An Evaluation of the Proposed Procurement Auction for the Purchase of Medicare Equipment: Experimental Tests of the Auction Architecture[1]

Caroline Kim, Brian Merlob, Kathryn Peters,
Charles R. Plott, Andre Pradhana and Yuanjun Zhang
California Institute of Technology
Preliminary Draft, October 2010

This study focuses on the basic structure of the Medicare supplies auction, which is proposed as a central feature of the Medicare Bidding Program. We report on experiments conducted with auctions that have the major features of the auction but are also sufficiently simple to allow the identification of the basic causes of successes and failures. [2]

While the experimental application of the auctions is simple relative to the intended application to Medicare equipment supplies sales, the auction architecture is the same as proposed for the Round One demonstration auctions. Thus, the experiments provide an informative test of the natural strategies the auction rules evoke. Auction architectures performing poorly in the simple cases provide a realistic warning about problems that can surface in complex cases. Furthermore, if the behavior observed in the simple auctions is understandable in terms of theory, then there is reason to take that theory seriously when applied to the complex cases.

The basic conclusions of the study are:

1. Good auction architectures for procurement applications do exist.
2. The proposed Medicare supplies auction is not a good procurement auction. It is based on an inappropriate architecture that cannot deliver services at competitive rates and qualities.
3. The Medicare supplies auction architecture cannot be adjusted in some simple way. There is no "quick fix". The two central pillars of the auction are flawed. First, the price determination by the median accepted bid is not an appropriate method for determining price. Second, the ability of bidders to cancel bids is an inappropriate guide for competitive bidding strategies.

The report contains four sections. The first section illustrates the operation of an auction architecture that is known to function well. The section introduces methods for evaluating auction performances and illustrates their application to the data from experiments. The second section focuses on an auction with the key feature of the proposed Medicare supplies auction and demonstrates both the existence and severity of the architecture flaws. The third section reports on auctions with variations of the central

[1] The financial support of the Caltech Laboratory for Experimental Economics and Political Science of the Gordon and Betty Moore Foundation are gratefully acknowledged.

[2] We conducted two experiments using identical experimental parameters and procedures with different subjects. For both experiments, five different auctions were tested. Each auction had the same experimental environment, but a different set of rules. Sellers in these auctions sell only one unit under the auction rules. Following classical experimental economics testing procedures, the costs are determined randomly from auction to auction and the seller keeps any profits made (the payments are not large but they are real)
The potential suppliers' cost of production was drawn independently from a uniform distribution between 100 and 1000 ECUs. The number of potential suppliers participating in the auction was always 12, and the number of units demanded was always 7. Participants were allowed a minimum bid of 50 ECUs and a maximum bid of 1050 ECUs. The number of trial periods per type of auction varied from 10 to 15 trial periods per experiment to prevent participants from altering behavior in anticipation of the experimental sessions ending. In each trial period, participants had a different cost of production. At the end of the experiment, participants exchanged their total profits for their value in dollars.

pillars of the Medicare services auction. The results of this third section suggest that simple removal of one of the faulty procedures do not correct the problems with the proposed Medicare equipment auction. Indeed the removal of only one feature may create new problems. The fourth section demonstrates the consistency of the data with the theory of bidding in auctions. It demonstrates that the Medicare equipment auction architecture flaws are understandable and are predicted by auction theory. Furthermore, theory indicates that the problems of the auction will become exacerbated with the scale of the application.

For convenience, we abbreviate the auctions as follows:

PVN meaning partial information (only market price is public) using the excluded bid auction architecture known to the literature as the Vickrey-Clark-Groves mechanism, **with no** cancellation option.

PMN meaning partial information (only market price is public) using the median price determination rule (market price set by median of accepted bids), **with no** cancellation option.

PMC meaning partial information (only market price is public) using the median price determination rule (market price set by median of accepted bids), **with** cancellation option.

FMC meaning **full** information (only market price is public) using the median price determination rule (market price set by median of accepted bids), **with** cancellation option.

PVC meaning partial information (only market price is public) using the excluded bid auction architecture known to the literature as the Vickrey-Clark-Groves mechanism, **with** cancellation option.

SECTION ONE: (PVN) THE EXCLUDED BID AUCTION

To serve as a reference point, we introduced the reader to an auction known to have good performance in theory and in practice: one that produces competitive revenue (cost), encourages participants to reveal their true costs, and assigns goods efficiently. In this auction - the Vickrey-Clarke-Groves mechanism - bids are binding and the price is determined by the *first excluded bid*.

A. PVN Auction rules:

Bids are ranked from lowest to highest. The lowest seven bids are chosen as winners and the price paid to all seven is the value of the first excluded bid, or in this case, the eighth lowest bid. The winning price is announced, but all bids and information remain private.

B. PVN Auction performance:

The number of excluded bids auctions studied is 24. In each auction, the buyer places a value of 1050 on each of seven units and wants to purchase all seven.

i. *Procurement success* is measured in terms of the number of units purchased. As illustrated in Figure 1 the excluded bid auction always delivers the number of units demanded. In success terms the measure of success is always 100%

ii. *Pricing success* is measured in terms of the degree to which auction prices approximate the competitive price. The competitive price is defined as the cost of the lowest cost excluded unit. The costs are known because the data comes from an experiment in which parameters are known to the experimenter. Figures 4 and 6 contain the pricing patterns. As can be seen the

prices in the excluded bid auction no cancellation (PVC) are near the competitive equilibrium price on average and are otherwise distributed near the competitive equilibrium price.

iii. *Efficiency success* has three related measures: social perspective, government perspective and seller perspective. In all cases the measure of what actually happens is taken relative to what would happen if prices and allocation were determined by the competitive price. Social efficiency is the classical cost/benefit ratio. Government efficiency is the buyer's (government) half of that ratio. Seller efficiency is the seller half of the ratio. Figure 7 reports that the PVN (the excluded price auction) is essentially 100% according to all three measures. The government gets all it needs and the sellers are those with the lowest cost among all sellers. Prices are near the competitive price so both the government and the seller's efficiencies are near 100%.

SECTION TWO: (PMC) THE MEDIAN WINNER PRICED AUCTION WITH CANCELLATION ALLOWED

To gauge the performance of the Medicare supplies, we conducted scaled versions of the median price auction with a cancellation option. Comparisons of these results to the excluded bid auction (Vickrey-Clark-Groves) demonstrate a disparity and relatively poor performance of the median price auction with the cancellation option along all performance measures: auction success, pricing and efficiency.

A. PMC Auction rules:

Bids are ranked from lowest to highest. The lowest seven bids are chosen as initial winners and the price paid to all of the ultimate winners is the value of the median of the seven chosen as initial winners. Cancellation is allowed and made simultaneously after price is announced. With any cancellation by an initial winner the bidder with the next lowest bid has the opportunity to become an ultimate winner at and receive a price equal to the previously announced median bid. The market price is announced but all bids remain private information.

B. PMC Auction performance:

i. Procurement success is reported in Figure 2 and Figure 3. As can be seen approximately 20% of these auctions have no procurements at all and 25% of the auctions succeed in procuring as much as 14% of the number of desired units. Less that 5% of the auction succeeds in 85% or more of the desired procurement. The rate of successful procurement is 47.7% with an average of 3.34 items sold per trial period.

ii. Pricing successes are reported in Figures 4, 5 and 6. On average the price is 54.3% of the completive price but as shown in Figure 6 the market price in the PMC auction is frequently much lower than the competitive price. This accounts for the poor procurement performance.

iii. Efficiency successes are reported in Figure 7. On average, social efficiency is 53.78%. Because prices tend to be so low the governmental efficiency level is high. The government gets a bargain when it manages to get anything at all but the efficiency at 73.8% is far from the 100% efficiency of the PVN. The low prices mean that sellers suffer. Seller efficiency is 29.3% on average. The implication is that insufficient resources will be drawn into the supply chain for providing equipment.

SECTION THREE: TESTING AUCTION ARCHITECTURE MODIFICATIONS

3.1. (FMC) Modification 1: Bidders participated in a median price auction with cancellation under conditions of full information. Bidders were shown costs and bids.

A. FMC Auction rules:

Bids are ranked from lowest to highest. The lowest seven bids are chosen as initial winners and the price paid to all of the ultimate winners is the value of the median of the seven chosen as initial winners. Cancellation is allowed and made simultaneously after price is announced. With any cancellation by an initial winner the bidder with the next lowest bid has the opportunity to become an ultimate winner at and receive a price equal to the previously announced median bid.

This auction is studied to determine the sensitivity of the auction to the information patterns held by bidders. All bidders knew all costs of all other bidders before placing any bids. After the auction the bids of all bidders became public and thus could be studied prior to following auctions. Collusion and discussions of strategies were prevented.

B. FMC Auction performance:

The number of median price auctions with full information is 26. Basically, revelation of information does not help and in fact hurts.

i. Procurement success is the poorest of all tested. The results reported in Figure 3 are that this auction that over half of the time there are fewer than 14% of the desired procurement successfully procured. The rate of successful procurement is 31.3% with an average of 2.19 purchases per trial period out of the seven demanded.
ii. Pricing success is the reason for the poor performance. As shown in Figures 4, 5, and 6 this auction achieves the competitive price less than 40% of the time and on average is 39.3% of the competitive price. Indeed in over 25% of the time the market price is less than 14% of the competitive market price.
iii. Efficiency success is the poorest of all auctions studied. The social efficiency is 35.3% on average and as a result neither the government nor the sellers benefit as is revealed by Figure 7.

3.2. (PMN) Modification 2: Subjects participated in a median price auction with no cancellation permitted.

A. PMN Auction rules:

Bids are ranked from lowest to highest. The lowest seven bids are chosen as winners and the price paid to all seven is the value the median of the seventh lowest bids, or in this case, the 4^{th} lowest bid.

B. PMN Auction performance:

The number of median price auctions with no cancellation is 26.

i. Procurement success of this auction is 100% as is revealed by Figure 3 (which is a bit hard to read). The government always gets 100% of what it wants but of course it must since winning sellers have no option except to sell at the market determined price.
ii. Pricing success is better than PMC but it is not as good as PVN. The auction results in higher bids than PVC as bidders try to avoid the loss exposure created by an auction in which they might be forced to sell at prices below their cost. The price data are reported in Figures 4, 5 and 6. On average, the price is 88.6% of the competitive price.
iii. Efficiency success is high from the social efficiency and government efficiency points of view. Social efficiency is high because the government gets all it needs and the successful sellers are those with the lowest cost. On average, the social efficiency of this auction is 97.4%. Efficiency from the government point view is high since it gets what it wants and prices are below the competitive price. Seller efficiency is low because some are forced to sell at prices below cost due to the uncertainty of the auction price. This auction scheme has an average of 124.6% of government surplus efficiency and 68.7% of seller surplus efficiency.

3.3. (PVC) Modification 3: Subjects participated in an excluded bid (Vickrey-Clark-Groves) auction with cancellation permitted.

A. PVC Auction rules:

Bids are ranked from lowest to highest. The lowest seven bids are chosen as initial winners and the price paid to all of the ultimate winners is the value of first excluded bid of the seven chosen as initial winners. Cancellation is allowed and made simultaneously after price is announced. With any cancellation by an initial winner the bidder with the next lowest bid has the opportunity to become an ultimate winner at and receive a price equal to the previously announced median bid.

B. PVC Auction performance:

The number of first excluded bid auctions with cancellation is 24.

i. Procurement success is in general, higher the success rates of median price auctions. The PVC sold at least 3 items in each trial period. It had a success rate of 83.3% with an average of 5.8 items sold per trial period out of the seven demanded.
ii. Pricing success is less than the competitive price as revealed in Figures 4, 5 and 6. The reason is due to suppliers who choose the cancellation option. They are indifferent because they will sell their unit at the market price in either case and the market price will never be lower than their own bid. However, the bidder indifference seems to lead them to choose the option but that means that the excluded bid, the 8^{th} lowest bid, can be lower than the cost of the eighth unit. Thus prices can be lower than the competitive equilibrium. This happens if those who have high costs and would ordinarily be excluded and perhaps expect to be excluded, bid low at no perceived cost to themselves, lower the value of the eighth lowest bid and thus lower the market price
iii. Efficiency success is reported in Figure 7. Social efficiency falls less than 100% since the lowest cost sellers do not always sell. This is caused by prices being lower than the competitive equilibrium. The low prices mean that government efficiency can be high even if it does not get all units that it wants. The less than 100% social efficiency falls on the sellers.

SECTION FOUR: BEHAVIOR AND THE THEORY OF AUCTIONS

Our focus turns to the details of bidding behavior and strategy. How do individual bids reflect the underlying cost that the individual faces, and how does the relationship change with different auction rules? Figure 8 reveals these relationships. The horizontal axis represents the cost of a bidder placing a bid, and the vertical axis represents the corresponding bid. The bids colored in blue represent the resulting winning bids in the auction and represent the transfer of the unit to the buyer. The bids in red did not result in a sale either because they did not meet the competition or because the seller refused to sell at the market price (exercising the cancellation option). A pattern between the blue and red data points reveals the relationship between costs and bids.

As illustrated by figure 8, the patterns of bidding are consistent with the predictions of theory. Moreover, the patterns of bidding are understandable. The evidence suggests that problems are not just theoretical, but are indeed real.

In the case of the excluded bid auction, theory predicts that a bidder will place a bid equal to the bidder's cost. Evidence from our experiments supports the theory (see Figure 8A). In the excluded bid auction, a seller receives a price equal to the value of the first excluded bid if the seller's bid is below

that value. He receives nothing if his bid is above the value. The price received by the seller is not influenced by his own bid, and as a result, any deviation from bidding his cost results in lower expected profit. Since costs are revealed by the bidding strategy, the efficiency and stability of the excluded price (PVN) auction with no cancellation option, as reported in section one, is guaranteed.

The ability to cancel is an "option" that presents bidders with an opportunity to sell after having seen the market price. Thus, it presents a natural advantage at no cost IF the bidder thinks that taking advantage of the option will not have a material effect on the market price.

The existence of the cancellation option has two effects. First, the median price rule is a source of risk for a seller who is among the lowest seven bidders. If the seller does not have the ability to cancel, and the price is below the seller's cost, then the seller experiences a loss. This means that the seller does not want to be among the lowest unless the prices are expected to be high. As a result, the seller bids higher than cost. These phenomena are clearly evident in the median price auction with no cancellation option (Figure 8B). Sellers' asking prices are higher than in any other auction form.

The cancellation option also works through a natural strategic response. Exercise of the option allows the seller to choose to accept or decline the offer at the market price after it is announced. However, the option has value only if the seller is a winner of the auction (i.e., among the lowest bidders). Consequently the seller has an incentive to place a low bid, thereby becoming a winner with the option to cancel if the market price is not as desired. These phenomena can be seen in all auctions where the cancellation option is available: the PMC (Figure 8C) the FMC (Figure 8D), the PVC (Figure 8E).

The combined consequences of the median price rule and the cancellation option are easy to understand. Sellers attempting to win bid very low and in particular those with high costs, who would ordinarily lose, bid low. The median price determined by the auction is low, and few, if any sellers can sell at the low price. As a result, the sellers do not sell and the auction fails to deliver; both the government and the sellers fail to receive the advantages promised by a properly functioning auction.

The median price auction with a cancellation option will probably have a perverse property with scale. Theory indicates that the problems will become worse with scale (numbers of bidders). As the number of bidders increases relative to the amount to be procured, the proportion of high cost producers increases. These high cost producers are those with an incentive to bid low. Thus, increasing the competition undermines the ability for the auction to succeed.

FIGURES

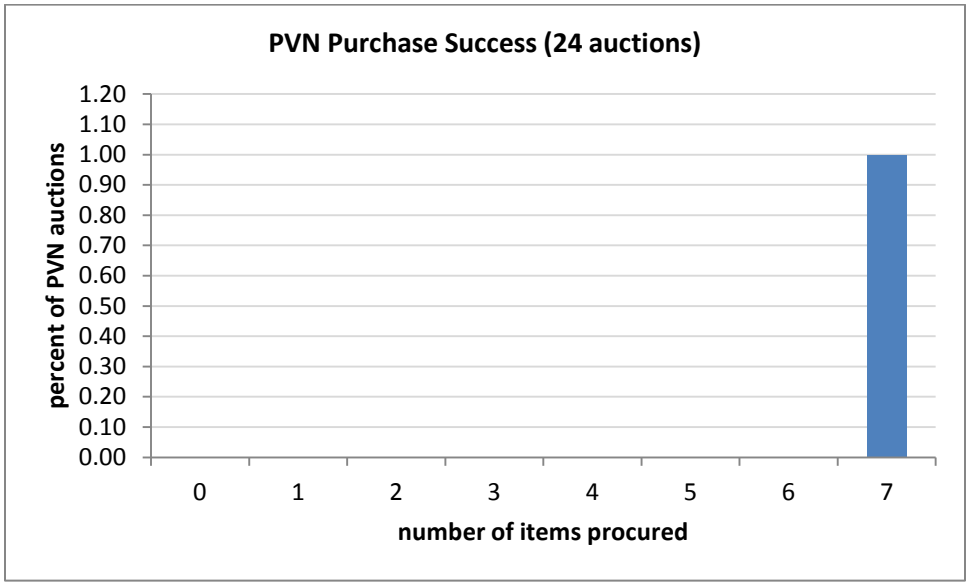

Figure 1 Purchase success for the partial information excluded bid (VCG) auction with no cancellation was 100%. All seven items were sold in each trial period.

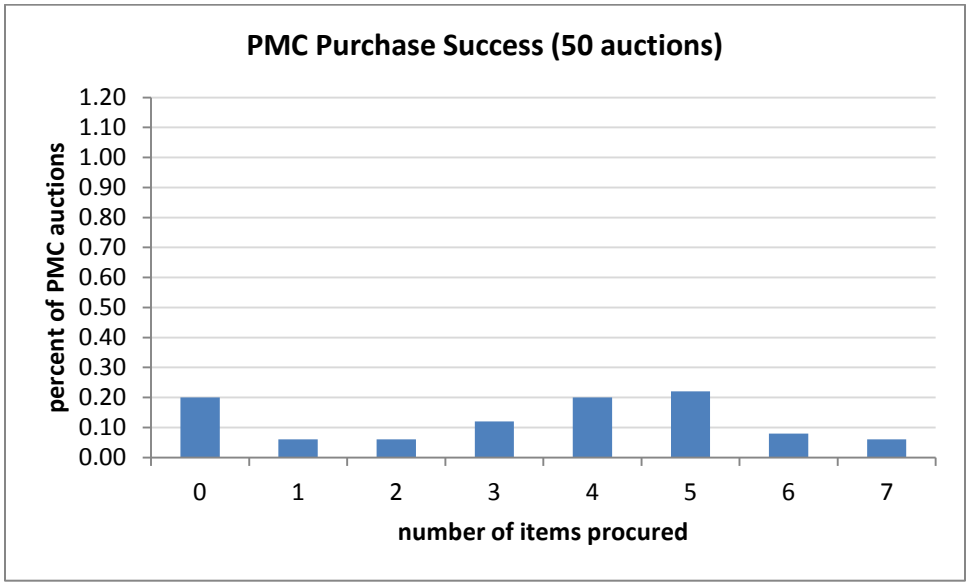

Figure 2 Variation of purchase successes for the median price auction with cancellation suggests that the option for sellers to cancel their bids significantly lowers number of items sold per trial period. Note that in 20% of the trial periods, zero items were sold. We expect if we scale up the auction, the chances of a failed auction increases as the number of sellers with high costs increases.

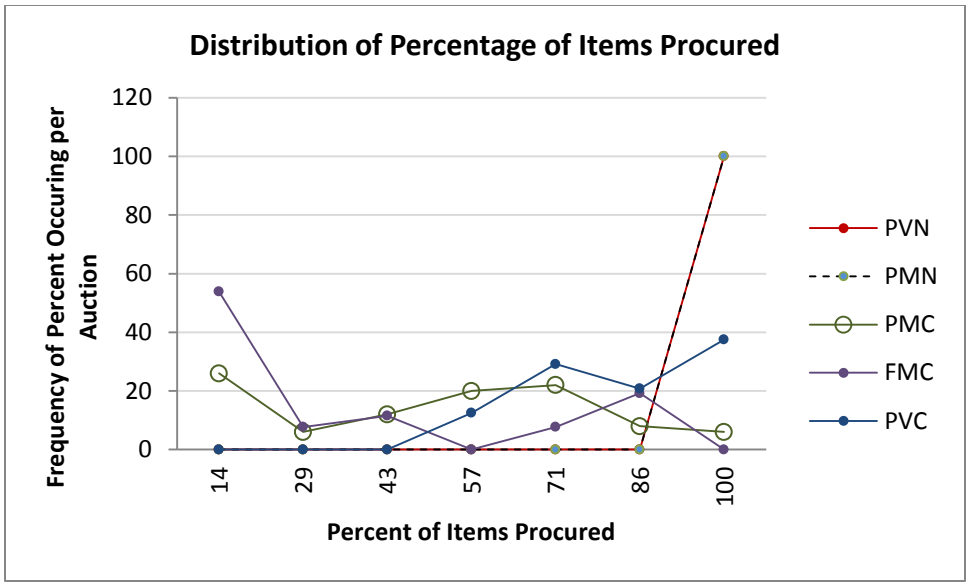

Figure 3 Auctions with no cancellation for the sellers to sell at market price, thus the buyer obtains all desired units. In median price auctions with cancellation, sellers with high costs have a tendency to submit lower bids in order to in the in the range of the lowest 7 bids. However, this has the effect of lowering the market price, thus fewer people accept and fewer items are sold.

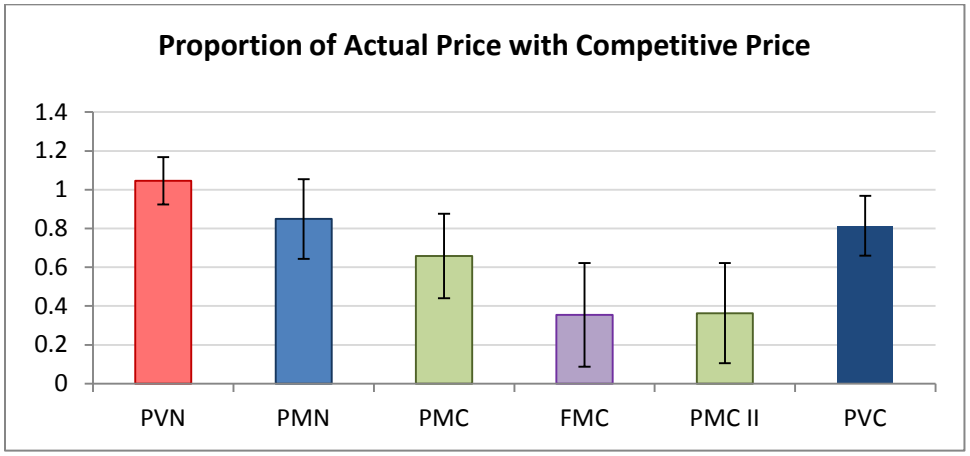

Figure 4 We see, again, the effects of cancellation on the market price, with high cost bidders bidding low.

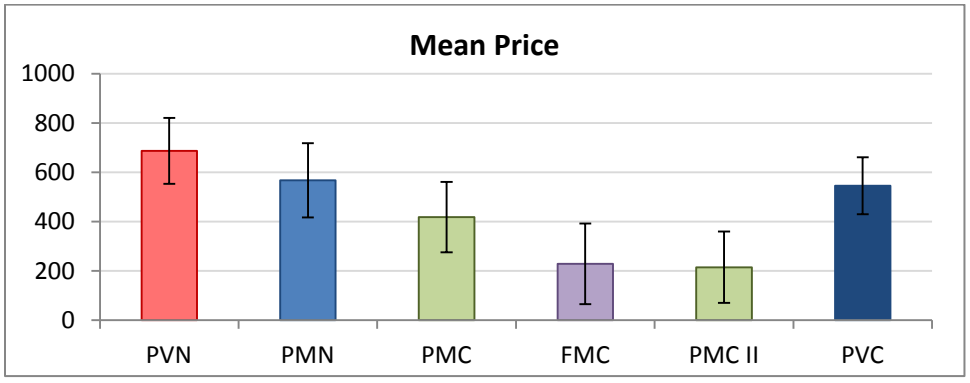

Figure 5 These are the mean prices for the auctions with data from both experiment days aggregated.

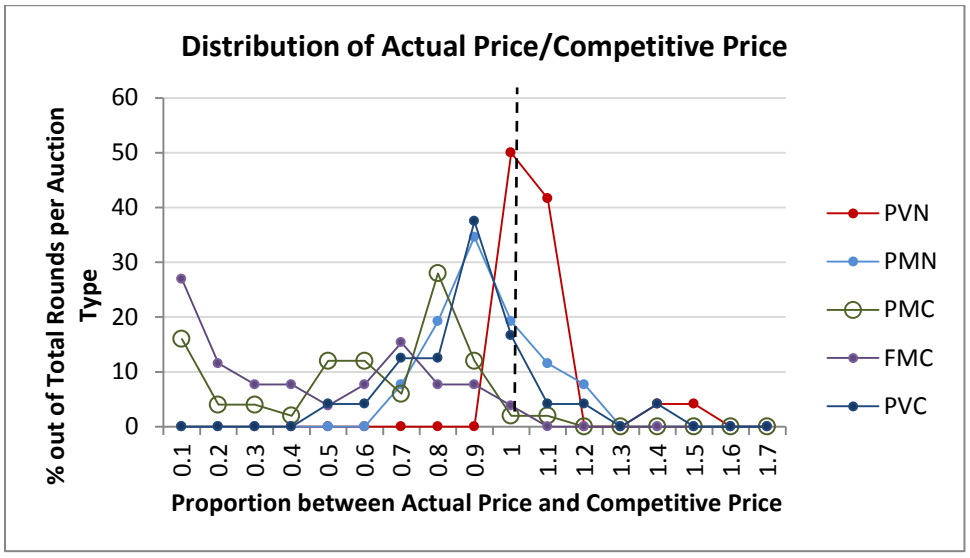

Figure 6 Prices were normalized against the competitive price for each auction. As data suggests, deviation from the excluded bid (VPN) auction lowers the average price throughout trials. Furthermore, adding cancellation decreases the number of items sold.

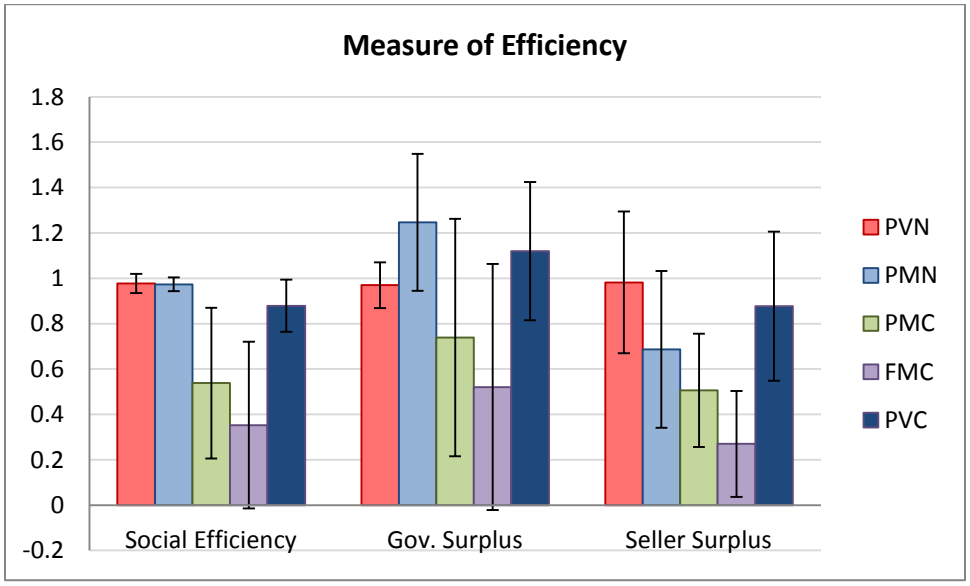

Figure 7 The social efficiency was calculated using the formula, $E_{social} = \frac{|W| \times 1050 - \sum_{i \in W} C(i)}{7 \times 1050 - \sum_{i=1}^{7} C(i)}$. Government surplus is given by $EG_{surplus} = \frac{|W| \times (1050 - P_{actual})}{7 \times (1050 - P_{theory})}$, and seller surplus is given by $EG_{surplus} = \frac{|W| \times (1050 - P_{actual})}{7 \times (1050 - P_{theory})}$.

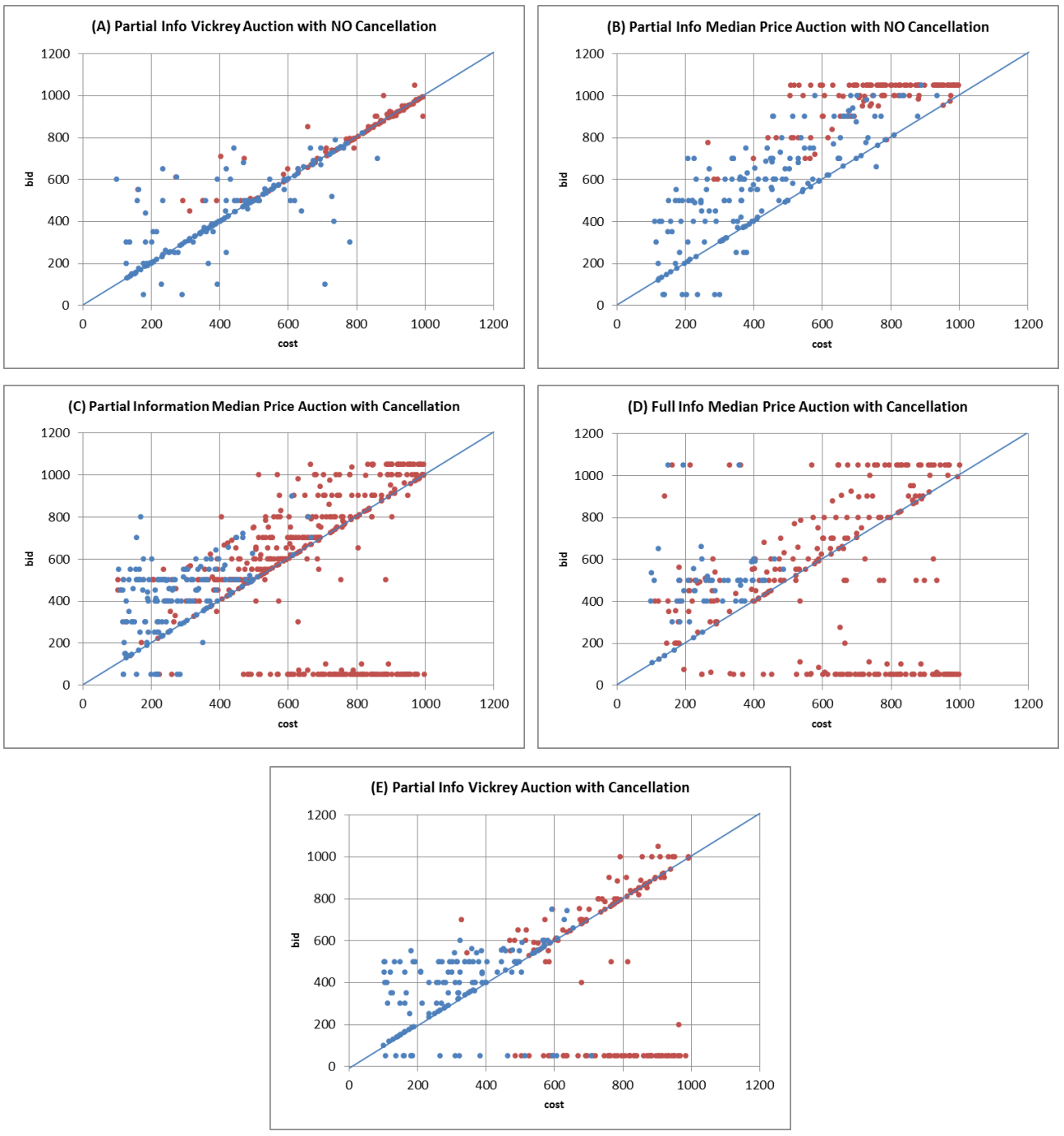

Figure 8 The point on each graph indicate a single participant's cost and bid for a particular round in the specified type of auction. The data from both experimental days are aggregated together. Points in blue indicate sellers who did not sell an item in that trial period, while points in red indicate sellers who were "winners" and successfully sold their item. (A) The Vickrey-Clark-Groves model was used as a control for comparison to other auction types. As expected by theory, sellers reveal information by bidding according to their value. In the median priced auction with no cancellation (B), sellers tend to bid higher than their value, which decreases social efficiency. Finally, the introduction of the cancellation option (C, D, and E) has perverse effects for both sellers and buyer. Sellers with high costs tend to bid low and shift the market price towards the left. This leads to more rejections of the market price and less items sold per trial period. This decreases the purchase successes and the efficiency of the buyer and seller. This cancellation effect is evident in both the median price auctions and in the VCG auction.

Appendices

Appendix A: Instructions

Appendix B: Screenshots