Spatial Coordination and Joint Bidding in Conservation Auctions*

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Abstract

Conservation auctions have been utilized in different parts of the world to implement pro-environmental land uses on private agricultural and forest landscapes. One key enhancement of such auctions would be to procure spatially adjacent land-use changes to magnify the delivery of various ecosystem services benefits. Spatial contiguity is also beneficial for enhanced biodiversity conservation in certain contexts. Recent reforms of agri-environmental policy in the Netherlands, Germany and the UK have stressed the desirability of participation by farmers in groups, rather than as individuals. We use a laboratory experiment to examine the performance of an iterative multi-round and a single-round spatial conservation auction both in the presence and absence of joint bidding opportunities. In keeping with real life interactions within farming communities, the subjects in our experiment can communicate with their neighbors before submitting an individual and/or joint bid. Preliminary results indicate that joint bidding opportunities do not increase auction efficiency or the amount of environmental benefits realized for the spatial configurations considered in the experiment. Overall efficiency is high, however, in all treatment conditions. Rent-seeking in the auction declines in the joint bidding condition in the multi-round auction compared to the single-round auction, but is highest under this single round treatment than with individual bids.

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1 Introduction

Since the mid to late 1990s, a comprehensive literature has emerged on the design and effectiveness of conservation auctions. Conservation auctions are one solution to the policy design problems concerned with procuring increases in the supply of biodiversity conservation and ecosystem service supply on private land. As originally proposed, conservation auctions were a means of increasing the cost-effectiveness of conservation actions relative to the uniform price subsidy regimes which characterize so much of agri-environmental policy in Europe and North America. This increase in cost-effectiveness is achieved by landowners bidding competitively against each other to supply environmental goods to a buyer, typically but not always a government body. Moreover, conservation auctions reveal information on the landowner's (seller's) type – their marginal costs of providing the environmental good, information which governments often lack at the individual farm level. Because of these perceived benefits, the use of conservation auctions has been growing world-wide, especially in Australia, the US and China.

Since the original papers by Latacz-Lohmann and Van der Hamsvoort (1997, 1998), researchers have explored a number of design issues in conservation auctions, such as the implications of using single price versus discriminatory price contracts, and the effects of repeating auction procedures. These papers have used both lab experiments and simulation modelling. One design issue of particular relevance to this paper is how to encourage the spatial coordination of bids within a conservation auction. Such coordination amongst landowners has been argued to result in improved delivery of environmental goods, since for objectives as various of water quality improvements, conservation of target species and wetland restoration, spatial coordination of awarded contracts can increase the amount of aggregate environmental benefit which the auction delivers. The Agglomeration Bonus (Parkhurst et al., 2002; Parkhurst and Shogren, 2007) is one mechanism which yields spatial conservation in flat rate payment settings. However, designing conservation auctions with explicit integrated spatial coordination devices is challenging (de Vries and Hanley, 2016), although recently work has been undertaken that addresses this challenge (Banerjee et al, 2015; Crawczyk et al., 2016). Such a goal is distinct from spatial targeting, whereby individual farmers are rewarded differentially based on the environmental quality of their land. Although spatial targeting and spatial coordination may both enhance the environmental effectiveness of agri-environmental schemes, they may not be mutually re-enforcing (Fooks et al., 2015).

Our paper considers a linked aspect of agri-environment scheme design which is growing in popularity in actual policy design, namely the encouragement of participation from groups of (neighboring) farmers, rather than simply encouraging individual-level participation. Such group participation is an increasing feature of agri-environment programme design in the Netherlands and the UK (Westerink et al., 2017). Encouraging joint actions by groups of farmers may be a useful way of achieving spatial coordination, but can also increase the productivity of environmental enhancements in other ways such as the sharing of best practices, sharing of information on environmental outcomes, or learning new methods for delivering environmental benefits.

So far, there is relatively little evidence on how such group bidding performs within conservation auction settings. Opportunities for landowners to submit joint bids in conservation auctions was part of the design in the "Auction for Landscape Recovery" (ALR) in Australia (Latacz-Lohmann and Schillizzi, 2005) and more recently in an auction to reduce nutrient runoff into Lake Erie in the US (Palm-Forster et al., 2016). Alongside these few implementations in the field, a number of studies attempt to assess the impact of joint/group bidding on auction performance via numerical simulations. Calel (2012) compares joint bidding with a uniform price auction and finds ambiguous results with respect to the impact of joint bidding on the auction's cost-efficiency. Iftekhar and Tisdell (2017) employ an agent-based simulation model to show that joint bidding raises auction procurement costs, in particular in a context of spatial targeting to create corridors. In a laboratory experiment, Rondeau et al. (2016) find that joint bidding increased auction efficiency, i.e., reduced bidder competition did not adversely affect auction performance.

Accordingly, the experiment reported here compares the economic and environmental effectiveness of auctions which not only allow bids from groups of neighbors, but actually encourage it through the setting of rules determining who wins a contract. Since we do not wish to force landowners (participants) into joint bidding – that would not be very realistic – in our treatments we either (i) allow both joint and individual bids or (ii) allow individual bids only. Where bids are submitted jointly, players had to agree benefit-sharing when submitting their bid. We also reward spatial coordination of individual bids, since this kind of spatial coordination delivers additional environmental bids, although by less than when spatially-coordinated bids are submitted competitively by a group. Finally, since we know from previous work that repeating an auction can change players' behavior over time we also compare single with repeated or multiple auction rounds.

The results in this paper are derived from an initial performance comparison of the main treatments implemented in the experimental design. Preliminary results indicate that joint bidding opportunities do not increase auction efficiency or the amount of environmental benefits realized for the spatial configurations considered in the experiment. Overall efficiency is however high in all treatment conditions. Rent-seeking in the auction declines in the joint bidding condition in the multi-round auction compared to the single-round one. Subsequent analysis will explore the sources of these treatment differences through an examination of individual behavior and analysis of bidders' communications.

2 Landscape Structure and Auction Design

Consider a networked landscape comprising a fixed number of N producers. Following Banerjee et al. (2014, 2015), we adopt a landscape that is structured by a circular network where each landholder $i = 1,2,\ldots,N$ is situated on a fixed position (a node) on a circle. With this circular network structure, each individual landholder has the same number of neighbors: one to the left and one to the right. This network structure avoids spatial complexities of location asymmetries and helps to eliminate the presence of potentially confounding factors that may undermine the experimental analysis, such as situations where certain producers at central or peripheral positions on the network could exercise bargaining power and thus intensify rent-seeking activity.

Each producer is assumed to possess a single parcel of land. The various land parcels around the network are heterogeneous in terms of both the opportunity costs of conservation, c_i, and their (potential) environmental benefits, b_i. Spatial (and substantial) variation in opportunity costs is frequently observed in agricultural landscapes subject to PES-type interventions (Hanley et al, 2012). Environmental potential also likely varies across space (Dallimer et al, 2009): we refer to these environmental potentials as *node* benefits. Opportunity costs are assumed to be spatially uncorrelated and are drawn randomly from the uniform distribution $c_i \sim [\underline{c}, \overline{c}]$. Environmental benefits are also assumed to be uniformly distributed and randomly drawn from the uniform distribution $b_i \sim [\underline{b^n}, \overline{b^n}]$. Further, although the node benefits are spatially uncorrelated, owing to complementarities from conservation uses on adjacent parcels, the sum of environmental benefits generated from placing these parcels in conservation use is greater than the individual parcel node benefits. Let us call the environmental benefits generated through two adjacent nodes *i* and *j* the *edge* benefits, denoted b_{ij}. The edge benefits are randomly drawn from the uniform distribution $b_{ij} \sim [\underline{b^e}, \overline{b^e}]$. Figure 1 below illustrates this spatial network structure consisting of eight producers, as implemented in the experiment.

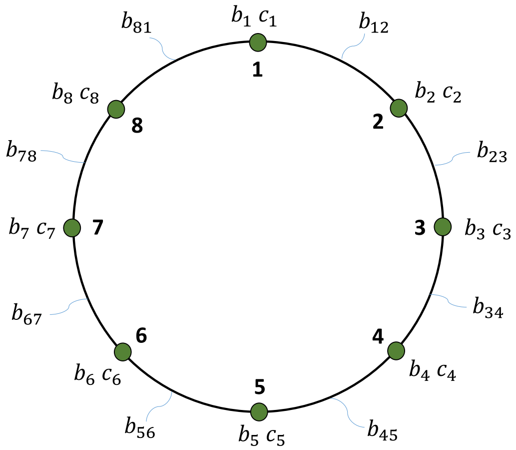

Figure 1: Network Structure

Given this landscape structure, the regulatory agency aims to maximise the sum of environmental benefits, given a fixed budget that it can allocate to producers for placing their land into conservation via PES-type payments. To facilitate a cost-effective budget allocation, the agency implements a conservation auction where producers can submit bids indicating the (minimum) payment they are willing to accept for their proposed conservation land use. In addition to assessing the performance of an auction that only allows bids from individual producers, we will also contrast and compare this with an auction design that allows for both single and joint bids from adjacent producers. Incorporating the possibility of joint bidding is particularly useful in assessing the performance of an auction tailored towards internalising spatial synergies across the landscape. In this respect it is important to highlight the importance of the edge benefits. In auctions that do not allow for joint bidding opportunities, edge benefits can only be realized through individual bids from two adjacent nodes, and only if these turn out to be accepted by the auctioneer (regulator), as in Krawczyk et al. (2016). In auctions that allow for both individual and joint bidding, in addition to independently-accepted adjacent parcels, edge benefits can now also be reaped through a joint bid from two adjacent nodes. Moreover, spatial coordination can be further steered by providing agglomeration bonuses to neighboring winning producers, depending on whether coordination with one or both neighbors turns out to be successful. On this condition, let us denote the bonuses paid to a producer i as s_j and s_k in case the bid offer with neighbor j and/or neighbor $k \neq j$ are, respectively, accepted in the auction (below we will provide more detail about the individual landholder's conditional payoff functions).

Assuming that the edge and node benefits are additively separable, the regulator's optimisation problem entails selecting those combinations of single and joint bids that maximise the total environmental benefits (B) across the N-player network for a given total budget:

$$(1) \quad \max B = \sum_i b_i + \sum_{ij} b_{ij}$$

$$\text{s.t.} \sum p_m + \sum s_j + \sum s_k \leq \text{budget}$$

where $p_m \in \Omega$ is the auction payment to acquire land use change resulting from bid combination m, with Ω being the set containing the total number of permissible bid combinations. In case of our circular network with eight producers, the set Ω contains 1,154 elements.[1] Note that joint bids from non-adjacent producers are not permissible in our experimental design and are therefore not included in this number. Finding an optimal solution is not a straightforward task for the auctioneer, who will need to consider and compare all possible bid combinations that are being proposed in the auction. We assume the auctioneer uses a discriminatory pricing rule to decide which offers to accept. Such a pricing rule implies that successful sellers are paid the price equal to their bid. We employ such a discriminatory auction setting over a uniform price auction as Cason and Gangadharan (2004) have shown that in a uniform price auction sellers could be over-compensated given their opportunity costs, which reduces auction efficiency.[2] Moreover, in reality most conservation auctions like those implemented as part of the Conservation Reserve Program (CRP) in the US involve a discriminatory price auction.

Using a discriminatory pricing rule, we implemented a computer algorithm that evaluates the proposed bid combinations during the experimental auctions, to be discussed in more detail in Section 3. Any combination of individual and/or joint bids could be accepted which maximises total environmental benefits. Whilst simultaneously allowing for single and joint bidding might be conducive to harnessing the spatial synergies on the network and increase environmental benefits, contiguity of land parcels might not be fully optimised and the regulator still may not be able to procure projects which they would have been able to in the absence of asymmetric information. To enhance the auction's potential to augment spatial coordination between producers, we incorporate a "bonus" payment in the auction design. In particular, the bonus is tied to the edge benefits and works as follows. First of all, note that, irrespective of whether two adjacent sites where conservation activities will be undertaken are accepted through a single or joint bid, the regulatory agency always secures the edge benefits. From an ecological point of view, the benefits of spatial agglomeration do not depend on how this is achieved. However, since we speculate that spatial coordination is more likely under joint bidding, we differentiate the bonus payment depending on the type

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[1] For a N-player circular network, and allowing for both individual and joint bids from adjacent nodes only, the permissible number of bids is equal to $R(N) = \left(1 + \sqrt{2}\right)^N + \left(1 - \sqrt{2}\right)^N$. We thank Pierre van Mouche for deriving this rule.

[2] A similar result is confirmed by Cason and Gangadharan (2005) for an auction designed to reduce non-point source pollution, showing that a discriminatory price auction delivers emissions reduction more efficiently relative to a uniform price auction.

of bid (single or joint), with a higher bonus paid to each landholder when adjacent parcels are accepted through a joint bid than with two accepted single bids. In either case, we assume that the bonus for accepted adjacent parcels is proportional to the edge benefits that are procured. In this way, the bonus payment provides a reinforcement mechanism to encourage joint bids and foster explicit spatial coordination.

Given this setup, and given that we only allow positive bids, the possible payoffs for an *individual* producer *i* in an auction with individual bidding only are:

$$(2a) \quad \pi_i = \begin{cases} p_i - c_i & \text{if bid accepted but none of neighbors accepted} \\ p_i - c_i + s_j & \text{if bid accepted and neighbor } j \text{ accepted} \\ p_i - c_i + s_j + s_k & \text{if bid accepted and both neighbor } j \text{ and } k \text{ accepted} \\ 0 & \text{if bid not accepted} \end{cases}$$

In an auction with joint bidding opportunities, an individual producer's payoffs are:

$$(2b) \quad \pi_i = \begin{cases} p_i - c_i & \text{if individual bid accepted but none of neighbors accepted} \\ p_i - c_i + s_j & \text{if individual bid accepted and neighbor } j \text{ accepted} \\ p_i - c_i + s_j + s_k & \text{if individual bid accepted and both neighbor } j \text{ and } k \text{ accepted} \\ p_i - c_i + \gamma s_j & \text{if joint bid with neighbor } j \text{ accepted} \\ p_i - c_i + \gamma s_j + s_k & \text{if joint bid with neighbor } j \text{ accepted and neighbor } k \text{ accepted} \\ 0 & \text{if bid not accepted} \end{cases}$$

with $\gamma > 1$ in Eq. (2b) reflecting the aforementioned "reinforcement parameter," which raises an individual's payoff from a successful joint bid with their neighbor relative to the payoff from the selected individual bids submitted by the individual and their neighbor.

Another important auction design feature concerns the number of rounds conducted before winners and payments are finalised. In its basic form, the auction only features single bidding rounds before winners are determined. However, in an extended format one can also allow for multiple bidding rounds. Such an extension fosters bidders' learning by allowing them to acquire and update their information and beliefs about auction functioning and bidding behaviour from auction participants (e.g., Rolfe et al., 2009). However, in a context where spatial coordination of selected projects is a key goal, the impact of multiple rounds on coordination rates and auction performance is unclear. For instance, in a field experiment in the southern Desert Uplands in Australia, Windle et al. (2009) found that multiple-round bidding was conducive to improving auction efficiency but it did not significantly enhance spatial coordination, as indicated by landscape connectivity. On the other hand, in a multi-round laboratory auction experiment, Reeson et al. (2011) obtain that spatial coordination improves if information about the specific location of bids in the landscape is provided to bidders. To provide more insight and evidence on the interdependency between auction efficiency and spatial coordination, we will explore the performance of individual and joint-bid auctions under both single and multiple bidding rounds. However, note that our study keeps information provision constant, i.e., varying information (on opportunity costs, location, or node and edge benefits) is not a treatment variable.[3]

A final common feature that we include in the auctions is the opportunity for participants to communicate. In practice it is impractical to prevent producers, particularly neighbors, from communicating about how to respond to a conservation auction. In our case, communication incentives are especially strong considering the bonus payments provided for successful joint bids. Therefore, we allow individuals to communicate with both their neighbors (on a one to one basis). This provides them with an opportunity to agree on whether they want to submit joint bids, coordinate their bid offers and to negotiate on the sharing of the surplus in case their joint bid is accepted.

In view of the above auction design considerations, we are now in a position to postulate some testable conjectures based on the experimental implementation:

1. Joint bidding improves auction efficiency and leads to greater spatial coordination.
2. Multi-round bidding improves auction efficiency and leads to greater spatial coordination.
3. Bids increase in producers' opportunity costs of conservation activities.
4. Bids increase in the node and edge benefits provided by conservation activities.
5. Joint bids increase in the amount of edge benefits provided.
6. Rent-seeking is more prevalent under joint bidding.

3 Experimental Design

We report data for 24 groups with 8 subjects per group as presented in Table 1, producing a data set with 192 individuals. The two treatment variables of interest include (*i*) the presence of joint-bidding opportunities with neighbors (denoted by JOINT and INDIVIDUAL) in addition to the opportunity to submit individual bids and (*ii*) the auction structure itself involving single round and multiple rounds (denoted by SINGLE and MULTI). The treatments are implemented in a full factorial balanced between-subject treatment implementation giving rise to four different types of experimental treatments as presented in Table 1.

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[3] For some relevant literature on the role of information provision/concealment and information structures in conservation auctions, see Cason et al. (2003), Glebe (2013), Banerjee et al. (2015) and more recent contributions by Conte and Griffin (2017), Duke et al. (2017) and Messer et al. (2017).

Table 1: Experimental Design

Auction-Structure Treatment	Bidding Protocol Treatment	
	Individual Bidding Only	Individual & Joint Bidding
Single-Round	SINGLE-INDIVIDUAL (6 groups)	SINGLE-JOINT (6 groups)
Iterative Multiple Rounds	MULTI-INDIVIDUAL (6 groups)	MULTI-JOINT (6 groups)

The experiment was implemented in Ztree (Fischbacher 2007) and consisted of three stages. Stage 1 involved risk attitudes elicitation through an incentivized Eckel-Grossman lottery (see Eckel and Grossman, 2008) presented in the Appendix. Stage 2 comprised of the conservation auction and Stage 3 involved a demographic survey. The instructions included a flow-chart to clearly represent auction progression. All lottery amounts were presented in real US$ and payoffs from the auction were recorded in experimental currency units (ECU) which was converted into real US$ at an exchange rate of 50 ECU for US$1. Payments from the risk attitudes elicitation exercise were determined at the end of Stage 2 in order to prevent any possible wealth effects arising from subjects having knowledge about the money they had made in Stage 1, which can potentially impact bidding behavior in the auction. Subjects also received a $4 show-up fee, except in the MULTI-JOINT treatment that required more time to complete. Subjects in that treatment received a $10 show-up fee because it required about 150 minutes to complete a session, compared to typically less than 75 minutes for the other three treatments. Average earnings per subject were $23.19.

At the beginning of Stage 2, subjects were provided with a randomly determined ID ranging between 1 and 8 to establish right and left neighbor identity as well as location on the circular networked landscape on which the conservation auction would be implemented.

Spatially, we used a fixed matching scheme whereby neighbor identity remained unchanged during the experiment. We made this choice to facilitate subject learning about the auction environment involving the joint bidding opportunities and to allow for the build-up of reputational incentives. This matching protocol also aligns closely with reality in which agricultural land is owned and/or management by the same individual or entity for long time periods.

Subjects received detailed instructions about bidding in the auction and how their earnings would be determined (see the Appendix for instruction from the MULTI-JOINT treatment). During the auction, each subject was endowed with an item representing a patch of land which had a cost and quality value associated with it. Subjects always had information about their cost values to reflect the fact that in reality, producers usually have a good idea about the (opportunity) costs of implementing specific pro-conservation projects on their lands. The experiment consisted of 9 auction periods across all treatments. After learning their costs at the start of each auction period, bidders could participate in a 2-minute free-form and private discussion through online chat windows with each of their left and right neighbors about auction features and joint (and possibly even individual) bidding strategies. After this communication the experiment moved to the bidding stage. Prior to communicating, subjects were informed that the computer serving the role of the auctioneer preferred blocks of adjacent items (to encourage spatial coordination) and that if neighboring items were selected as auction winners then item owners would receive bonus payments. They were also informed that if joint bids were selected by the auctioneer, winners would receive 2.5 times the bonus amount while if adjacent individual bids were selected, they would receive one times the bonus amount (to encourage joint bidding).

At the beginning of this stage, in the JOINT treatments, the computer first prompted subjects about their willingness to submit joint offers with their neighbors. If a subject agreed to submit a joint offer with either of their neighbors and their corresponding neighbor reciprocated, the computer randomly selected the subject or the neighbor to submit the joint bid. At that point two offer submission boxes appeared on the screen left and/or right of the screen (one set each for the left and/or right neighbors) in which the joint bid submitter entered information about the bid they are willing to accept and the amount their neighbor is willing to accept. Once this information is entered, it would be displayed to the corresponding neighbor who confirmed whether or not the joint bid amounts are acceptable. If the responding player did not confirm the bid submission, only individual bids (which are submitted in addition to joint bids) would be considered to determine winning subjects.

After everyone had made their selections, the winning combination of projects was calculated by the computer – the auctioneer – according to Eq. (1) and announced to every subject. In the SINGLE treatments, the winning projects would determine the final winners for that auction period while in the MULTI treatments the winners would be announced as provisional winners only and were given an opportunity to bid again in the next round. At this point, bidders again had the opportunity to submit individual (and possibly joint) bids, and the winner determination routine repeated until a minimum number of rounds (3 in our study) were played. Then the stopping condition which involved checking whether the identity of winning and losing bidders in the current round is same as the previous round was evaluated. If the stopping condition was satisfied, the auction ended at the end of round 3. If it was not satisfied then the auction period repeated for another round at the end of which the condition was evaluated again. This exercise could repeat for a maximum of 6 rounds before ending at which point final winners of that period were determined and announced. Neither the stopping conditions nor the minimum and maximum round values are announced to the subjects to prevent any possible end game effects which have been found in public goods games (Isaac et al., 1984; Isaac et al., 1985) and conservation auctions (Reeson et al., 2011).

For convenience and to prevent confusion, in the MULTI treatments, subjects' individual bids from the previous round bid were automatically submitted by the computer. They could then maintain or reduce, but not increase, the amount of the bid.[4] The computer flashed a warning message if either the individual or joint bid submitted was less than the item's cost, but below-cost bids were permitted since farmers might well choose to submit such a bid if motivated by non-pecuniary considerations. At the end of a round in a period and after a period ended, subjects received feedback about auction outcomes on a Results Screen. This included information about (*i*) whether their individual or joint offer had been selected, (*ii*) whether one or both neighbors' individual or joint offers had been selected,[5] (*iii*) their provisional earnings for the round or their actual earnings if they were final winners in the period and (*iv*) the total bonus earned. The results screen also displayed the cost, quality and bonus value of the subject's item to clarify how earnings were being calculated. This information was also provided in the instructions and handouts. Finally, this screen included a History Table that recorded the above values for all rounds of a period and all auction periods. Since the information presented in these tables are similar, the round-level and period-level History tables were clearly highlighted on the Results screen to prevent any potential confusion.

We used three different sets of cost, quality and bonus values to calibrate auction parameters for each subject in every period. Each set was used in three of the nine auction periods thus minimizing the influence of any possible scale effects. We also assigned the values to periods in three different ways to minimize order effects. The values were randomly drawn from uniform distributions: $cost \sim [600, 1000]$, $quality \sim [200, 300]$ and $bonus \sim [50, 150]$. They were chosen such that in the absence of asymmetric information the first-best allocation procured by the regulator would comprise of 4 projects in all periods, have the highest net benefit calculated according to Equation (1), and involve different spatial configurations in keeping with varying objectives of reserve design for species conservation (Diamond 1975; May 1975).[6] Table 2 includes the parameter values, the different features of the first-best allocation for each set and the periods in which they were used. Finally, endowments of cost, benefit, and bonus values were shifted between subjects such that (*i*) even if neighbors exchanged endowment information through chat windows, subjects could not determine that the endowments from the past periods were being repeated, (*ii*) individual subjects never faced the same endowment in multiple periods, and (*iii*) if everyone bid at cost, then across

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[4] We did not permit subjects to increase bids between consecutive rounds because in actual conservation auctions such as the ones conducted in the Southern Desert Uplands of Australia in 2006 (Windle et al., 2007) subjects reduced bids across successive iterations.

[5] Note that if a subject's joint bid with say their left neighbor is selected, this automatically implies that the left neighbor's joint bid is selected as part of the winning allocation and not their individual bid. If this subject submitted a joint bid with her right neighbor and the right neighbor was also selected as a winner, this would be possible through selection of the individual bid by the right neighbor, or a joint bid between the right neighbor and their corresponding right neighbor.

[6] We implemented the 4-project cap to introduce enough competition in the auction to balance possible efficiency reduction arising from collusion incentives owing to the presence of communication opportunities. Following the SLOSS debate (Abele and Connor, 1979; Etienne and Heesterbeek, 2000), the spatial configurations involved creating two small clusters of two players each in Set 1, a single large core area made up of four players in Set 2 and a smaller core of three players and an isolated winner in Set 3. These configurations are highlighted in Table 2.

all 9 periods, 4 people would win 4 times and the other 4 would win 5 times. In order to facilitate understanding of auction features, subjects answered a quiz before bidding in the actual auction.

Table 2: Cost, Quality and Bonus Values for Items

Several Small – Set 1			**Single Large – Set 2**			**Core-Fragment – Set 3**		
Cost	**Benefit**	**Bonus**	**Cost**	**Benefit**	**Bonus**	**Cost**	**Benefit**	**Bonus**
821	273	135	767	203	111	868	225	76
762	291	126	818	260	76	740	219	98
987	255	51	745	237	120	708	274	111
679	266	105	626	201	61	825	285	61
708	274	111	855	273	100	821	273	135
626	260	98	655	244	69	717	291	126
862	237	76	944	224	85	862	298	51
825	285	61	708	266	145	602	266	105
Total Cost	**Total Benefit**	**Total Expense**	**Total Cost**	**Total Benefit**	**Total Expense**	**Total Cost**	**Total Benefit**	**Total Expense**
2917	1344	3409	2881	1236	3443	3006	1317	3360
Order 1				**Order 2**		**Order 3**		
E1E2E3/E1E2E3/E1E2E3 8 groups – 2 groups per treatment				E2E3E1/E2E3E1/E2E3E1 8 groups – 2 groups per treatment		E3E2E1/E3E2E1/E3E2E1 8 groups – 2 groups per treatment		
Shared Borders between Selected Projects								
2				3		2		

The experiments were conducted at Purdue University in 2018. Subjects were recruited from the University student population. Experiments did not include contextual terminology relevant to farmland conservation policies, conservation auctions and PES since context-loaded terminology can influence subject behaviors and confound the treatment comparisons (Cason and Raymond 2011).

4 Results

The experimental results focus on the impact of our treatment variables on auction performance as measured by a series of metrics – degree of auction rent seeking, total environmental quality procured, auction cost-effectiveness and finally levels of agglomeration achieved in the auction. We first describe these metrics in the next section followed by the discussion of the results.

4.1 Performance metrics

The principle goal of an auction is to incentivize truthful bidder cost revelation and minimize the auction rents that winning bidders can command. Thus our first performance metric is the total information rent earned by all winning subjects in the auction as presented in Eq. 3:

$$(3) \quad Auction\ Rent = \sum_{i=1}^{N}(p_i - c_i)x_i \qquad x_i = 1 \text{ if i}^{\text{th}} \text{ subject is a winner, 0 otherwise}$$

The total environmental benefits provided has already been presented in Expression (1). Given the budget constrained nature of the auction we measure efficiency in terms of level of cost-effectiveness of the realized auction outcomes relative to the cost-effectiveness of the winning allocation. The metric POCER – Percentage of Optimal Cost Effectiveness Realized (Cason et al. 2003; Banerjee et al., 2015) is computed for this purpose. It is presented in Expression (4) and is a ratio of two ratios. The ratio in the denominator represents the environmental benefit procured per unit money spent at the optimum allocation in the absence of asymmetric information so that producers receive only their costs (plus edge benefits). A similar ratio in the numerator denotes the environmental benefits actually realized as a result of competitive bidding per unit money spent in the auction.

$$(4) \qquad POCER = \frac{\left(\sum_i b_i + \sum_{ij} b_{ij}\right)x_i \Big/ \left(\sum p_i + \sum s_j x_j + \sum s_k x_k\right)x_i}{\left(\sum_i b_i + \sum_{ij} b_{ij}\right)x_i^* \Big/ \left(\sum p_i + \sum s_j x_j + \sum s_k x_k\right)x_i^*}$$

$$x_i = 1 \text{ if i}^{\text{th}} \text{ subject is a winner, 0 otherwise}$$

$$x_i^* = 1 \text{ if i}^{\text{th}} \text{ subject is winner in the first-best allocation, 0 otherwise}$$

Finally, the level of agglomeration at the network level is measured as the number of instances in which two or more winning projects are adjacent to each other giving rise to one or more shared borders between them.

4.2 Analysis of Auction Outcomes and Performance

Given our environmental goal of spatially contiguous project selection, Figure 2 presents histograms displaying the incidence of agglomeration across all treatment conditions. First, we find that in most conditions, two shared borders are achieved in the auction either through the selection of three adjacent projects forming a medium sized core or two small clusters of two adjacent projects each (with each cluster separated by unselected projects or an isolated winning project). Second, barring the MULTI-INDIVIDUAL and SINGLE-INDIVIDUAL treatment under the Core-Fragment condition and the SINGLE-JOINT treatment under the Single Large setting, in all other treatments three shared borders are obtained. This should not be surprising for the Single-Large condition (middle column) since the first-best allocation under this condition includes four adjacent winners with three shared borders. Additionally, fewer agglomeration levels of 3 in the Core-Fragment condition (right column) is also to be expected given that this setting involves the selection of an isolated project as the winner. However, the fact that we obtain instances of three shared borders under all conditions of Several-Small (left column) suggests that despite the first best allocation requiring producing agglomeration level of two, auction participants sometimes can coordinate amongst themselves to submit bids which lead to higher levels of contiguity than what would be achieved without asymmetric information. As a result, on average agglomeration levels are greater than 2 in 7 out of the 12 treatment conditions as presented in Figure 3. Notably, average agglomeration is always greater when bidders are restricted to submit individual bids, with differences being particularly large for the single-round auction condition.

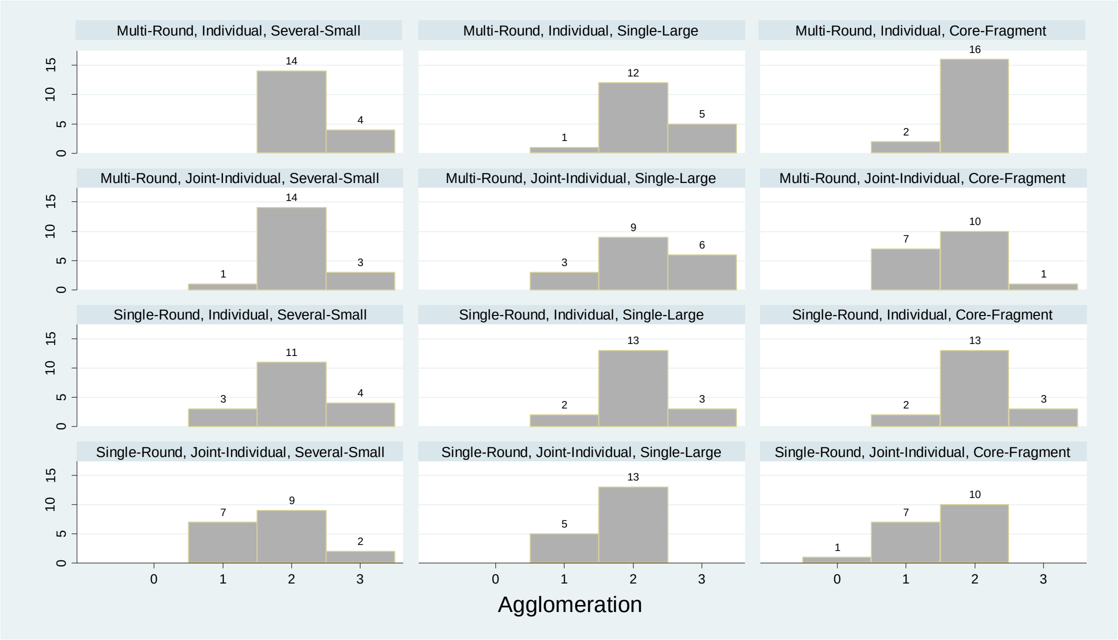

Figure 2: Histogram of Agglomeration for Auction Treatment

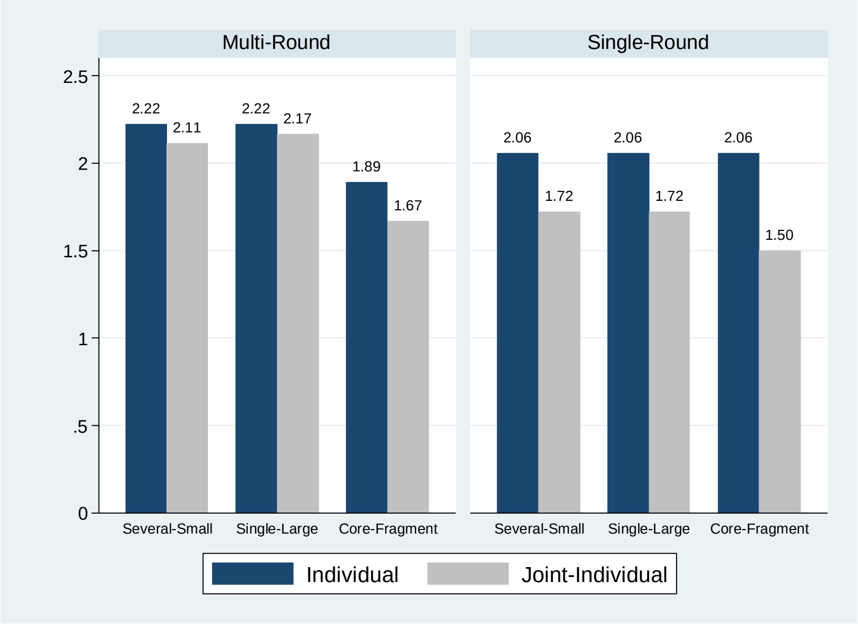

Figure 3: Average Agglomeration

The agglomeration findings indicate that the individual and joint bonuses provided by the auction are successful in incentivizing bid submission that leads to spatially adjacent project selection under the different treatment conditions. We next analyze the levels of auction efficiency measured by the cost-effectiveness metric, associated with the realized levels of agglomeration in the auction. Figure 4 presents the average POCER value across treatments and indicates that auction cost-effectiveness is 85% or higher in all treatments, and reaching as high as 99% under individual-bidding protocol for both Single Round and Multi-Round auctions for the Single-Large setting. Moreover, performance seems on average to be no different between Single Round and Multi-Round auctions when considering treatments with no joint bidding. However, when comparing auctions with Joint bidding opportunities to those where subjects can submit only individual bids, we find performance to be lower. Non-parametric Wilcoxon Mann-Whitney tests presented in Table 3 comparing POCER values across treatments finds efficiency to be significantly higher under individual bidding treatments than under joint bidding treatments (except for the Single-Large Core condition for Multi-Round bidding).[7]

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[7] The unit of observation for Mann-Whitney tests is each individual session with data averaged for each configuration type.

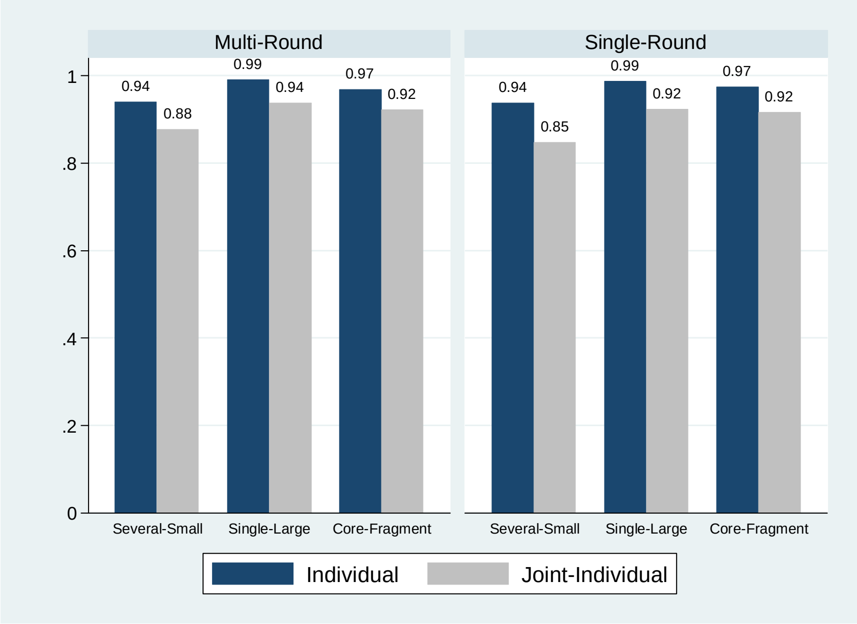

Figure 4: Average Percentage Optimal Cost-Effectiveness Realized (POCER)

Table 3: Average POCER values and Treatment comparisons

POCER	Multi Round			Single Round		
	Individual	Joint-Individual	Treatment Comparison	Individual	Joint-Individual	Treatment Comparison
Several Small	0.94 (.012)	0.88 (.011)	1.922*	0.94 (0.015)	0.85 (.019)	2.242**
Single Large	0.99 (.009)	0.94 (.015)	1.601	0.99 (0.014)	0.92 (.018)	1.761*
Core-Fragment	0.97 (.007)	0.92 (.011)	2.402***	0.97 (0.007)	0.92 (.012)	2.402***

***, ** and ** indicates significance at 1%, 5% and 10% levels of significance for the Mann-Whitney tests statistics shown in the Treatment Comparison columns. Standard errors of the mean are shown in parentheses.

Since the POCER metric incorporates both the level of environmental quality procured in the auction and the total cost of the supporting allocation, we focus on these components to identify where the treatment differences in auction cost effectiveness stems from. Figure 5 presents the total environmental benefits procured on average in the auction and indicates that realized levels of environmental benefits are close to those obtained under the first best allocation (presented in Table 2) for all spatial configurations for the Individual bidding treatment. This is however not the case for the auctions that permit Joint bidding for all configurations. Table 4 presents treatment comparisons across individual and joint-bidding conditions for each configuration for Single and Multi-round auctions and indicates that treatment induced differences POCER are driven in part by the significant differences in environmental benefits realized in the auction under the different conditions.

Figure 5: Average Environmental Benefit

Table 4: Average Environmental Quality Procured and Treatment Comparisons

Environmental Quality Procured	Maximum Feasible	Multi Round			Single Round		
		Individual	Joint-Individual	Treatment Comparison	Individual	Joint-Individual	Treatment Comparison
Several Small	1344	1278.44 (15.46)	1187.83 (15.33)	2.242**	1263.44 (18.378)	1139.56 (26.36)	2.402***
Single Large	1236	1233 (12.46)	1162.94 (19.11)	1.601	1219.28 (17.443)	1139.28 (22.99)	1.761*
Core-Fragment	1317	1306.61 (11.48)	1240.11 (13.87)	2.722***	1312.11 (8.598)	1221.5 (21.52)	2.887***

***, ** and ** indicates significance at 1%, 5% and 10% levels of significance for the Mann-Whitney tests statistics shown in the Treatment Comparison columns. Standard errors of the mean are shown in parentheses.

The data also indicate that on average more than 3400 ECUs of the total budget of 3500 ECU is expended under all treatment conditions with no significant treatment effect when comparing outcomes for auction with and without joint-bidding opportunities. Given this finding, we next turn to rent seeking levels in the auction to better understand the factors driving differences in environmental procurement (and hence efficiency) despite there being no significant differences in auction expenditures across treatments. Figure 6 presents the average levels of rent seeking associated with the winning bidders in the auction.

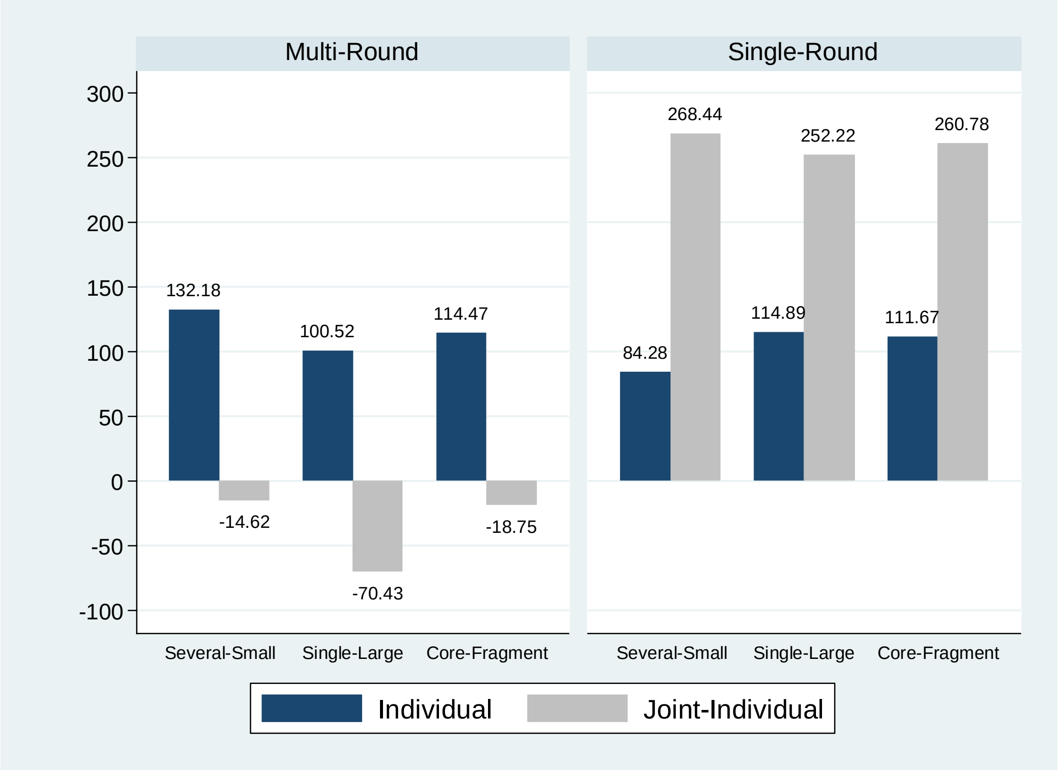

Figure 6: Average Rent Seeking

We observe that on average rent seeking is higher under joint bidding in the single round auction than when only individual bids are possible. These differences are statistically significant as presented in Table 5. Thus, winning subjects are able to retain higher rents in the presence of joint bidding opportunities leading to lower levels of environmental procurement under each spatial configuration.

Table 5: Average Rent Seeking Levels and Treatment Comparisons

Auction Rent Seeking	Multi Round			Single Round		
	Individual	Joint-Individual	Treatment Comparison	Individual	Joint-Individual	Treatment Comparison
Several Small	132.18 (9.19)	-14.62 (27.63)	1.922*	84.28 (8.381)	268.44 (5.22)	-1.761*
Single Large	100.52 (5.74)	-70.43 (6.42)	1.922*	114.89 (5.101)	252.22 (9.23)	-2.242**
Core-Fragment	114.47 (5.99)	-18.75 (5.79)	0.32	111.67 (2.868)	260.78 (4.95)	-2.082**

***, ** and ** indicates significance at 1%, 5% and 10% levels of significance for the Mann-Whitney tests statistics shown in the Treatment Comparison columns. Standard errors of the mean are shown in parentheses.

Interestingly, when subjects have the opportunity to revise bids in the multi-round auction, average rent seeking is negative under all spatial configurations under joint bidding. Additionally, there is a significant treatment effect when comparing rent seeking across individual only and joint-bidding conditions for the Several Small and Single Large configurations. Since bid submissions below cost are allowed under all conditions, this finding indicates that many bidders were submitting bids below cost in the joint-bidding auction to ensure their selection as winners which would allow them to win the bonus payments (depending upon whether their individual or joint bids were selected). Thus, while rent seeking on average between winners is lower, owing to the high bonus payments under the joint bidding treatments, total environmental procurement and auction cost-effectiveness is lower.

Finally, comparing across joint bidding treatments only we see higher levels of rent seeking under the single-round joint-bidding treatments than in the iterative, multi-round case for all but the Core-Fragment condition. These differences are significant on the basis of Wilcoxon Mann-Whitney tests although there is no difference in POCER and total environmental benefits procured. Thus, if the auctioneer has alternative uses for funds remaining after paying auction winners and is interested in implementing an auction with joint bidding opportunities, they are better off implementing an auction that allows subjects to revise bids over successive iterations.

5 Discussion and Conclusions

This paper studies a conservation auction that allows for both individual and joint bidding opportunities in support of spatially coordinated land-use management decisions to procure environmental benefits. Our research motivation comes from two features of agri-environmental policies (i) depending on environmental targets, the desire to encourage specific kinds of spatial coordination between landowners enrolling in the scheme; and (ii) recent moves in several countries to encourage participation by groups of farmers, rather than participation by individuals. We speculated that combining spatial incentives for coordination in an auction with the possibility of group bidding would lead to higher environmental benefits through greater spatial coordination.

Using a laboratory experiment to test-bed the auction mechanism in both a single-round and multi-round setting, we find however that allowing for joint bidding does not enhance auction efficiency nor generates significantly larger environmental benefits. Indeed, individual bidding produces the highest degree of spatial coordination and the highest environmental benefits. Overall auction efficiency is high in all treatments; whilst rent seeking is highest under joint-bidding. This erodes the degree of environmental improvement that can be bought. However, how much rent seeking happens varies for joint bids between multi-round settings compared to the single-round auction – in a multi-round setting, groups accept bids below cost in order to win bonuses.

Our overall finding at this stage is that group bidding does not seem to be superior to individual level bidding in conservation auctions in terms of improving spatial coordination or environmental benefits. However, we need to investigate individual level behavior, which is not reported here and which may cast a different light on the question of whether our intuition in designing this experiment was in any sense correct.

A number of qualifications are in order in terms of the basic results presented here. First, we used a very specific network structure to test the effects of group bidding. On a circle, the number of neighbors is the same for every subject on the circle providing us the opportunity to evaluate bidding behavior without having to worry about people bidding differently because they have different number of neighbors and hence a different spatial bonus earning potential (which can confer locational advantages to some and disadvantages to others). A different spatial setup involving an asymmetric neighborhood profile will cause different people at different locations to have different communication profiles (since they talk to different number of neighbors). While this feature is realistic and interesting, we trade-off some realism in favor of establishing behavioral benchmarks for a symmetric neighborhood setup to which results of future experiments (which consider asymmetric neighborhood structures) can be compared. Moreover, Chwe (2000) indicates that different network communication profiles can impact strategic behavior (in his case coordination) differently. Higher order networks with many weak links are not conducive to coordination whereas smaller order networks with fewer but stronger links are. Despite our focus on an auction and not a coordination game, in our experiment the prospect of joint bidding signifies that subjects have to coordinate their decisions. In that sense, we implemented the simplest communication setting where subjects would communicate only with their left and right neighbors. Second, our results clearly depend on the payment structure implemented in our auction.

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