with information regarding the common value component as bidders reduce their demand for units, comparing outcomes to the static Vickrey auction. One short section of their paper deals

[3] It is clearly beyond the scope of the present paper to define bounded rationality in terms of whether it is the inability to solve a complex maximization problem, involves limited memory, or involves agents learning how to play the game with some mechanisms easier to learn than others.

[4] In the same vein Kagel and Levin (2001) compare the Ausubel auction with a uniform-price auction when bidders have multiple-unit demands.

with (pure) value auctions, the main concern of our paper. Although the outcomes for their private value auctions are similar in a number of respects to ours (overbidding in the static Vickrey auctions and closer to sincere bidding in the Ausubel auctions), Manelli *et al*. find no efficiency differences between the two auction formats, while we find significantly lower efficiency in the static Vickrey auction.[5] Engelmann and Grimm (2004) compare the Ausubel auction with the sealed-bid Vickrey auction for the private-values case. Bidders have flat demand for two units, with two bidders competing with each other over several auction periods. They report results similar to those found here (superior performance of the Ausubel auction).

The most important difference between the present paper and these last two papers is that we compare outcomes in the Ausubel and static Vickrey auctions to several alternative implementations designed to induce sincere bidding in order to better understand the superior performance of the Ausubel auction.[6] Our results show that the closer proximity to sincere bidding in the Ausubel auction is not due to the introduction of a dynamic format alone, but that the feed back information is an important component of its superior performance.[7] In particular, we provide evidence that a key structural element underlying this positive feedback effect involves the fact that (i) when bidding above value in an effort to win an item, bidders clearly

[5]There are a number of differences between Manelli *et al's* experimental design and ours which we believe help explain why we find efficiency differences between the two auction formats and they do not. These will be discussed in footnotes in the process of characterizing our experimental design.

[6]Kagel, Harstad, and Levin (1987) compared bidding in sealed-bid second-price to ascending English auctions. They report overbidding in the first and almost immediate converges to dominant strategy of truth telling in the later. However, unlike the present study they dealt with single unit demand auctions that are theoretically isomorphic, with both implemented via a dominant strategy. Although these earlier observations suggest that in the multi-unit demand context a dynamic version of the Vickrey auction with a weaker solution concept will outperform the static version, actually demonstrating such an effect is another thing.

face the prospect of losses should they be successful and (ii) if they are successful in these efforts, they always earn negative profits.

The paper proceeds as follows: Section I briefly outlines our experimental design and the alternative auction mechanisms. Section II reports our experimental results. Section III reports results from related single unit and multi-unit demand auction experiments that, in conjunction with the results reported here, help us to better understand the basis for the superior performance of the Ausubel auction. We end with a brief discussion and summary of our results as they apply to auctions and to other experiments investigating mechanism design issues.

I: Experimental Design

Theoretical Considerations: We investigate bidding in IPV auctions with n bidders and m *indivisible* identical objects for sale, where $n \geq m$. Each bidder i (i = 1, ... , n) demands up to two units of the good, placing value v_{ij} on good j. All bidders' values are drawn *iid* from a *uniform* distribution on the interval [0,V].

In the Vickrey auction each bidder simultaneously submits a separate sealed-bid for each unit demanded. These are ranked from highest to lowest, with the m highest bids each winning an item and paying the amount of the k^{th} highest rejected bid**,** other than that bidder's own, for the k^{th} object won. Thus, in cases where a bidder wins only one item she pays the m + 1 highest bid *provided this is not her bid* (in which case she pays the m + 2 highest bid). And in cases where a bidder wins both items the total payment is the sum of the m +1 and the m + 2 highest bids.

The Ausubel auction employs a price "clock" which starts at zero and increases continuously thereafter. Bidders start out actively bidding on all units demanded, choosing what

[7] Harstad (2000) considers many of the issues investigated here in the context of single-unit Vickrey and English clock auctions for the IPV case. We will discuss this work in relationship to ours in section III below.

price to drop out a unit of the bidding. Dropping out a unit is irrevocable. Winning bidders pay the price at which they have "clinched" an item. Clinching works as follows: With *m* objects for sale, suppose at a given price, p_o, bidder *i* still demands two units, but the aggregate demand of all *other* bidders just dropped from *m* to *m*-1. Then, in the language of team sports, bidder *i* has clinched a unit no matter how the auction proceeds. As such, at that moment, bidder *i* is awarded one unit at the clinching price, p_o. This process repeats itself with the supply reduced from *m* to *m*-1 and with *i*'s demand reduced by one unit. In this way the auction sequentially implements the Vickrey rule that each bidder pays the amount of the $k^{\mathbf{th}}$ highest rejected bid, other than his own, for the kth unit won.

With dropout information, all dropout prices are publicly reported as they occur, along with units clinched and the price at which they were clinched. No such information is provided in the Ausubel* auction (the dynamic Vickrey auction *without* dropout information). As a consequence, sincere bidding is a weakly dominant strategy in the Ausubel* auction since bidders have the same information set at their disposal as in the static sealed-bid auctions. In contrast, in the Ausubel auction with dropout information, sincere bidding is the unique equilibrium surviving *iterated* deletion of (weakly-) dominated strategies (Ausubel, 2004).[8]

Experimental Procedures: All valuations were i.i.d. draws from a *uniform* distribution with support [0, $7.50] with new, random draws, in each auction period.[9] There were four bidders in

[8] The Ausubel auction has a number of theoretical advantages over the static Vickrey auction or the Ausubel* auction when valuations have a common value component.

[9]In contrast, Manelli et al. employed only six discrete private values with bidders quoting amounts demanded as prices increased discretely. In one of their two experimental sessions, if the market went from excess demand to excess supply as a result of more than one unit reduction in demand following a price increment unassigned units were not allocated and the auction ended. In the other session the excess units were assigned randomly among active bidders in proportion to the stated demands at the previous price. Our tie-breaking rules and the use of a much finer grid of values eliminate any potential excess supply problems. We also conduct substantially more auctions than Manelli et al.

each auction market, with each bidder demanding two units. In each experimental session two or more markets operated simultaneously, with subjects randomly reassigned to markets between auctions. Demands were weakly decreasing. Supply, *m*, was either 2 or 3 units. All of the clock auctions employed a "digital" price clock with a price increment of $0.25 every 3 seconds. In the Ausubel auctions, information posted on each bidder's screen reported at all times the current price of the item, the number of items for sale, the number of units actively bid on, prices at which bidders had dropped out, as well as any units won and the prices paid for those units. There was a brief pause following any demand reduction so that bidders could recognize that a dropout had occurred and the price at which it occurred. Other units dropping out during this pause, or within the time period between price increments, were recorded as dropping at the same price, but are indexed as dropping later than the dropout that initiated the pause.[10] When bidders clinched an item the clinching price was automatically recorded on their computer screen just below the value of the item, with the profits earned for that item reported just below this. In order to make this information hard to ignore it was posted on the computer screen just above the price clock. Following completion of an auction all dropout prices and valuations were reported back to subjects ranked by dropout prices sorted from highest to lowest, and with own bids clearly distinguished from rivals.[11]

In the Ausubel* auctions all of the information feedback reported above was suppressed until the clock price reached its maximum value of $7.50. At that time all dropout prices and valuations were reported back to subjects in exactly the same format as the clock auctions with

[10]The auction is formally modeled as a continuous-time game. However, we want to take into account the possibility that bidder *j*'s strategy is to reduce his quantity at the soonest possible instant after bidder *i* drops out. This requires allowing "moves that occur consecutively at the same moment in time" (Simon and Stinchcombe, 1989; also see Ausubel, 2004).

[11]The clock auctions with dropout information reported **xxx** in place of the winning (censored) bids.

dropout information. Thus, the computer screens only recorded subjects *own* dropout prices while the auction was in progress. Finally, auctions rules were explained using the same language as in the Ausubel auctions. That is, we continued to use the clinching metaphor to characterize how units were awarded and at what prices.[12]

In the sealed-bid auctions subjects submitted bids on both units simultaneously. All bids and corresponding valuations were reported back to subjects, with bids ranked from highest to lowest, and with own bids clearly distinguished from one's rivals so that subjects had essentially the same end of auction feedback as in the other two cases. Pricing rules were explained to subjects in terms of having earned zero, one or both units, along with the general pricing principle underlying the payoffs. Subjects were required to submit bids on unit 1 followed by unit 2. Any non-negative bid was accepted for unit 1, with the unit 2 bid required to be the same or lower than the unit 1 bid. Earlier multi-unit demand auctions demonstrate that this restriction on unit 2 bids has no effect on bidding (Kagel and Levin, 2001).

Instructions were read out loud with subjects having copies to read. The instructions included examples of how the pricing rules worked. The examples employed placeholders for valuations (instead of actual valuations) in order to minimize any possible inadvertent guidance for how to bid.[13]

All sessions began with two dry runs followed by 12 "wet" runs with $m = 2$, followed by 12 "wet" runs with $m = 3$, and finishing with 12 wet runs with $m = 2$ (see Table 1). Bidders were given starting capital balances of $8 with profits and losses added to this as they occurred. End of session

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[12]A natural alternative is to use the same terminology as in the sealed-bid auctions. For evidence that this makes a difference see Kagel, Kinross, and Levin (2001).

[13]A complete set of instructions are maintained at the web site htpp://www.econ.ohio-state.edu/kagel/MultunitVick.instructions.pdf.

earnings, including the starting capital balances, were paid in cash at the end of the session. Profits were sufficiently high that no participation fee was provided.[14] Sessions lasted for approximately 2 hours. Subjects were recruited through fliers placed throughout the Ohio State University campus and through e-mail solicitation of students taking economics undergraduate classes at the university. This resulted in recruiting a broad cross-section of mostly undergraduate students. Finally, note that in the Ausubel auction, the number of subjects participating in the final $m = 2$ treatment was halved to eight, as this session was running past the time period for which we had recruited subjects, and we had to release several of them given their prior obligations.

II: Experimental Results

Bid Patterns: Table 2 reports the frequency of sincere bidding between the three auction procedures. The unit of observation employed is the mean frequency with which individual bidders were bidding sincerely computed over all 12 auctions for each value of m. Mann-Whitney tests are used to check for significant differences between auction institutions. Further, since winning units auction are censored in the Ausubel as a result of units being won automatically as they are clinched, units won are excluded from these calculations for all three auction institutions to ensure that the data are on the same footing. (These will be dealt with separately below.) Finally, since 25¢ bid increments were employed in the clock auctions, bids are counted as sincere in the clock auctions if the dropout occurred at the clock tick just below the actual value or just above the actual value.[15] To give the sealed-bid auctions the same

[14]Potential profits were large enough that no subject even came close to going bankrupt.

[15]For example, suppose the value was $4.12, the bid would be counted as sincere if the drop occurred at 4.00 or 4.25.

flexibility, a bid is counted as sincere if it occurred within plus or minus 12.5¢ of the actual value.[16]

A methodological aside is perhaps relevant at this point. In using subject averages as the unit of observation we have eliminated possible repeated measures problems associated with observing behavior of the same subject repeatedly within a given experimental session for a given value of *m*. However, we do treat these subject means as independent observations, an issue that is quite controversial in some quarters where it is asserted that data for each experimental session represents a single observation. This is not the place to begin to grapple with the many complex issues that this methodological critique raises (see Frechette, 2006 for discussion of these issues). What is relevant here is the empirical validity of such a claim as it applies here. On this score we note that we have conducted an earlier series of auctions that closely parallel those reported here (Kagel, Kinross, and Levin, 2001). Only in these auctions human bidders with demand for two units compete against computerized rivals each of which demand a single unit and adopt the dominant strategy of bidding their value. In this set-up the behavior of each individual human bidder is clearly an independent observation according to the "each experimental session represents a single observation" critique Results from this experiment closely parallel those reported here.[17] It is these supporting results in conjunction with the fact that there is no empirical support to date for the controversial "each experimental

[16]Effectively it was, ±13¢ of the actual value.

[17] See http://www.econ.ohio-state.edu/kagel/kkl.Vickrey.pdf. In light of these results and the argument offered here a reader might reasonably ask, why conduct the sessions with all human bidders. There are two reasons for this: (1) With computerized rivals the Ausubel auctions involve a single round of deletion of dominated strategies to achieve sincere bidding but there are many more rounds with all human bidders and (2) it is quite natural to ask in the face of these earlier results, whether these results still hold with all human bidders. Nevertheless we consider these earlier results as providing essential support to the present results, with many more observations than those reported here regardless of one's position on the methodological issue that each session is a single observation.

session represents a single observation" critique *as it applies to auctions,* that support our assumption that the behavior of each subject as an independent observation here.

Looking at the data reported in Table 2, there is substantially more sincere bidding in the Ausubel auction than in the sealed-bid auctions for *both* high and low valued units for all values of m, with these differences statistically significant at conventional levels in all cases. Comparing the Ausubel auction to the Ausubel* auction reveals that the differences are quite substantial for the higher valued unit throughout, with statistical significance for the first $m = 2$ and the $m = 3$ treatments, but not for the final $m = 2$ treatment. The latter reflects rather substantial improvement in bidding for the Ausubel* auctions along with the fewer number of subjects over which to conduct the Mann-Whitney tests in the final $m = 2$ treatment. With respect to the lower valued unit, the difference between the Ausubel and Ausuble* auctions is substantial and statistically significant in the first $m = 2$ treatment. But the gap closes and is not significant after that. This reflects both improvement of bidding in the Ausubel* auctions and some deterioration of bidding in the Ausubel auction.

> *Conclusion 1:* There is substantially more sincere bidding to begin with in the Ausubel auction than in either the sealed-bid or the Ausubel* auctions. These differences persist for the sealed-bid auctions, but are gradually eliminated for the Ausubel* auctions.

Table 3 reports the pattern of deviations from sincere bidding between auction institutions. Results for sealed-bid Vickrey auctions are quite clear. There is massive overbidding as evidenced by the frequency of winning items and earning negative profits as a consequence (averaging between 17% - 29% on higher valued units) and the high frequency of bidding above value and not winning.[18] As shown below, the high frequency of winning a unit

[18] The base for the category, "won and earned negative profits," is all units actually won. The base for "all bids greater than v and not win" (as well as all bids less than v), is all non-winning bids. The excluded category "bids

and earning negative profits as a consequence does result in substantially lower profits than would have been obtained with sincere bidding. However, in the static Vickrey auction a bidder does *not* necessarily lose money when bidding above value and wining, so that despite all the overbidding subjects still earned substantial profits, averaging $23.90 per subject (with a range of $7.02 to $39.45). In short, the negative feedback resulting from losses associated with bidding above value and losing money as a consequence were simply not strong enough to deter bidders from overbidding as (i) in a number of cases bidding above value and winning results in earning positive profits and (ii) the dominant strategy of bidding sincerely is not transparent.[19]

In contrast, the major source of deviations from sincere bidding, at least initially, in the Ausubel* auctions consists of bidding *below* value: In the initial $m = 2$ treatment 48% of all bids were below value on the higher valued unit with 33% of all bids below value on the lower valued unit. This persists for the higher valued unit through the $m = 3$ treatment (32% still bidding below value versus 18% above, including units won that earned negative profits), only to be replaced by a somewhat higher frequency of bidding above value for the final $m = 2$ treatment (20% below value versus 28% above, again counting units won that earned negative profit). For the lower valued unit this underbidding is overtaken by bidding above value with the $m = 3$ treatment, and results in even more overbidding with the final $m = 2$ treatment. Thus, the Ausubel* auctions make it clear that the dynamic (clock) format does not, by itself, produce the superior performance of the Ausubel mechanism. Rather, the Ausubel* auction generates a substantial amount of biding below value to begin with, only to be replaced by bidding above

equal to value for non-winning bids" are reported in Table 2. Note that the high frequency with which bidders win and earn negative profits on their lower valued unit masks the fact that this does not happen very often.

[19]We can rule out rivalrous bidding as being responsible for these outcomes as we obtain similar results when subjects compete against computerized rivals (Kagel, Kinross and Levin, 2001).

value as subjects gain experience with the mechanism. We will return to discuss the factors behind the superior performance of the Ausubel auction in Section III where we bring to bear results from related experiments dealing with these issues.

> *Conclusion 2:* Deviations from sincere bidding in the sealed-bid auctions typically involve bidding above value and occasionally suffering losses as a consequence. In contrast, deviations from sincere bidding in the Ausubel* auction, at least initially, usually involve bidding below value. Results from the Ausubel* auctions indicate that it is *not* simply the dynamic nature of the Ausubel mechanism that is responsible for its superior performance relative to the static-Vickrey mechanism. Rather, the feed-back provided by the drop-out information would seem to play a critical role as well.

Efficiency, Profits and Revenue: Table 4 provides data on efficiency, profits and revenue between the three auction mechanisms. Efficiency is measured in the usual way - the sum of the values of the two winning units (three winning units with m = 3) as a percentage of the sum of the values of the highest two (three) units. Efficiency in the Ausubel auctions is consistently in the 98% plus range. In contrast, efficiency in the sealed-bid auctions ranges between 95% in the first m = 2 treatment and 96.9% in the last m = 2 treatment, with the differences from the Ausubel auctions significant at the 5% level or better in all three treatments.[20] Efficiency in the Ausubel* auctions is no better to begin with than in the sealed-bid auctions, averaging 95.7% in the initial m = 2 treatment. Further, efficiency is significantly less than in the Ausubel auctions for all values of m. However, in contrast to the sealed-bid auctions, efficiency losses here result primarily from under**,** rather than over**,** bidding relative to value on the higher valued units.[21]

[20]Manelli et al find no significant differences in efficiency between sealed-bid and Ausubel auctions for their (pure) private value auctions. We suspect this is a result of the far fewer observations in Manelli et al. and/or the coarseness of bidder valuations in their auctions, so that bidding errors comparable to those reported here are less likely to produce inefficient allocations.

[21]In all cases efficiency is significantly better than totally random bidding, where bidders totally ignore their values in determining what to bid, which yields average efficiency rates in the neighborhood of 60%. Random bidding that is restricted to be at or below a bidders own valuations improves efficiency substantially to around 92%, quite close to where the sealed-bid and Ausubel* auctions start.

> *Conclusion 3:* Ausubel auctions have significantly higher efficiency levels than either the static Vickrey auctions or the Ausubel auctions for all auction periods.

We compute average profits across auctions for each value of m and compare them to those *that would have been with sincere bidding*. The most notable result here is that profits per auction won are close to $1.50 and $2.70 *below* what they would have been with sincere bidding in the static Vickrey auction with $m = 2$ and $m = 3$ respectively. This is significantly below the profits earned in the Ausubel auctions in both cases. In the first $m = 2$ treatment profits are significantly higher in the Ausubel* auctions than in the Ausubel auctions. This is a direct result of the high overall frequency of bidding below value, so that winning bidders pay less than they would have with everyone bidding sincerely. The differences from the Ausubel auctions in the $m = 3$ and the final $m = 2$ treatments are no longer statistically significant as the high frequency of underbidding has been reduced substantially.

We compute average revenue across auctions for each value of m and compare them to those that would have been with sincere bidding. Revenue is consistently closest to the predicted outcome in the Ausubel auctions. Consistent with the overbidding found in the sealed-bid auctions, revenue for these auctions is higher than predicted and significantly higher than in the Ausubel auctions. The underbidding in the Ausubel* auctions results in consistently lower revenues than predicted and is significantly below revenue in the Ausubel auction in the initial $m = 2$ treatment, when underbidding was most pronounced.

> *Conclusion 4:* Bidders earn significantly lower profits than predicted in the sealed-bid auctions as a result of overbidding. Bidders earn higher than predicted profits in the Ausubel* auctions due to the underbidding resulting in lower than predicted prices. Consequently, sellers' revenue is significantly higher in the sealed-bid auctions compared to the Ausubel auctions, and lower in the Ausubel* auctions compared to the Ausubel auctions.

III: Further Understanding the Superior Performance of the Ausubel Auction: Results from Other Experiments

In this section we consider two leading explanations for the fact that bids are closer to the predicted truthful bidding norm for the Ausubel auction, with it's weaker solution concept, over the dominant strategy Vickrey and Ausubel* auctions: (1) the *auction format* (*framing effects*) and (2) the *information feedback* bidders receive in the Ausubel auction. Both explanations rely in one way or another on the fact that bidders are either still learning and or are not fully rational.

In what follows we will show that a pure format/framing effect can *not* account for the superior performance of the Ausubel auction. This is demonstrated by Harstad's (2000) single-unit price-list auctions and the Ausubel* auctions reported here. Rather we provide new evidence that the key element behind the high levels of sincere bidding in the Ausubel auction result from the feedback that bidders get as a result of clinching items in real time as the auction progresses. By clinching items as the auction progresses, bidders who are paying reasonably close attention to the clock should be aware that given the auction rules as long as you are actively bidding on a unit and the price is below the value of the item it is necessary to stay active to win the item and make a profit. However, once the price is greater than the value of the item you are bound to lose money should you win the item (and indeed *always* suffer losses with such bids). This feedback is not present in the Ausubel* or static Vickrey auctions. Further, feedback regarding others drop-out prices as the auction proceeds appears to play the secondary role of speeding up this learning process. Insight into this critical role of clinching is obtained from a new, single-unit English clock auction experiment that is described below, along with the results of other experiments demonstrating that format/framing effect do not explain the higher frequency of sincere bidding in the Ausubel auction.

To better understand how the auction format/framing might explain sincere bidding in the Ausubel auction we start by considering second-price sealed bid and English clock auctions for the single-unit IPV case. The two auction formats are strategically equivalent, both having a dominant strategy: Bid one's value in the second-price auctions and stay “in” in the English auction until you win the item or the price reaches your value. Past studies show that while there is almost an immediate convergence to the dominant strategy in the English auction, there is small, but consistent and statistically significant bidding above value in the second-price auctions (Kagel, Harstad and Levin, 1987; Harstad, 2000). Although both auctions are strategically equivalent, they have quite different requirements in terms of bidders' cognitive abilities. In the second-price auction one must find an optimal real number to bid, a strategy which until Vickrey's (1961) seminal paper had not been reported in the literature. Further, anyone who has taught the subject knows that the dominant bidding strategy is not immediately absorbed by a number of students.[22] As such figuring out the correct answer within an experimental session with no prior coaching is quite remarkable.

In contrast, in the ascending price English clock auction the mechanism helps walk the bidder through the logic as they only have to answer the following simple question at each price: “My private value is v, the clock price now shows $x < v$ ($x > v$) do I want to continue to stay active or do I want to drop out?” Further, bidders are aided in answering this question sensibly by the fact that the auction stops once the next-to-last bidder has dropped out. As a consequence,

[22] See Nalebuff and Bulow (1993) cited in the introduction for the multi-unit case. Also see Kagel and Levin (2001) for experimental evidence that explaining the dominant bidding strategy, although increasing the frequency of sincere bidding, is still far from achieving full compliance.

if you are bidding above your value and the clock is still moving a bidder should realize that the price they would have to pay is above their value and respond accordingly. Further, if a bidder is somehow oblivious to this fact, when they win with such a bid, unlike in the second-price auction, they are sure to suffer a loss. Finally, bidders are encouraged to stay active by the fact that as long as the clock price is below their value, there is clearly some potential profit to be made by staying active. Thus, the clock auction format would seem to go a long way towards enabling subjects to reach the right answer, either because of the formatting alone or the formatting in conjunction with the feedback bidders get.

Kagel, Harstad, and Levin (1987) discuss these issues and conjecture that they account for the fact that outcomes are closer to truthful revelation in the clock auctions. Harstad (2000) follows up on this conjecture designing and implementing a new mechanism - “price acceptance list” auctions (p-list for short). After learning their value, subjects are handed a long list of prices around the range of conceivable market prices and asked to name which prices are acceptable for purchasing the item (“yes” or “no”). These lists are then submitted with the bidder with the highest acceptable price winning the item and paying the second-highest acceptable price. Thus, the p-list auction is similar to a second-price sealed bid auction, but instead of naming a price, subjects are encouraged to ask a series of yes/no type questions with respect to price, similar to the clock auction. Mean bids are below valuations in the p-list auction but have a very high variance around the mean indicating considerable heterogeneity in over and under bidding across bidders, as well as possibly for individual bidders over time. Thus, Harstad (2000) rejects the idea that it is the format alone that is responsible for the superior performance of the English clock auction.

To push this inquiry further we conducted what we will refer to as an English** clock auction: a single unit IPV auction with no dropout information provided. However, the auction does have the feature that once the next to last bidder has dropped out of the bidding the auction stops, with the last bidder winning the item at this drop-out price. As a result, bidders in an English** auction who are still active at clock-prices above their values should be aware that they will actually lose upon winning the item. However, no dropout information is provided *prior* to the auction ending. Thus, like the p-list and regular English auction it preserves the yes/no nature of bidders' deciding how much to bid while adding (i) a dynamic element in real time and (ii) information feedback to the effect that as long as they are actively bidding and the price is below their value they must keep active to win the item in order to make a profit and that once the price is greater than their value they are bound to lose money should they win the item (and indeed *always* suffer losses with such bids). However, it stops short of the full English clock auctions in not reporting dropout information prior to the end of the auction.

The experiment was conducted with thirteen subjects bidding in three markets of size four. IPV values were uniformly distributed on the support [0, $8.00], with new valuations drawn following each auction period. Subjects were given starting cash balances of $10 with profits added to this and losses subtracted from it. Bankrupt bidders (one such bankruptcy occurred) were no longer permitted to bid and sent home with the $6 show up fee. A total of 37 auctions were conducted, including two dry runs at the beginning. Bidders were randomly assigned to markets following each auction, with the standby bidder rotated back into the bidding process following each auction, with a new (randomly chosen) subject sitting out. The price clock ticked up by $0.25 every second.

The data are reported in Figures 1 and 2 where the band around the 45^o line is set equal to ±$0.25 to account for the coarseness of the clock. Figure 1 reports data for *all* the auctions, with Figure 2 limited to the *last 15* auctions. The filled circles represent winning bids which are censored. The x's represent drop-outs prices for non-winning bids. Notice that in Figure 1 there are a number of filled circles above the 45^o line indicating that units were won and earned negative profits. There are also a number of drop-out prices above the 45^o line as well, with overall very few drop-outs below the 45^o line. However, for the last 15 auctions these deviations from the dominant bidding strategy have essentially disappeared. In short, subjects in the English** auction start out with significant overbidding in contrast to the almost immediate convergence to the dominant strategy reported for the English auction (Kagel, Harstad and Levin, 1987). However, even here, the frequency of such overbidding is lower than in a typical second-price auction. In contrast, when we restrict attention to the last 15 auctions, bidding is remarkably close to the dominant strategy. Thus, the primary difference between the standard, single-unit, English clock auction with drop-out prices reported and the present auction is that the additional drop-out information speeds up learning and convergence to the dominant bidding strategy.

These results, taken as a whole, strongly suggest that an essential feature of the English clock auction producing the dominant bidding strategy is the feedback inherent in the auction structure. Support for this conclusion is derived from our results for the multi-unit Ausubel* auction, which only stops when everyone has dropped out or the clock reaches the maximum possible private valuation. As already noted, these auctions have significantly less sincere bidding than in the Ausubel auction. The Ausubel* auction has the same format/framing effect as the Ausubel auction but is missing the feedback inherent in the real time clinching structure which is the same as in the single unit clock auction: as long as you are actively bidding on a unit and the price is below the value of the item it is necessary to stay active to win the item and make a profit, but once the price is greater than the value of the item you are bound to lose money should you win the item (and indeed *always* suffer losses with such bids).

A natural question that remains here is why do the deviations from sincere bidding result in bidding below value in the Ausubel* auctions compared to bidding above value in the static Vickrey auctions? We believe that this difference results from a rather subtle framing effect. Kagel, Kinross, and Levin (2001) report results from an experiment in which human bidders demanding two units were competing against computer rivals, each of which demanded a single unit.[23] They conducted two sessions with the dynamic Ausubel* auction that differed only with respect to the way outcomes and payoffs were characterized: One session used the same terminology as in the static Vickrey auctions. The other session used the same clinching terminology as in the Ausubel auctions. When using the sealed-bid terminology the subjects typically deviated from sincere bidding by bidding above their values, just as in the static Vickrey auction. In contrast, using the clinching terminology subjects typically deviated from sincere bidding by bidding below their values.[24] That is, there appears to be a clear framing effect as a consequence of the language employed in the instructions in terms of whether the deviations from sincere bidding involve bidding above or below bidders' values in the Ausubel* auctions.

[23] The computers were programmed to follow the dominant strategy of sincere bidding (a fact known to the human bidder).

[24] For example, in auctions with 3 computer rivals 46.7% (17.1%) of all bids were above (below) value by more than $0.25 using the sealed bid terminology versus 18.8% (33.8%) above (below) value using the clinching terminology.

IV: Discussion and Concluding Remarks

Bidding in the Ausubel auctions is much closer to equilibrium than in the static sealed-bid Vickrey auction. This superior performance of a dynamic auction with drop-out information over a static sealed-bid auction mechanism replicates results reported for a variety of auction institutions and demand structures: uniform-price multi-unit demand auctions with and without synergies (Kagel and Levin, 2001, 2005), single-unit, private-value auctions (Kagel, Harstad, and Levin, 1987), and single-unit common value auctions (Levin, Kagel, and Richard, 1996). It is consistent with, and supports the intuition that dynamic auctions with dropout information provide a transparency that simplifies the bidding task, which is lacking in static sealed-bid auctions. The fact that the Ausubel auctions outperform the Ausubel* auctions strongly suggests that the closer proximity to sincere bidding is not due just to the introduction of a dynamic format alone but that the feed back information inherent in the auction structure is an important component of the superior performance. In particular, we provide new evidence that a key structural element underlying this positive feedback effect involves the fact that clinching occurs in real time. As such bidders paying a reasonable amount of attention to the clock price relative to their values should be aware that as long as they are actively bidding on a unit, and the price is below the value of the item, it is necessary to stay active to win the item and make a profit. But once the price is greater than the value of the item, they are bound to lose money should they win the item (and indeed *always* suffer losses with such bids).

Differences in behavior between the theoretically isomorphic static Vickrey auctions and the Ausubel* auctions, as well as between the strategically equivalent survivor auctions (Kagel, Pevnitskaya, and Ye, in press) and the Ausubel auctions, make it clear that there are strong behavioral elements involved in bidding that economic theory does not capture. Similar breakdowns between theoretically isomorphic auction institutions have been reported for single-unit auctions (Cox, Roberson and Smith, 1982; Kagel, Harstad and Levin, 1987). Further, Chen and Tang (1998) report *systematic* differences between two incentive-compatible mechanisms for public goods provision that have the same Nash equilibrium outcome.[25] They even report systematic differences within the same mechanism between a low and high punishment parameter when the Nash equilibrium predicts that the magnitude of the punishment parameter should have no effect. However, in all of these cases the *same* solution concept underlies the mechanisms in question.

Here, however, although all three auction mechanisms investigated - the static Vickrey auction, the Ausubel* auction and the Ausubel auction - predict sincere bidding, the clear "winner," the Ausubel auction, implements it by a weaker solution involving *iterated deletion of weakly-dominated strategies.* In contrast, the Vickrey and Ausubel* auctions implement it with the stronger *dominant strategy* solution. The ascending prices in the Ausubel auction in conjunction with the provision of dropout information underlie *both* the greater transparency of the auction rules and the weakening of the solution concept.[26]

In the mechanism design literature, it is taken for granted that the stronger the solution concept used to implement an allocation, the more likely the mechanism is to achieve its predicted outcome, with a dominant strategy mechanism constituting the most preferred solution concept (see, for example, Kreps, 1990). There is no argument that with fully rational agents this approach is the correct one. Implementation by a dominant strategy mechanism is extremely

[25] Also see Healy (2006).

[26] The ascending prices, along with the dropout information, enrich the strategy space, allowing strategies that are contingent on other agents' previous moves, which is what weakens the solution concept.

valuable because it is robust: It does not depend on common-knowledge of rationality, and assumptions on preferences and/or distributions of signals which weaker solution concepts do. However, even a dominant strategy implementation requires full individual rationality. But what if agents are still learning how to play the game or are less than fully rational? In this case a possible tradeoff emerges: Although the richer strategy space that underlies the weaker solution concept may introduce all kinds of "misbehavior," it may also help agent's converge to the equilibrium outcome. When the simplifications help more than the additional strategic ambiguity hurts, as is the case here, we might expect the surprising result of closer proximity between behavior and theoretical predictions with the weaker solution concept. This insight is codified in the following conclusion:

> *Conclusion 5:* Implementation by a mechanism that has a weaker solution concept but that is more transparent may result in closer conformity to the planner's desired outcome. The closer conformity to sincere bidding in the Ausubel auction compared to the sealed-bid Vickrey auction and the Ausubel* auction provide demonstrations of such an effect.

The potential tradeoff identified here between strength of the solution concept versus simplicity is not just relevant to the multi-unit Vickrey auction, but to the applied mechanism design literature in general.[27] From this perspective a number of important questions remain to be answered. First, will the tradeoff generalize beyond the present situation? Will it extend to situations when the more transparent mechanism is substantially weaker than the one employed here, i.e., one with a Nash equilibrium not supported in iterated deletion of dominated strategies? Second, can we establish quantifiable measures for simplicity/transparency that enable us to predict *in advance* what kind of simplifications will improve mechanism performance even at the

[27] In this respect also see Healy (2006) who shows that in comparing between alternative public good mechanisms the best response pattern to out-of-equilibrium play is critical to determining the best performing mechanism.

expense of strength of solution concept? These and related questions provide the agenda for future research.

References

Ausubel, L. M., “An Efficient Ascending-Bid Auction for Multiple Objects,” *American Economic Review* 95, 2004, 1452-1475.

__________ and Cramton, P. C., “Demand Revelation and Inefficiency in Multi-Unit Auctions,” mimeographed, Un. Maryland, 1996.

Brenner, D. and Morgan, J., “The Vickrey-Clarke-Groves versus the Simultaneous Ascending Auction: An Experimental Approach,” Princeton University, 1997.

Cassady, Ralph, Auctions and Auctioneering, Berkeley: University of California Press, 1967.

Chen, Yan and Fang-Fang, Tang, “Learning and Incentive-Compatible Mechanisms for Public Goods Provision: An Experimental Study,” *Journal of Political Economy* 106, 1998, 633-62.

Cox, C. R., Roberson, B. and Smith, V. L. “Theory and Behavior of Single Object Auctions,” in Research in Experimental Economics, Vol, 2, V. L. Smith (ed.). Greenwich, Conn: JAI Press, 1982.

Engelmann, Dirk and Grimm, Veronica, “Bidding Behavior in MultiUnit Auctions – An Experimental Investigation and Some Theoretical Insights,” working paper, Department of Economics, University of London, 2004.

Frechette, Guillaume R., “Session Effects in the Laboratory,” unpublished paper, 2006.

Fujishima, Y, McAdams, D. and Shoham, Y., “Speeding Up Ascending Bid Auctions,” *Proceedings, International Journal Conference in Artificial Intelligence*, 1999.

Harstad, Ronald, “Dominant Strategy Adoption and Bidders’ Experience with Pricing Rules,” *Experimental Economics* 3: 2000, 261–280.

Healy, Paul J., “Learning Dynamics for Mechanism Design: An Experimental Comparison of Public Goods Mechanisms,” *Journal of Economic Theory* 129, 2006, 114-149.

Isaac, R. M. and James, D., “Robustness of the Incentive Compatible Combinatorial Auction,” *Experimental Economics*, 3, 2000, 31-54.

Kagel, J. H., Kinross, S, and Levin, D., “Implementing Efficient Multi-Object Auction Institutions" mimeographed, Ohio State University, September 2001.

Kagel, J. H., Harstad, R. M. and Levin, D., “Information Impact and Allocation Rules in Auctions with Affiliated Private Values: A Laboratory Study,” *Econometrica* 55, 1987, 1275-1304.

Kagel, John H. and Levin, Dan, "Behavior in Multi-Unit Demand Auctions: Experiments with Uniform Price and Dynamic Vickrey Auctions," *Econometrica* 69, 2001, 413-454.

__________ and _________, "Multi-Unit Demand Auctions with Synergies: Behavior in Sealed-Bid versus Ascending-Bid Uniform-price Auctions," *Games and Economic Behavior* 53, 2005, 170-207.

Kagel, J. H., Pevnitskaya S., and Ye, L., "Survival Auctions," *Economic Theory* (in press).

Kreps, David M., A Course in Microeconomic Theory, Princeton, Princeton University Press, 1990.

Levin, D., Kagel, J. H., and Richard, J-F, "Revenue Effects and Information Processing in English Common Value Auctions," *American Economic Review*, 86, 1996, 442-460.

List, John A. and David Lucking-Reiley, "Demand Reduction in Multi-Unit Auctions: Evidence from a Sportscard Field Experiment," *American Economic Review*, 90, 2000, 961-72.

Manelli, Alejandro M., Sefton, Martin, and Wilner, Benjamin S., "Multi-unit auctions: A Comparison of Static and Dynamic Mechanisms," *Journal of Economic Behavior and Organization* (in press).

Milgrom, Paul and Robert Weber, "A Theory of Auctions and Competitive Bidding," Econometrica 50, 1982, 1089-1122.

Nalebuff, Barry J. and Bulow, Jeremy I., "Designing the PCS Auction," Comment to the FCC on behalf of Bell Atlantic, 1993.

Perry, Motty and Reny, Philip, "An Ex-Post Efficient Ascending Auction," *Review of Economic Studies* 72, 2005, 567-592.

Porter, David and Vragov, Roumen, "An Experimental Examination of Demand Reduction in Multi-Unit Versions of the Uniform-Price, Vickrey and English Auctions," *Journal of Management and Decision Economics* (in press).

Simon, L. K. and Stinchcombe, M. B., "Extensive Form Games in Continuous Time: Pure Strategies," *Econometrica* 57, 1989, 1171-1214.

Vickrey, William, "Counterspeculation, Auctions, and Competitive Sealed Tenders," *Journal of Finance* 16, 1961, 8-37.

Table 1
Experimental Treatments

Institution	Session	Units Supplied[a]	Number of Subjects
Static (sealed-bid) Vickrey Auction	1	2 per 1-12 3 per 13-24 2 per 25-36	8
	2	2 per 1- 12 3 per 13-24 2 per 25-36	12
Ausubel Auction (dynamic Vickrey auction with feedback Information)	3	2 per 1- 12 3 per 13-24 2 per 25-36	16[b]
Ausubel* Auction (dynamic Vickrey auction with no feedback Information)	4	2 per 1- 12 3 per 13-24 2 per 25-36	12
	5	2 per 1- 12 3 per 13-24 2 per 25-36	16

a Preceded by two dry runs with 2 units supplied.
b Eight subjects in periods 25-36 as time constraint required several subjects to leave after completing period 24

Table 2

Frequency of Sincere Bidding

(Standard errors of the mean in parentheses.
Differences from Ausubel auctions in bold.)

	Higher valued unit			Lower valued unit		
	Ausubel	Sealed-Bid	Ausubel*	Ausubel	Sealed Bid	Ausubel*
m=2	0.828 (0.052)	0.175 (0.046) **0.653****	0.430 (0.058) **0.398****	0.761 (0.077)	0.167 (0.042) **0.594****	0.451 (0.055) **0.310****
m=3	0.833 (0.042)	0.134 (0.063) **0.699****	0.523 (0.076) **0.310***	0.676 (0.083)	0.222 (0.055) **0.454****	0.596 (0.056) **0.080**
m=2	0.783 (0.079	0.233 (0.073) **0.550****	0.571 (0.073) **0.212**	0.556 (0.135)	0.205 (0.067) **0.351***	0.510 (0.064) **0.046**

* Significantly different from 0 at the 5% level
** Significantly different from 0 at the 1% level

Table 3

Comparison of Bid Patterns Between Auction Mechanisms

(Standard errors of the mean in parentheses.
Differences from Ausubel auctions in bold.)

	Higher Value Unit			Lower Valued Unit		
m=2	Ausubel	Sealed-Bid	Ausubel*	Ausubel	Sealed-Bid	Ausubel*
Won and earned negative profits	0.009 (0.047)	0.290 (0.130) **0.281****[**]	0.046 (0.023) **0.037**	0.125 (0.210)	0.611 (0.232) **0.486**[*]	0.222 (0.147) **0.097**
Bid > v and not win	0.050 (0.112)	0.575 (0.137) **0.525**[**]	0.089 (0.017) **0.039**	0.180 (0.134)	0.642 (0.128) **0.462**[**]	0.217 (0.054) **0.037**
Bid < v	0.122 (0.089)	0.250 (0.127) **0.128**	0.481 (0.063) **0.359**[**]	0.060 (0.079)	0.192 (0.108) **0.132**[*]	0.332 (0.055) **0.272**[**]
m=3						
Won and earned negative profits	0.000 (0.000)	0.175 (0.093) **0.175**[**]	0.028 (0.013) **0.028**[+]	0.103 (0.148)	0.474 (0.192) **0.371**[*]	0.110 (0.055) **0.007**
Bid > v and not win	0.069 (0.101)	0.710 (0.143) **0.641**[**]	0.156 (0.064) **0.087**	0.294 (0.142)	0.643 (0.134) **0.349**[**]	0.230 (0.053) **-0.064**
Bid < v	0.098 (0.094)	0.156 (0.126) **0.058**	0.321 (0.073) **0 .223**	0.031 (0.055)	0.135 (0.108) **0.104**	0.174 (0.053) **0.143**[+]
m=2						
Won and earned negative profits	0.000 (0.000)	.282 (0.088) **0.282**[**]	0.054 (0.018) **0.054**[+]	0.250 (0.421)	0.550 (0.223) **0.300**	0.308 (0.121) **0.058**
Bid > v and not win	0.139 (0.174)	0.652 (0.143) **0.513**[**]	0.225 (0.065) **0.086**	0.400 (0.215)	0.695 (0.135) **0.295**[+]	0.321 (0.052) **-0.079**
Bid < v	0.078 (0.124)	0.115 (0.109) **0.037**	0.204 (0.064) **0.126**	0.044 (0.106)	0.101 (0.099) **0.057**	0.169 (0.052) **0.125**

+ Significantly different from 0 at the 10% level
* Significantly different from 0 at the 5% level
** Significantly different from 0 at the 1% level

Table 4

Comparisons of Efficiency, Profits and Revenue

(Standard errors of the mean in parentheses.
Differences from Ausubel in bold.)

	Efficiency			Bidder Profits (difference from sincere bidding)			Seller Revenue (difference from sincere bidding)		
	Ausubel	Sealed-Bid	Ausubel*	Ausubel	Sealed-Bid	Ausubel*	Ausubel	Sealed-Bid	Ausubel*
m = 2	98.3% (0.77)	95.0% (0.15) **-3.31%****	95.7% (0.81) **-2.60%****	0.018 (0.138)	-1.465 (0.254) **-1.483****	0.314 (0.188) **0.296**+	-0.211 (0.101)	0.856 (0.197) **1.067****	-0.833 (0.147) **0.622****
m = 3	98.8% (0.59)	95.2% (0.12) **-3.56%****	97.4% (0.57) **-1.40%****	-0.061 (0.114)	-2.726 (0.369) **-2.665****	0.203 (0.240) **0.264**	-0.134 (0.089)	1.964 (0.341) **2.098****	-0.672 (0.239) **-0.538**
m = 2	98.8% (1.24)	96.9% (1.34) **-1.90%***	96.8% (0.67) **-2.00%****	-.316 (0.228)	-1.523 (0.238) **-1.204****	-.203 (0.148) **0.113**	.154 (0.098)	1.20 (0.180) **1.046****	-.212 (0.133) **-0.366**

+ Significantly different from 0 at the 10% level
* Significantly different from 0 at the 5% level
** Significantly different from 0 at the 1% level

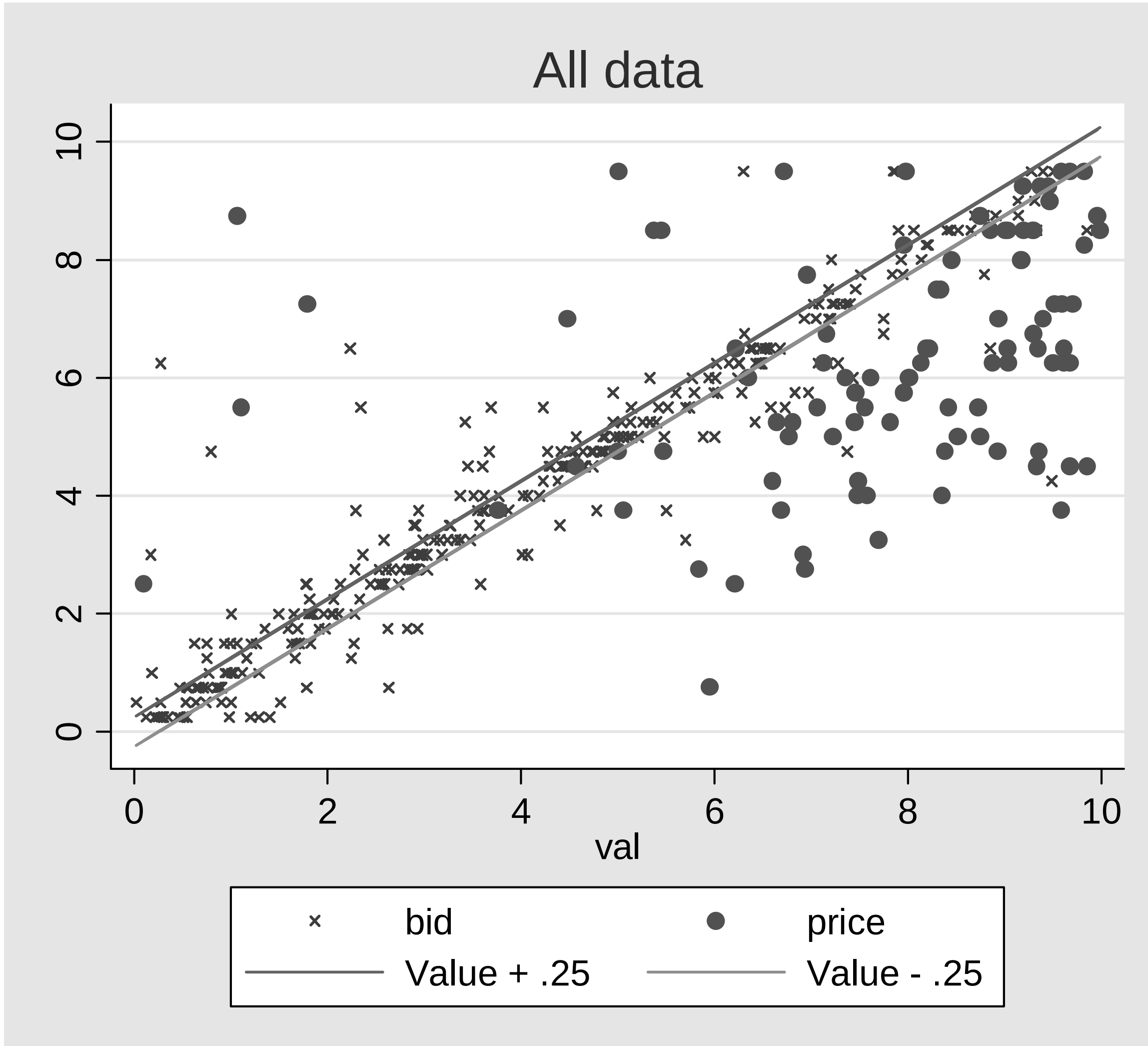

Figure 1

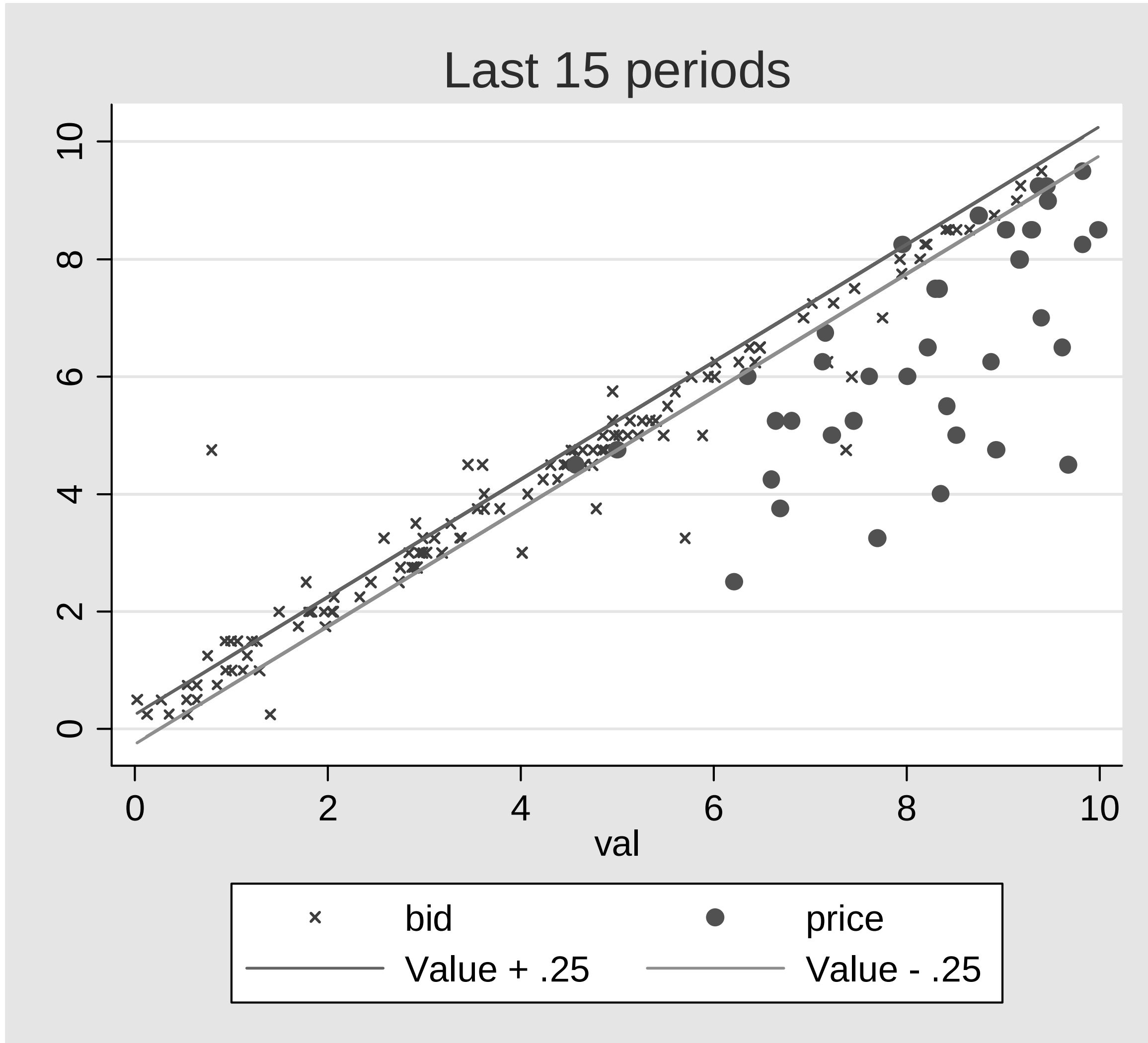
Last 15 periods
0
2
4
6
8
10
0
2
4
6
8
10
val
bid
price
Value + .25
Value - .25

Figure 2