

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

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Abstract

We report on the experimental results of simple auctions with (i) a median-bid pricing rule and (ii) bid cancellation allowed – the two central pillars of the competitive bidding program designed by the Centers for Medicare & Medicaid Services (CMS). Comparisons between the performance of the CMS auction and the performance of the Vickrey-Clarke-Groves (VCG) mechanism, an auction with well-known theoretical properties, reveals the problematic nature of the CMS auction. The CMS auction fails to produce competitive prices of goods and fails to satisfy demand. In all proposed efficiency measures, we find the VCG mechanism significantly outperforms the CMS auction.

Introduction

On September 30, 2010, the *New York Times* published "[Fix Medicare's Bizarre Auction Program](#)," which claimed that "for the last ten years, the Centers for Medicare and Medicaid Services [CMS] has been testing an auction approach that is incredible in the inefficiency of its flawed design." We conducted experiments to determine the types of behavior and outcomes that could be expected from the proposed auction.

This report contains six sections. The first section illustrates the operation of an auction architecture that is known to function well. The second section focuses on an auction with the key features of CMS's competitive bidding program and demonstrates both the existence and severity of the architecture flaws. The third section reports on auctions with variations of the central pillars of the CMS auction. The results of this section suggest that simple removal of one of the faulty procedures does not correct the problems with the proposed auction and may create new problems. The fourth section addresses further variations, which exacerbate the negative effects of the auction proportional to the scale of the application as well as the experience of the bidders. The fifth section describes the effects of imposing a small fee for bidding in both a good auction and the CMS auction. The sixth and final section is a summary and conclusion of the results observed from the experiment.

Section One: Good Auctions Exist

To serve as a reference point, we introduce the reader to an auction with good theoretical properties: one that produces competitive revenue, encourages suppliers to reveal their true costs, and assigns goods efficiently. In this auction – the Vickrey-Clarke-Groves (VCG) mechanism – the price is determined

by the *first excluded bid*, the lowest bid for which a unit is not sold. Furthermore, *bids are binding*, so a bidder must sell if he wins.

A. VCG Mechanism: Procedures

The market price is determined by the value of the first excluded bid, and is announced publicly. Due to the structure of our auctions, the first excluded bid is the 8th lowest bid. The lowest 7 bidders sell their unit at the market price. Bidders are only privy to their own cost and are required to bid.

B. VCG Mechanism: Performance

- i. *Procurement success*: The VCG mechanism always delivers the number of units demanded, because bids are binding and suppliers must bid (Figure 1).
- ii. *Pricing success*: Prices in the VCG mechanism are distributed near the competitive equilibrium price, with an average of 103.9% ($\sigma = 11.5\%$) of the competitive price. This accuracy is achieved because suppliers tend to reveal their true costs of production (Figure 4).
- iii. *Efficiency success*: The VCG is essentially perfect in all three measures of efficiency. The government gets all units near the competitive price, and the sellers are those with the lowest costs.

Section Two: The CMS Auction is not a Good Auction

To gauge the performance of the CMS auction, we conducted scaled-down auctions with the central features intact: price determination by the *median price of the lowest 7 bids* and *non-binding bids*. Figures 1-3 in the Appendix demonstrate the disparity and relatively poor performance of the CMS auction along all performance measures (as compared to the VCG mechanism).

A. CMS Auction: Procedures

The market price is determined by the value of the median of the lowest 7 bids and is announced publicly. All bidders are then simultaneously given the option to cancel their bid and withdraw from the auction or to indicate their willingness to sell their unit at the market price. The lowest 7 bidders who indicate their willingness to sell are eligible to sell their unit at the market price. A bidder who is unwilling to sell at the market price will never be forced to sell under these provisions. Bidders are only privy to their own cost and are required to bid.

B. CMS Auction: Performance

- i. *Procurement success*: One out of five auctions had no procurements at all, and only one out of twenty auctions succeeded in procuring the number of desired units (Figure 1). The average number of procured units is 3.34 units ($\sigma = 2.2$ units) per trial period, slightly less than half of the number of units demand.

- ii. *Pricing successes*: On average the price is 54.3% ($\sigma = 28.0\%$) of the competitive price, but, as shown in Figure 2, the price in the CMS auction tends to approach the minimum allowable bid (see Figure 5); one out of nine bids is a low-ball bid. These low-ball bids lower the market price and accounts for the poor procurement success.
- iii. *Efficiency success*: On average, social efficiency is 53.78% ($\sigma = 33.2\%$). The government receives a bargain on the units it procures, but procures few units. The efficiency falls to 73.8% ($\sigma = 52.3\%$) and varies considerably. The low prices mean that sellers suffer – the seller surplus is 29.3% ($\sigma = 25.0\%$). As illustrated in Figure 3, the CMS auction performs poorly in comparison to the VCG mechanism.

Section Three: The CMS Auction Cannot Be Easily Fixed

The CMS auction has two central pillars that contribute to its poor performance: a median-bid pricing rule and a bidder cancellation option (non-binding bids). To determine the effects of the two pillars individually, we conducted two variants of the CMS auction: one with a first-excluded-bid pricing rule and the other with binding bids.

A. CMS Auction with First-Excluded-Bid Pricing Rule: Procedures

The market price is determined by the value of the first excluded bid, the 8th lowest bid in our mechanism, and is announced publicly. All bidders are then simultaneously given the option to cancel their bid and withdraw from the auction or to indicate their willingness to sell their unit at the market price. The lowest 7 bidders who indicate their willingness to sell are eligible to sell their unit at the market price. A bidder who is unwilling to sell at the market price will not be forced to sell under these provisions. Bidders are required to bid, and are only privy to their own cost.

B. CMS Auction with First-Excluded-Bid Pricing Rule: Performance

- i. *Procurement success*: At least 4 units were procured in each trial period, with an average procurement of 5.8 units ($\sigma = 1.1$ units), This is a better result than that of auctions with the median-bid pricing rule. However, this outcome is far from the perfect procurement in auctions with binding bids. Figure 6 illustrates the distribution of units procured for this auction.
- ii. *Pricing success*: This auction results in lower bids compared to bids in the CMS auction. In particular, some suppliers with high costs will submit the minimum allowable bid and then withdraw (Figure 9). Even so, the first-excluded-bid pricing rule holds the pricing success at an average of 83.9% ($\sigma = 17.9\%$) of the competitive price. Figure 7 illustrates the distribution of prices for this auction.
- iii. *Efficiency success*: Social efficiency falls short of perfect at an average of 87.9% ($\sigma = 11.5\%$). This result is expected because suppliers will not sell at prices lower than their costs. This does not preclude government surplus from being artificially high at an average of 112% ($\sigma = 30.5\%$), because it procures some units at ultra-low prices by not procuring others. Predictably then, seller surplus is artificially low at an average of 68.5% ($\sigma = 32.9\%$).

C. CMS Auction with No Cancellation Option (Binding Bids): Procedures

The market price is determined by the value of the median of the lowest 7 bids and is announced publicly. The lowest 7 bidders sell their unit at the market price. Bidders are only privy to their own cost and are required to bid.

D. CMS Auction with Binding Bids: Performance

- i. *Procurement success*: All demanded units are procured, as expected of auctions with binding bids and required participation.
- ii. *Pricing success*: This auction results in higher bids than the CMS auction as bidders try to avoid selling at prices below their cost (see Figure 10). Even so, the median-bid pricing rule holds the pricing success at an average of 88.6% ($\sigma = 13.7\%$) of the competitive price.
- iii. *Efficiency success*: Social efficiency is nearly perfect at an average of 97.4% ($\sigma = 3.0\%$), but government surplus is artificially high at an average of 124.6% ($\sigma = 30.2\%$) while seller efficiency is artificially low at an average of 68.7% ($\sigma = 34.1\%$). This auction violates the principle of voluntary participation because suppliers may be required to sell at a loss regardless of their bid. For a comparison of all auctions in this section, see Figure 8.

Section Four: The CMS Auction Gets Worse with Scale and Experience

The CMS auction performs poorly, but theory suggests that it will perform even worse with the scale of application (the number of bidders) and the experience of the bidders. Experimental data supports this claim, showing a greater percentage of low-ball bids, both as the number of bidders increased 25% (from 12 to 16) and as bidders gained experience.

A. CMS Auction with 25% More Bidders: Procedures

Procedures are identical to those of the CMS auction described in Section 2.

B. CMS Auction with 25% More Bidders: Performance

- i. *Procurement Success*: Out of 32 trial periods, **0** procured the demanded number of units, with 12 trial periods (37.5%) procuring no units at all. On average, this auction procured 1.7 units ($\sigma = 1.8$ units). The effects of scaling up on procurement success are presented in Figure 12.
- ii. *Pricing Success*: The average price is only 33.4% ($\sigma = 18.6\%$) of the competitive price, explaining the low procurement. Even more drastic, in this auction with 16 bidders, **one in five bids is a low-ball bid (20%) to be compared to the one in nine (10%) low-ball bids observed in the CMS auction with 12 bidders.** (See Figure 11) As illustrated in Figure 13, scaling up significantly reduces the proportion between the market price and competitive price.
- iii. *Efficiency Success*: Social efficiency drops to an average of 25.3% ($\sigma = 26.8\%$), government surplus drops to 37.2% ($\sigma = 40.9\%$) and the average seller surplus *drops below 1%* ($\sigma = 8.4\%$). Figure 14 displays how dramatically scaling up affects the performance of the CMS auction.

C. CMS Auction: Worsens with Experience

- i. *Procurement Success*: The average number of units procured in the first five trial periods is 2.8 units while the average number of units procured in the last five trial periods is .8 units, with 60% more trial periods procuring no units at all. Figure 15 provides the time series.
- ii. *Pricing Success*: The average market price in the first five trial periods is 42.3% of the competitive price while the market price in the last five trial periods is 20.6% of the competitive price, with significantly more at minimum allowable bid. Figure 16 provides the time series.
- iii. *Efficiency Success*: Social efficiency drops from an average of 40.8% in first five periods to an average of 10.6% in the last five periods; government surplus drops from an average of 59.0% in first five periods to 20.7% in the last five periods; seller surplus stays put at **0%**.

Section Five: Results are Robust

If suppliers face only nominal fees for placing a bid the low-ball bid provides a free option for deciding whether or not to accept the market price. A fee for placing bids provides an incentive to suppliers with high costs to not to submit bids rather than simply submitting a low-ball bid and reserving the right to sell if the price happens to be satisfactory. The absence of that incentive changes the character of the market. To test the robustness of our results, we conducted experiments with a small cost imposed.

A. VCG Mechanism with Small Fee to Bid: Procedures

The market price is determined by the value of the first excluded bid (or is set at 1050 if fewer than 8 suppliers bid) and is announced publicly. The lowest 7 bidders sell their unit at the market price. Bidders are only privy to their own cost and must pay a small fee of 50 ECUs to bid (or opt out).

B. VCG Mechanism with Small Fee to Bid: Performance

- i. *Procurement Success*: Only 3 of 28 trial periods had less than perfect procurement.
- ii. *Pricing Success*: The average price across all trial periods is 119.8% ($\sigma = 32.4\%$) of the competitive price, but this is somewhat misleading because the price is set particularly high (at 1050 ECUs) when fewer than 8 suppliers bid. Discounting the periods in which this outcome occurs, the average price is 105.7% ($\sigma = 19.2\%$) of the competitive price. For the distribution of prices, see Figure 18. Bidding behavior matches expectations and is depicted and explained in Figure 20.
- iii. *Efficiency Success*: Social efficiency is, on average, 95.5% ($\sigma = 5.8\%$); government surplus is, on average, 66.5% ($\sigma = 37.8\%$), though discounting the trial periods when the price is set at 1050 ECUs brings it up to 84.6% ($\sigma = 14.7\%$); seller surplus is artificially high at 162.5% ($\sigma = 77.0\%$), and discounting those same trial periods brings it down to 131.8% ($\sigma = 41.6\%$).

C. CMS Auction with Small Fee to Bid: Procedures

The market price is determined by the value of the median of the lowest 7 bids (or the median of submitted bids if fewer than 7 suppliers bid)⁴ and is announced publicly. All bidders are then simultaneously given the option to withdraw from the auction or to indicate their willingness to sell

their unit at the market price. The lowest 7 bidders who indicate their willingness to sell are allowed to sell their unit at the market price. Bidders are only privy to their own cost and must pay a small fee of 50 ECUs to bid (or opt out).

D. CMS Auction with Small Fee to Bid: Performance

- i. *Procurement Success*: Imposing a bidding fee increases the average number of units procured to 3.8 units ($\sigma = 1.60$ units), which is still far from the nearly perfect procurement of the VCG mechanism with a small bidding fee. For a comparison, see Figure 17.
- ii. *Pricing Success*: As low-ball bids are drastically reduced, the average price rises to 60.3% ($\sigma = 15.8\%$) of the competitive price, still held down by the median-bid pricing rule. Low prices not only discourage suppliers with high costs from bidding, but also suppliers that could expect to have one of the 7 lowest costs (see Figure 21). For the distribution of prices, see Figure 18.
- iii. *Efficiency Success*: Social efficiency is, on average, is 59.9% ($\sigma = 19.3\%$), government surplus is, on average, 74.6% ($\sigma = 24.9\%$), and seller surplus is, on average, 34.4% ($\sigma = 23.0\%$). For a comparison between the CMS auction without a bidding fee and the CMS auction with a bidding fee (as well as the VCG mechanism with a bidding fee), see Figure 19.

Section Six: Summary and Conclusion

Our experiments provide an informative test of the natural strategies these features evoke and the efficiencies that can be expected. Auction architectures performing poorly in 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 more complex cases.

In our simplified version of CMS's proposed auction, bidders submitted low-ball bids, which reduced the price below most suppliers' costs, causing most suppliers to withdraw and resulting in fewer units procured. The addition of a small fee for the right to bid reduced low-ball bids, but greatly decreased the number of suppliers bidding at all. By all proposed efficiency measures, the CMS auction performs poorly.

We conclude that (1) good auction architectures do exist; (2) the CMS auction is not a good procurement auction because it is based on an inappropriate architecture that cannot deliver services at competitive rates and qualities; and (3) the CMS auction cannot be adjusted in some simple way – there is no “quick fix.” The two central pillars are intrinsically flawed. Price determination by the median accepted bid is not an appropriate method for determining price and the ability of bidders to withdraw bids is an inappropriate guide for competitive bidding strategies.

Section Seven: Appendix

Experimental Environment

We conducted four experiments using identical experimental parameters and procedures with different subjects. Each experiment had multiple auctions, which shared the following elements:

- 1) All auctions were procurement auctions in which the experimenter was the only buyer.
- 2) The number of units demanded by the experimenter was 7 units.
- 3) Each supplier's cost of production was drawn independently from a uniform distribution on the interval [100, 1000] ECUs and suppliers could submit bids on the interval [50, 1050] ECUs. In each trial period, participants had a different cost of production.
- 4) Each auction was conducted for multiple consecutive trial periods (one session). Participants were not informed of the number of trial periods there would be. The number was deliberately varied to prevent participants from altering their behavior in anticipation of the session ending.
- 5) Participants were provided with information about previous trial periods, including their cost of production, their bid, the market price, whether they were among the 7 lowest bidders, whether they had sold their unit, and their profit for that period.
- 6) Profits in ECUs were converted into cash and paid to participants at the end of the experiment.

Auctions differed only in the following features:

- 1) The price was determined either by the first excluded bid or by the median of the lowest 7 bids.
- 2) Bids were either binding commitments, or suppliers were given an option to withdraw their bid.
- 3) Suppliers were either provided with only information about their own costs, or provided with information about the costs and bids of all suppliers.
- 4) The number of suppliers was either 12 or 16 (but held constant within each experiment).
- 5) Suppliers were either required to bid (for no fee) or asked to pay a small fee to bid (or opt out).

Measures of Performance

We measured performance of each auction by the number of units procured (*procurement success*), how closely the price approximates the competitive price² (*pricing success*), and how efficiently it allocated units and money from the perspective of society³ (*social efficiency*), the government (*government surplus*), and the suppliers (*seller surplus*). We note that the first excluded cost is set as the competitive price with the reasoning that, theoretically, the first excluded bidder could make a profit by proposing a bid that is slightly above the cost. The equations for other measures of efficiency are provided below:

$$\text{Procurement success} = \frac{\# \text{ of Units Purchased}}{\# \text{ of Units Demanded}}$$

$$\text{Pricing success} = \frac{\text{Auction Price}}{\text{Competitive Price}}$$

$$\text{Social Efficiency} = \frac{\# \text{ of Units Purchased} \times \text{Value} - \sum_{w \in W} \text{Cost}(w)}{\# \text{ of Units Demanded} \times \text{Value} - \sum_{l \in L} \text{Cost}(l)}$$

$$\text{Government Surplus} = \frac{\# \text{ of Units Purchased} \times (\text{Value} - \text{Auction Price})}{\# \text{ of Units Demanded} \times (\text{Value} - \text{Competitive Price})}$$

$$\text{Seller Surplus} = \frac{\# \text{ of Units Purchased} \times \text{Auction Price} - \sum_{w \in W} \text{Cost}(w)}{\# \text{ of Units Demanded} \times \text{Competitive Price} - \sum_{l \in L} \text{Cost}(l)}$$

Figures

Figures: Sections One and Two:

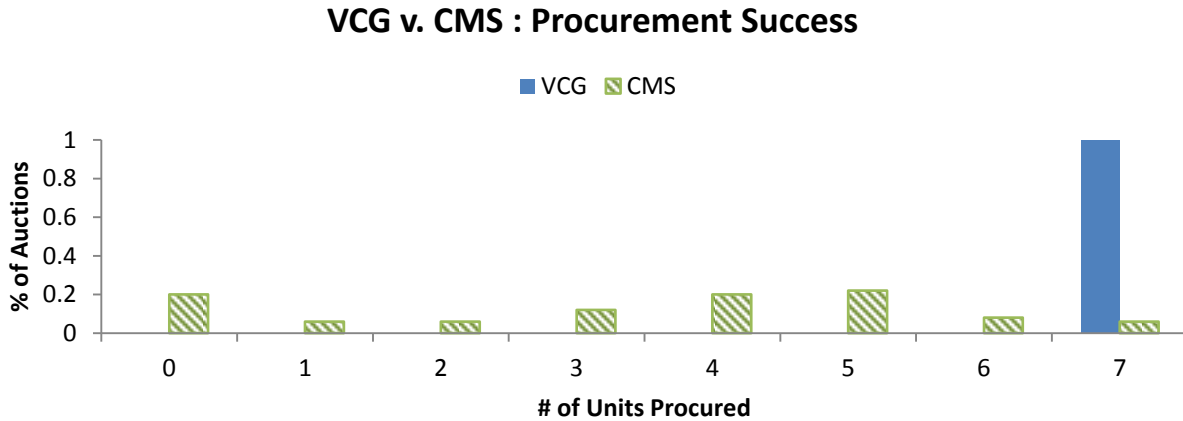


Figure 1. A good auction, such as the VCG mechanism (blue), has perfect procurement because bids are binding commitments. In the CMS auction (green) bids are not binding and so suppliers can submit low-ball bids that they later withdraw. These low-ball bids, combined with the median-bid pricing rule, lower prices below the cost of production of most suppliers. To avoid losing profit, these bidders withdraw from the auction, resulting in few units being successfully procured.

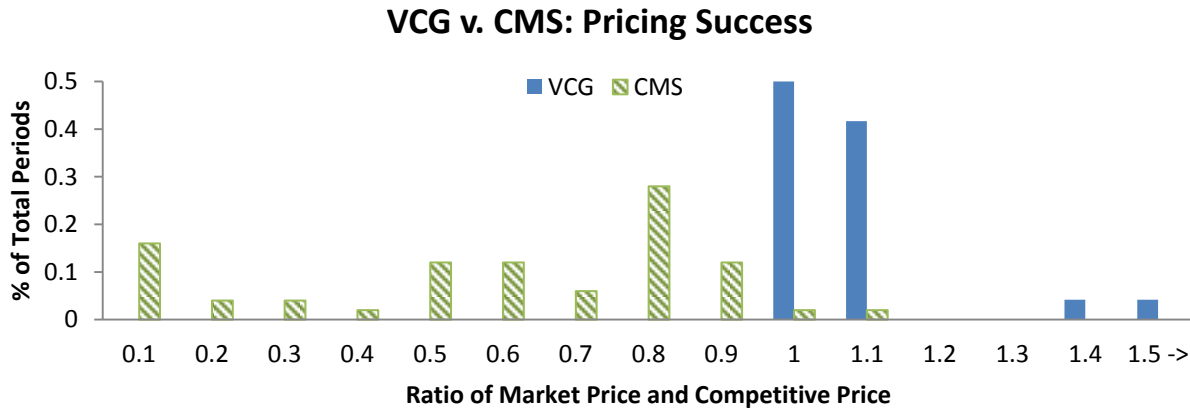


Figure 2. In the CMS auction (green) bids are not binding and so suppliers can submit low-ball bids that they later withdraw. These low-ball bids, combined with the median-bid pricing rule, lower prices below the competitive price. In contrast, the VCG mechanism (blue), with a first-excluded-bid pricing rule and binding bids, returns prices that are at or slightly above the competitive price.

VCG v. CMS: Efficiency Success

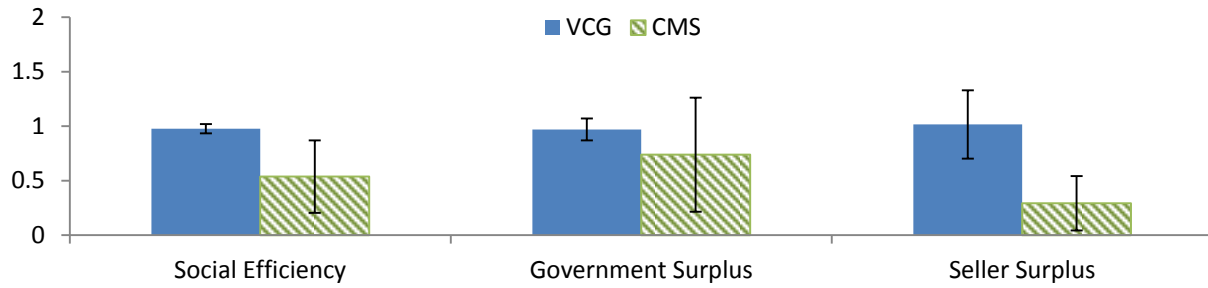


Figure 3. With perfect procurement at competitive prices, the VCG mechanism (blue) has nearly perfect efficiency in all three measures. In contrast, the CMS auction (green) does quite poorly in all three measures.

VCG Mechanism: Bidding Behavior

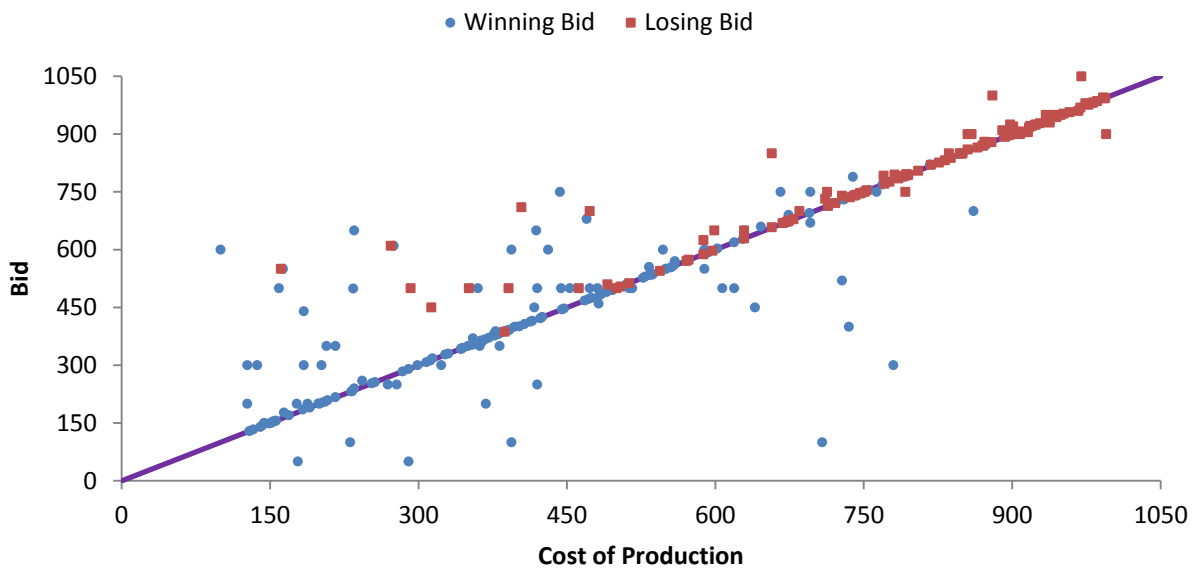


Figure 4. In the VCG mechanism, theory suggests that suppliers should bid their cost of production because if they bid above their cost, they may forfeit the chance to sell their unit at a profit (note the red dots on the left) and if they bid below their cost, they may be forced to sell their unit at a loss (note the blue dots below the 45° line (purple line)). As displayed, suppliers seem to adhere to this theory, with a minority of suppliers responsible for the majority of bids not conforming to theory.

CMS Auction: Bidding Behavior

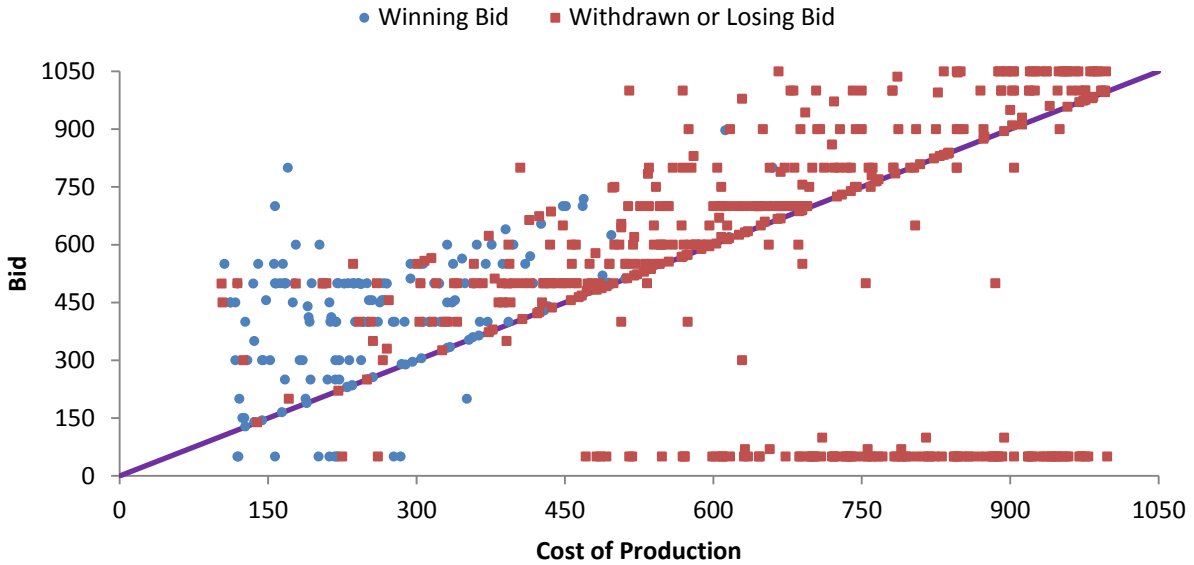


Figure 5. In the CMS auction, suppliers do not have an incentive to reveal their true cost. Instead, suppliers with low costs should submit bids higher than their costs, as this figure depicts, in an attempt to increase the value of the median bid and thus their profits. However, bids are not binding and so suppliers with high costs of production are not punished for submitting the minimum allowable bids (*low-ball bids*) and then withdrawing (note the red dots in the bottom right).

Figures: Section Three

Changing a Pillar: Procurement Success

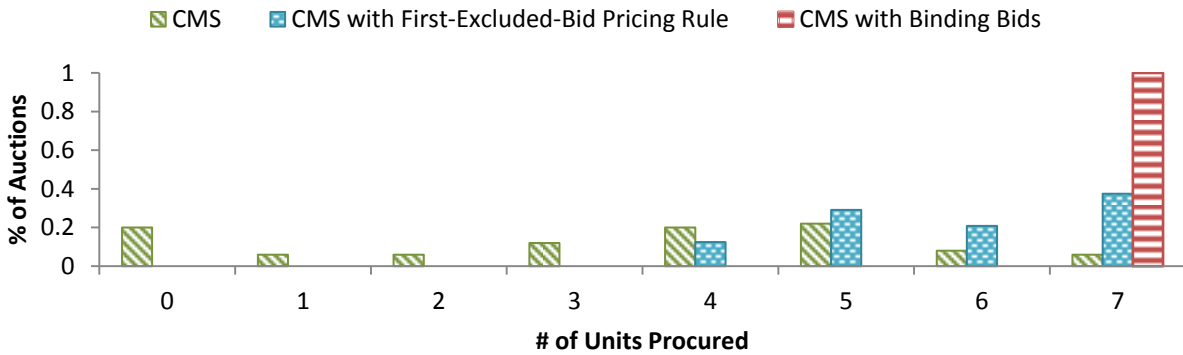


Figure 6. The CMS auction (green) has two central pillars that contribute to its poor performance: a median-bid pricing rule and non-binding bids. Changing to a first-excluded-bid pricing rule (light blue) dramatically improves the procurement success (because it increases the price), but it is still far from the

perfect procurement achieved by auctions with binding bids (red).

Changing a Pillar: Pricing Success

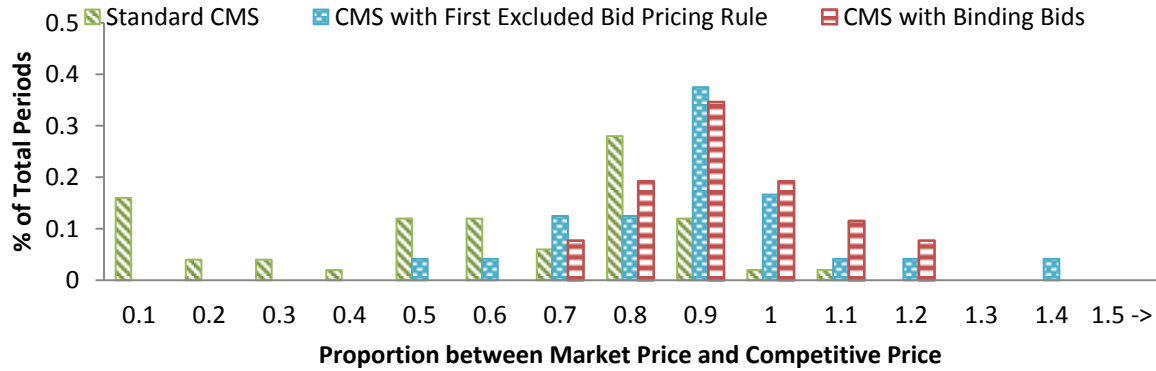


Figure 7. The CMS auction (green) returns market prices that are lower than the competitive price because of the median-bid pricing rule, occasionally returning a market price at the minimum allowable bid (note the peak at .1) due to low-ball bids. Changing to either the first-excluded-bid pricing rule (light blue) or binding bids (red) results in better pricing success.

Changing a Pillar: Efficiency Success

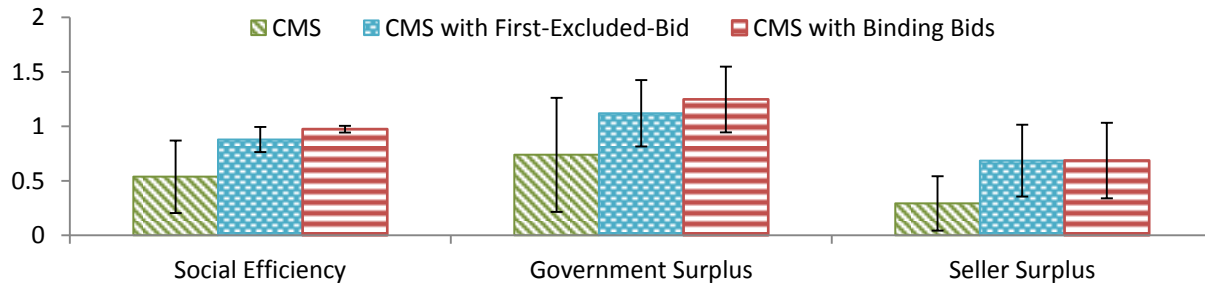


Figure 8. The CMS auction (green) returns market prices that are lower than bidder costs and since bids are non-binding, suppliers choose to withdraw from the auction rather than sell below their cost of production (and lose profit). The low procurements contribute to the low efficiencies. Higher efficiencies result from higher procurements, which can be achieved by changing the pricing rule (generating higher prices) or making bids binding (and perhaps requiring suppliers to sell at a loss).

CMS with First-Excluded-Bid Pricing: Bidding Behavior

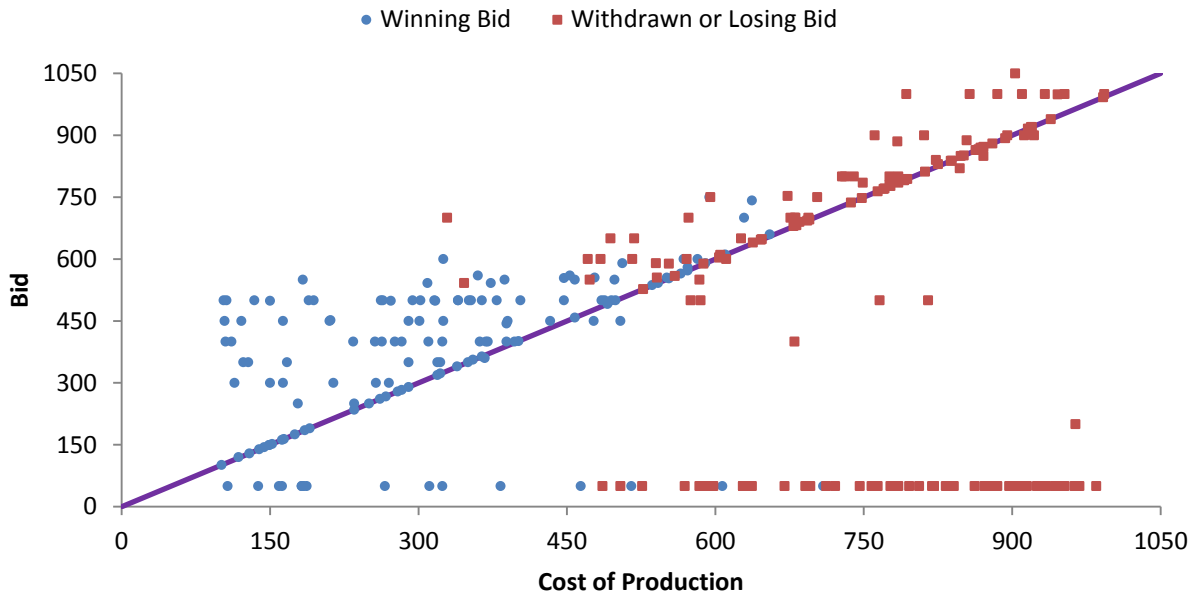


Figure 9. Behavior is similar to the standard CMS auction, but the first-excluded-bid pricing rule generates higher prices, so a greater number of bidders will be willing to sell (note that blue dots are present further to the right than in the standard CMS auction). Still though, suppliers with high costs are not punished for submitting low-ball bids (note the red dots on the bottom right) and withdrawing when the market price is below their cost.

CMS with Binding Bids: Bidding Behavior

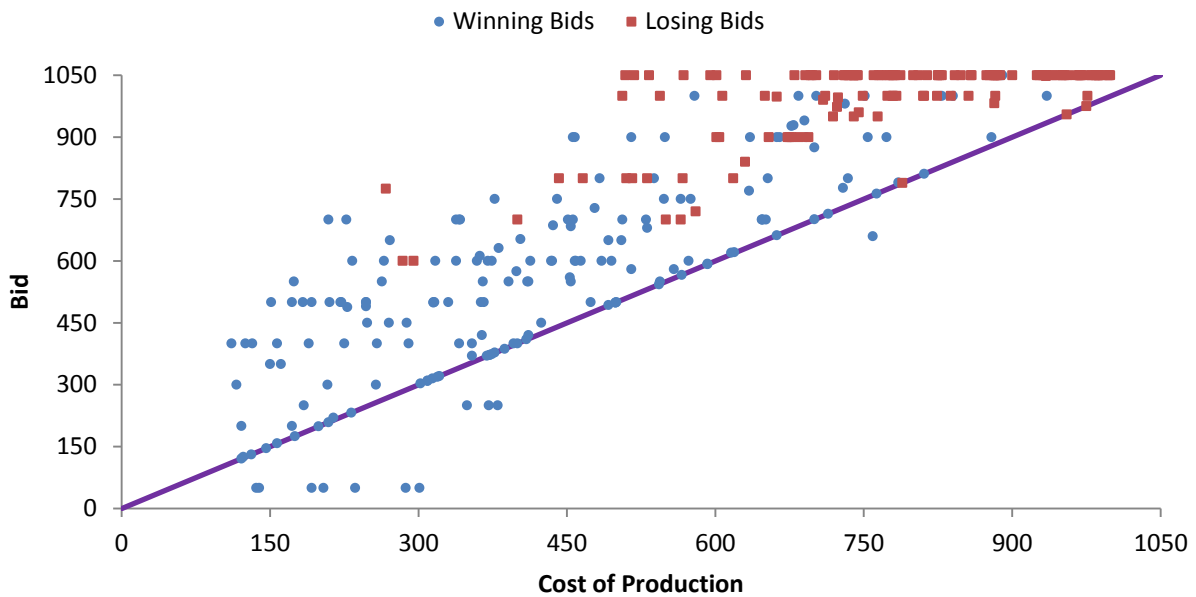


Figure 10. Behavior is radically different than the standard CMS auction – rather than submitting bids near the minimum allowable bid, suppliers with high costs bid the maximum allowable bid in order to escape being forced to sell below their cost of production (and lose profit). All blue dots in the top right indicate suppliers required to sell at a loss.

Figures: Section Four

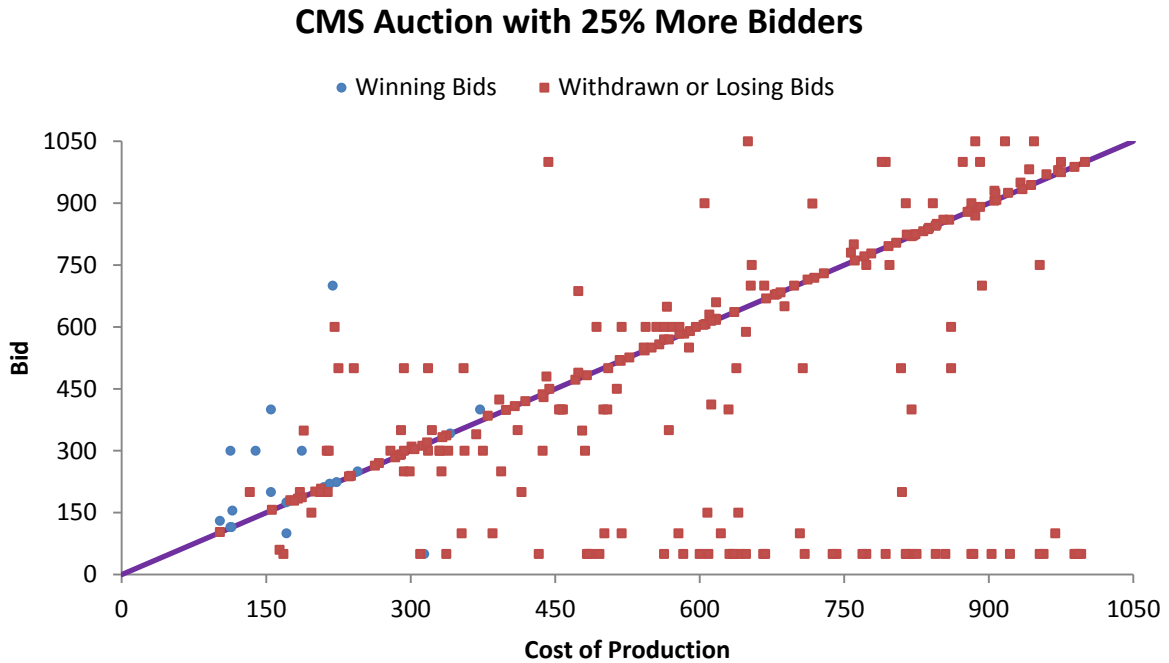


Figure 11. Behavior is similar to the CMS auction with fewer bidders, but the negative aspects are exacerbated – there are 9% more low-ball bids (note the red dots in the bottom right) per auction and thus there are dramatically fewer winning bids (note the sparseness of blue dots).

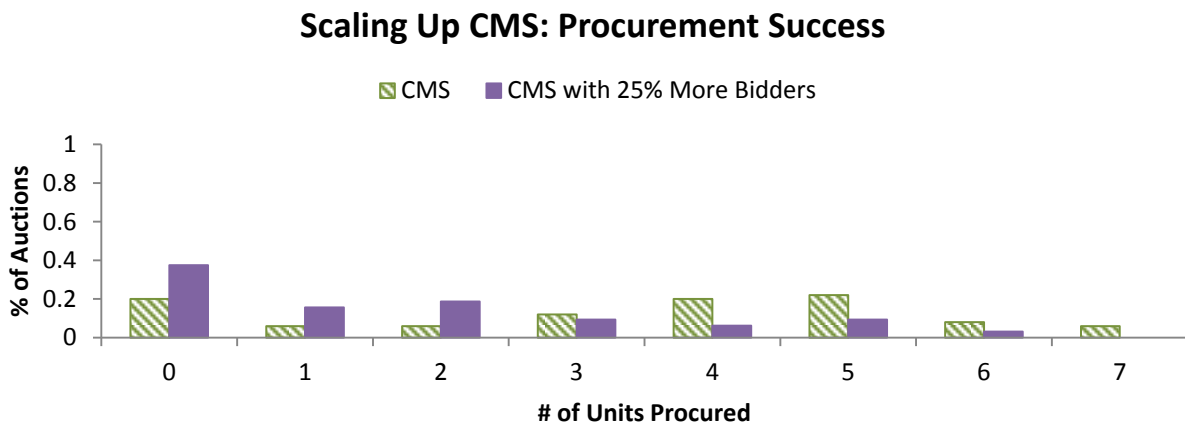


Figure 12. As the CMS auction (green) is scaled up by 25% (purple), the number of auctions that produce no procurements doubles while the number of perfect procurements drops to zero. Over 80% of the trial periods in the scaled up CMS auction procure less than half the demanded number of units.

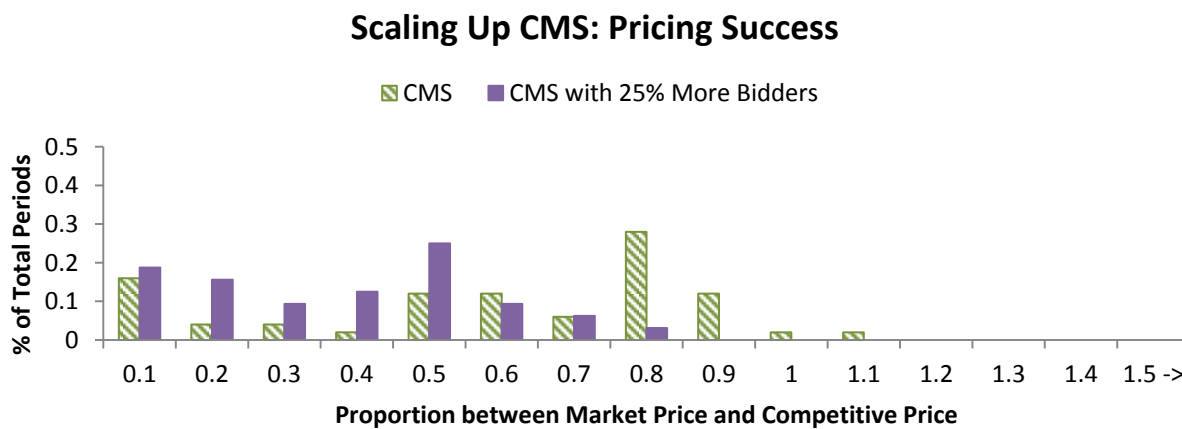


Figure 13. In the CMS auction (green), a fourth of the auctions were within a reasonable range of the competitive price. However, in the scaled up CMS auction (purple), none are. As the CMS auction is scaled up, the pricing distribution shifts left.

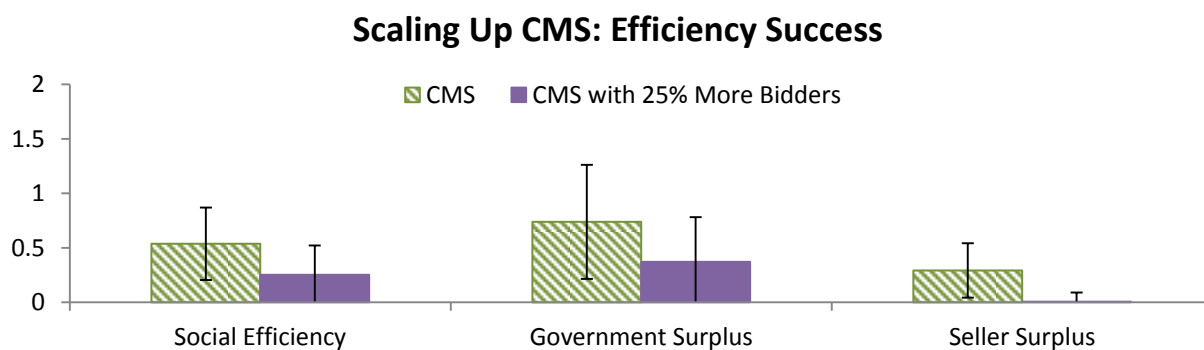


Figure 14. The CMS auction (green) already performs poorly in comparison to a good auction like the VCG mechanism, but when scaled up (purple), efficiencies drop even further. From the supplier perspective, this auction is completely inefficient. This auction does not fare much better from the perspective of the government or society.

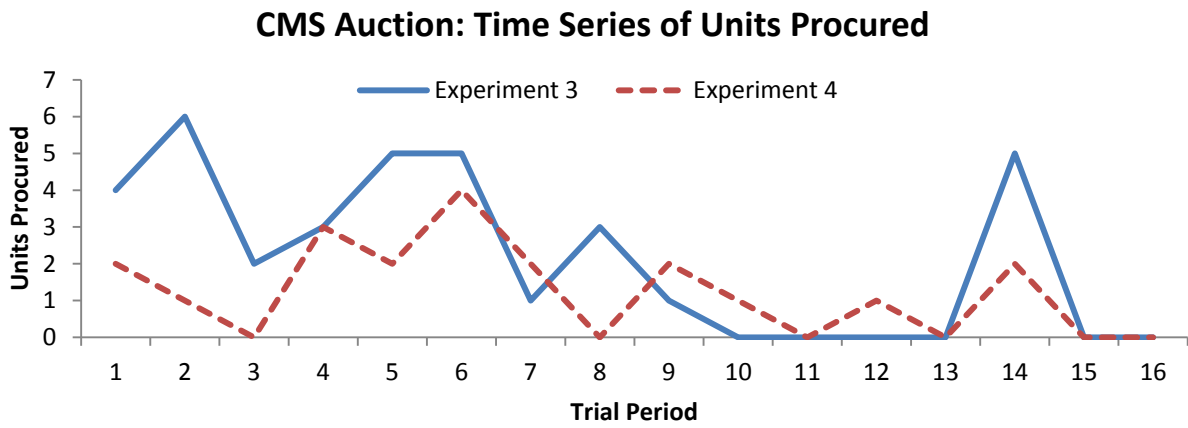


Figure 15. As bidders gain experience in the CMS auction, there is a trend towards procuring less units.

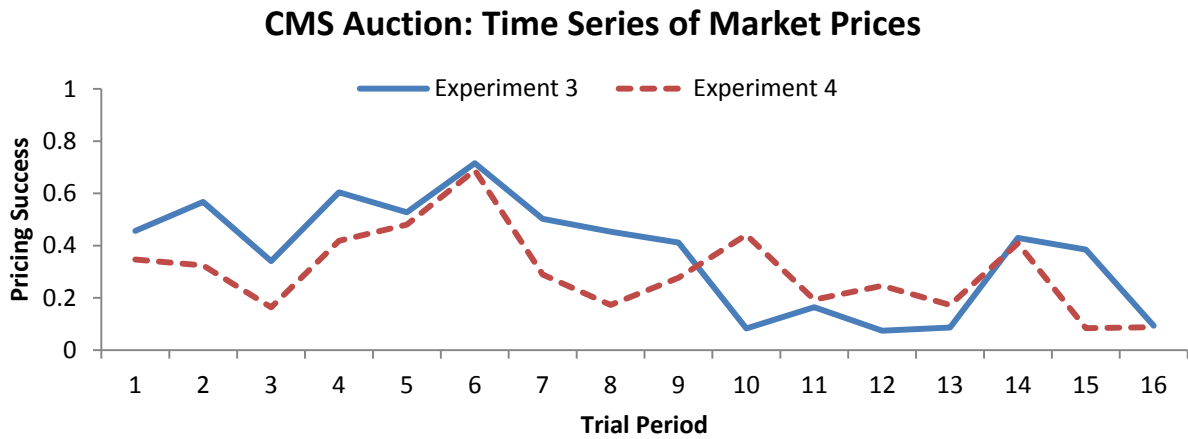


Figure 16. As bidders gain experience in the CMS auction, there is a trend towards lower prices.

Figures: Section Five

Imposing a Bidding Fee: Procurement Success

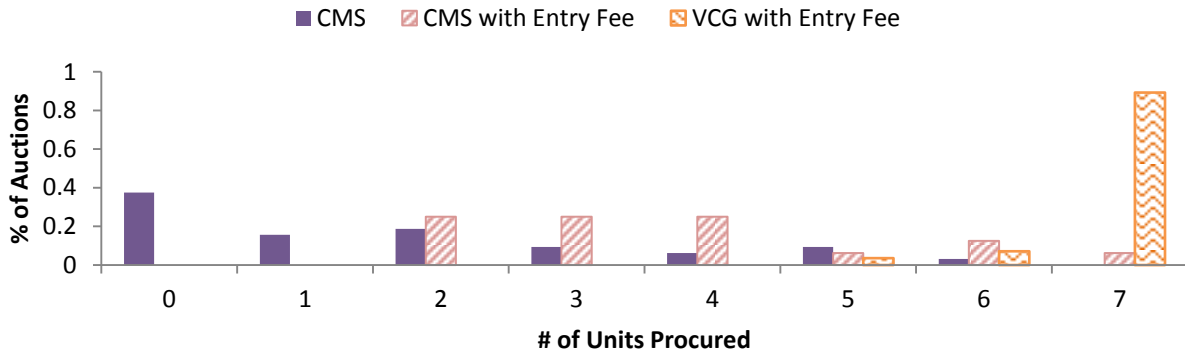


Figure 17. The CMS auction with a small bidding fee reduces low-ball bids, increasing prices and thus the number of units procured. However, the procurement is still significantly lower than the nearly perfect procurement of the VCG mechanism.

Imposing a Bidding Fee: Pricing Success

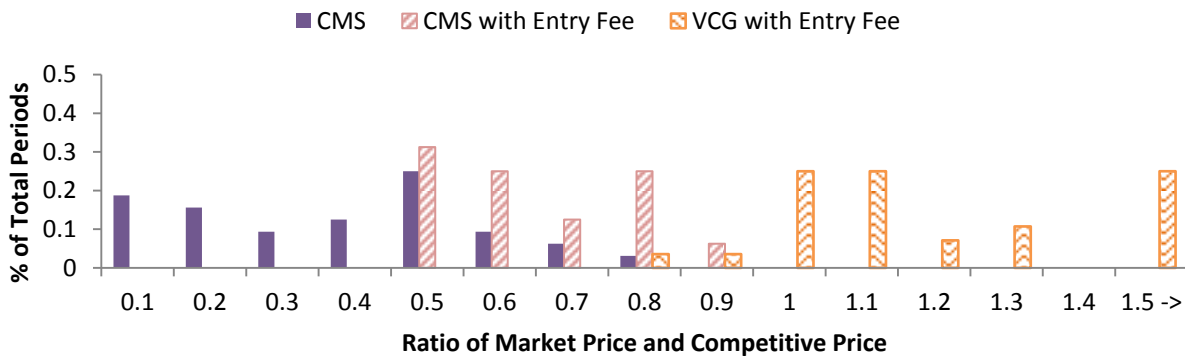


Figure 18. The CMS auction with a small bidding fee (pink) generates prices much closer to the competitive price than the CMS auction (purple), but still fails to be close enough to consistently procure the number of demanded units. Meanwhile, the VCG mechanism with a small bidding fee (orange) suffers from a dearth of excluded bidders, thus tending to generate above the competitive prices. This is one of the weaknesses that can be easily accounted for by using a more sophisticated good auction.

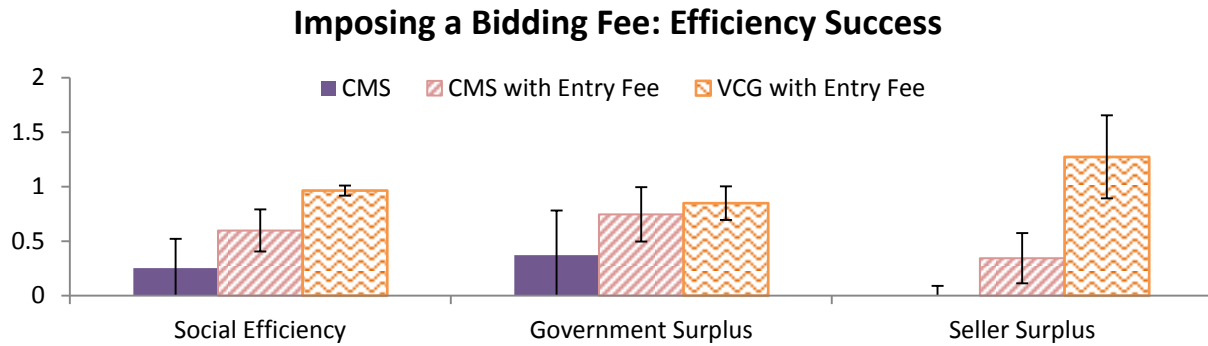


Figure 19. Imposing a bidding fee greatly improves the efficiency of the CMS auction in all three measures. The VCG mechanism with a small bidding fee still performs admirably from society’s perspective, occasionally shortchanging the government in favor of the suppliers (The VCG mechanism figures discount periods where the price was set at 1050).

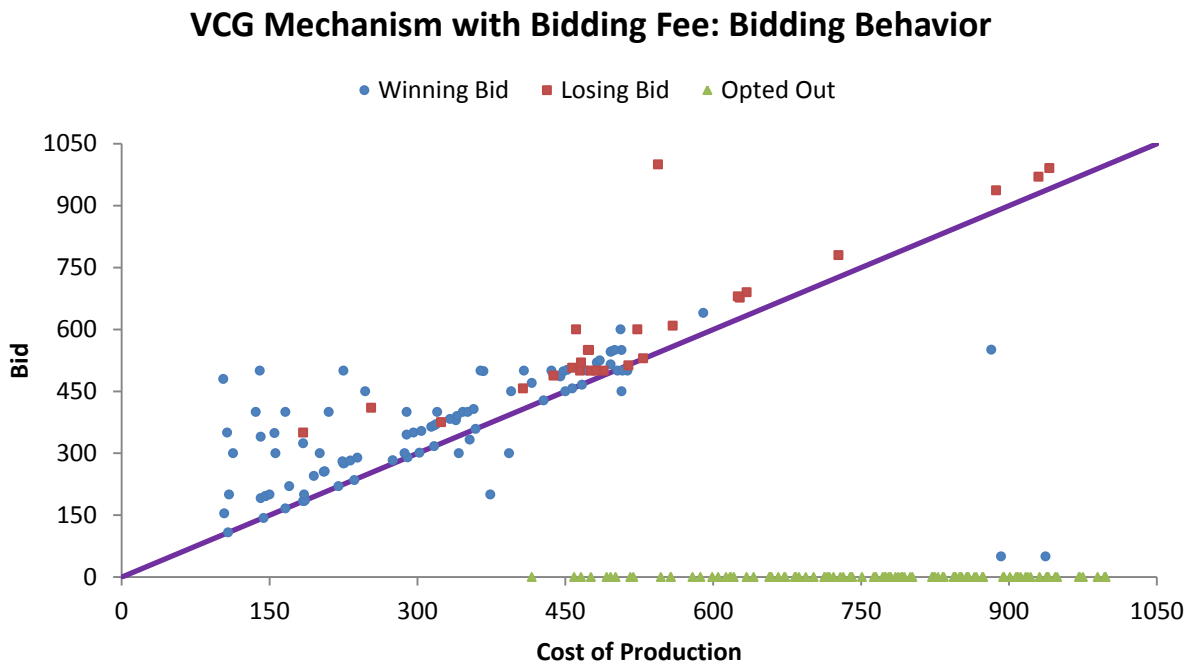


Figure 20. In the VCG auction with a small bidding fee, suppliers who believe that they do not have one of the seven lowest costs should, according to theory, opt out of the bidding process, and as depicted above, suppliers do just that (note all the green dots on the bottom right). The majority of losing bids are clustered together with winning bids in an “area of indecision,” where the 7th lowest cost is expected to be.

CMS Auction with Bidding Fee: Bidding Behavior

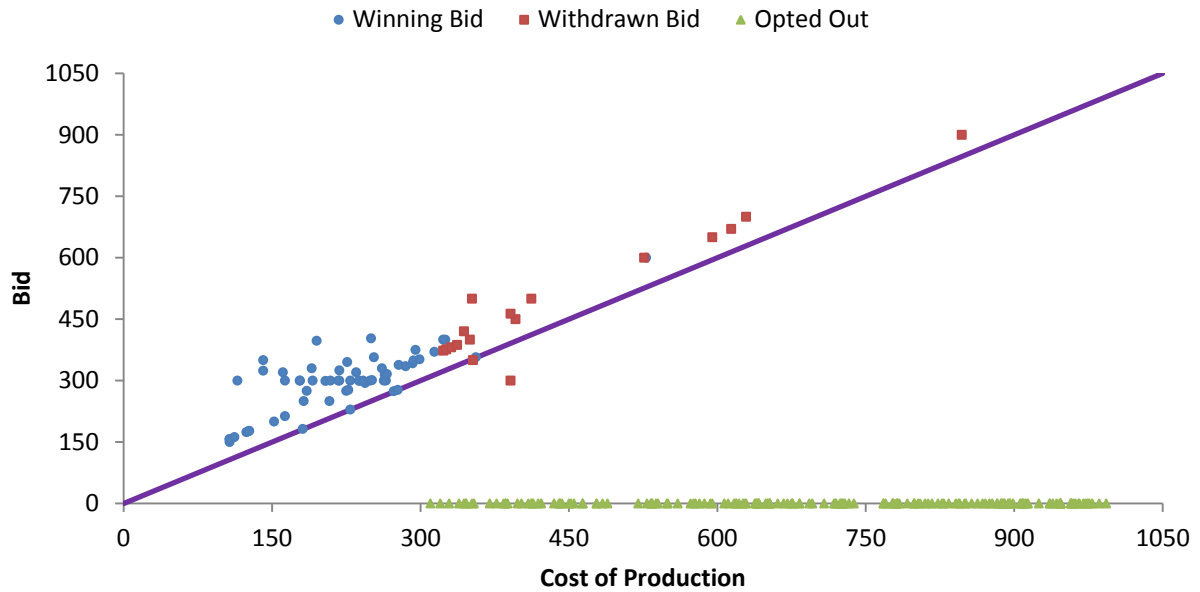


Figure 21. In the CMS auction with a small bidding fee, suppliers who believe that they do not have one of the seven lowest costs should opt out of the bidding process (just as in the VCG mechanism with a small bidding fee), and suppliers do just that. However, due to the nature of the median-bid pricing rule, bidders who expect to have the sixth or seventh highest cost also choose to opt out rather than pay a bidding fee to find that the market price is below their bid.