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Complexity and Efficiency in Conservation Auctions: Evidence from a Laboratory Experiment

Market Report	Year Ago	4 Wks Ago	3-30-18
Livestock and Products, Weekly Average			
Nebraska Slaughter Steers, 35-65% Choice, Live Weight.	124.00	126.50	120.38
Nebraska Feeder Steers, Med. & Large Frame, 550-600 lb.	166.78	195.06	180.18
Nebraska Feeder Steers, Med. & Large Frame 750-800 lb.	137.77	152.56	142.54
Choice Boxed Beef, 600-750 lb. Carcass.	217.15	221.18	221.72
Western Corn Belt Base Hog Price Carcass, Negotiated	60.99	62.20	46.56
Pork Carcass Cutout, 185 lb. Carcass 51-52% Lean.	75.47	77.46	69.83
Slaughter Lambs, wooled and shorn, 135-165 lb. National.	145.56	137.80	142.74
National Carcass Lamb Cutout FOB.	347.91	363.22	366.53
Crops, Daily Spot Prices			
Wheat, No. 1, H.W. Imperial, bu.	2.84	4.67	NA
Corn, No. 2, Yellow **Columbus**, bu.	3.34	3.52	3.58
Soybeans, No. 1, Yellow **Columbus,** bu.	8.47	9.82	9.52
Grain Sorghum, No.2, Yellow Dorchester, cwt.	5.17	5.84	5.84
Oats, No. 2, Heavy Minneapolis, Mn, bu.	2.90	2.97	2.69
Feed			
Alfalfa, Large Square Bales, Good to Premium, RFV 160-185 Northeast Nebraska, ton.	128.75	150.00	NA
Alfalfa, Large Rounds, Good Platte Valley, ton.	67.50	98.00	97.50
Grass Hay, Large Rounds, Good Nebraska, ton.	65.00	*	NA
Dried Distillers Grains, 10% Moisture Nebraska Average.	100.50	152.50	156.50
Wet Distillers Grains, 65-70% Moisture Nebraska Average.	42.50	50.25	50.50

*** No Market**

Payment-for-ecosystem-services (PES) schemes financially compensate producers for implementing various conservation practices on their properties that generate ecosystem-service benefits for society. Conservation auctions have been adopted in several PES programs such as the Conservation Reserve Program (CRP) (Hellerstein et al., 2015) and involve producers submitting bids for one or more environmental practices for consideration in the auction.

Both the general and conservation auction design and implementation literature have focused on how the auctioneer can generate improved auction performance by modifying various auction features. One such feature is adopting different information revelation strategies about various aspects of the auction. Procurement auctions in general, and conservation procurement auctions in particular, can be quite complex for bidders, as the goods and services being procured are often evaluated based on multiple characteristics in addition to their price, including quality, quantity, delivery time, etc. In these settings, providing additional information can facilitate bid construction and improve auction performance by reducing the difficulty of generating a successful bid. However, the improved auction performance resulting from information access that reduces the difficulty of bid formation must be evaluated against the possibility of increased rent premiums due to this additional information. Another feature that is important to bidding and auction performance is the bid-submission protocol. One common protocol, the bid-menu format, involves all bidders submitting bids for all of their available practices, from which the auctioneer selects the best allocation per some criterion. A second protocol, the single-item format, requires the bidder to select one of the available practices for submission.

To the best of our knowledge, there is no study that provides a comparative analysis of the effects of information revelation and bid-submission protocol on auction performance while also considering auction complexity in a multi-round auction i.e. an auction where bidders submit bids through multiple iterations before a final set of winners is determined. We use an induced-value laboratory experiment (involving student subjects) to address this gap in the literature. The results of our study provide some benchmark findings which can inform field experimental trials on conservation auctions which can involve actual producer participants.

Experimental Design

Experimental participants earned cash payouts based on their choices in the conservation auction in which they were endowed with three items for which they would submit bids to sell them to the regulator – the auctioneer. No conservation framing was used in the experiment. There were two information treatments implemented in a between subject format: *Quality Value*, in which participants were shown the magnitude of the environmental quality value of the three available items, and *Quality Rank*, in which only the relative ranking of the three items was revealed. The bid-submission treatment (implemented in a within-subject format) compared outcomes in the *Item* and *Menu* treatments. The *Item* treatment involved participants submitting one bid for one of their items only. In the *Menu* treatment, participants submitted offers for all items. Given this experimental design, there were four treatments overall: *Value-Item*, *Value-Menu, Rank-Item*, and *Rank-Menu*.

We conducted eight experimental sessions, each with twelve participants recruited from undergraduate student population at Fordham University. Participants earned a mean payment of $33.25, including a $10 show-up payment. Earnings were recorded in Experimental Currency Units (ECUs) and the experiment was conducted in Z-tree (Fischbacher, 2007). Each session included a Menu treatment and an Item treatment, with Sessions 1 through 4 involving Value treatments and Sessions 5 through 8 the Rank treatments. Within a session, each bid submission treatment included eight multi-round periods, with a minimum of three and a maximum of five rounds per period. Participants were not informed of the fixed budget of 4,500 ECUs, in each auction period, a figure that was constant across treatments.

Each session included the four components: a paid risk preferences elicitation exercise (Holt and Laury 2002); an unpaid practice auction to familiarize participants with the user interface; and two experimental treatments on the basis of which participants were paid. Immediately prior to data collection, instructions were read aloud to participants to maintain an environment of common knowledge in the experiment. After bid submission in a round of the auction period was complete, offers were given a score equal to the quality of the submitted item divided by the offer price. These scores were then ranked in descending order and bids were provisionally accepted based on their score until the budget was exhausted. Participants were informed whether or not their offer had been provisionally accepted at the end of the round. In the Menu treatments, the notification of provisional acceptance specified which of the three items, if any, had been accepted. Participants then had the opportunity to adjust their offers in response to the information about the provisional status of their offer from the previous round, although the submitted offers could only be reduced in subsequent rounds of the period.

Auctions proceeded through the bid submission and winner determination routine to a subsequent round until the minimum of three rounds had been played. At this point, a stopping rule was evaluated to determine if the auction would end or if another round of bidding would be conducted. If the stopping rule was never satisfied, the auction repeated through the maximum of five rounds. At the conclusion of each period, participants were informed about whether or not their offer had been accepted and winners' earnings were updated on the basis of the difference between their winning item's offer and its corresponding cost.

Metrics of Analysis

In order to analyze auction performance, we consider two metrics. The first metric termed Percentage of Optimal Cost-Effectiveness Ratio (POCER) measures the degree of cost-effectiveness of the conservation auction. POCER is defined as $\frac{\sum_i q_i^a / \sum_i p_i}{\sum_i q_i^o / \sum_i c_i^o}$. In the numerator, $\sum_i q_i^a$ represents the sum of environmental benefits of all items accepted by the auctioneer from set of winning bidders *i* and $\sum_i p_i$ represents the sum of selected bids from set of winning bidders *i* representing the total expenditure of the auction. In the denominator $\sum_i q_i^o$ represents the sum of environmental benefits that would result from auction procurement if the regulator/auctioneer had full information about item costs (i.e. in the absence of asymmetric information) and $\sum_i c_i^o$ represents the sum of expenses in procuring the optimal set of items at cost. The second metric is termed Percentage of Optimal Score (POScore) and measures bidder-level rent seeking relative to the situation when the bidder submits their optimal item. The optimal item is the one which has the highest cost to benefit ratio. POScore is defined as $\frac{q_i^s / p_i^s}{q_i^o / c_i^o}$ where q_i^s and p_i^s represents the quality and offer for the item selected and submitted by the subject in the auction. It is to be noted that in the Item treatment the POScore is computed for one item only since participants submit an offer for a single item only while in the Menu treatment, the metric is calculated for all three items.

Similarly q_i^o and c_i^o represent the quality and cost associated with the optimal item for that bidder. This metric indicates that for bidders' optimal item, POScore value will not be influenced by that item's environmental quality.

Results

Table 1 reports treatment effects for data pooled for every auction period and all sessions. We see that the total environmental quality procured by the auctioneer is, on average, significantly (at 5% level) higher in the Rank treatment than in the Value treatment. Given that both treatments consider bidding on identical conservation action items, it is not surprising that total expenditures are not statistically different across treatments, though it is worth noting that the budget is, on average, not fully spent in either treatment. Also, the average amount of quality provided per unit of expenditure is significantly higher in the Rank treatment. Moreover, the constant endowments across treatments leads to the same ratio of optimal quality per unit of expenditure, so that the higher and significant POCER value in the Rank treatment can be attributed to the aforementioned higher mean quality per unit of expenditure. Observing Columns 4 through 6 of Table 1 to consider the impact of the bid-submission process on auction performance, we see that the total quality provided is significantly higher in the Menu treatment relative to the Item treatment. This leads to a higher ratio of actual to optimal quality in this treatment. Given the indistinguishable total expenditures across treatments, this leads to a significantly higher mean realized quality per unit of expenditure in the Menu treatment. Finally, POCER is significantly higher in the Menu treatment than in the Item condition.

Table 2 presents results of regression models that utilize a random-effects method, with standard errors clustered at the session level and confidence intervals generated through bootstrapping. Considering the results of Model 1, POCER is lower in each of the *Value-Item*, *Rank-Item*, and *Value-Menu* treatments relative to the base *Rank-Menu* treatment. These results are robust, with similar magnitudes, when controlling for treatment experience (Model 2). Our results indicate that when the auctioneer is responsible for item selection in the Menu treatment, auction complexity is reduced which in turn facilitates bid formation thereby improving auction performance. Table 2 also indicates the tension inherent in the Value treatment - access to quality information makes it easier for bidders to identify their best item but simultaneously increasing the opportunity for increased rent-seeking. The *Value-Item* treatment is the worst-performing design of the alternative designs explored. Given the magnitudes of the coefficients on the *Rank-Item* indicator, the results also suggest that the bid-menu format is better able to reduce the complexity of bid formation and mitigate the rent-seeking opportunities afforded through access to quality value information. Finally, experience in the experiment is detrimental (although marginally so) to auction performance.

Next, we consider the determinants of POScore for all submitted final-round offers across all iterative auction periods for each treatment to obtain insights about bidding behavior. These results are presented in Table 3 and are somewhat unexpected. For bidders who submit offers for their optimal item, POScore will be independent of item quality and may be either increasing or decreasing in item cost. For bidders who do not select the optimal item, POScore will be increasing in item quality and decreasing in item cost. Considering the first row of Table 3, we see that the coefficient on item cost is negative and statistically significant in all treatments, save the *Value-Item* treatment. In the Menu treatments, bidders had to generate offers for all available items. It is possible that bidders might have generated intentionally-high, and thus unsuccessful, offers for their lower-score items to ensure that their optimal item would be accepted by the auctioneer. This behavior, potentially beneficial in the Menu treatments, is sub-optimal and decreases expected payoffs in the Item treatments. The negative coefficient on the cost variable in the *Rank-Item* condition suggests that the lack of accurate quality information in this treatment is a real challenge to successful offer formation. The results in the second row of Table 3 shows the relation between POScore and item quality. Although POScore should be independent of item quality if the optimal item is selected, we find that the coefficient is positive and statistically significant. This relationship should only occur if participants were not submitting bids for their optimal item in the Item treatments. The result could be obtained in the Menu treatments if bidders knew that they were forming offers for their non-optimal items. To ensure that participants were able to identify successful strategies despite the complexity of some of the treatments, we present results in Table 4 of the same models as in Table 3, but only for bids that included the optimal item for each bidder.

Here, we see that POScore is increasing in cost across all treatments. This result is intuitive, as rent-seeking is less viable for high-cost items. Although we are considering bids only for optimal items, we do see negative and significant relationships between POScore and item quality. This finding suggests that these bidders are engaging in increased rent-seeking behavior for high-quality, optimal items, which is supported by the negative coefficients on the maximum-quality indicator variable, though these coefficients are only strongly statistically-significant in the Menu treatments. These results are a testament to strategic bidding and gaming in the auction. Finally, considering the entire data set, there is a reduction in POScore in the *Value-Item* treatment and *Value-Menu* treatments relative to the *Rank-Menu* treatment, which confirms previous results.

Conclusion:

Our results show that providing ranked environmental quality information and removing item selection from the bid-submission process improves auction performance. While access to only ranked quality information means that participants cannot compute the exact score of their items to identify their optimal item for submission, this form of environmental quality information successfully reduces rent seeking. Overall, these countervailing effects lead to improved performance under both of the bid-submission protocols explored in our experimental setting. In addition, implementation of a bid-menu format relaxes the computational cost associated with bid formation, leading to a reduction in complexity contributing to improved performance under both quality information treatments. We find that the bid-menu protocol can be useful in managing the trade-offs associated with the provision of quality information to bidders in conservation procurement auctions. The finding that the treatment with ranked benefit information and bid-menu format achieved the best auction performance in our multi-round auction in which offer adjustments across rounds were constrained to be reductions, highlights the importance of the choice of auction format. This outcome suggests that regulatory agencies might prefer to implement a conservation auction with a bid- menu submission protocol with ranked environmental-quality information to enhance auction performance, while lowering the computational costs and hence private transaction costs associated with offer-formation.

Providing environmental quality information can also promote greater auction transparency and hence producers' trust in the government, which could be useful in encouraging their participation and subsequent enrollment of high-quality lands in the PES program. One challenge to the policy-relevance of a bid-menu protocol is the extent to which procuring agencies possess sufficiently-detailed understanding of the various conservation practices available across the landscape and the cost involved in identifying the preferred subset of these practices that should be included for eligibility in the auction. Training of officials at procuring agencies and guidance offered to potential auction participants can thus be instrumental in effective implementing conservation auctions (Messer et al., 2016).

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Table 1. Period-level descriptive statistics

	Value Treatment	Rank Treatment	Difference	Item Treatment	Menu Treatment	Difference
Total quality provided	549.05	563.95	-14.91	547.36	565.64	-18.28
	(4.32)	(5.20)	0.0331	(4.56)	(4.90)	0.0123
Total expenditures	4,140.52	4,121.19	19.33	4,140.38	4,121.27	19.17
	(23.85)	(28.45)	0.500	(26.71)	(25.78)	0.6320
Average quality/ optimal quality	0.8721	0.8964	-0.0243	0.8697	0.8988	-0.0292
	(0.005)	(0.006)	(0.0501)	(0.006)	(0.007)	0.0071
Average quality/ expenditures	0.1326	0.1369	-0.004	0.1323	0.1372	-0.005
	(0.001)	(0.001)	0.0001	(0.001)	(0.001)	0.0001
Optimal qualities/ expenditures	0.1505	0.1505	0.0000	0.1505	0.1505	0.0000
	(0.001)	(0.001)	1.0000	(0.001)	(0.001)	1.0000
POCER	0.8814	0.9093	-0.0279	0.8789	0.9118	-0.0329
	(0.004)	(0.004)	0.0000	(0.005)	(0.004)	0.0000
Observations	64	64	128	64	64	128

Notes: All offers. Standard errors in parentheses. The third and fifth columns report the difference between column one values and column two values and column three values and column four values, respectively with the p-value from a Wilcoxon rank-some test of the quality of each variable across the two samples presented beneath each difference.

Table 2. Auction performance. Percentage of optimal cost-effectiveness ratio

	Model 1	Model 2
Value x Menu Treatment	-0.0248***	-0.0190**
	(0.0077)	(0.0100)
Value x Menu Treatment	-0.0608***	-0.0550***
	(0.008)	(0.0117)
Rank x Item Treatment	-0.0298***	-0.0298***
	(0.0071)	(0.0070)
Period Indicator		-0.0027*
		(0.0015)
Period x Item Interaction		-0.0013
		(0.0022)
Constant	0.9242***	0.9362***
	(0.0068)	(0.0062)
Observations	128	128

Notes: The dependent variable is the percentage of the optimal cost-effectiveness ratio achieved. The unit of observation is an auction period. The Rank-Menu treatment is the base case. Boot-strapped standard errors clustered at the session level are reported in parentheses. One, two, and three stars indicate 10 percent, 5percent, and 1 percent significance for a two-tailed hypothesis test based on a t distribution with 7 degrees of freedom, respectively.

Table 3. Bidder behavior. Percentage of optimal score (final-round offers)

	Value x Menu	Value x Item	Rank x Menu	Rank x Item	All Observations
Cost	-0.0003***	0.0000	-0.0003***	-0.0001***	-0.0002***
	(0.0000))	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Quality	0.0039***	0.0016*	0.0043***	0.0023***	0.0036***
	(0.0001)	(0.0009)	(0.0001)	(0.0002)	(0.0001)
MinCost	0.1182***	0.0548***	0.1251***	0.0660***	0.1079***
	(0.0014)	(0.0138)	(0.0023)	(0.0126)	(0.0030)
MaxQual	0.0763***	0.0409***	0.0772***	0.0386***	0.0726***
	(0.0028)	(0.0108)	(0.0024)	0.0054)	(0.0033)
Quality Value x Single Item Treatment					0.0012
					(0.0051)
Quality Rank Single Item Treatment					0.0203***
					(0.0076)
Quality Value x Bid Menu Treatment					-0.0026
					(0.0037)
Period Indicator	-0.0034***	0.0015	-0.0025***	-0.0022	-0.0027***
	(0.0003)	(0.0036)	(0.0005)	(0.0031)	(0.0005)
T Order	0.0059*	0.0149	-0.0095***	0.0275*	0.0026
	(0.0032)	(0.0102)	(0.0019)	(0.0146)	(0.0038)
H and L Switching Round	-0.0020*	0.0024	0.0037	0.0087	0.0007
	(0.0012)	(0.0017)	(0.0031)	(0.0063)	(0.0018)
Constant	0.6203***	0.5974***	0.5831***	0.5749***	0.6010***
	(0.0057)	(0.0965)	(0.0195)	(0.0377)	(0.0165)
Observations	1,152	384	1,152	384	3,072

Notes: The dependent variable is the percentage of the optimal score achieved. The unit of observation is an auction period. Bootstrapped standard errors clustered at the session level are reported in parentheses. One, two, and three stars indicate 10 percent, 5 percent, and 1 percent significance for a two-tailed hypothesis test based on a t distribution with 7 degrees of freedom, respectively.

Table 4. Bidder behavior. Percentage of optimal scope (final-round offers for optimal items)

	Value x Menu	Value x Item	Rank x Menu	Rank x Item	All Observations
Cost	0.0004***	0.0004***	0.0003***	0.0003***	0.0003***
	(0.0000))	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Quality	-0.0029***	-0.0038***	-0.0020***	-0.0021***	-0.0026***
	(0.0003)	(0.0003)	(0.0003)	(0.0004)	(0.0003)
MiniCost	-0.0157**	-0.0031	-0.0047	-0.0054	-0.0092***
	(0.0069)	(0.0053)	(0.0040)	(0.0071)	(0.0032)
MaxQual	-0.0278***	-0.0032	-0.0306***	-0.0096*	-0.0195***
	(0.0015)	(0.0048)	(0.0059)	(0.0052)	(0.0026)
Quality Value x Single Item Treatment					-0.0376***
					(0.0066)
Quality Rank x Single Item Treatment					-0.0106
					(0.0084)
Quality Value x Bid Menu Treatment					-0.0141**
					(0.0061)
Period Indicator	-0.0027**	-0.0009	0.0002	-0.0031***	-0.0015***
	(0.0011)	(0.0014)	(0.0010)	(0.0012)	(0.0006)
Torder	0.0070***	0.0051	-0.0159***	0.0225	0.0039
	(0.0013)	(0.0054)	(0.0027)	(0.0190)	(0.0047)
H and L Switching Round	-0.0005	0.0020	0.0038	0.0059	0.0018
	(0.0012)	(0.0016)	(0.0044)	0.0048)	(0.0019)
Constant	0.9756***	0.9270***	0.9442***	0.8911***	0.9538***
	(0.0257)	(0.0280)	(0.0213)	(0.0364)	(0.0170)
Observations	384	292	384	266	1,326

Notes: The dependent variable is the percentage of the optimal score achieved. The unit of observation is an auction round. Bootstrapped standard errors clustered at the session level are reported in parentheses. One, two, and three stars indicate 10 percent, 5 percent, and 1 percent significance for a two-tailed hypothesis test based on a t distribution with 7 degrees of freedom, respectively.