Auction Design for Voluntary Conservation Programs

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Auctions have been used to trade commodities as diverse as electricity, residential property, broadcast spectra and emission rights. The effectiveness of auctions as allocation mechanisms has been well documented (McAfee and McMillan, Wolfstetter, and Klemperer). Using auctions to conserve natural resources on private land, however, is a relatively new concept (Latacz-Lohmann and Hamsvoort, 1997, 1998). Land use practices such as commercial agriculture, livestock grazing and firewood collection have lead to environmental problems ranging from rising salt and nutrient levels in rivers and bays and wetlands degradation, to destruction of remnant vegetation and salinity. Non-point sources in agriculture generate a large fraction of certain types of pollution and farms are home to substantial native vegetation which has high conservation value. Unfortunately, existing non-point source regulation and conservation programs have not been fully successful in engaging private landowners.

One reason for this limited success is that, unlike conventional markets and point source emissions trading markets, it is difficult to clearly specify and observe the output in non-point source markets. A crucial problem therefore in the provision of

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environmental services arises from the uneven distribution of information between landowners and the regulatory agency (Latacz-Lohmann and Hamsvoort, 1997, 1998). Regulatory agencies have limited information about the costs landowners would incur in changing their management practices. For example, a landowner using a low polluting input may not reveal this information to the regulatory agency and if given a land management contract, the contract will result in small marginal environmental benefits and hence an overcompensation of the landowner's opportunity costs. On the other hand, the regulatory agency has access to scientific expertise and a relative advantage in obtaining information about the significance of the environmental assets or the environmental impact of different land management changes. For example, regulators have access to biophysical modelers and hydrologists, and they have inventory and quality information about flora and fauna. Hence optimal land use decisions would depend on the information revealed from both private landowners and government regulators. Auction mechanisms can be useful in reducing opportunistic behavior that arises due to these information asymmetries.

Auctions for natural resource management, though few in number, are increasing in popularity. Environmental agencies around the world are implementing a number of such market policy mechanisms to provide incentives for nature conservation on private land. The Conservation Reserve Program (CRP) in the United States has a broad environmental objective with a requirement that funds be allocated on a competitive basis. Landowners make offers to obtain CRP cost share assistance which is allocated to them based on an environmental benefits index (EBI). This index incorporates individual scores on six environmental factors: wildlife, water quality, erosion, enduring benefits,

air quality and conservation priority areas. The Conservation Stewardship Scheme and the Nitrate Sensitive Areas Scheme in the United Kingdom offer a fixed payment to landowners for pre-specified environmental actions (such as reducing nitrates in water) and chooses landowners who offer the best quality land management plan. In Australia, auctions are proposed in areas such as salinity control, nutrient control and conservation of existing vegetation where land use change is required to achieve environmental improvement (Stoneham et al.).

Designing auctions that work well in the field, however, can pose significant challenges. The literature on auction design is littered with examples of failure (see, e.g., Klemperer) and highlights the need for auctions to be tailored to suit the specific characteristics of different situations. Auctions in the environmental area are still in their infancy and can be expensive. Data from the field therefore are scarce and limit research progress in this area. Fortunately, experimental methods are available and are well suited to evaluate some fundamental design features of auctions intended to improve environmental quality.

This paper summarizes results from two laboratory experiments that investigate alternative auction mechanisms that are useful for conservation and natural resource management. The first experiment examines the relationship between an auction's information structure and landowners' incentives to reveal their costs, with the goal of identifying information conditions that allow the regulator to award land management contracts to maximize the pollution abated for a fixed auction budget. The experiment manipulates the amount of information available to landowner sellers as the primary treatment variable. In one treatment the auctioneer does not reveal to sellers the

environmental benefit of their proposed land use changes. In the other treatment sellers learn their projects' environmental benefits before submitting offers. Revealing information about environmental benefits could lead to an increase in the perceived fairness and transparency of the auction, and it could also educate landowners about the most beneficial land use changes and encourage investment in conservation. We find, however, that revealing this information reduces the auction's overall performance because sellers' offers misrepresent their costs more for high benefit projects. The results from this experiment were employed in a biodiversity preservation auction in Australia.

The second experiment focuses on the pricing rule for conservation and land management auctions. It compares discriminative price auctions with uniform price auctions to determine whether the pricing rule has an impact on the landowners' profits and on the environmental benefits acquired for a given, fixed auction budget. In the uniform price auctions the successful sellers receive a price determined by a rejected seller's price offer, which substantially increases the incentive to reveal costs compared to the discriminative price auction. But due to the heterogeneity of landowners' cost some landowners are "overpaid" in the uniform price auction because they receive payments from the regulator that substantially exceed their opportunity cost. Consequently, we find that the discriminative price auction has superior overall market performance. The two experiments are described in greater detail in Cason, Gangadharan and Duke and in Cason and Gangadharan, respectively.

The research reported here does not attempt to test any specific auction theory. The standard revenue equivalence theorem does not apply in these auctions since many of its assumptions are violated. The research questions, experimental hypotheses and

auction design are guided by intuition from auction theory, but the environmental features included in these auctions, to make them realistic, introduce complications that are not tractable using existing auction theory techniques. For example, suppliers can offer multiple projects at different costs that also differ in the amount of environmental benefit provided, and the fixed monetary budget for the auction makes the acquired quantity of environmental projects endogenous. The research agenda therefore is deliberately policy-oriented and considers economic environments where theoretical research is unable to give clear predictions. This highlights an important advantage of the experimental method. It permits comparing alternative auction designs in "wind tunnels" that are more complex and realistic than typical theoretical environments. This "market engineering" provides a critical link between economic theory and field implementation.

Experimental Designs

Table 1 summarizes the experimental designs. All subjects who participated in the experiments were undergraduate students from the University of Melbourne and Purdue University. Sessions lasted less than two hours and subjects earned an average of US $24. In both experiments eight sellers participate in each session and these sellers have three items each which represent three land management changes that they can undertake. These "items" can have different costs and environmental benefit levels that vary across sellers. Sellers submit offers for these three items using a web browser and the offers are ranked by the experimenter's computer according to the price per unit of benefit of the items. The experimenter purchases the lowest price items per unit of environmental benefit, and spends a constant budget in every auction. The amount of the budget is unknown to the sellers but it remains unchanged across auction rounds, so as in the field

the sellers could form reasonably accurate expectations.

Although sellers submit offer prices for three different items, the experimenter buys no more than one item from each seller. We impose this restriction because sellers would not obtain the same marginal environmental impact of a land use or management change if another land use change has already been implemented. This interaction is important but difficult to incorporate in the design. For example, if a landowner installs drains with sediment traps to reduce the amount of pollution runoff, this would reduce the marginal environmental impact of reducing fertilizer applications. The environmental benefits provided by different landowners' projects could also be interrelated. For example, if one landowner leaves a buffer zone between his production land and a major creek, this can reduce the environmental benefits provided by an uphill landowner's reduced fertilizer applications. We leave the study of these types of interactions for future research.

The designs varied in the two experiments to reflect their different research focus. All the auctions in the first experiment use a discriminative, "receive-your-own-offer" pricing rule, whereas in the second experiment the pricing rule is the treatment variable. The second experiment includes sessions in which the sellers receive a uniform price per unit of environmental benefit equal to the best rejected offer, as well as discriminative price sessions in which successful sellers receive the actual price offered rather than a price uniform to all sellers. In the first experiment we conducted multiple auction rounds in each period, and sellers could revise their offers after learning whether any of their projects were tentatively accepted. A multi-round auction could increase efficiency if it allows inexperienced landowners to avoid costly mistakes that could arise due to strategic

bidding. However, multiple rounds could also increase administrative costs since offers would need to be assessed and feedback provided to the landowners after each round. Moreover, in the first experiment we find that offers tended to increase and efficiency decreased in the later rounds; hence, the second experiment conducted only one round of offers each period. In the first experiment, we allow subjects to communicate verbally between auction periods to verify that the auction rules are robust to collusion opportunities, whereas we did not allow any communication in the second experiment. Finally, the first experiment focuses on identifying the information conditions that improve auction efficiency, and it determined that efficiency suffers due to more strategic bidding when sellers learned their projects' environmental benefits before submitting offers. Therefore, in the second experiment we do not reveal the environmental benefit to sellers in all sessions.

Both experiments employ cost and environmental benefit parameters for specific environmental problems: nitrogen reduction and salt reduction, calibrated for the state of Victoria, Australia. Using realistic parameters should strengthen the parallelism between the experiment and the field. The lessons learned from these experiments however can be extended to other environmental problems and regions. Throughout both experiments subjects had different cost and quality parameters to represent the heterogeneity of cost and environmental benefits between implementing different projects on the same land, and between the same project implemented on different plots of land.

Results

We are interested in examining the impact of the design of the auction on market performance and on individual behavior. In this section we summarize results on overall

market performance and seller offer functions.

Market performance in environmental auctions must take into account economic gains from trade and environmental benefits incurred from the land use change. We summarize the environmental performance with a measure called P-MAR (the percentage of maximum abatement realized), the amount of pollution abatement realized by the auction as a percentage of the highest amount of abatement that could be realized with the regulator's auction budget. Results are similar when using an alternative measure based on the price paid per unit of abatement. We also measure performance with seller profits: the profits received minus project costs. Lower seller profits could be considered better from the regulator's viewpoint as seller profits represent public money that the regulator overspends relative to the actual cost of implementing the land use change.

The first experiment focuses on the information revealed to sellers as the main treatment variable and finds that P-MAR is significantly higher and seller profits are significantly lower when sellers do not learn the environmental benefits associated with their projects. We provide statistical evidence with panel data regressions based on a random effects error structure. The empirical model shown in table 2 allows the information treatment effects to differ in the early and late periods, since 1/period is one in the first period but declines as periods progress, and (period-1)/period is zero in the first period but rises toward one as periods progress (Noussair, Plott and Riezman). The estimates show that performance is not different across information treatments in early periods, since the Benefits Revealed dummy interaction with 1/period is never significant. Performance declines, however, in later periods in both treatments. More importantly, P-MAR decreases to about 92 percent in the benefits unknown treatment,

but it decreases to about 91.8 - 11.6 = 80 percent when information about environmental benefits is revealed. Similarly, seller profits are significantly higher in later periods when information is revealed. Seller profits also rise in later periods in both treatments, but the greater increase when benefits are revealed is not statistically significant.

To understand why the market performance is lower in sessions where environmental benefits are revealed, we examine seller behavior in more detail. Seller offers are not higher on average in the benefits revealed treatment, but the variance of the offer/cost ratio is twice as high in this treatment as compared to the benefits unknown treatment. This high variance is caused by the substantially higher markups by informed sellers for high benefit projects, as illustrated in figure 1. These high benefit projects are often bought in the auction, and since sellers offer these projects at a higher price the regulator cannot buy as many. This leads to lower abatement and lower efficiency.

In the second experiment we examine the impact of the pricing rule on market performance and on seller behavior. As mentioned above it is not possible to obtain exact theoretical predictions for these auction environments once realistic features of the conservation problem are incorporated. It is nevertheless still useful to have some approximate benchmarks based on simplifying assumptions. For the uniform price auction the sensible benchmark to use is one of full revelation, i.e. offer that exactly equal cost. Sellers have an incentive to offer their projects at cost because submitting an offer below cost does not increase the probability of acceptance except when the price received falls below cost, and submitting an offer above cost is unlikely to increase price. In the case of discriminative price auctions, standard auction theory suggests an approximate

benchmark, which has a nonlinear equilibrium offer function that substantially exceeds costs for low cost projects.

These benchmarks suggest that performance should be better for the uniform price auction. For example, P-MAR should range between 72 and 87 percent in the uniform price auction, but should range between only 55 to 63 percent in the discriminative price auction. Using both parametric and nonparametric tests, however, we find that the discriminative price auction has significantly better performance. In particular, table 3 indicates that pollution abatement is greater and seller profits are lower in the discriminative price auction compared to the uniform price auction. We again look to seller offer behavior to understand these performance differences.

Sellers in the uniform price auctions made offers near their costs, as predicted, and P-MAR was within the anticipated 72 to 87 percent range. Sellers in the discriminative price auctions, however, did not submit offers consistent with the theoretical benchmark. In particular, sellers who had low-cost projects in the discriminative price auctions did not submit offers much higher than their costs as anticipated. For example, for our parameters in the nitrogen reduction environment the risk-neutral benchmark from multiunit auction theory suggests that offers should be twice as great as costs on average for costs less than 5000 experimental dollars. Actual offers for these low cost draws, by contrast, only exceeded costs by 24 percent on average. These low-cost projects are very important for the overall efficiency and abatement realized in the auction, since they have a high probability of being accepted by the regulator. Since sellers offered these projects at prices relatively close to costs, the discriminative price auction performed better than the uniform price auction.

Discussion

Results from these laboratory experiments indicate that the design of auctions for land management changes could have a critical effect on seller behavior and market performance. The experiments indicate that revealing the environmental benefits associated with land management options reduces market performance, although it does increase profit transfers to landowners. Sellers behave strategically when they know the environmental benefits of their projects, raising their offer price for higher benefit projects. This implies that fewer projects can be bought using the regulator's fixed auction budget and this reduces the efficiency of the auction when information is revealed. Some of the results from this experiment are now being used to inform policy. For example, based on these results, the Bush Tender project (a pilot project initiated by the Victorian Department of Natural Resources and the Environment, in Australia) does not reveal information about environmental benefits to landowner sellers in their auction for biodiversity preservation.

Auction competition with more limited information appears to have the beneficial effect of reducing strategic behavior of participants. What is the optimal amount of information that should be provided to the sellers? Additional experiments are required for a more complete answer to this question, but our results provide some guidance that can be used in current, practical design. If auctions are conducted annually in the same region then sellers might be able to infer the private information of the regulator regarding environmental benefits. To reduce the impact of this information leakage, regulators with multidimensional environmental objectives could change the weights attached to each dimension each year. For example, the relative weights in the

environmental benefit index used in the CRP could be adjusted each year both to reflect changing environmental priorities, but also to preserve the information advantage of the USDA and to limit the scope for landowners to extract information rents.

The second experiment examines the pricing rule of the auctions and finds that discriminative price auctions perform significantly better on all market performance measures. Uniform price auctions have better cost revelation properties and sellers on average made offers in this auction format that were consistent with the revelation incentives of this institution. This auction format does not achieve full efficiency, however, since the uniform price was set by the first rejected seller's offer, and all successful sellers received this price per unit of environmental benefits. Successful sellers therefore receive prices that exceed their offers and costs.

The finding that the uniform price auction had greater inefficiency than the discriminative price auction was not anticipated by our risk neutral theoretical benchmarks. The offers closer to costs than this benchmark in the discriminative price auction are not anomalous, however, since they are consistent with the overbidding relative to the risk neutral benchmark extensively documented in buyer auctions. Several explanations, including risk aversion and bounded rationality, have been advanced to explain these deviations (e.g., see Goeree, Holt and Palfrey and the references cited therein). This highlights the importance of evaluating actual performance with human decision makers prior to implementation in the field, since a purely theoretical comparison could be misleading.

We envision this research project as the first step of a multi-step process from concept to field application. The laboratory results provide a "proof-of concept" and

preliminary comparison of alternative rules for some new auction formats. We have employed environmental cost and benefit parameters calibrated from the field in these experiments to improve the potential practical application of these design lessons. As already mentioned, however, the experiments do not include some potentially important features relevant for some environmental applications, such as the interaction of environmental benefits across different land use changes. We have also used student subjects and neutral (non-environmental) terminology, as is the standard practice in experimental economics. All of these simplifications and standard controls should be relaxed, perhaps in field experiments and small-scale pilot auctions with landowner participants. We acknowledge that there are limitations on the conclusions one can draw from these laboratory experiments. This does not imply that the experimental method is not useful for practical policy design; in fact, it implies the opposite: a need for additional experiments to fine tune the institutions and rules to improve chances for success in the field.

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Table 1. Summary of the Experimental Designs

First Experiment: Impact of Information about Environmental Benefits	Second Experiment: Impact of the Pricing Rule
Subjects: • 3 types of subjects, 4 representing broadacre and grazing on pasture land, 2 representing non-agricultural built up areas and 2 representing horticulture. **Sessions:** • 11 sessions with 5-10 periods in each session. • Multiple offer rounds in each period. **Treatments:** • Sellers have information about the environmental benefits of the land use change they offer (6 sessions) or not (5 sessions). • All parameters relating to nitrogen reduction. **Procedure:** • Pricing rule used: all discriminative price. • The offers are ranked according to price per unit of benefit. • A maximum of 1 project is bought from each seller. • After a round, sellers learn if their offers have been provisionally accepted and they are allowed to revise their offers. • The results from the final round determine who sells and at what price.	**Subjects:** • All subjects of one type. **Sessions:** • 30 sessions with 36 periods in each. • No multiple offer rounds. **Treatments:** • Pricing rule: discriminative (15 sessions) or uniform (15 sessions). • Parameters relating to nitrogen reduction and salt reduction. **Procedure:** • Sellers do not know the environmental benefit of their land use changes. • The offers are ranked according to price per unit of benefit. • A maximum of 1 project is bought from each seller.

Table 2. Market Performance Model Estimates for First Experiment

Explanatory Variable	Percentage of Maximum Abatement Realized = Actual/Maximum Abatement for market in period *t*	Individual Seller Profits = Earnings for Each Individual Seller *i*, in period *t*
1/period	0.938*	-474.9
	(0.069)	(946.6)
(period-1)/period	0.918*	371.1
	(0.041)	(563.9)
(Quality Revealed dummy)×(1/period)	0.005	25.9
	(0.075)	(1061.6)
(Quality Revealed dummy) × (period-1)/period	-0.116*	357.7
	(0.035)	(606.6)
Observations	50	400
Significance of the regression (*p*-value)	<0.0001	<0.0001

Notes: Standard errors in parentheses. Asterisks denote a coefficient that is significantly different from zero at the 1-percent level (two-tailed test). Due to the differing session lengths, to provide comparable data all estimates employ only the data up to and including period 5. The table reports results after dropping one obviously collusive session. All models are estimated with a random effects error structure, with the session as the random effect for the session-level analysis in the P-MAR model and the individual seller as the random effect for the seller-level analysis of the profits model.

Table 3. Overall Performance by Session for Second Experiment

	Average Percentage of Maximum Abatement Realized (P-MAR)		Average Seller Profits	
	Discriminative Price	Uniform Price	Discriminative Price	Uniform Price
Nitrogen Reduction *(Ten Individual Sessions in Each Treatment)*				
	82.8%	69.4%	4722	6723
	85.2%	72.6%	3923	6682
	84.3%	72.4%	4383	6528
	80.8%	74.2%	4840	5467
	88.6%	69.6%	2501	7828
	90.7%	70.4%	2108	7242
	88.8%	71.1%	2387	6593
	88.8%	71.7%	2555	6962
	88.4%	73.4%	2527	6098
	88.4%	67.2%	2932	5952
Treatment Mean	86.7%	71.2%	3288	6608
Salt Reduction *(Five Individual Sessions in Each Treatment)*				
	89.0%	84.6%	59.4	95.6
	89.5%	85.4%	68.7	78.2
	89.4%	83.2%	67.9	107.1
	89.1%	83.1%	62.0	88.5
	88.3%	84.7%	60.5	96.2
Treatment Mean	89.1%	84.2%	63.7	93.1

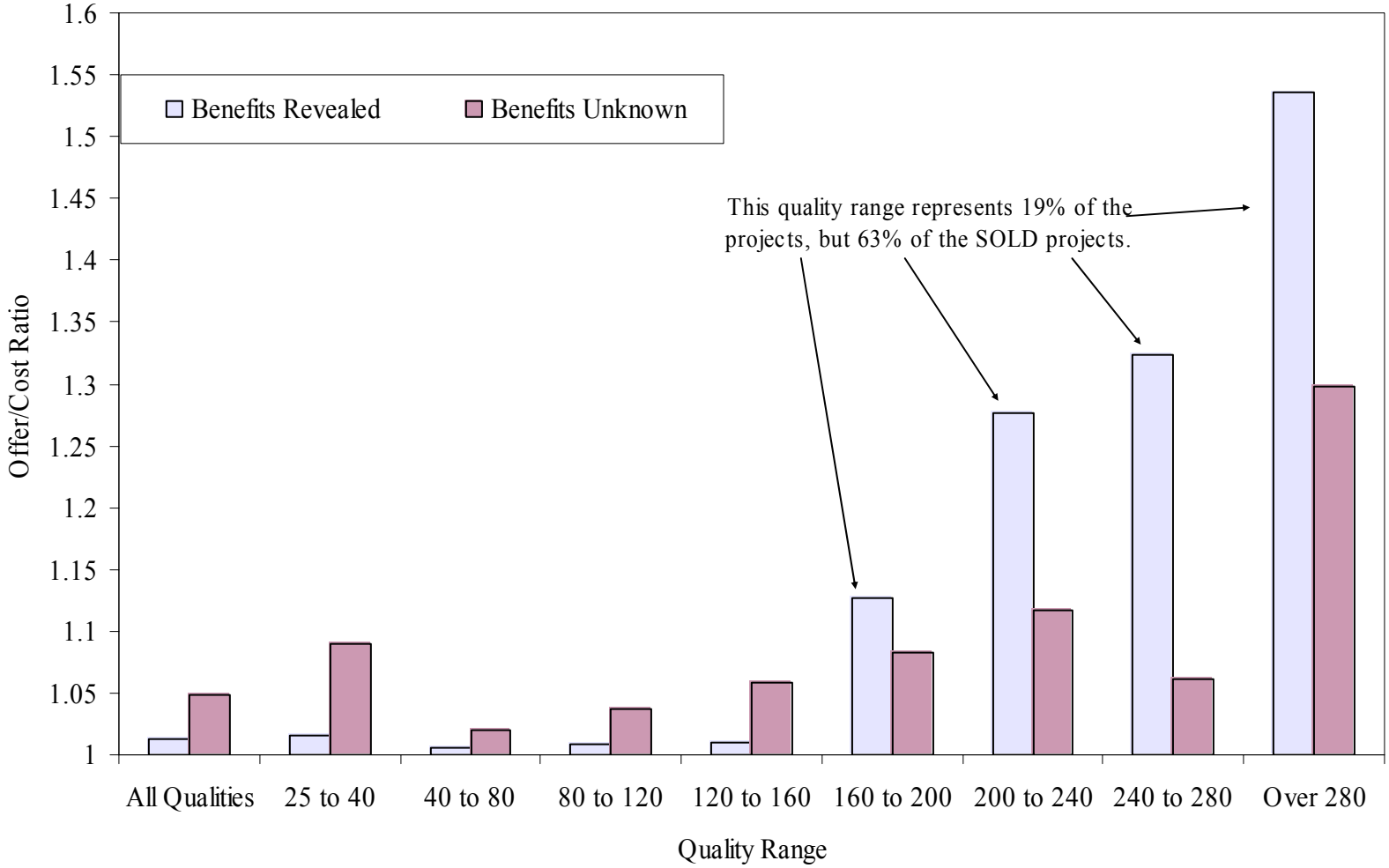

Figure 1. Median offer/cost ratio by information treatment and quality range in first experiment (periods 1-5 final round offers)