

Information and Auction Performance: A Laboratory Study of Conservation Auctions for Spatially Contiguous Land Management

Simanti Banerjee · Anthony M. Kwasnica · James S. Shortle

Accepted: 22 May 2014 / Published online: 4 June 2014
© Springer Science+Business Media Dordrecht 2014

Abstract Conservation auctions are used by public agencies to procure environmental friendly land uses from private landowners. We present the structure of an iterative conservation auction that ranks bids according to a scoring rule intended to procure spatially adjacent conservation land use projects. Laboratory experiments are conducted to compare the performance of this auction under two information conditions. Under one condition subjects have knowledge about the spatial goal implemented by the scoring rule and in the other case they don't. The results indicate that rent-seeking is intensified with more information and increased bidder familiarity with the auction. Revealing the spatial information on the other hand has no impact on auction efficiency.

Keywords Conservation auctions · Ecosystem services · Information · Lab experiments · Spatial contiguity

1 Introduction

The natural environment produces multiple ecosystem services which are valuable to humans. The supply of many of these ecosystem services (e.g. biodiversity and natural habitat protection, reduction in soil erosion and flood control) is strongly influenced by the structure of agricultural and other landscapes, with some land uses and spatial patterns of land use being more

S. Banerjee (✉)
Department of Economics, Rice Hall 227, Oberlin College, Oberlin, OH 44074, USA
e-mail: sbanerjee4@unl.edu

A. M. Kwasnica
Department of Risk Management, Pennsylvania State University, University Park, PA, USA
e-mail: kwasnica@psu.edu

J. S. Shortle
Department of Agricultural Economics, Sociology and Education, Pennsylvania State University,
University Park, PA, USA
e-mail: jshortle@psu.edu

ecologically productive than others. These ecosystem services benefits usually have public good features implying that private landowners don't have an economic incentive to provide them at their optimal levels. In consequence, governments have implemented incentive-based policies referred to as Payment for Ecosystem Services (PES) schemes (Wunder 2005; Jack et al. 2008; Scarlett and Boyd 2011) to pay landowners to adopt environmentally beneficial land uses on their properties for increased delivery of these ecosystem services.

Many PES schemes implement reverse auctions to avoid or mitigate rent seeking (and the resulting inefficiencies) in conservation agency project procurement arising from asymmetric information about the private opportunity costs of land use change (Latacz-Lohmann and Van der Hamsvoort 1997). Prominent examples are the Conservation Reserve Program—CRP (Kirwan et al. 2005; Ferris and Siikamäki 2009; Cowan 2010) in the US, the Higher Level Stewardship Schemes in the UK and the Bush Tender Trial (Stoneham et al. 2003) and subsequent auctions/tenders in Australia. These auctions are expected to generate competition between landowners and reduce rent seeking and achieve conservation goals at the lowest possible cost given the program budget. As evidence, the Conestoga Watershed Reverse Auction implemented by the World Resources Institute, the Pennsylvania Environmental Council and other organizations led to a reduction in phosphorous runoff in the watershed at a much lower cost than the traditional Environmental Quality Incentives Program—EQIP (Selman et al. 2008). According to the EQIP data from 2005, average cost of phosphorous reductions in the watershed was \$26.19 compared to \$5.06 achieved in 2007 by the reverse auction. Such cost savings have also been documented for reverse auctions relative to a uniform payment scheme by Connor et al. (2008) in the Australian context.

Conservation auctions can have both uniform price (Jack et al. 2009) and discriminatory price (Stoneham et al. 2003) formats. These mechanisms include a scoring metric to evaluate the bids submitted by individual landowners for their land management projects on the basis of various environmental criteria and costs of land management. For example, the CRP uses the “Environmental Benefit Index” an additive metric (sum of environmental values less the bid value) and the Bush Tender used a “Biodiversity Benefit Index” which had a benefit-cost ratio format to rank projects on the basis of submitted bids. In all cases, once bids are submitted, projects are ranked in descending order by their scores and offers are selected according to the metric ranking until the program budget is exhausted. These metrics are constructed in a manner that higher bids receive lower scores for any given benefit level reducing the likelihood of acceptance.

Scoring rules in these conservation auctions however do not reward pairs or sets of bids for adjacent land use projects or those within some specific distance of each other. Yet, agglomeration of land uses can often produce much greater conservation benefits than if they are fragmented or disconnected (Margules and Pressey 2000; Dallimer et al. 2010). For example, animal mobility is enhanced by the creation of corridor linkages between core areas of habitat (Bartelt et al. 2010). Similarly foraging patches on marginal cropland within the dispersal distance of natural pollinators produce much larger pollination benefits and associated marketable benefits by increasing crop production than if these patches are further out and can only be accessed by flying greater distances (Carvell et al. 2007).

In recognition of this fact Tanaka (2007), Windle et al. (2009), Reeson et al. (2011), Bamière et al. (2013) and Polasky et al. (2014) present conservation and land consolidation auctions which target spatial objectives. They suggest that the auction format, possibility of bid revision and resubmission and the information available to bidders impact the auction's environmental and economic performance. The key features of these studies are that the conservation agency informs the landowners about the format of the scoring metric, their projects' cost or benefits, and the identity of winning bidders. However they do not

provide information about the auctioneer's spatial goal. Yet, revealing this information can prove important for multiple reasons. First, from a policy performance perspective, the spatial information can facilitate bidders' understanding of the bid-selection process and avoid conflicting situations where participants may view selection of multiple neighboring projects as being biased on the regulator's part. Second, disclosing the spatial feature may incentivize greater participation rates i) as landowners become aware that neighbors' inclusion increases their own chances of selection and ii) by reducing the overall complexity associated with bid preparation and submission that may deter participation and reduce auction performance (Hill et al. 2011).

The beneficial impact of providing more information has been scientifically documented for strategic environments where coordination (here spatial) is desired: in Stag Hunt, Chicken and Prisoner's Dilemma games (Duffy and Feltovich 2002) and in the Critical Mass game (Devetag 2003). The experimental evidence from these studies indicates that additional information improves the likelihood of coordination and efficiency. In the procurement auction literature however, the effect of information is not definitive and depends upon the features of the environment. Theoretical procurement auction models by Gal-Or et al. (2007) and Doni and Menicucci (2010, 2011) suggest that the impact of revealing the auctioneer's objective is dependent on the strategic environment's features. These features include bidders' risk attitudes and variability in cost and benefit values of items to be procured. Experiments by Haruvy and Katok (2012) indicate that objective disclosure reduces auction performance. In the conservation auction domain, Cason et al. (2003) find that revelation of information to individual bidders about environmental benefits from their non-point source pollution reducing projects lowers an iterative auction's economic efficiency (in terms of the projects selected) and cost effectiveness in terms of costs of project procurement; Glebe (2013) on the other hand provides a theoretical model where information disclosure produces efficiency improvements by incentivizing entry of new landowners and competition between them. However, both these studies focus on non-spatially targeted conservation auctions.

To the best of our knowledge there has not been any explicit evaluation of the impact of announcing the auctioneer's targeted environmental goals to bidders on mechanism performance and bidding behavior for conservation auctions with spatial targeting. This gap in the literature is important to address because first, it is possible that the perceived environmental benefits of revealing the spatial goal will be negated by possible efficiency losses arising from landowners exploiting their locational advantage and rent seeking because they have many neighbors; second, announcing the spatial goal may lead to collusive bidding by neighbors or properties within a given distance of each other especially if these auctions provide feedback information about the winners and losers and the reasons for selection; and finally, landowners may not participate in these auctions perceiving their chances of selection to be low because they have fewer neighbors.

Given these multiple possibilities, we use laboratory experiments to investigate the impact of information revelation on the performance of an iterative auction with spatial targeting. We also provide an analysis of individual bidding behavior to obtain insights about the nature of agent learning and the factors that affect bid submission in this spatially targeted strategic setting. The lab provides a low-cost means to study auction performance in a simple context-free environment termed a testbed prior to costly field implementation with actual landowners in context-rich settings (Plott 1997). On the basis of the experimental design and parameterization, our key result is that the public disclosure of the spatial goal intensifies rent seeking reducing cost-effectiveness without any impact on auction efficiency. Rent seeking is also exacerbated at higher levels of bidder experience independent of the information treatment. Additionally, the nature of costs and benefits associated with environmental projects

significantly impacts bidding patterns and performance. These results have important policy significance as we discuss in subsequent sections.

2 Auction Design

This section describes the structure of a descending price iterative auction with a discriminatory price format for the procurement of spatially adjacent land use projects. We implement a discriminatory price rule following experimental evidence about cost effectiveness of a discriminatory price auction relative to a uniform price one (Cason and Gangadharan 2005). In the auction, bidding progresses in a series of iterations or trials. After placing bids in an iteration, bidders are provided information regarding all bids and the identity of the winners and losers. Then they have the opportunity to bid again in the next iteration. We consider this iterative structure as landowners may often submit very high bids because (i) of excessive rent-seeking tendencies, (ii) they don't have accurate information about their own costs of conservation practices or (iii) they have little or no experience with bidding in conservation auctions. An iterative auction permits bid revisions and provides landowners multiple opportunities to resubmit bids that may reflect their costs more accurately. Such resubmissions can improve their chances of selection in subsequent trials and improve auction efficiency and reduce the costs of procurement (Shogren et al. 2000; Rolfe et al. 2009; Hill et al. 2011). For example, in 2006 under the Wetland Reserve Program (WRP), a two-iteration discriminatory price auction pilot in seven US states realized cumulative annual cost savings of US\$820,000 reducing conservation land use acquisition costs by 14 % for the USDA for that year (Selman et al. 2008; Knight 2010).

The spatial feature is introduced in the strategic environment by attaching location specific identities to all N bidders whereby they are located on a ring or circular landscape. Any bidder i 's neighbors are assumed to be the bidders indexed immediately before (left) and after (right) them where bidders with indices of $i = 1$ and $i = N$ are assumed to be left and right neighbors of each other respectively. For notational convenience we define left $l(i)$ and right $r(i)$ neighbor functions that allow us to succinctly identify the appropriate neighbors. The functions are

$$l(i) = \begin{cases} i - 1 & \text{if } i > 1 \\ N & \text{if } i = 1 \end{cases} \quad (1)$$

$$r(i) = \begin{cases} i + 1 & \text{if } i < N \\ 1 & \text{if } i = N \end{cases} \quad (2)$$

The symmetric circular landscape is adopted to avoid edge effects. Edge effects arise on landscapes where properties are located near water bodies or other geographical barriers such as roads which prevent the creation of contiguous land use project areas; or at the edge of the administrative jurisdiction beyond which government agencies may not be able to implement the auction. However the geographical scale of conservation schemes in practice is such that the share of agents located on landscape edges is sufficiently small. Thus, we don't necessarily abstract away from reality by considering the circular arrangement. Additionally, since every player has two neighbors the impact of the information treatment between groups can be isolated without any potential confounding arising from some players behaving differently as they have more neighbors and hence a potential locational advantage.

The environmental benefits resulting from conservation projects on the i th bidder's property independent of projects undertaken on adjacent properties are denoted by v_i . If projects

are implemented by neighboring landowners, additional environmental benefits accrue owing to agglomeration of land uses and the positive synergies from it. The agglomeration benefits for any two adjacent projects is assumed to be the same, and denoted by d . This assumption corresponds to our previously mentioned objective of ensuring that the likelihood of selection of any set of adjacent projects is not influenced by their location on the circle: attaching different values to the contiguity benefit would imply that adjacent projects at specific points on the landscape are more valuable to the auctioneer than others independent of their intrinsic benefits and costs. While that is an interesting and realistic scenario, it could confound identification of our information revelation treatment effect.

During the iterative auction bidders can submit bids in multiple iterations but in any trial t can submit at most one bid for conservation agency funding denoted by b_{it} . Given all submitted bids, the auctioneer calculates a score for every bid using the following scoring rule:

$$Score_{it} = x_{it} \left\{ \frac{v_i + d(x_{l(i)t} + x_{r(i)t})}{b_{it}} \right\} \tag{3}$$

In Expression (3), $x \in \{0, 1\}^N$ is a vector defining an allocation of winning and losing bidders in iteration t where element $x_{it} = 1$ indicates that the i th bidder has been selected in the auction in iteration t and $x_{it} = 0$ otherwise. The scoring rule is designed to make a project’s likelihood of selection depend positively on their project’s intrinsic environmental benefit and additionally be higher if neighboring projects are selected i.e. if $x_{r(i)t}$ and/or $x_{l(i)t}$ are equal to 1. This benefit-cost ratio format also ensures that higher bids lower the score and consequently the chances of selection. Using the scores, the auctioneer selects a set of bids that maximizes the combined scores associated with the winning projects subject to the conservation budget (denoted M). Formally, the constrained optimization problem is:¹

$$\begin{aligned} \max_{x_i} \quad & \sum_{i=1}^N x_{it} \left\{ \frac{v_i + d(x_{l(i)t} + x_{r(i)t})}{b_{it}} \right\} \\ \text{Subject to} \quad & \sum_{i=1}^N x_{it} b_{it} \leq M \end{aligned} \tag{4}$$

In determining the auction solution for a trial, in the first step of the optimization exercise, the computer uses an algorithm to select all combinations of projects which can be supported by the budget. In the next step, it evaluates the sum of scores of these project combinations. If a combination comprises of neighboring projects, then each project receives a higher score on the basis of Expression (3) which in turn contributes to the overall value of the scoring metric in Expression (4). Finally, the configuration that has the highest score is identified. This allocation is a *provisional allocation* for trial t , denoted as x_t^* and is announced to the bidders at the end of iteration t and the auction proceeds to trial $(t + 1)$.

To avoid confusion and spurious bidding, bids are restricted to exceed costs in all trials. Additionally, iteration t ’s bids are automatically considered to be the final bids in iteration $(t + 1)$ unless bidders submit a revised lower bid. This automatic bid submission feature serves as an activity rule (Harsha et al. 2010) and ensures that participants do not sit out trials without bidding, potentially leading to gaming tendencies and possible auction efficiency

¹ In Expression (3), for a winning bidder i in trial t , the expression $x_{it}(x_{l(i)t} + x_{r(i)t})$ takes a value of 0, 1 or 2 depending on the number of selected neighbors. For example, $x_{it}x_{l(i)t}$ represents adjacency between a selected player i and their left neighbor generating the contiguity benefit d . For a losing bidder i in trial t this expression is always zero as $x_{it} = 0$.

losses.² In any iteration $(t + 1)$ the previous trials's bids can be revised on the basis of a minimum bid decrement rule determined by the auction. When all bids are submitted the optimization exercise is repeated and $x_{(t+1)}^*$ is determined and announced. This process continues over multiple iterations until one or more stopping or ending rules apply. Such rules ensure that iterative auctions end within a reasonable period of time and maximize auctioneer surplus by reducing game tendencies on the part of the bidders (Kwasnica and Sherstyuk 2013). For our study the following stopping rules need to be satisfied for trial t :

1. $\bar{t} \leq t \leq T$ where \bar{t} represents the minimum number of trials and T the maximum number of trials.
2. The value of the objective function is the same between consecutive trials.

The minimum trials condition is intended to help bidders understand the bidding procedure before a final allocation is selected. This condition ensures that allocations are not chosen on the basis of inaccurate or spurious bids from early iterations of a period. The second condition requires that the final allocation is obtained at the point when all bid improvement possibilities have been potentially exhausted and the objective function has converged to its maximum value given the auction parameters. If none of these stopping rules are satisfied, the auction repeats for all T trials to generate the final allocation x^* .

3 Experimental Design and Procedures

The data used in this study was obtained from 12 experimental sessions with six subjects each. During the experiment, all subjects were arranged in a circle and participated in the iterative auction presented in the previous section. The location of players on the circle remained unchanged throughout a session to enable subject learning and reputation building between adjacent players. This fixed matching feature also reflects the fact that private property ownership usually remains unchanged for long periods of time on geographical landscapes. In order to analyze the impact of publicly disclosing the spatial goal on auction performance and individual behavior, a between-subject experimental design was considered and two types of sessions termed INFO and NO-INFO were implemented. In both treatments, subjects received information about the benefit-cost ratio format of the scoring metric. Additionally, subjects in the six INFO sessions were informed that their score and hence chances of winning could improve if their neighbors were selected in the auction. This information was suppressed in the NO-INFO sessions.

Furthermore, taking advantage of the laboratory setting and the fact that conservation auctions such as the CRP and WRP involve multiple signups or repetitions; we implemented multiple periods or repetitions of the auction during each session. Such repeated interactions are useful in analyzing the effect of increased familiarity with the mechanism on individual bidding behavior and the associated impact on auction efficiency and rent seeking. Each session consisted of 13 periods with Period 1 being a non-paying practice period. This extra period was included to ensure that subjects were familiar with the experimental procedures. Every period had a minimum of five and a maximum of ten trials.³ At the end of each trial, subjects received feedback about all submitted bids in the current trial, identity and location

² The activity rule also gives rise to an auction environment in which participation is mandatory whereby we don't have to worry about issues such as different numbers of participants in the auction and how this feature interacts with our treatment specifications and influences bidding in the experiment.

³ Period 1 had only two trials with arbitrarily chosen parameters. Subjects were informed that this was a non-paying period.

of winners, number of neighbors selected and also had access to their own bid history for all trials within a given period (in the history table on the results screen). Since we maintained a considerably transparent strategic environment in terms of information feedback about auction outcomes, we did not implement a communication treatment which would most likely facilitate spatial coordination but could produce collusive bidding tendencies between neighbors.

In addition to the between-subject information treatment, we considered a within-subject cost-benefit parameter variation treatment. This was done for two reasons. First, given the nature of information feedback, it is likely that subjects may succeed in learning about others' environmental value and project cost parameters leading to possible collusive bidding and/or unilateral rent seeking that can reduce the cost-effectiveness of the auction. A change in the parameter values during multiple periods can serve to mitigate both these tendencies. Moreover this within-subject treatment allows us to study how auction performance varies under different cost-benefit conditions as documented in the cited theoretical models of Gal-Or et al. (2007) and Doni and Menicucci (2010, 2011).

A few simple rules were followed in choosing the cost benefit parameter values and assigning them to the 12 periods. The parameter choices for the six subjects' land management projects were based on the benchmark efficient allocation obtained as the solution to Expression (4) if submitted bids were equal to costs i.e. the allocation obtained in the absence of asymmetric information about the costs of conservation procurement. Let this allocation be denoted by x_f . We used four sets of values termed G1, G2, G3 and G4. Values for sets G1 and G4 were selected such that x_f comprises of four adjacent projects. This configuration can be compared to the creation of a large area of contiguous habitat that encompasses the home range of different species and can serve as their nesting and roosting grounds and/or a reliable site for food (Kaufman 1962; Ford 1983). For G2 and G3 the parameter values involved isolated project selection and reduced levels of contiguity: for G2, x_f comprised of 3 selected projects with only 2 of them adjacent to each other; in the case of G3 there were two shared borders between 3 of the 4 selected projects. The efficient allocation x_f for each parameter group is represented by the blank diamonds in Fig. 1. Values of experimental parameters (along with means and standard deviations) are presented in Table 1 with the cost-benefit values pertaining to projects constituting x_f marked in bold.

In order to assign these parameters to projects within a period, we classified the 12 periods into four groups of three periods such that no two consecutive periods fall into the same parameter group. Such a classification is intended to minimize order effects in subject learning. All periods within a group were then assigned parameter values corresponding to a particular parameter set. Table 1 indicates this classification. For example subjects in Periods 2, 4 and 10 had cost and benefit parameters corresponding to set G1. Similarly, in Periods 3, 5 and 11 all cost-benefit values pertained to parameters from set G3. Additionally, the order of parameter assignment was changed in every period so that i) subjects faced a different cost-benefit parameter value in all 12 periods and ii) on average all subjects within a session could potentially win three times if everyone submitted bids equal to project costs. This parameter assignment feature was common to all 12 sessions.

At the onset of the experiment players were informed that the auction would have 12 paying periods with a minimum of 5 iterations. However information about the maximum number of trials was not provided to prevent any gaming tendencies at the end of the auction period. Bidders also knew that their cost-benefit parameters would be different in each period. Neutral terminology was used in the instructions and terms such as environmental benefit, land use and conservation were not included to minimize contextual framing in the experiment. We adopted this context-free approach since we did not want the information treatment to

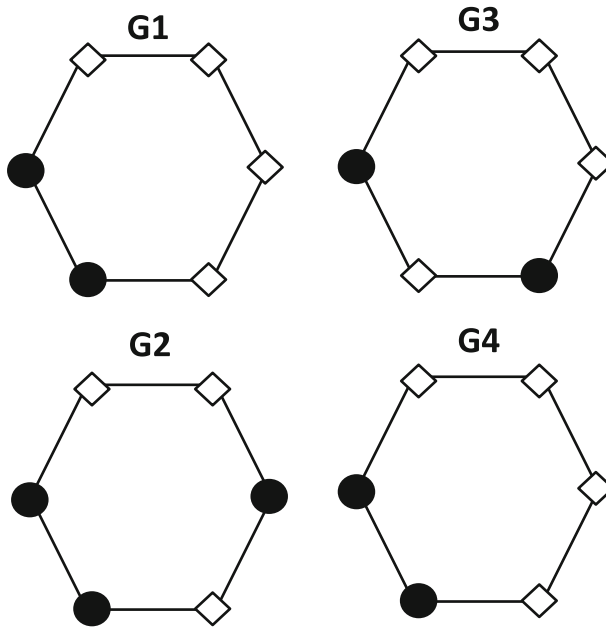


Fig. 1 Economically efficient spatial configurations

Table 1 Experimental parameters

Period 1: practice period

Budget—\$350

Environmental benefit from two adjacent projects—50

	G1		G2		G3		G4	
	Benefit	Cost	Benefit	Cost	Benefit	Cost	Benefit	Cost
	209	95	213	89	215	95	241	100
	195	85	295	146	220	103	280	137
	285	112	363	95	265	85	235	51
	245	100	271	110	145	130	277	69
	150	40	204	112	145	60	252	87
	215	90	349	105	210	140	269	124
Mean	216.5	87	282.5	109.5	200	102.17	259	94.67
Standard deviation	45.71	24.82	66.61	19.95	46.9	29.43	19.05	32.57
Periods in which parameter used	2, 4, 10		3, 5, 11		6, 8, 12		7, 9, 13	

be confounded by subjects’ motivations towards pro-environmental behavior (or otherwise). The term Item was used to refer to a land management project and Quality to refer to the intrinsic environmental benefit of the project for which the participants submitted bids.

Usually the regulator has more accurate knowledge about the environmental benefit of a project on a particular private property than its owner. Thus, we did not announce any information on individual project Quality and Total Quality (sum of intrinsic and contiguity

benefits from a project) to the subjects at any point of time during the auction. Conversely since private landowners have a fairly accurate idea about the costs of conservation land use on their properties, all subjects were able to see their project’s cost value when they submitted a bid in any trial of a period. Additionally when making a bid decision, the subjects’ screens also displayed their previous trial’s bid except if the current trial was a period’s first one.

Instructions indicated that if subjects wanted to place a lower bid in the current trial, it had to be at least 50 experimental cents less than the previous trial’s bid. But the fact that the previous trial’s bid would be automatically considered as the current trial’s bid if the subject did not change their bids was not mentioned in the instructions. This is because we did not want to focus subjects’ attention to this feature and have them actually test out this strategy of not changing bids over consecutive trials. A detailed example of the winner determining procedure was included in the instructions to help subjects understand how their scores and the provisional and final allocations would be determined. Before starting the experiment, subjects participated in a quiz to ensure that they understood the features of the auction environment.

Experiments related to this study were conducted at the Laboratory for Economics, Management and Auctions (LEMA) at the Pennsylvania State University between March and April 2010 using participants randomly selected from the University’s student population. The software Z-Tree (Fischbacher 2007) was used to run the experiments. The subjects were paid \$7 for showing up. All experimental earnings were converted to real money at the rate of US\$1 for every 15 experimental dollar. Sessions lasted between an hour and an hour and half. Average earnings for the NO-INFO treatment including the show up was \$14.81 and was \$15.36 for the INFO treatment.

4 Results

The auction results are evaluated on the basis of multiple criteria. We consider the number of periods in which the efficient allocation is selected i.e. the allocation that would be chosen in the absence of asymmetric information and the instances in which the correct number of projects corresponding to the number under the efficient allocation are selected. In addition, following Cason et al. (2003), we use an environmental effectiveness performance metric (denoted by *EE*) that measures the total environmental benefit from the selected allocation x^* relative to the benefits corresponding to the efficient full information outcome x_f . The metric is expressed as

$$EE(x^*, x_f) = \frac{V(x^*)}{V(x_f)} = \frac{\sum_{i=1}^{N-1} \{v_i x_i^* + d x_i^* x_{(i+1)}^*\} + v_N x_N^* + d x_N^* x_1^*}{\sum_{i=1}^{N-1} \{v_i x_{fi} + d x_{fi} x_{f(i+1)}\} + v_N x_{fN} + d x_{fN} x_{f1}} \quad (5)$$

In this expression, $V(x^*)$ is the environmental benefit from an allocation x^* calculated as the sum of the intrinsic benefit from individual projects v_i selected in x^* and the contiguity benefit which is d times the number of adjacencies or shared borders between selected projects. The same formula is used to calculate the environmental value from the efficient allocation in the denominator. This metric can have a maximum value of 1 when the auction selects the efficient allocation i.e. $x^* = x_f$. Values of *EE* closer to 1 imply improved auction performance relative to the efficient allocation. Yet, a high *EE* value (even equal to 1) does not necessarily signify cost-effectiveness: even if the efficient allocation is procured with the budget, winning bids may be above costs. Thus, as a measure of cost effectiveness, the sum of rents earned by all selected bidders in a session in excess of their project costs is analyzed.

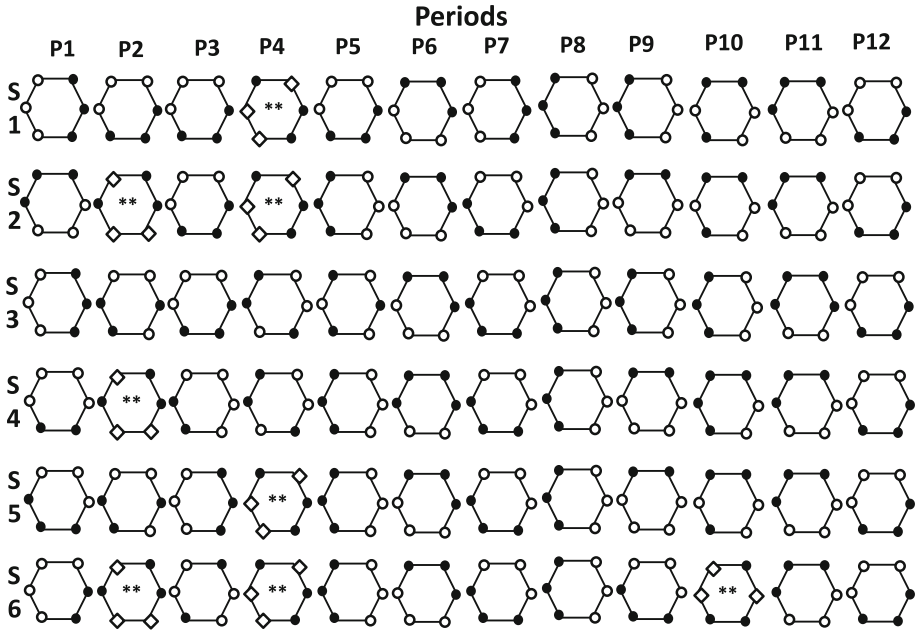


Fig. 2 Spatial configurations in NO-INFO sessions for all periods

4.1 Analysis of Auction Performance

The auction performance analysis uses data from the last trial from each of the 12 periods of the experiment, since this is the binding trial that determines the winning allocation for any period. Figures 2 and 3 present the location of selected projects for all 72 periods for NO-INFO and 69 periods for INFO sessions.⁴ The selected projects are marked in blank circles and diamonds with all diamond on a grid representing an efficient allocation $x^* = x_f$. All efficient patterns are marked with the sign ** in the two figures.

Considering each information treatment specification separately, the data in the contingency Table 2a indicates that there are only 5 periods in INFO and 8 in NO-INFO where the auction produces the efficient allocation. In all other instances, an inefficient allocation is selected. Second, consider the number of projects selected in the auction under both treatments relative to the number of projects in the efficient allocations in all periods. The contingency Table 2b shows that there are only 16 periods in INFO and 23 in NO-INFO sessions, where the correct number of projects (either 3 or 4 depending on the parameter set for these periods) are chosen. Of these 39 periods, only 13 cases correspond to an efficient pattern as previously noted on the basis of data in Table 2a and these correspond to parameter set G2. Thus although the correct number of projects are selected under the remaining three sets, the allocations are inefficient. In the remaining 102 periods fewer projects are chosen. Given the budget constraint, these two observations indicate that high bids submitted in excess of actual costs reduces the capacity of the auction to select the correct number of projects pertaining to the economically efficient allocation that maximizes environmental

⁴ We are able to record the data for only 11 periods for INFO sessions 2, 3, and 4 since the last period was lost owing to programming error.

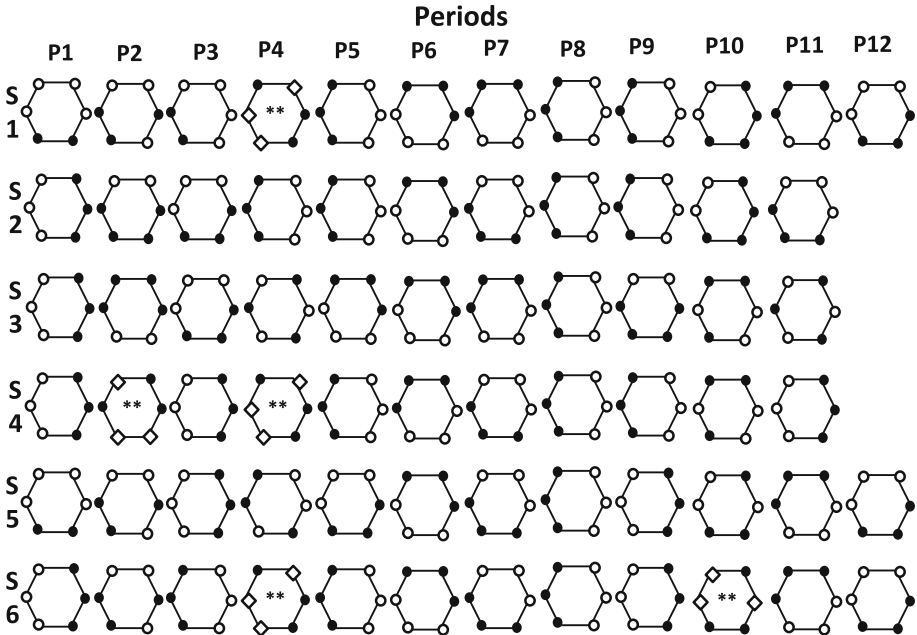


Fig. 3 Spatial configurations in INFO sessions for all periods

Table 2 Contingency table for efficient project allocations (a) and correct number of selected projects (b)

Treatment	(a) Project allocations		Total
	Correct/efficient	Incorrect/inefficient	
NO-INFO	8	64	72
INFO	5	64	69
Total	13	128	141
	(b) Number of projects		
	Fewer projects	Correct number	
NO-INFO	49	23	72
INFO	53	16	69
Total	102	39	141

benefits. Thus rent seeking is endemic to the current iterative auction independent of whether the spatial goal is announced or nor.

For a systematic analysis of the information treatment, we conduct non-parametric Mann-Whitney tests using average *EE* and total session rents values for all 12 periods taken together for every session. The results of this test are presented in Table 3. We find that the knowledge of the spatial goal of the auctioneer produces a significant difference (at 10% level of significance: *p* value—0.086) in the degree of rents earned by the bidders. There is however no significant difference in environmental effectiveness between treatments. Thus, given our experimental parameterization, in the presence of a fixed budget with opportunities to revise bids between iterations and information feedback about auction outcomes, disclosure

Table 3 Average session level *EE* and total rent values for all 12 periods

Session	Environmental effectiveness		Total rent	
	NO-INFO	INFO	NO-INFO	INFO
1	0.773	0.795	66.666	66.708
2	0.831	0.748	50.837	82.363
3	0.759	0.707	76.083	73.166
4	0.812	0.811	66.333	59.863
5	0.839	0.824	50.916	71.416
6	0.855	0.822	45.75	57.041
Wilcoxon Mann Whitney test	0.115		0.086	

Table 4 Average metric values by information treatment and parameter group

Parameter group	Environmental effectiveness		Rents	
	NO-INFO	INFO	NO-INFO	INFO
G1	0.783	0.731	45.77	58.47
G2	0.934	0.872	40.66	48.02
G3	0.813	0.786	56.94	62.13
G4	0.716	0.747	94.33	110.26

of the spatial goal can prove detrimental to auction cost-effectiveness relative to the baseline condition with no significant impact on allocations selected (and environmental benefits) and hence economic efficiency. This result suggests that the conservation agency’s information disclosure decision will largely be a function of what is its priority: reducing the costs of conservation procurement or minimizing chances of public alienation in the event that the agency does not announce its preference for spatially adjacent projects.

Finally, we focus on the within-subject parameter treatment. We first consider the ratio of the *EE* and session rents metrics for every individual session for groups G1, G3 and G4 to group G2. Group G2 is used as the base category because on the basis of data in Table 4, the average total rents obtained from the experiment are the lowest and the *EE* metric values the largest under this category. The ratio data for each parameter regime is presented in Table 5 and graphically represented in Figs. 4 and 5. The solid line in these figures represents a value of 1 corresponding to a situation where the value of the two metrics are the same under G2 and any one of the three parameter groups.

According to Fig. 4a, b, there are only two instances each in NO-INFO and INFO sessions, where the value of *EE* is greater than 1 in a session. Wilcoxon matched-pair signed-rank tests comparing session level averages of *EE* values (i.e. taking average of three period metric values) for each parameter regime to group G2 yield significant differences. Considering the NO-INFO groups, there is a difference at 5% level of significance between G2, and G1 and G3 (p value=0.027) and between G2 and G4 (p value=0.04). In the INFO groups for the *EE* values, we find a significant difference at the 5% level (p value=0.027) for G2 and G1 and at the 10% level (p value=0.07) for G2 and G3.⁵ Thus relative to group G2, the environmental effectiveness of the auction is on an average lower under all most other parameter groups.

⁵ There is no significant difference between G2 and G4 for the INFO sessions. This might be because three data points for Period 13 that had parameters corresponding to the G4 regime was lost owing to programming error as mentioned in footnote 4.

Table 5 Ratio of *EE* and total rents for regimes G1, G3 and G4 to G2

Environmental effectiveness			Total rents		
G1	G3	G4	G1	G3	G4
<i>NO-INFO</i>					
0.733	0.814	0.788	1.888	1.267	2.741
0.798	0.848	0.744	1.222	1.706	2.231
0.746	0.794	0.804	1.368	2.202	3.132
1.040	1.041	0.763	0.735	1.150	2.531
0.882	0.894	0.772	0.951	1.260	1.756
0.845	0.847	0.730	1.051	1.367	2.184
<i>INFO</i>					
0.965	0.944	0.867	0.832	1.342	2.092
0.974	1.148	1.215	1.111	0.676	1.528
0.811	0.867	0.928	1.438	1.631	2.931
0.715	0.811	0.756	1.707	1.716	2.147
0.837	0.832	0.759	1.423	1.195	2.684
0.776	0.877	0.757	0.927	1.938	3.266

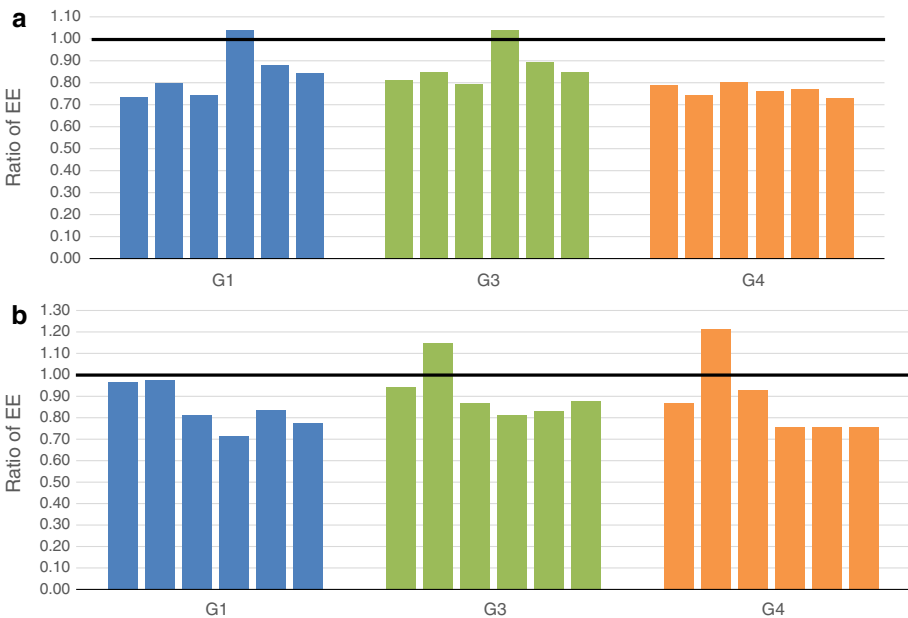


Fig. 4 Ratio of average EE for 12 periods for G1, G3 and G4 to G2. **a** NO-INFO, **b** INFO

Focusing on the rent seeking data from both panels in Fig. 5, we find that there are only 5 instances where total rents earned under the other regimes in any session are less than that under regime G2 (these cases are under regimes G1 and G3). In fact under G4, group performance is the lowest for both groups relative to G2. Wilcoxon matched-pair signed-rank tests between session level averages of rent values (i.e. taking average of three

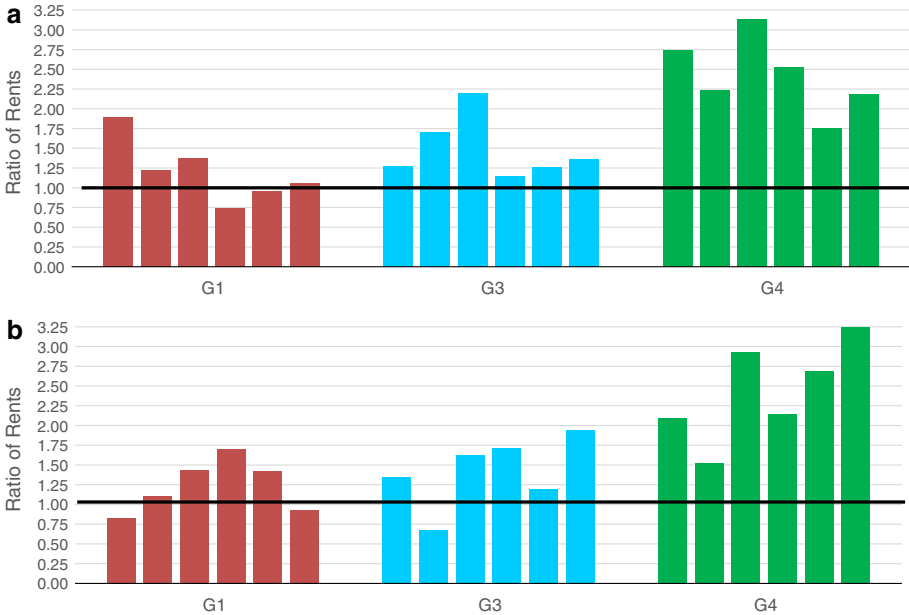


Fig. 5 Ratio of average total rents for 12 periods for G1, G3 and G4 to G2: **a** NO-INFO, **b** INFO

period metric values) for each parameter regime and G2 yields significant differences at 5% level of significance (p value=0.02) for both G3 and G4 under the NO-INFO treatment. Under the INFO condition we obtain a significant within-treatment difference at 5% level (p value=0.027) between G4 and G2.

That there are more scenarios where rents are significantly lower in G2 than in other parameter groups is an interesting finding when we consider that under the G2 parameterization, i) the configuration of projects in x_f has fewer shared borders than under the other three regimes (as in Fig. 1) and ii) the average cost values for the six projects taken together is the highest (Table 1). Thus, given our experimental parameterization the importance on spatial agglomeration of projects proves detrimental for economic efficiency and cost-effectiveness in regimes where cost values for the efficient allocation are on an average lower than those under G2 but where the efficient allocation pertains to selection of more projects adjacent to each other.

4.2 Analysis of Individual Behavior

In this section, we analyze individual bidding behavior, using data from the final iteration of each auction period to obtain insights about the degree of rent seeking practiced by bidders. Fig. 6 presents the average bidder markup over costs for all periods by both information treatment.⁶ In this figure the average bid markup in the INFO sessions is greater than that in the NO-INFO sessions in all but three periods (5, 10 and 12)⁷. In addition, there is a positive trend in the bid markups with increasing period value.

⁶ We consider markup values rather than actual bids to eliminate variability due to subjects facing different cost parameters in every period.

⁷ These periods correspond to Periods 6, 11 and 13 in the experiment.

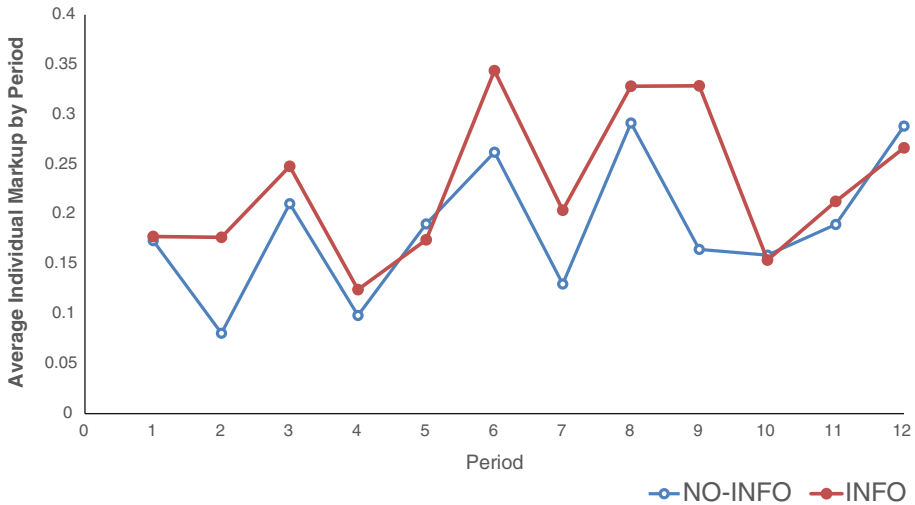


Fig. 6 Individual markup in final trial

To examine factors affecting bidding, we estimate a pooled OLS regression model for the individual bid markups for every period with standard errors clustered at the subject level since errors are expected to be correlated for the same subject across multiple time periods. The dependent variable is the bid markup over costs submitted by the subjects in the final trial of each of the 12 periods. The independent variables include an information treatment dummy taking a value of 1 for the INFO sessions and 0 otherwise. We also include three parameter dummies $G1$, $G3$ and $G4$ (taking a value of 1 in periods falling under the respective cost-benefit regime and 0 otherwise) to capture the impact of the within-subject parameter treatment on individual bidding patterns. The Final Trial variable representing the length of each experimental period is included to control for the effect of period length on bidding behavior. The model also includes the $1/Period$ variable that picks up the impact of subject learning that is greater in the initial periods when familiarity with the economic environment is low and lower in later periods as subjects become more experienced with the bidding process with repeated interactions.

We also consider a dummy variable termed Win taking a value of 1 if a subject won in the penultimate iteration of a period and 0 otherwise. This variable is included because by virtue of the experimental design, bidders possess information about whether they were chosen in all previous trials of a period or not. Thus, it is likely that bidders' propensity to retain higher markups rather than revise and resubmit a lower bid in an iteration will be a function of whether they won in the previous iteration or not. Finally, we include a variable termed Neighbor Status to control for the impact of neighbors' selection in the previous iteration on a subject's propensity to retain a higher markup by not submitting a lower bid in the final trial of a period. This variable takes a value of 0 if no neighbors are selected in the last-but-one trial and 2 if both neighbors are chosen.⁸

Table 6 presents the results of the estimation. As noted in the previous section, the estimate for the information dummy is positive (significant at 1% level) indicating that when the

⁸ Interaction terms between Neighbor Status and $1/Period$ and Neighbor Status and Win are not included as they are not significant in the pooled regression after error clustering.

Table 6 Estimation results for pooled OLS with clustered standard errors

Independent variables	Dependent variable
	Individual cost markup in final trial of each period
Information treatment	0.06*** (0.02)
G1	0.107*** (0.024)
G3	0.042*** (0.013)
G4	0.158*** (0.018)
Win	0.166* (0.014)
1/Period	-0.092* (0.05)
Neighbor Status	-0.033** (0.013)
Final trial	-0.016*** (0.005)
Constant	0.199*** (0.043)
Number of observations	846 ⁺
Cluster variable	Individual subject (72 clusters)

Standard errors in parentheses;
 * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
⁺Number of observations = $12 \times 72 - 6 \times 3 = 846$ (18 data points lost for Period 12 of 3 INFO sessions owing to programming error)

auctioneer explicitly reveals the spatial goal to the subjects, they end up bidding higher and retaining greater rents upon winning relative to those in the baseline sessions. The estimates for all the parameter dummies are positive and significant as well implying higher markups, greater degree of rent seeking and overall inferior performance in regimes G1, G3 and G4 relative to the omitted category corresponding to regime G2. This result in conjunction with the fact that x_f constitutes four projects in G1, G3 and G4 implies that the possibility of contiguous selection of more projects (relative to G2) translates into intensified rent seeking and inferior performance. The fact that the estimate for G4 is higher than G1 also corresponds to our previous observations regarding average rents values being lower and *EE* values higher under G4 than under G1 (relative to G2). The sign of the Final Trial variable is also negative (significant at 1% level) as expected given the descending iterative price auction format.

Of interest is the estimate for the Win variable which is positive and significant (at 1% level of significance). Since, a subject's previous winning (or losing) status is revealed to them at the end of an iteration, they are aware of their advantage (disadvantage) relative to the provisional winning allocation. Hence, they are less likely to reduce their bid, implying a significantly higher markup submission in the current iteration than if they were not in the provisionally winning allocation previously. As the amount of the markup reflects the degree of rent-seeking, the positive estimate implies higher levels of rent seeking by winners.

The negative and statistically significant (at 10% level of significance with a p value of 0.054) estimate for 1/Period is supportive of the presence of experience induced rent seeking

in the auction. In the initial periods when the rates of learning are high and subjects are still unfamiliar with the environment so that bids and hence markups submitted are small. However over multiple periods of interaction that increases their experience and familiarity in the auction (and which is associated with a slowdown in the learning rate), subjects submit higher bids. Such experience induced rent seeking has been observed in the implementation of existing auction-based policies: under the CRP, in later signups (which would correspond to latter periods in the experiment) landholders submitted bids near the bid cap—the maximum reserve price for a project in an area (Kirwan et al. 2005). Herein, the negative and significant (at 1 % level of significance) estimate for the Final Trial variable lends hope for the continual appeal of conservation auctions as it suggests that greater the number of iterations during the period, lower is the degree of rent seeking by the participants. Thus, while rent seeking is endemic to our conservation auction, the iterative format serves to ameliorate the degree to which subjects can exploit their private information advantage.

Finally, the estimate for the Neighbor Status variable is negative and significant (at 5 % level). Thus, players are more likely to submit lower bids when they observe that one or both their neighbors have won in the previous trial. This is an interesting result especially in the light of the fact that subjects receive information about their neighbors' winning or losing status after every trial and are even told that winning neighbors improve one's own chances of winning in INFO sessions. Such behavior implies that subjects respond to neighbors' winning or losing statuses by submitting a lower markup in the current trial in order to maximize their likelihood of being selected in this trial. This form of bid reduction also signifies that our auction is suitably collusion proof since a likely manifestation of collusive bidding would require that bidders submit a higher markup in the current trial in response to more neighbors being selected in the previous trial.

5 Conclusion

Economic instruments such as auctions have been routinely implemented by government agencies to procure conservation land use projects from private individuals. Historically increasing participation and acreage has been the main goal of these schemes. However it is now widely recognized that the delivery of environmental benefits can be further increased by targeting ecological attributes which influence the structure of the agricultural landscape on which conservation schemes are implemented. Spatial coordination of similar or complementary land use efforts is one such attribute.

In this paper, we present the structure of an auction for spatially adjacent land use project procurement on a circular landscape with every project being adjacent to two others. This auction has an iterative format whereby landowners can revise and resubmit bids in multiple trials. We then use experiments to investigate whether the auctioneer's spatial objective should be made public to participants by informing them about the structure of the scoring metric's benefit component that incorporates the spatial feature. We are also able to evaluate auction performance under various project benefit-cost scenarios in multiple periods. On the basis of constructed performance metrics, the results indicate that such information disclosure significantly exacerbates rent seeking tendencies without any impact on efficiency measured in terms of the environmental benefits from the projects within the selected allocations. This result should be considered in conjunction with the high amounts of information provided to participants about auction outcomes at the end of every trial. Thus on the basis of our design and parameterization, we can conclude that if conservation auctions have provisions for bid revisions and resubmissions, and information about outcomes are made available to

participants, preference for spatially adjacent project procurement need not be separately revealed to the participants.

Additionally persistent experience induced rent seeking so much so that in most cases neither the efficient allocation nor the correct number of projects are selected under both information treatments, suggests that we should be conservative about the promise afforded by these auctions in addressing cost-effective delivery of ecosystem services from private farmland ecosystems (Schilizzi and Latacz-Lohmann 2007; Arnold et al. 2013). Since many conservation auctions such as the CRP in the US and auction based Stewardship schemes in the UK involve multiple signups often with the same set of participants, this efficiency loss is a concern especially in today's era of financial austerity when conservation budgets are dwindling.⁹ One way to reduce such rent seeking would be to assign varying weights to different environmental practices in the scoring metrics during multiple repetitions that change the ranking of scores associated with participants. Also similar reserve prices for projects producing comparable environmental benefits within a given area can serve as a benchmark against which to evaluate bids and can control rent-seeking tendencies. As threats to the environment are increasing, research identifying desirable features of conservation auctions will contribute to enhancing their environmental and economic performance and popularity in policy circles.

6 Appendix: Experimental Instructions

(Italicized expressions are included in info sessions only)

6.1 General Information

This is an experiment in decision making. In today's experiment you will participate in an auction. In addition to a \$7 show up fee, you will be paid the money you accumulate during the auction which will be described to you in a moment. Upon the completion of the experiment, your earnings will be added up and you will be paid privately, in cash. The exact amount you will receive will be determined during the experiment and will depend on your decisions and the decisions of others. From this stage onwards all units of account will be in **experimental dollars**. At the end of the experiment, experimental dollars will be converted to U.S. dollars at the rate of 1 U.S. dollar for 15 experimental dollars.

If you have any questions during the experiment, please raise your hand and wait for the experimenter to come to you. Please do not talk, exclaim, or try to communicate with other participants during the experiment. Participants intentionally violating the rules may be asked to leave the experiment and may not be paid. Once you are ready, please press Continue.

6.2 Description of the Player Environment

In this experiment, you will participate in 13 auction periods where you will bid to sell your item to a **single buyer**. In each auction period you will be in a group with **5** other participants. All of you will be arranged around a **circular grid**. On this grid you have two neighbors, one on each side. Your neighbors will be the **SAME** in all periods. Your Subject ID determines who your neighbors are. For example, if you are player **5** then your neighbors are players **4** and **6** and player **6** has **you** and player **1** as neighbors.

⁹ The Office of Management and Budget in the US has mandated a reduction in conservation outlays of nearly US\$977 million between 2013 and 2022 (OMB 2013).

During each auction period you will submit offers to sell your item. You have a cost associated with selling the item, which will be known to you at the time you bid in the auction. You make money by selling the item above your cost i.e.

$$\text{Profits} = \text{Selling Price} - \text{Cost}$$

For example, if your cost is 50 this period, and you sell the item for 100, then your profits this period would be $(100-50)$ or 50. If you do not sell the item, you do not pay the cost and don't receive your offer so that your profits for that period are zero. Your costs may also change from period to period, and they may be different from the costs of other participants.

Your item also has a **QUALITY** that is known and valued by the buyer. Your quality levels may change from one period to another period, and may be different from the quality levels of other participants.

The computer will play the role of the buyer in the auction. Each auction period will have **multiple rounds** during which you will be able to submit an offer for your item. The value of your offer, the quality of your item and the quality and offers of others' items will determine whether you will win in the auction or not. If you win and your item is selected, you will be able to sell your item and obtain the value of your offer.

Notice that if you sell your item for a price that is less than its cost, then you lose money on that sale. The quality of your item will play an important role in determining the winners in the auction. Higher the quality of your item; higher are your chances of winning. Also while you cannot influence the quality of your item, you can choose the value of your offer to improve your chances of winning. High offer values increase your earnings if you win in the auction but may have a negative impact on your chances of winning. Please raise your hand if there are any questions otherwise click "Continue"

6.3 Description of Auction Environment

Every auction period will have multiple rounds. In each round you will submit an offer that indicates the amount you wish to receive for your item. After everyone submits their offers, the computer will evaluate the *total* quality and the costs (on the basis of offers submitted) of different **combinations** of items. We will describe this process in more detail shortly.

Once all possible combinations have been evaluated, the computer will compute a **SCORE—a sum of ratios of total quality (to be defined later) and offer**—for each item in a combination and rank them in decreasing order of magnitude. It will then choose the combination of items that has the highest rank, spending all or a part of the fixed and constant **budget** that is available in the auction. In the case of a **tie**, between two or more combinations, where the computer cannot purchase both, it will randomly determine which combination to select.

6.4 Description of Bidding Across Rounds

In any auction period there are multiple rounds. You will have multiple chances to submit offers in these rounds. If you are not selected in a round, you can submit a different offer in the next round. If you have not won in the current round, you can improve your chances of winning in the next round by submitting a different offer. Please note that the computer wants to buy items from you and 5 other players—your opponents, spending the least amount of money. Thus if your offer has not been accepted in the current round a decrease in your offer may improve your chances of winning in the next round. Please raise your hand if there are any questions otherwise click "Continue"

6.5 Information Available to You After Your Have Made an Offer

At the end of every auction round, you will see a results screen. On this screen you will be informed whether your offer has been accepted in the current round, which other participants have been accepted in the current round and your SCORE in the current round. Your SCORE in a round depends on your **total quality and your offer**. Please note that in the table on the top left of the Results screen, a 1 indicates that a subject has been accepted provisionally in the current round and a 0 indicates that they have not been accepted in the current round.

The total quality of your item is calculated on the basis of the quality of your item, a constant term B and the number of selected neighbors. Thus

$$Total\ Quality = Quality + N * B$$

N represents the number of your neighbors that are selected. Since every player has two neighbors, N can either be 2 or 1. If N = 0, this implies that none of your neighbors are selected.

Please remember that the computer chooses the combination of offers which has the highest SCORE in the current round. This combination determines the set of **provisional winners** in the round. If the SCORE of the winning combination in the next round is **the same** as the SCORE for the current round, then the auction period will end and the winners of the current round will become the winners of the current period.

The final offer round will not be announced until after it is completed, and which round is final may vary from auction period to period. In every auction period at least **5** rounds will always be played.

Please raise your hand if there are any questions otherwise click “Continue”

6.6 Example of how winners are determined in an auction period

Subject ID	Quality	Cost	Offer submitted in Round 1	Offer submitted in Round 2	Offer submitted in Round 3
1	11	8	8	7.5	7.5
2	16	6	8	8	8
3	9	7	7	7	7
4	25	13	15	13	13

Let us consider an example of how winners are determined in the auction. Suppose there are four participants arranged around the circular grid. The table below contains their items’ cost, quality and the offers they submit. Let the total budget be \$20 and $B = 5$. Let there be three rounds in the auction. **Please note that in the actual auction, you will not know the total number of rounds, which round is the final round, your quality as well as the quality levels or the cost levels of others participants’ items.**

Once the offers have been made in Round 1, the computer calculates the SCORE—a sum of ratio of total quality and cost of each item in a combination on the basis of quality and offer of each item in a combination. Please note that in order to evaluate a combination, the sum of offers must be less than or equal to the budget \$20.

In this example with a budget of \$20 and offers in Round 1, the combinations of items (1, 2), (2, 3) and (3, 1) can be bought. Now the computer evaluates the scores for these

combinations and it finds that both (1, 2) and (2, 3) has the same score of 4.625. Since the computer cannot purchase all the three items, suppose it picks combination (2, 3) at random. Thus participants 2 and 3 are chosen as the **provisional winners** in the current Round 1.

This information is announced to all participants. The auction then proceeds to the next round. Suppose every losing participant must reduce their offers by an amount **at least** equal to **50 experimental cents** if not more. As a result, we get a new set of offers in Round 2 as represented in the table. Please note that since participants 2 and 3 win in the preceding round they have no incentive to change their offers in the current Round 2.

With the new set of offers the computer repeats the same procedure and combination (1, 2) has the highest score of 4.758. Thus in the current round participants 1 and 2 are selected to be provisionally winning. Now the auction moves to Round 3. Now since 1 and 2 were provisionally winning it is not in their best interest to change their bids. Again for 3 and 4 they have already submitted offers equal to their costs so that a reduction in their offers will cause them to lose money if they are selected in Round 4. Thus all participants submit the same set of bids in Round 4. As a result the SCORE remains the same and the period ends and participants 1 and 2 become the winners of the auction in the current period. They are then paid the value of their offers. There will be a practice round in the beginning of the experiment to give you an idea about how the auction will proceed.

6.7 Quiz

Your neighbors are the same in all periods of the auction	TRUE
Your costs and benefits can change from auction period to period	TRUE
Your earnings depend on your costs and your bids	TRUE
The auction period ends if the SCORE of the provisionally winning allocation in the current round is the same as the SCORE of the provisionally winning allocation in the preceding round and at least a minimum number of rounds have been played	TRUE
If the cost of your item is \$100 and your offer is \$150 and you are a winner in the auction, your earnings are?	\$50

Please raise your hand if there are any questions otherwise click “OK” to participate in the auction.

References

- Arnold M, Duke J, Messer KD (2013) Adverse selection in reverse auctions for environmental services. *Land Econ* 89(3):387–412
- Bamière L, David M, Vermont B (2013) Agri-environmental policies for biodiversity when the spatial pattern of the reserve matters. *Ecol Econ* 85:97–104
- Bartelt PE, Klaver RW, Porter WP (2010) Modeling amphibian energetics, habitat suitability, and movements of western toads, *anaxyrus* (=Bufo) boreas, across present and future landscapes. *Ecol Model* 221(22):2675–2686
- Carvell C, Meek WR, Pywell RF, Goulson D, Nowakowski M (2007) Comparing the efficacy of agri-environment schemes to enhance bumble bee abundance and diversity on arable field margins. *J Appl Ecol* 44(1):29–40
- Cason TN, Gangadharan L, Duke C (2003) A laboratory study of auctions for reducing non-point source pollution. *J Environ Econ Manage* 46(3):446–471
- Cason TN, Gangadharan L (2005) A laboratory comparison of uniform and discriminative price auctions for reducing non-point source pollution. *Land Econ* 81(1):51–70

- Connor JD, Ward JR, Bryan B (2008) Exploring the cost effectiveness of land conservation auctions and payment policies. *Aust J Agric Resour Econ* 51:303–319
- Cowan T (2010) Conservation reserve program: status and current issues. In United States Department of Agriculture. <http://crs.ncseonline.org/nle/crsreports/10Oct/RS21613.pdf>. Cited 14 April 2014
- Dallimer M, Gaston KJ, Skinner AMJ, Hanley N, Acs S, Armsworth PR (2010) Field level bird abundances are enhanced by landscape level agri-environmental scheme uptake. *Biol Lett* 6(5):643–646
- Devetag G (2003) Coordination and information in critical mass games: an experimental study. *Exp Econ* 6(1):53–73
- Doni N, Menicucci D (2011) Alternative information disclosure policies in buyer-determined procurement auctions. <http://www.webmeets.com/files/papers/earie/2011/265/versione%2018%20cpl.pdf>. Cited 14 April 2014
- Doni N, Menicucci D (2010) A note on information revelation in procurement auctions. *Econ Lett* 108(3):307–310
- Duffy J, Feltovich N (2002) Do actions speak louder than words? An experimental comparison of observation and cheap talk. *Games Econ Behav* 39(1):1–27
- Ferris J, Siikamäki J (2009) Conservation reserve program and wetland reserve program: primary land retirement programs for promoting farmland conservation. RFF Background, Resources for the Future. http://www.rff.org/RFF/Documents/RFF-BCK-ORRG_CRP_and_WRP.pdf. Cited April 14 2014
- Fischbacher U (2007) Z-tree: Zurich toolbox for ready-made economic experiments. *Exp Econ* 10(2):171–178
- Ford RG (1983) Home range in a patchy environment: optimal foraging predictions. *Am Zool* 23:315–326
- Gal-Or E, Gal-Or M, Dukes A (2007) Optimal information revelation in procurement schemes. *Rand J Econ* 38(2):400–418
- Glebe TW (2013) Conservation auctions: should information about environmental benefits be made public? *Am J Agric Econ* 95(3):590–605
- Harsha P, Barnhart C, Parkes DC, Zhang H (2010) Strong activity rules for iterative combinatorial auctions. *Comput Oper Res* 37(7):1271–1284
- Haruy E, Katok E (2012) Increasing revenue by decreasing information in procurement auctions. *Prod Oper Manage* 22(1):19–35
- Hill MRJ, McMaster DG, Harrison T, Hershmillier A, Plews T (2011) A reverse auction for wetland restoration in the assiniboine river watershed Saskatchewan. *Can J Agric Econ* 59(2):245–258
- Jack BK, Kousky C, Sims KRE (2008) Designing payments for ecosystem services: lessons from previous experience with incentive-based mechanisms. *Proc Natl Acad Sci* 105(28):9465–9470
- Jack BK, Leimona B, Ferraro PJ (2009) A revealed preference approach to estimating supply curves for ecosystem services: use of auctions to set payments for soil erosion control in Indonesia. *Conserv Biol* 23(2):359–367
- Kaufman JH (1962) Ecology and social behavior of the coati *Nasua nirica* on Baro Colorado Island Panama. *Univ Calif Publ Zool* 60(3):95–222
- Kirwan B, Lubowski RN, Roberts MJ (2005) How cost-effective are land retirement auctions? Estimating the difference between payments and willingness to accept in the conservation reserve program. *Am J Agric Econ* 87(5):1239–1247
- Knight T (2010) Enhancing the flow of ecological goods and services to society: key principles for the design of marginal and ecologically significant agricultural land retirement programs in Canada. Canadian Institute for Environmental Law and Policy. <http://www.cielap.org/pdf/EnhancingTheFlow.pdf>. Cited 18 April 2014
- Kwasnica AM, Sherstyuk K (2013) Multiunit auctions. *J Econ Surv* 27(3):461–490
- Latacz-Lohmann U, Van der Hamsvoort C (1997) Auctioning conservation contracts: a theoretical analysis and an application. *Am J Agric Econ* 79(2):407–418
- Margules CR, Pressey RL (2000) Systematic conservation planning. *Nature* 405(6783):243–253
- Office of Management and Budget (2013) Cuts, consolidations and savings: budget of the U.S. Government. White House. <http://www.whitehouse.gov/sites/default/files/omb/budget/fy2013/assets/ccs.pdf>
- Plott CR (1997) Laboratory experimental testbeds: application to the PCS auction. *J Econ Manage Strategy* 6(3):605–638
- Polasky S, Lewis DL, Plantinga AJ, Nelson E (2014) Implementing the optimal provision of ecosystem services. doi:10.1073/pnas.1404484111
- Reeson AF, Rodriguez LC, Whitten SM, Williams K, Nolles K, Windle J, Rolfe J (2011) Adapting auctions for the provision of ecosystem services at the landscape scale. *Ecol Econ* 70(9):1621–1627
- Rolfe J, Windle J, McCosker J (2009) Testing and implementing the use of multiple bidding iterations in conservation auctions: a case study application. *Can J Agric Econ* 57(3):287–303
- Scarlett L, Boyd J (2011) Ecosystem services: quantification, policy applications, and current federal capabilities. Resources for the Future Discussion Paper (11–13). <http://www.rff.org/RFF/Documents/RFF-DP-11-13.pdf>. Cited April 14 2014

- Schilizzi S, Latacz-Lohmann U (2007) Assessing the performance of conservation auctions: an experimental study. *Land Econ* 83(4):497–515
- Selman M, S. Greenhalgh M, Taylor, Guiling J (2008) Paying for environmental performance: potential cost savings using a reverse auction in program sign-up. World Resources Institute Policy Note, Environmental Markets: Farm Bill Conservation Programs, No: 5. http://www.wri.org/sites/default/files/pdf/paying_for_environmental_performance_reverse_auctions_in_program_signup.pdf
- Shogren JF, List JA, Hayes DJ (2000) Preference learning in consecutive experimental auctions. *Am J Agric Econ* 82(4):1016–1021
- Stoneham G, Chaudhri V, Ha A, Strappazzon L (2003) Auctions for conservation contracts: an empirical examination of victoria's BushTender iteration. *Aust J Agric Resour Econ* 47(4):477–500
- Tanaka T (2007) Resource allocation with spatial externalities: experiments on land consolidation. *BE J Econ Anal Policy* 7(1):1–33
- Windle J, Rolfe J, McCosker J, Lingard A (2009) A conservation auction for landscape linkage in the southern desert uplands Queensland. *Rangel J* 31(1):127–135
- Wunder S (2005) Payments for environmental services: some nuts and bolts. CIFOR Bogor