Spatial Coordination and Joint Bidding in Conservation Auctions*

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Abstract

Spatial coordination of land use change is pivotal in agri-environmental policy to improve the delivery of environmental goods. This paper implements a laboratory experiment to study spatial coordination in a conservation auction. In addition to letting individual producers bid competitively against each other to supply environmental goods, we ask whether opportunities for joint bidding can enhance spatial coordination in the auction cost-effectively. Auction performance depends on the nature of incentives for individual bids; in particular, whether an agglomeration bonus is offered for individual bids. With an individual bonus in place, joint bidding gives no improvement in either environmental benefits procured or cost-effectiveness. Absent an individual bonus, joint bidding improves environmental performance but can decrease cost-effectiveness. Further, across both individual and joint bidding treatments, the average environmental benefits, degree of spatial coordination and cost-effectiveness is greater, and amount of seller markups lower, with multi-round bidding compared to single round bidding.

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1 Introduction

In designing Agri-Environment Schemes (AES), both ecologists and economists have argued that greater spatial coordination of producer participation can improve environmental outcomes for a range of important environmental targets such as wetlands restoration, nutrient pollution reduction and species conservation (Parkhurst et al., 2002; Williams et al., 2012; Lamb et al., 2016; Kremen and Merenlender, 2018). Economists have suggested two price-based mechanisms for achieving such spatial coordination: the Agglomeration Bonus (AB) (Parkhurst et al., 2002; Parkhurst and Shogren, 2007) and spatially-connected auctions (Banerjee et al., 2015; Krawczyk et al., 2016). However, a majority of the analyses to date have focused on incentives aimed at individual land manager participation in such schemes (e.g., Fooks et al., 2016). In contrast, a number of countries have recently introduced changes in the design of AES which encourage joint participation by groups of producers; for example, under the Higher Tier Countryside Stewardship in the UK[1] and under all AES in the Netherlands (Westerink et al., 2017).

Such joint participation can have at least two potential benefits. First, if joint participation involves groups of neighboring producers coming together to improve the environmental outcomes of their land management, then this is one way of achieving spatial coordination. Second, collaboration between neighboring producers could lead to an increase in local social capital, which could in turn lead to higher levels of pro-environmental behavior (Zabel, 2019). In this paper, we will focus on the first aspect of joint participation and study the effects of allowing for joint bidding by groups of producers on spatial coordination and cost effectiveness within a conservation auction.

As originally proposed, conservation auctions are a means of increasing cost-effectiveness relative to the fixed price subsidy regimes which characterize agri-environmental policy in many parts of the world. This increase in cost-effectiveness is achieved by producers bidding competitively against each other to supply environmental goods to a buyer, typically but not always a government body. Moreover, conservation auctions reveal information about the producers' (sellers') type, since offers are dependent on their marginal costs of providing the environmental good. This marginal cost information is what governments often lack at the individual producer (farm) level. Because of these perceived benefits and given asymmetric information, the use of conservation auctions has been growing world-wide, especially in Australia, the US and China

[1] The Facilitation Fund adds 10% to the points score for bids by farmers who are part of collective applications under the Higher Tier Countryside Stewardship scheme (DEFRA, 2019).

(Whitten et al., 2015; Rolfe et al., 2018).

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 uniform price versus pay-as-bid payment rules (Cason and Gangadharan 2005; Duke et al., 2017) and the effects of revealing information about the auction budget versus not providing this information (Messer et al., 2017). The design issue of particular relevance to the current paper is how to encourage the spatial coordination of bids in a cost-effective manner. Windle et al. (2009), Banerjee et al. (2015), Fooks et al. (2016), Krawczyk et al. (2016) and Liu et al. (2019) have explored the effects of including spatial coordination incentives within a conservation auction, and we build upon that work in this new experiment by incorporating joint bidding opportunities.

Relatively little evidence exists on how joint bidding performs within conservation auction settings. Opportunities for producers to submit joint bids in conservation auctions was part of the design in the "Auction for Landscape Recovery" 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., 2016a). Alongside these limited implementations in the field, other studies attempt to assess the impact of joint bidding on auction performance via numerical simulations. Calel (2012) compares joint and individual bidding within 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 the context of spatial targeting to create conservation corridors. In a laboratory experiment, Rondeau et al. (2016) find that joint bidding increased auction efficiency and that reduced bidder competition from fewer bid submissions did not adversely affect auction performance. However, their study did not focus on spatial conservation auctions. Smith and Day (2018) consider the negotiation between joint (two) purchasers who make an offer to one provider (here the farmer) in a general AES. Our experiment studies the opposite setting, with competition on the provider/bidder side, and negotiations between multiple bidders who make offers to one purchaser – a government agency. We also consider an auction where neighboring bidders can coordinate bids through direct communication rather than through a sequence of alternating offers.

The experiment reported in this paper compares the economic efficiency and environmental performance of auctions that not only allow bids from groups of participants, but explicitly encourages them by providing additional pecuniary rewards from winning a joint bidding contract. Since we do not wish to "force" auction participants into joint bidding (that would not be very realistic), in our experiment we always allow individual bid submissions with joint bid submission opportunities in treatment sessions. In studying the impact of these joint bidding options, we additionally vary the magnitude of pecuniary rewards associated with winning joint or individual bids. These rewards take the form of AB payments which are intended to (*i*) incentivize spatially coordinated bid submission, (*ii*) compensate for the higher transaction costs associated with joint bid formation (Palm-Forster et al., 2016b), and (*iii*) reward winners for the extra environmental benefit produced from spatially coordinated conservation practices. In some experimental sessions we vary whether an AB is offered for spatially contiguous *individual* bids or not, while in others we vary the size of a "super-bonus" awarded to winning *joint* bids.

At the end of Section 2, three expected effects from our experiment are set out, to aid interpretation of results. But it is worthwhile outlining, in an informal manner, what mechanisms might drive these effects, and thus the results of allowing joint bidding in spatial conservation auctions. These mechanisms can be seen from the viewpoint of the producer and the regulator. For the producer, the individual-level AB increases the value of winning a contract from an individual bid so long as their neighbors also bid successfully. That is, the individual-level AB gives producers an incentive to lower their bids relative to their opportunity costs, hence making bids more competitive. From the regulator's perspective a similar tradeoff exists. While lower bid markups over cost for individual bids can lead to higher spatial coordination, paying the individual-level AB uses up scarce funds and reduces the number of contracts that can be selected. Producers may reduce bid markups for joint bids even more than for individual bids in order to increase their chances of winning the joint bidding super-bonus. Consequently, more joint bids may be selected, as on average these may be priced lower than individual bids. Since joint bids can only be submitted with neighbors, this increases the likely degree of spatial coordination of land switched to conservation, over and above what could be achieved with the individual bonus only. When individual bid bonuses are combined with joint bidding bonuses, however, these two mechanisms become entangled. The relative levels of bid shading for joint and individual bids can be influenced by the magnitudes of the bonus payments, which can impact the total number of projects selected and auction performance.

Finally, conservation auctions are complex mechanisms and a focus on spatial coordination and joint bidding adds to this complexity. It is therefore worthwhile to consider whether the presence of bid revision opportunities across multiple rounds can ameliorate some of the cognitive complexities associated with bidding (Banerjee and Conte, 2018). Tradeoffs exist between single-round and multiple-round iterative auctions. These could include greater transaction costs of implementing a multi-round auction for the implementing agency because it requires more time. This can significantly limit efficiency (Mettepenningen et al., 2011), not to mention strategic tendencies arising from bidders submitting inflated bids in different auction rounds. Although single round auctions may be appropriate for certain applications, multiple bidding rounds may improve outcomes when there are combinatorial benefits or interdependencies between bids (Rolfe et al., 2009; McAfee and McMillan, 1996). Joint bidding clearly introduces such interdependencies. We therefore also compare behavior and auction performance under single and multiple auction rounds settings.

For the analysis, we focus on both environmental and economic performance of the auction. Environmental performance measures the total environmental benefits procured and the level of spatial coordination achieved. Economic efficiency is represented by cost-effectiveness; and the information markup earned by sellers, which is measured as the difference between total payments (bids and bonuses) for winning projects and their costs. Our results indicate that when spatial coordination is rewarded by bonus payments for both adjacent individual and joint bids, no significant difference in performance exists between individual-only and joint bidding auctions that allow for revision and resubmission of bids. If bid revision opportunities are absent, then an auction with joint bidding is worthwhile only if the super-bonus reward for winning joint bids is not too generous. If a higher reward needs to be paid, the policy maker is better off implementing an auction with individual bidding only, a testament to the overall higher cost of auction implementation. Results change when there is no bonus incentive associated with individual bid submissions. Then joint bidding significantly improves environmental performance of the auction independent of bid revision opportunities. However, economic performance is not improved for the single-round auction and is worse in the multi-round auction compared to the situation when adjacent winning bidders receive bonus rewards if their individual bids are selected.

2 Landscape Structure and Auction Features

Consider a landscape comprising a fixed number of N producers. Following Banerjee et al. (2014, 2015), we adopt a landscape that is represented by a circular network where each producer $i = 1,2, \ldots, N$ is situated on a fixed position (a node) on the circle. With this circular network structure, each individual producer has the same number of neighbors: one to the left and one to the right.[2] 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, which can be generated via environmentally friendly land-uses. Spatial (and substantial) variation in opportunity costs arises frequently on agricultural landscapes subject to AES-type interventions (Hanley et al., 2012). The environmental benefit potential also varies across space (Dallimer et al., 2009, 2010): we refer to the site-specific environmental benefit potentials associated with each parcel as *node* benefits. For the experiment, opportunity costs are assumed to be spatially uncorrelated and are drawn randomly from the uniform distribution $c_i \sim \left[\underline{c^n}, \overline{c^n}\right]$. Environmental benefits are also assumed to be uncorrelated, uniformly distributed and randomly drawn from the distribution $b_i \sim \left[\underline{b^n}, \overline{b^n}\right]$.

Owing to potential complementarities from conservation uses on adjacent parcels in real landscapes (Kremen and Merelender, 2018), the sum of environmental benefits generated from placing neighboring parcels in conservation use is assumed to be greater than the individual parcel node benefits. Let us call the complementary environmental benefits generated through land uses on two parcels at two adjacent nodes i and j the *edge* benefits. These are denoted b_{ij} and represent the environmental benefits of spatial coordination. The edge benefits are randomly drawn from the uniform distribution $b_{ij} \sim \left[\underline{b^e}, \overline{b^e}\right]$.[3]

[2] This circular network structure allows us to explicitly incorporate a spatial element, with linked players serving as each other's neighbors. It is a simplification of reality since different producers could have a different number of neighbors leading to location asymmetries. While a different network structure might be more realistic, a circular network avoids location asymmetries that could complicate the experimental analysis, such as situations where certain producers at central or peripheral positions on the network exercise bargaining power and intensify rent-seeking activity. Joint bidding on more realistic and representative networks can be the subject of future research.

[3] Node benefits are the benefits from pro-environmental land uses and edge benefits are the benefits accruing from having projects adjacent to each other. These are two distinct ecological impacts from a change in land use. Examples exist in the ecological literature where these benefits are correlated and others where they are not (Lamb et al., 2016; Hodgson et al., 2011). Given that both cases are possible and that in our paper we are focused on studying the impact of joint bidding opportunities, we specified edge benefits from a change in land use as being un-correlated with node benefits from a change in land use (see also Dallimer et al., 2010). This feature could be studied in future experiments with the results of the current study providing a baseline for comparison.

Given this landscape structure, the regulatory agency aims to maximize the sum of environmental benefits given a fixed budget through the use of a conservation auction. This economic and policy environment is, unfortunately, considerably more complex than what can be analyzed using frontier theoretical auction models. Bidders have multidimensional types, defined by private information over their opportunity costs, as well as heterogeneous environmental quality and edge benefits. And although each bidder can supply only one conservation activity in the auction, these conservation projects differ in their environmental benefits supplied—which is the quantity that the auctioneer seeks to maximize. Moreover, the repeated interaction of bidders across periods on a fixed landscape, consistent with stable land ownership or management by the same individual or entity, would make the application of any results from a static auction model highly questionable. Nevertheless, we provide some informal reasoning below, based on principles and intuition from auction theory as applied to more tractable environments.

Our starting point is a discriminatory (pay-as-bid) auction, since it is unclear how to apply uniform price rules to account for heterogeneous conservation benefits. In addition to assessing the performance of an auction that only allows bids from individual producers, we compare the discriminatory price auction with a new design that allows for both individual and joint bids from pairs of *adjacent* producers.[4] Joint bidding may be particularly useful for promoting auction outcomes that are tailored towards internalizing 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 are both accepted by the auctioneer (regulator), as in Banerjee et al. (2015), Krawczyk et al. (2016) and Liu et al. (2019). 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 selection of joint bids from producers at two adjacent nodes. This spatial coordination can be targeted by providing AB payments to neighboring producers, depending on whether coordination with one or both neighbors turns out to be successful.

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

[4] In our design we did not allow joint bids from non-adjacent bidders.

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

$$\text{s.t. } (a) \quad \sum p_m \leq \text{budget}; \quad (b) \quad i \in \{m_i^*, m_{ij}^*\}$$

where $p_m \in \Omega$ in constraint ($1a$) is the total auction expenditure including any AB payments to acquire land use change resulting from bid combination m, with Ω being the set containing the total number of permissible bid combinations. For our circular network with eight producers and joint bidding, the set Ω contains 1,154 elements.[5] Constraint ($1b$) indicates that an individual producer i can only be part of one successful bid, either through an individual bid (m_i^*) or a joint bid with neighbor j (m_{ij}^*).

Finding an optimal solution is not a straightforward task for the auctioneer, who needs to compare the net benefits of all possible bid combinations that are being proposed in the auction. As mentioned above, we use a discriminatory (pay-as-bid) pricing rule to decide which offers to accept, such that successful sellers are paid their bid price. We employ such a discriminatory price auction setting over a uniform price auction because of its greater simplicity, and because Cason and Gangadharan (2004) found empirically that in a uniform price auction sellers could be over-compensated given their opportunity costs, which reduces auction efficiency.[6] Moreover, in reality most conservation auctions involve a discriminatory price auction, such as those implemented as part of the Conservation Reserve Program in the US and schemes implemented in Australia. Using this pricing rule, we implement a computer algorithm that evaluates the proposed bid combinations during the experimental auctions, to be discussed in more detail in Section 3. The algorithm accepts the combination of individual and/or joint bids which maximizes total environmental benefits subject to the budget constraint.

Simultaneously allowing for individual and joint bidding, and rewarding spatial coordination via AB payments, might be conducive to harnessing the spatial synergies on the network and increase environmental benefits and cost-effectiveness. However, we further enhance

[5] 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 $R(N) = \sum_{m=0}^{[N/2]} 2^{n-2m} \frac{N}{N-m} \binom{N-m}{m}$. We thank Pierre van Mouche for pointing us to this rule.

[6] A similar result is obtained 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. Such empirical results could be sensitive, however, to the size of supply elasticities.

the auction's potential to augment spatial coordination between producers by incorporating in some treatments a "super-bonus" payment in the auction design, whereby a higher AB payment is made to each winner when adjacent parcels are accepted through a joint bid rather than with two individual bids. In this way, the super-bonus payment provides a reinforcement mechanism to encourage joint bids (since, in reality, the transactions costs to the individual producer from participating in a joint bid are likely to be higher than those associated with individual bidding).

Almost all real-world conservation auctions feature individual bidding. The rationale for extending this to joint bidding is that where individual bidding fails to generate spatial coordination, joint bidding may increase the chances of delivering meaningful levels of ecological improvement. However, joint bidding is challenging, since it incurs higher transaction and cognitive costs owing to the need to collaborate with neighbors as well as participating in an unfamiliar bidding exercise. In that sense the presence of a higher AB reward for joint bids and a lower one for individual bids for the same property seems a reasonable proposition. Yet given the challenges associated with joint bidding, bidders might not end up submitting the best set of joint bids which would maximize the chances of spatial coordination, or even worse not submit a joint bid at all. Thus, in order to provide joint bidding the "greatest chance to succeed," we also evaluate auction performance when accepted adjacent *individual* bids do not receive any AB payments. As a result, our auction affords us the option to evaluate the relationship between individual and joint bids when bidders are faced with different types of strategic incentives under different AB payment settings. In all these cases, we assume that the AB and super-bonus (joint bidding) rewards depend on and are proportional to the *edge* benefits that are generated.[7] Given this setup, the possible payoffs for a producer *i* in an auction with *individual* bidding only are:

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

[7] From an ecological perspective, the *edge* benefits from spatial agglomeration do not depend on whether they are achieved through the selection of adjacent individual or joint bids. Procuring projects with joint bids will therefore be costlier for the auctioneer than the same projects acquired through selection of individual bids, owing to super-bonus payments. However, this is not problematic, since the super-bonus incentivizes the submission of competitive joint bids which may otherwise not be submitted. Moreover, bid formation can be cognitively complex (Banerjee and Conte, 2018) and joint bid formation might be even more so. In that sense, super-bonus payments can also be thought of as compensating producers for undertaking this complex coordination and bidding activity.

In an auction with *joint* bidding opportunities and individual AB and super-bonus payments, an individual producer's payoffs are:

$$(2b) \quad \pi_i = \begin{cases} p_i - c_i & \text{if individual bid accepted but no neighbors accepted} \\ p_i - c_i + s_j & \text{if individual bid accepted and neighbor } j \text{ accepted} \\ p_i - c_i + s_j + s_k & \text{if individual bid accepted and both neighbor } j \text{ and } k \text{ accepted} \\ p_i - c_i + \gamma s_j & \text{if joint bid with neighbor } j \text{ accepted} \\ p_i - c_i + \gamma s_j + s_k & \text{if joint bid with neighbor } j \text{ accepted and neighbor } k \text{ also accepted} \\ 0 & \text{if bid not accepted} \end{cases}$$

with p_i denoting the payment to producer i specified in the accepted individual or joint bid. The term $\gamma > 1$ in Eq. (2b) reflects the aforementioned reinforcement mechanism, which generates the super-bonus payment γs_j that raises an individual's payoff from a successful joint bid with their j^{th} neighbor relative to the bonus payoff s_j from selected individual bids submitted by the individual and this neighbor. Note that if the joint bid with neighbor j is accepted and neighbor k is also accepted, producer i receives the individual AB, s_k, but without the super-bonus benefit γ. Also as noted earlier, s_j (and γs_j) $\propto b_{ij} \sim [\underline{b^e}, \overline{b^e}]$.

We also consider an auction setting with joint bidding opportunities and super-bonus payments but no AB payments from adjacent individual bids. In this case an individual producer's payoffs are:

$$(2c) \quad \pi_i = \begin{cases} p_i - c_i & \text{if individual bid accepted but no neighbors accepted} \\ p_i - c_i & \text{if individual bid accepted and neighbor } j \text{ accepted} \\ p_i - c_i & \text{if individual bid accepted and both neighbor } j \text{ and } k \text{ accepted} \\ p_i - c_i + \gamma s_j & \text{if joint bid with neighbor } j \text{ accepted} \\ p_i - c_i + \gamma s_j & \text{if joint bid with neighbor } j \text{ accepted and neighbor } k \text{ also accepted} \\ 0 & \text{if bid not accepted} \end{cases}$$

Another important auction design feature concerns the number of rounds conducted before winners and payments are finalized. In its simplest form, a conservation auction features a single bidding round before winners are determined. However, multiple bidding rounds fosters bidders' learning by allowing them to acquire and update their information and beliefs about potential payments and bidding behavior of other participants (Rolfe et al., 2009). This experience can alleviate the complexity associated with bid formation and submission (Banerjee and Conte, 2018) and promote transparency and bidder validation of auction outcomes (Parkes, 2006; Messer et al., 2016). Again, in the context of the Wetland Reserve Program in the US, Knight (2010) reports cost-savings of about $820,000 from implementing a two-round iterative auction for procurement of conservation easement projects. However, in a context where spatial coordination of selected projects is a key objective, the impact of multiple rounds on coordination rates and auction performance is unclear, although most lab experiments on spatial auctions in the literature involve multiple rounds (Reeson et al., 2011; Iftekhar and Tisdell 2014; Banerjee et al., 2015, Fooks et al., 2016; Krawczyk et al., 2016). For instance, in a field experiment in the southern Desert Uplands in Australia, Windle et al. (2009) found that multiple-round bidding helped improve auction efficiency over a single-round setup - bid prices fell by 34% across the three rounds. But this feature did not significantly enhance spatial coordination, as measured by landscape connectivity. Moreover, iterative or multi-round bidding in a spatial conservation auction might lead to collusive bidding, hence eroding auction efficiency. To provide evidence on the interdependency between auction efficiency and spatial coordination, we therefore explore the performance of individual and joint-bid auctions under both single and multiple bidding rounds.

Finally, we permit neighboring participants to communicate with each other during the experiment in all treatments. We make this choice due to the potential complexity associated with bid formation in general and joint bid submission in particular. Moreover, communication can have a positive impact on outcomes in strategic coordination game settings (Charness, 2000; Banerjee et al., 2014), although it can also facilitate collusion which is why it is *per se* illegal in many antitrust statutes. Nevertheless, we allowed communication in all our treatments because in reality it is impractical to prevent (neighboring) producers from communicating with each other, especially given long-standing social relationships which characterize farming communities. In our case, communication incentives are enhanced by the bonus payments provided for successful joint bids. Communication during the experiment is expected to provide bidders with an opportunity to exchange information about the cost and benefit values of their projects and other auction features, transmit information to different network locations through neighbors' links to other participants, build social capital, agree on whether they want to submit joint bids or not, coordinate their bids, and negotiate and commit to sharing the value of the joint bid in case it is accepted (such pre-commitments are binding).[8]

As noted above, the environment we are studying is more complicated than that represented in frontier auction theory, meaning that no quantitative predictions can be made about the expected effects of allowing for joint bidding. Nevertheless, individuals still face the fundamental tradeoff seen in all auctions between the amount of profit they earn conditional on winning and the probability of winning. The novel incentives introduced by the AB affect whether bidders submit joint bids in addition to individual bids, and how this depends on the AB size and any extra joint bidding bonuses. We offer the following reasoned arguments on what effects can be expected in a specific empirical setting such as that generated by our experiment based on the foregoing discussion. These arguments can be compared with the results reported in Section 4.

1. *Expected Effect 1*: Joint bidding will produce higher total environmental benefits than individual bidding when benefits are magnified with spatial coordination. Joint bidding provides an incentive for neighbours to work together on bid preparation (and submission) that is additional to an AB offered for individual bids (e.g., Liu et al., 2019). This result would be influenced by whether an AB is or is not offered for individual adjacent bids. The size of the expected effect on environmental benefits will depend on the magnitude of the super-bonus offered for joint bidding, since this will partly determine how many bids the regulator can accept given the budget allocation.

2. *Expected Effect 2*: Producers will offer bids that are closer to opportunity cost when joint bidding is allowed, compared to a situation with individual bidding only. This is because of competition to win the super-bonus paid on joint bids. Thus, the higher the super-bonus,

[8] The overlapping network structure that allows for transmission of information from one part of the network to another implies that subjects' bidding behavior is directly impacted by their left and right neighbors, and indirectly by everyone. We recognize that this feature can make it difficult to ascertain if subjects are responding to information obtained from non-neighbors from another part of the network, or the opportunity to earn joint bonus payments by working with their neighbors or both. This concern can be potentially addressed by eliminating the network setup and considering joint bid submissions by randomly generated pairs of players. However, such random pairing would also eliminate the basis for considering joint bidding, which requires that neighboring farms on the landscape or those within a given distance from each other work together to submit a joint bid. This is what generates greater environmental benefits in settings where spatial coordination matters. The fixed network structure also represents fixed geographic locations across multiple auction periods, which is consistent with stable land ownership and/or management by the same farmer who leases the land from a landowner.

the greater this effect. Moreover, a higher super-bonus will increase the number of joint bids offered, since the expected gains from joint bid preparation and submission will exceed the transactions costs of forming a joint bid for a larger number of bidders.

3. *Expected Effect 3*: Since the economic efficiency of the auction depends on both the environmental benefits delivered and the costs of winning bids, combining *Expected Effects 1* and *2* would suggest that allowing for joint bidding should improve auction cost-effectiveness. However, the need to pay joint bidding bonuses to adjacent winning joint bids can increase the regulator's expense for procuring a set of contracts, or reduce the number of contracts that can be purchased altogether, given a fixed budget. This runs counter to the potential increase in environmental benefits of joint bidding (effect 1) and more aggressive bids closer to costs (effect 2), which can lead to reduction in auction cost-effectiveness and performance.

3 Experimental Design

We report data for 48 groups with 8 subjects per group as presented in Table 1, producing a data set with 384 individuals. The treatment variables of interest include (*i*) the presence of joint-bidding opportunities with neighbors in addition to the opportunity to submit individual bids, (*ii*) the auction structure involving single and multiple rounds, (*iii*) the size of the individual and joint bidding bonus multiplier (γ) which would determine the total value of the individual bonus and super-bonus payments obtained if individual or joint bids are selected, and (*iv*) whether an AB payment is offered for adjacent individual bids. The treatments are implemented in a balanced between-subject 2×4 treatment design, giving rise to eight different experimental treatments described in further detail below.

The experiment was implemented in z-Tree (Fischbacher, 2007) and consisted of three stages. Stage 1 involves a short risk preference elicitation through an incentivized Eckel-Grossman lottery (Eckel and Grossman, 2008) presented in the Appendix.[9] Stage 2 comprised the conservation auction and Stage 3 involved a demographic survey. The instructions included a flow-chart to clearly represent auction progression (see Appendix A).

[9] In this task, subjects have to choose one of five gambles which are increasing both in expected returns and risk level incurred as measured by the standard deviation of the gamble payoffs. Gamble 1 has the lowest risk but also the lowest reward while Gamble 5 has the highest risk and the highest reward.

Table 1: Experimental Design

Auction-Structure Treatment	Bidding Protocol/Bonus Treatment			
	Individual Bidding Only	Individual & Joint Bidding with γ=2.5 Joint Bonus Multiplier	Individual & Joint Bidding with γ=1.5 Joint Bonus Multiplier	Individual & Joint Bidding with γ=1.5 Joint Bonus Multiplier and 0 Individual Bonus
Single-Round	SINGLE-INDIVIDUAL (6 groups)	SINGLE-Joint-2.5 (6 groups)	SINGLE-Joint-1.5 (6 groups)	SINGLE-Joint-1.5-Ind0 (6 groups)
Multiple Rounds	MULTI-INDIVIDUAL (6 groups)	MULTI-Joint-2.5 (6 groups)	MULTI-Joint-1.5 (6 groups)	MULTI-Joint-1.5-Ind0 (6 groups)

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 and their location on the circular network landscape. 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 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 managed 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 Appendix A for instructions of the MULTI-JOINT-2.5 treatment). During the auction, each subject was endowed with an item (project) representing a parcel of land which had a cost and environmental quality value (the *node* benefit) associated with it. This cost and benefit information was always available to subjects when they made decisions in the auction.[10] The bonus values were also displayed so that subjects knew the bonus payments they would receive if their joint bids would be accepted in the auction. Our study keeps this information provision constant across all treatments, i.e., varying information on opportunity costs, node and edge benefits is not a treatment variable.[11]

Each session consisted of 9 auction periods. After receiving information about their item's costs, benefits and bonuses at the start of the period, bidders participated in 2-minute free-form

[10] Wichmann et al. (2017) considered an auction setting in which farmers face risks associated with the cost of switching to alternative management practices. The authors find that subjects' degree of risk aversion significantly impacts bidding negatively, i.e., the more risk averse the person, the lower the bid.

[11] 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).

discussions through online chat windows with their left and right neighbors. These chats occurred in separate, private windows for each pair of neighbors. This communication was unrestricted, although the instructions requested subjects to be civil to each other. Post-communication the experiment moved to the bidding stage. 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 super-bonus payments equal to 2.5 times the bonus amount in the JOINT-2.5 treatments and 1.5 the bonus amount in the JOINT-1.5 treatments. Since *edge* benefits represent the environmental benefits from procurement of adjacent projects, we set the bonus values equal to these *edge* benefits. Finally, subjects were told that if adjacent individual bids were selected, they would receive one times the bonus amount (this is the individual AB payment) in all but the relevant Joint-1.5-Ind0 sessions.[12] Varying the value of the joint-bonus multiplier is beneficial for evaluating behavior and auction performance under policy regimes involving differential joint bonus payments. But this treatment variation cannot evaluate behavior and performance when strategic incentives for individual and joint bids vary. Therefore, in the JOINT-1.5-IND0 treatments we eliminate the individual AB payment and maintain the joint (super-) bonus multiplier value at 1.5. Compared to the Joint-1.5 treatments, this may cause subjects to submit significantly different individual and joint bids in order to increase the likelihood of receiving super-bonus payments in the absence of individual AB payments.

In all treatments subjects submitted individual bids. In the JOINT treatments prior to any bid submission, the computer first prompted subjects about their willingness to submit joint offers with their neighbors. Both neighbors had to agree to submit a joint bid, which was first entered by one neighbor and then confirmed by the other. A subject could submit a joint bid with both or either of their neighbors.[13] Joint bids would subsequently be considered in the winner determination exercise, although only one of them could be selected as the winning joint bid (reflecting that a

[12] We did not include a treatment with a joint bonus multiplier of 1. Such a baseline could provide a comparison of the marginal impact of allowing joint bids relative to individual bids only under similar pecuniary incentives. The relative transactions costs of bid submission would still differ between these two cases, to a much greater extent in the field than in this laboratory setting. Therefore, the relative performance comparison would be imperfect due to unknown differences in transaction costs in the field.

[13] Since joint bidding can be a cognitively challenging exercise, we did not place any time limits on how long a "submitter" could take to come up with a bid value and a "confirmer" to confirm it.

subject cannot "sell" their conservation project twice). The joint bid consisted of payment amounts to be received by each party in the joint bid, not including potential bonus payments. For subjects who submitted joint bids with both neighbors, it is possible that their own portion of the joint payment for each bid is different. If joint bid partners did not confirm the joint bid amount, that bid would not be considered to determine auction winners.

After all subjects had made their decisions, the winning combination of projects was calculated by the computer according to Eq. (1) and announced to every subject. In all the SINGLE treatments, the winning projects would determine the *final* winners for that auction period while in all the MULTI treatments the winners would be announced as *provisional* winners. At this point bidders again had the opportunity to submit individual and joint bids, and the winner determination routine repeated until a minimum number of rounds (3 in our study) were conducted. The auction period concluded when the identity of winning and losing bidders in the current round was the same as the previous round, or until a maximum of 6 rounds was reached. At that point the period ended and final winners of that period were determined and announced. Neither the stopping conditions nor the minimum and maximum round values were described explicitly to the subjects to prevent any possible end-game effects which have been found in studies on 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' bids from the previous round were automatically entered into the bid submission boxes by the computer for the next round. Subjects could then maintain or reduce, but not increase, the amount of the bid for the next round.[14] 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 producers might choose to submit such a bid in order to win the AB and super-bonuses. The instructions included in Appendix A display the feedback screen subjects saw at the end of each auction period, which included detailed information for all previous periods.

To reflect variation in the precise nature of spatial coordination desired by the regulator (the environmental objective), 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

[14] We did not permit subjects to increase bids between consecutive rounds because in actual conservation auctions such as those conducted in the Southern Desert Uplands of Australia in 2006 (Windle et al., 2007) subjects reduced bids across successive iterations. Moreover, in the absence of this restriction, bidding behavior may potentially not stabilize, which might prevent convergence and also be problematic for auction cost-effectiveness (Plott et al., 2019).

auction periods, thus minimizing the influence of any possible scale effects. We also assigned the values to periods using a Latin Square design to minimize order effects. The values were randomly drawn from uniform distributions: $cost \sim [600, 1000]$, $quality \sim [200, 300]$ and $bonus \sim [50, 150]$. These ranges and the budget were chosen such that in the absence of asymmetric information the first-best allocation procured by the auctioneer would comprise of 4 projects in all periods, have the highest net benefit following Eq. (1), involve different spatial configurations in keeping with varying objectives of reserve design for species conservation (Diamond, 1975; May, 1975), and align with the AB literature that focuses on which kinds of spatial configuration of conserved land is possible to achieve with this incentive (Parkhurst et al., 2002; Parkhurst and Shogren, 2007). Three spatial configurations were included, here termed "Several Small," "Single Large" and "Core-Fragment."[15] Table 2 includes the parameter values for these spatial targets, the different features of the first-best allocation marked in grey (the total cost of the allocation, the total benefit produced including benefits from contiguity, and the total expense for supporting the allocation – the expense value includes the bonus paid), and the order in which they were assigned to subjects in the 9 auction periods.[16]

The experiments were conducted at Purdue University in 2018 and 2019 and subjects were recruited broadly from the university student population. Experiments did not include contextual terminology relevant to farmland conservation policies, conservation auctions and AES, since context-loaded terminology can influence subject behaviors and confound the treatment comparisons (Cason and Raymond, 2011). In order to verify understanding of the auction features, subjects completed a comprehension quiz before bidding in the actual auction. All auction rounds were used to determine payoffs, denoted in experimental currency units (ECU) that were converted into real US$ at an exchange rate of 50 ECU for US$1. Payments from the Stage 1 risk attitude elicitation exercise were determined at the end of session in order to prevent any possible behavioral differences arising from subjects having information about the money they had made in

[15] The allocation of cost, benefit, and bonus values were shifted between subjects such that (*i*) even if neighbors exchanged this information through chat windows, they could not determine that the values drawn from the past periods were being repeated, and (*ii*) individual subjects were never assigned the same values in multiple periods.

[16] Following the SLOSS debate (Abele and Connor, 1979; Etienne and Heesterbeek, 2000), and the literature on spatial coordination and the AB (e.g., Parkhurst et al., 2002; Parkhurst and Shogren, 2007), the spatial configurations created two small groups 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. The 4-project maximum allowed by the budget introduces enough competition in the auction to balance possible efficiency reduction arising from collusion incentives owing to the presence of communication opportunities and AB payments.

the experiment already before participating in the auctions. Subjects also received a $4 show-up fee, except in the three multi-round joint bidding treatments that required more time to complete. Subjects in these treatments received a $10 show-up fee because those sessions lasted about 150 minutes, compared to typically less than 75 minutes for the other five treatments. Average earnings per subject were $23.43.

Table 2: Cost, Quality and Bonus Values for Items

"Several Small" – Set 1 (S1)			"Single Large" – Set 2 (S2)			"Core-Fragment" – Set 3 (S3)		
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 of Parameter Assignment Across 9 Auction Periods in a Group								
Order 1			**Order 2**			**Order 3**		
S1S2S3/S1S2S3/S1S2S3			S2S3S1/S2S3S1/S2S3S1			S3S2S1/S3S2S1/S3S2S1		
2 Groups per Parameter Assignment Order for Each Treatment								
Shared Borders between Selected Winning Projects								
2			3			2		

4 Results

The experimental results first focus on the impact of our treatment variables on auction performance. This is followed by a description of bidding behavior and the factors influencing the submission of individual and joint bids, as well as the relationship between them for the different treatments. Auction performance is measured by a series of environmental and economic performance metrics. The environmental performance metrics are given by the total environmental benefits procured calculated on the basis of Eq. (1) and the level of spatial coordination achieved in the auction, measured as the number of shared borders between selected projects. The economic performance metrics include auction cost-effectiveness and the level of information markup, which is the difference between total payments made to winning bidders (bids and bonuses) and costs.[17]

4.1 Analysis of Auction Outcomes and Performance

Procured Environmental Benefits and Level of Spatial Coordination

Tables 3a and 3b show the average environmental benefits and average levels of spatial coordination across all treatments separately for single round and multi-round treatments. Comparing auctions with individual bidding and joint bidding under the two bonus multiplier conditions (JOINT-2.5 and JOINT-1.5), we find that average benefits and agglomeration levels realized are sensitive to the availability of bid revision opportunities. Average environmental benefit is significantly lower under SINGLE-Joint-2.5 treatment compared to the SINGLE-INDIVIDUAL treatment (Column 5s in Table 3a). Due to the relatively high cost to the auctioneer from having to provide large super-bonus payments for winning joint bids, the auction budget cannot support higher benefit projects. The tables also include the total number of winning bidders, combining those winning through individual and joint bids.[18] Interestingly, there is no difference in the number of winners nor the level of agglomeration suggesting that when bidders have no bid revision opportunities, a generous super-bonus does not necessarily impact the strategic incentives faced by bidders with regards to spatial coordination. By contrast, in the MULTI treatments no significant difference exists in environmental benefits procured and agglomeration achieved for the JOINT-2.5 and JOINT-1.5 conditions relative to the INDIVIDUAL treatment (Columns 5m and 6m in Table 3b).[19] This result suggests that, despite generous super-bonus payments, downward bid revision opportunities reduce the portion of the total outlay that goes towards supporting the winning bid amounts in excess of item costs, so much so that the auction with joint bidding performs as well as one with individual bidding only and individual AB payments.

[17] Prior to the analysis we dropped observations for all eight subjects from Period 1 for one session of the SINGLE-Joint-1.5-Ind0 treatment owing to a software error. We also dropped observations corresponding to 9 periods, since subjects in these periods had comprehension problems or typographical errors – their individual and/or joint bids were such that, if accepted, subjects would earn negative profits even after including individual and joint bonuses.

[18] Across all periods and experimental sessions, 8 joint bids were accepted in the SINGLE-Joint-2.5 treatment and 76 joint bids were accepted in the SINGLE-Joint-1.5 treatment, resulting in super-bonus payments.

[19] Across all periods and experimental sessions, 56 joint bids were accepted in the MULTI-Joint-2.5 treatment and 72 were accepted in the MULTI-Joint-1.5 treatment, resulting in super-bonus payments.

Table 3a: Summary Statistics & Treatment Comparisons for Single Round Treatments

Performance Metric	Single Round							
	Column 1s	Column 2s	Column 3s	Columns 4s	Column 5s	Column 6s	Column 7s	Column 8s
	Individual	Joint-2.5	Joint-1.5	Joint-1.5-Ind0	Treatment Comparison (Individual Vs Joint-2.5)	Treatment Comparison (Individual Vs Joint-1.5)	Treatment Comparison (Joint-2.5 Vs Joint-1.5)	Treatment Comparison (Joint-1.5 Vs Joint-1.5-Ind0)
Average Environmental Benefit	1261.37 (10.52)	1172.25 (14.22)	1207.66 (17.1)	1328 (17.25)	2.882 (0.0039)**	1.761 (0.0782)	-0.801 (0.4233)	-2.562 (0.0104)**
Average Level of Spatial Coordination	2.01 (0.07)	1.64 (0.07)	1.88 (0.09)	2.86 (0.05)	2.100 (0.0357)	0.727 (0.4673)	-0.971 (0.3315)	-2.727 (0.0064)**
Average Cost-Effectiveness (POCER)	0.963 (0.005)	0.899 (0.008)	0.935 (0.012)	0.920 (0.009)	2.882 (0.0039)**	1.281 (0.2002)	-1.281 (0.2002)	0.641 (0.5218)
Average Level of Information Markups	532.53 (12.83)	604.48 (26.39)	538.92 (31.85)	328.16 (23.351)	-1.922 (0.0547)	0.16 (0.8728)	1.121 (0.2623)	2.402 (0.0163)**
Average Number of Winners	4 (0.00)	3.8 (0.017)	3.8 (0.019)	3.96 (0.016)	2.292 (0.0219)	2.309 (0.0209)	-0.416 (0.6775)	-1.171 (0.2416)
Number of Observations	51	54	53	52	12	12	12	12

Note: Means and Standard Errors are noted in Columns 1s through 4s. Statistical comparisons of treatment effects using Wilcoxon Mann-Whitney tests in columns 5s through 8s (with p-values in parenthesis) consider data from 12 experimental sessions. Controlling for the family-wise error rate owing to multiple hypotheses testing, using the Holm-Bonferroni correction, ** represents statistical significance at 5% level.

Result 1: Relative to individual bidding auctions, joint bidding auctions that pay bonuses for both individual and joint bids either leave environmental benefits and agglomeration rates unchanged or lower them. Realized performance depends upon the size of the joint bidding multiplier and bid revision opportunities. In the single-round auction, environmental benefits are significantly lower for the generous ($\gamma = 2.5$) joint-bidding multiplier than for individual-only bidding.

Our two joint multiplier treatments also allow us to evaluate whether the outlay for buying a set of items could matter for auction performance. Columns (7s) and (7m) of Tables 3a and 3b show, however, that environmental performance is not significantly different under the JOINT-2.5 and JOINT-1.5 auction treatments for both SINGLE and MULTI conditions. Thus, the two joint-bidding multiplier values considered in the experiment do not lead to substantial differences in behavior to generate significant differences in environmental performance.

Table 3b: Summary Statistics & Treatment Comparisons for Multi- Round Treatments

Performance Metric	Multi Round							
	Column 1m	Column 2m	Column 3m	Column 4m	Column 5m	Column 6m	Column 7m	Column 8m
	Individual	Joint-2.5	Joint-1.5	Joint-1.5-Ind0	Treatment Comparison (Individual Vs Joint-2.5)	Treatment Comparison (Individual Vs Joint-1.5)	Treatment Comparison (Joint-2.5 Vs Joint-1.5)	Treatment Comparison (Joint-1.5 Vs Joint-1.5-Ind0)
Average Environmental Benefit	1270.1 (9.09)	1250.25 (11.43)	1281.48 (11.4)	1373.98 (11.33)	1.121 (0.2623)	-0.961 (0.3367)	-1.441 (0.1495)	-2.882 (0.0039)**
Average Level of Spatial Coordination	2.08 (0.06)	1.98 (0.08)	2.24 (0.08)	2.96 (0.03)	0.494 (0.6217)	-1.292 (0.1962)	-1.546 (0.1222)	-2.903 (0.0037)**
Average Cost-Effectiveness (POCER)	0.962 (0.004)	0.952 (0.007)	0.977 (0.007)	0.925 (0.006)	0.32 (0.7488)	-1.601 (0.1093)	-1.601 (0.1093)	2.402 (0.0163)**
Average Level of Information Markups	546.33 (9.94)	530.77 (19.64)	491.06 (21.64)	323.31 (22.372)	1.281 (0.2002)	1.121 (0.2623)	1.281 (0.2002)	2.402 (0.0163)**
Average Number of Winners	4 (0.00)	3.9 (0.011)	4 (0.009)	4.03 (0.009)	0.000 (1.000)	0.00 (1.000)	-1.369 (0.1709)	-0.962 (0.3359)
Number of Observations	50	54	54	53	12	12	12	12

Note: Means and Standard Errors are noted in Columns 1m through 4m. Statistical comparisons of treatment effects using Wilcoxon Mann-Whitney tests in columns 5m through 8m (with p-values in parenthesis) consider data from 12 experimental sessions. Controlling for the family-wise error rate owing to multiple hypotheses testing, using the Holm-Bonferroni correction, ** represents statistical significance at 5% level.

Next we consider the effect of eliminating the bonus payment for the selection of adjacent individual bids in the Joint-1.5-Ind0 treatments and compare performance under this treatment to the Joint-1.5 condition (columns 8s and 8m of Tables 3a and 3b). The Joint-1.5-Ind0 treatments consistently and significantly outperform the Joint-1.5 treatments for both SINGLE and MULTI auction formats in terms of the environmental performance metrics. Interestingly, the number of joint bid winners under SINGLE-Joint-1.5-Ind0 and MULTI-Joint-1.5-Ind0 are respectively 18 and 12 only. Making joint-bid submissions more attractive than individual bids from a pecuniary standpoint, therefore, does not necessarily translate into more joint bids being chosen as winners relative to the two Joint-1.5 treatments. This outcome arises in part from the auction's winner-determination algorithm, which chooses item combinations with highest net benefits, while the lack of bonus payments for adjacent individual bids lowers their procurement cost relative to the joint bids for the same projects. This increases the likelihood that individual bids are accepted instead of joint bids. Also, subjects know that they can earn bonus payments only if their joint bids are selected, which could lead them to submit more competitive joint bids than they would with bonuses for individual bids. Hence, for all the joint bids selected as winners, more money is available to be used to select more projects or higher-benefit projects which are adjacent to each other (largely through individual bid selection). In essence, while more joint bids are not procured as winners, the overall ability of the auction to promote spatially coordinated project selection increases, which is the overall policy goal. Table 3 provides supporting evidence with the average levels of agglomeration in the Joint-1.5-Ind0 treatments at 2.86 or greater, meaning that in many instances blocks of at least 3 adjacent projects are selected.

Result 2: Setting the individual AB payment to zero, but still paying a super-bonus for joint bidding, increases the procured environmental benefit and improves spatial agglomeration rates for both the single- and multi-round auction.

Relating both of these results back to the Expected Effects outlined at the end of Section 2, we thus find limited evidence to support a preference for joint bidding on the basis of environmental outcomes. Better environmental outcomes are only achieved by allowing joint bidding when no individual-level agglomeration bonus is offered.

Cost-Effectiveness and Information Markups

Given the budget-constrained nature of the auction, we measure efficiency as the level of cost-effectiveness of the realized auction outcomes relative to the cost-effectiveness of the first-best winning allocation. For this purpose, we use the metric POCER – Percentage of Optimal Cost Effectiveness Realized (Cason et al., 2003; Banerjee et al., 2015). POCER is the actual quantity of environmental benefit procured per dollar spent in the auction, relative to the maximum environmental benefit possible per dollar spent at the optimum allocation where producers receive only their costs plus bonus payments.[20] This efficiency measure accounts for the fact that some auction outcomes commit more of the total budget than others due to the selection of a discrete set of winners. Presumably, the unspent part of the auction budget has some alternative value, and a

[20] This involves paying bid values and bonuses (when applicable) for adjacent winning bids. The joint bid bonus multiplier is used to adjust the bonus value to generate the super-bonus payment if the winning allocation involves joint bids by two adjacent bidders. The value of the bonus associated with individual bids is simply the bonus value, except in the JOINT-1.5-IND0 treatments where the individual bonus is 0.

higher value for POCER indicates more environmental benefit per dollar spent, so it is indicative of better auction performance. The second performance metric is the total information markup earned by all auction winners (the sellers). This metric is calculated as the difference between the total payment made to bidders (sum of the winning bid *and* any bonus payments made) and the item cost, which is the bidder earnings summed over all winners.

Results for these two economic performance metrics are similar to those obtained for the environmental performance metrics (see Table 3). Cost-effectiveness (POCER) is overall high across all treatments (at least 90%).[21] Cost-effectiveness and information markups submitted are no better in the INDIVIDUAL treatments relative to the Joint-2.5 and Joint-1.5 treatments for the MULTI condition, while they are significantly worse in the SINGLE-Joint-2.5 than the SINGLE-INDIVIDUAL treatment. The lack of bid revision opportunities and the requirement to make super-bonus payments increases total expenditures associated with auction implementation. This reduces the performance of joint-bidding auctions relative to individual bidding. Last, our information markup measure falls in both single- and multi-round auctions when the individual level AB is not offered, compared to when it is offered. These differences are significant at the 1% level.

Result 3: Joint bidding does not improve and can even harm auction efficiency when the regulatory agency provides AB rewards for projects selected via both joint and individual bids, as opposed to providing these rewards for individual bids only.

Result 4: Higher information markups are prevalent when bidders can earn a bonus for individual bids in addition to super-bonus payments for joint bids, compared to when only super-bonus payments are available and winning through individual bid selection does not garner extra rewards.

We thus find no support for Expected Effect 3: joint bidding seems to worsen the economic efficiency of a conservation auction, and can increase payments won by successful bidders.

Multi-Round versus Single-Round Bidding

Cognitive complexity of bid preparation, especially when working with neighbors, can be

[21] The average number of winners across all treatments is very close to 4 indicating that in most cases the same number of projects as would be selected in the absence of asymmetric information (4 out of 8), are picked as winners. This is true for at least 5 out of 9 auction periods across all auction treatments.

alleviated by allowing for revision and resubmission of previously submitted bids. Yet, this convenience for bidders needs to be compared to the increase in agency transaction costs of policy implementation. Thus, it is insightful to evaluate how environmental and economic metrics perform in the presence and absence of bid revisions. Comparison of Tables 3a and 3b shows that every performance metric is superior in the multi-round auction relative to the single-round auction, for all four treatment conditions. Table 4 reports statistical tests for these differences, and shows that with a generous joint-bidding multiplier of 2.5, the average environmental benefits and POCER is greater, and the amount of information markups lower, in the multi-round auction. The bid revision opportunities across rounds appears to increase competition in the auction and leads to a significant improvement in performance for the auction with the high joint-bidding multiplier.

Result 5: Auction performance in the multi-round auction is never lower than the single-round auction, and is significantly better with the higher (γ=2.5) joint-bidding multiplier.

Table 4: Treatment Comparisons for Multi-Round versus Single-Round Bidding

Variable	Multi vs. Single Treatment			
	Column 1	**Column 2**	**Column 3**	**Column 4**
	Individual	**Joint-2.5**	**Joint-1.5**	**Joint-1.5-Ind0**
Average Environmental Benefit	0.961 (0.3367)	2.722 (0.0065)**	1.922 (0.0547)	1.441 (0.1495)
Average Level of Spatial Coordination	0.573 (0.5669)	1.693 (0.0904)	1.524 (0.1275)	0.5 (0.6171)
Average Cost-Effectiveness (POCER)	0.32 (0.7488)	2.562 (0.0104)**	1.601 (0.1093)	0.16 (0.8728)
Average Level of Information Markups	0.801 (0.4233)	-2.242 (0.025)	-0.641 (0.5218)	-0.16 (0.8728)
Average Number of Winners	-	1.272 (0.203)	2.068 (0.0387)	1.074 (0.283)
Number of Observations	12	12	12	12

Note: All statistical comparisons of treatment effects reported use Wilcoxon Mann-Whitney tests (with p-values in parenthesis) and considers data from 12 experimental sessions. ** represent significance at 5% level after correcting for family-wise error rate owing to multiple hypotheses testing, using Holm-Bonferroni correction. – signifies identical and no variation in results for this treatment. Comparisons using data from Periods 5 – 9 yield no qualitatively different results.

In summary, our results suggest that the decision to adopt joint bidding will be influenced by issues beyond the goal of environmental benefit provision. If the program budget is high and the transaction costs of policy implementation not too high, then both joint and individual bidding will be suitable in a multi-round setup. However, transaction costs are rarely (if ever) low and budgets are usually tight. In this case a single round auction with a less generous super bonus payment may be more suitable. Finally, if the agency were to eliminate the bonus for adjacent individual bids, the results suggest that economic and environmental performance move in opposite directions. Cost-effectiveness is significantly lower with joint bidding, but environmental performance improves. These apparently contrasting results can be explained by the fact that eliminating bonus payments for adjacent individual bids lowers information markups paid out for winning individual bids. As a result, many more adjacent projects are selected leading to significantly higher environmental benefits and agglomeration by virtue of realized *edge* benefits. At the same time, cost-effectiveness (POCER) declines because the maximal environmental benefit per dollar spent is larger when no bonus is paid for winning adjacent bids. Adjacent projects can be accepted and the associated edge benefits be reaped without paying any bonuses in the "optimal" auction outcome, setting a difficult target to achieve full cost-effectiveness. Yet the realized information markups are significantly lower, implying that changing strategic incentives associated with individual and joint bidding helps mitigate the problem of asymmetric information (since markups at least for the multi-round auction are lower), the chief reason for implementing the auction in the first place.[22]

4.2 Analysis of Bidding Behavior

This section focuses on aspects of bidding behavior unique to our experiment. We first evaluate the factors that influence subjects' individual and joint-bid submissions. We then present a discussion on behavior as it relates to the submission of joint bids by a subject and their neighbor(s) for the six joint-bidding treatments. Finally, we consider the relationship between individual and joint bids and analyze how this relationship is influenced by our experimental treatments.

[22] We also evaluate behavior and performance after bidders have had the opportunity to get familiar with bidding. Table B1 in Appendix B presents results for performance when restricting data to the last 5 periods of the auction only. Comparing this data to that in Tables 3 and 4 indicates similar outcomes, with only one minor change in statistical significance for one treatment comparison.

Analysis of Individual and Joint Bidding Behavior

In every auction period, all subjects have to submit individual bids. Submitting joint bids is optional, however, and some joint bids are not confirmed by neighbor(s). Unconfirmed bids are not used for the determination of final winners, so for this analysis we consider only those joint bids which have been confirmed by both subjects in the final round, in addition to all individual bids from the final round. As a result, we have an unbalanced panel of individual and joint bids for every player for every period which we analyze to evaluate the role of different auction features on bidding behavior. We run clustered OLS regressions with standard errors clustered at the session level. Table 5 presents a set of five models for individual and joint bids separately. Model 1 includes only individual bids from the INDIVIDUAL treatments; Model 2 considers individual bids for the Joint-2.5 and Joint-1.5 treatments; Model 3 presents results for individual bids for the Joint-1.5 and Joint-1.5-Ind0 treatments; Models 4 and 5 analyze joint bids from the Joint-2.5 and Joint-1.5 and the Joint-1.5 and Joint-1.5-Ind0 treatments, respectively.

For all models the independent variables include the value of items' cost (included as a linear and quadratic term)[23] and quality, a Period variable to control for the time trend, and a dummy variable to capture subjects' level of risk aversion. This Risk Averse dummy variable takes a value of 1 if a subject made a choice corresponding to the most risk averse first three rows of the Risk Preference Elicitation task in Stage 1.[24] In addition to these variables we include a dummy variable for the joint-bidding treatments to differentiate the auction formats, for Models 2 and 5. For Models 2 and 4, the dummy variable takes a value of 1 for the Joint-1.5 treatment and 0 otherwise. For Models 3 and 5, the dummy variable has a value of 1 for the Joint-1.5-Ind0 treatment and zero otherwise. The two joint bid models also include the corresponding value of the edge benefit, labelled Bonus Value, which is used to calculate the super-bonus paid if the left or right joint bid is selected as a final winner.[25] All regressions also include dummy variables representing the different spatial configurations of cost and quality parameters considered in the auction, as well as dummy variables to control for the within-subject ordering of the different configurations, but

[23] All models employ a linear specification for the relationship between bids and project quality, and both a linear and quadratic cost specification. The latter is an approximation since alternative nonlinearities might be possible.

[24] We replaced the linear time trend with period dummy variables in an alternative specification (not reported), but this had no meaningful impact on the conclusions. Similarly, alternative specifications for the risk averse variable had no meaningful impact on results.

[25] We did not include the Bonus variable for individual bid regressions since the bonuses are different for both neighbors and it is not possible to determine how they can be combined and included in the analysis.

Table 5: Analysis of Bidding Behavior

Independent Variables	Model 1 Individual Bids – INDIVIDUAL Treatments	Model 2 Individual Bids – Joint-2.5 & Joint-1.5 Treatments	Model 3 Individual Bids – Joint-1.5 & Joint-1.5-Ind0 Treatments	Model 4 Joint Bids – Joint-2.5 & Joint-1.5 Treatments	Model 5 Joint Bids – Joint-1.5 & Joint-1.5-Ind0 Treatments
Cost	0.746*** (0.272)	-0.361 (0.505)	0.397 (0.75)	0.0255 (0.389)	1.384*** (0.531)
Cost Squared	0. 00007 (0.00017)	0.000775** (0.00031)	0.00034 (0.00048)	0.000519** (0.00024)	-0.000314 (0.00033)
Quality	0.276 (0.187)	0.684*** (0.23)	0.836** (0.346)	0.540*** (0.185)	0.475*** (0.146)
Bonus Value				-0.279** (0.133)	-0.328*** (0.0889)
Joint-1.5 Treatment Dummy		-7.842 (23.033)		5.630 (13.19)	
Joint-1.5-Ind0 Treatment Dummy			31.61 (22.27)		41.42*** (11.46)
Single Round Treatment Dummy	20.63** (8.17)	58.108*** (15.64)	66.88** (28.21)	124.43*** (31.84)	77.79*** (19.42)
Joint-1.5 Dummy x Single-Round Dummy		9.949 (28.608)		-45.85 (38.42)	
Joint-1.5-Ind0 Dummy x Single-Round Dummy			44.45 (40.71)		-21.49 (25.70)
Risk Averse Dummy	19.11*** (5.64)	-4.35 (10.237)	23.85 (19.03)	-27.04 (20.18)	-8.68 (13.36)
Period	-9.52*** (1.36)	-15.95*** (3.501)	-9.16** (4.095)	-19.60*** (2.597)	-15.45*** (2.307)
Constant	141.52* (80.32)	522.816** (217.8)	138.83 (272.073)	422.4*** (160.6)	-148.0 (214.0)
Number of Observations	857	1,726	1,724	1,290	1,181
Number of Subjects	96	192	192	189	191
R-squared	0.657	0.180	0.079	0.405	0.435

Note: Standard errors (in parentheses) are clustered at the session level; *** p<0.01, ** p<0.05, * p<0.1. Base Category for Model 1 is MULTI-INDIVIDUAL treatment, for Models 2 and 4 is MULTI-Joint-2.5 treatment and for Models 3 and 5 is MULTI-Joint-1.5 treatment. Estimates control for different spatial configurations and their ordering across periods (not shown). Rather than eliminating data for all subjects for an entire period, only data for individuals who made errors or had comprehension problems in a period not included.

these estimates are not displayed. Finally, these bid function estimates pool the MULTI and SINGLE treatment data but allow for differences with a SINGLE treatment dummy variable and interaction terms.[26]

The regression results across models systematically confirm the importance of the item's cost (in linear or quadratic form) across different models as a positive and significant determinant of bidding. The environmental benefit (quality) is another key variable which drives bidding behavior. Bids are higher when environmental quality is greater, as bidders know (from the auction instructions) that the auctioneer gives priority to purchase items with greater quality. For all models the estimate for the Period variable is negative and significant, indicating greater competition and a significant improvement in auction performance (due to lower bids) as bidders gain experience.

Further, we find that the impact of the Bonus variable is negative and statistically significant for Models 4 and 5. Thus, the higher the bonus value, the lower are the joint bids submitted as subjects seek to maximize the likelihood of being selected in the auction to earn higher bonus payments. Bids are significantly higher in the single-round auction than in the multi-round auction, across all 5 models, consistent with the superior auction performance documented earlier for the multi-round auction (Table 4). Lastly, the estimate for the Risk Averse dummy variable is positive and significant for Model 1 – the treatments with only individual bidding. At first glance this appears to be inconsistent with the standard result from pay-as-bid auctions that more risk averse subjects bid lower and closer to cost (e.g., Cox et al., 1982). In our environment with bonuses however, more risk-seeking subjects might bid low – and often below cost – to increase the likelihood of receiving the AB payments associated with adjacent individual bids. By that logic, the more risk averse subjects who wish to avoid negative profits might often make higher offers, giving rise to the positive coefficient estimate(s) on risk aversion. In essence, the standard intuition from first-price auctions that risk averse subjects would submit lower bids (closer to cost), in order to increase their likelihood of winning, does not apply to this setting because of the additional incentive for risk seekers to offer even lower bids to try to capture the individual-level AB payments.

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[26] For our experimental design there are interdependencies between individual and joint bid submissions and confirmations. However, we present our analysis separately for individual and joint bids since these bid types are inherently different.

Result 6: Auction bids increase in the bidders' opportunity cost, in the level of environmental quality delivered, and are higher in the single-round auction than in the multi-round auction. Joint bids are lower when bonus payments for joint bidding success are greater.

Note that the last part of Result 6 indicates some support for part of Expected Effect 2, as joint bids are lower when joint-bidding bonuses are greater. Note also that significantly higher joint bids are submitted in the absence of the individual AB payments (Model 5), a result consistent with findings about the economic performance of the auction noted in the previous section. These more expensive joint bids (when selected as final winning bids) may be contributing to the significant differences and higher levels of cost-effectiveness observed in the MULTI-Joint-1.5 treatment relative to the MULTI-Joint-1.5-Ind0 treatment shown in Table 3b.[27]

Incidence of Joint Bidding

Given the differential pecuniary rewards and strategic incentives associated with joint bidding, we summarize the incidence of joint bidding across our treatments. For this, we focus on the following three steps through which joint bidding is executed. Step 1 enumerates the expressions of interest to submit a joint bid— a binary choice made by each bidder, for each neighbor. However, not everyone agrees to submit a joint bid. Step 2 therefore considers the pairs of joint bids which were submitted for consideration by a confirming neighbor. Finally, since neighbors may choose not to confirm a joint bid, in Step 3 we count the pairs of joint bids were confirmed and therefore evaluated in the final winner determination for a period.[28]

Table 6 presents the average incidence of joint bidding across treatments for all sessions and periods. Most individuals express interest in joint bidding as shown in the first row. Typically, at least 5 to 7 pairs (out of 8 possible) submit joint bids (information in the second row). Some of these joint bids are however not confirmed, so the number of joint bids considered for winner determination ranges at least between 4 and 6 (the third row). Focusing on treatment effects, the

[27] Table B2 in Appendix B presents results of bid regressions for data from Periods 5 – 9 of the experiment. We do not observe major qualitative changes in the estimates except that in Model 3, individual bids are significantly higher without the individual AB payments than when these payments are possible.

[28] Communication between neighbors only occurs at the start of each period, before bidders make their joint bidding decisions. No additional communication takes place within the period, regardless of whether the specific terms of a proposed joint bid are confirmed or rejected. Rejections could occur for a variety of reasons, such as when the bid does not offer sufficiently favorable terms or when the non-confirming bidder believes they can obtain greater profits by having another bid (i.e., their individual bid or the joint bid submitted with the other neighbor) accepted in the auction.

Table 6: Summary Statistics of Joint Bidding at Three Bidding Steps and Between-Session Treatment Comparisons between Joint Bidding Treatments

Variable	Single-Round					Multi-Round				
	Column 1s	Column 2s	Column 3s	Columns 4s	Columns 5s	Column 1m	Column 2m	Column 3m	Columns 4m	Columns 5m
	Joint-2.5	Joint-1.5	Joint-1.5-Ind0	Treatment Comparison (Joint-2.5 Vs Joint-1.5)	Treatment Comparison (Joint-1.5 Vs Joint-1.5-Ind0)	Joint-2.5	Joint-1.5	Joint-1.5-Ind0	Treatment Comparison (Joint-2.5 Vs Joint-1.5)	Treatment Comparison (Joint-1.5 Vs Joint-1.5-Ind0)
Average of Expressions of Interest by Subjects to Submit Joint Bids (Maximum possible = 16 per period per session, 2 for every participant with left and right neighbor)	13.79 (0.23)	13.81 (0.29)	13.32 (0.29)	0.16 (0.8726)	0.722 (0.4704)	14.91 (0.24)	14.52 (0.24)	12.32 (0.40)	0.723 (0.4696)	1.761 (0.0782)
Average of Number of Pairs of Joint Bids Submitted for consideration (Maximum possible = 8 pairs per period per session)	6.56 (0.15)	6.58 (0.17)	6.09 (0.19)	0.08 (0.9361)	0.722 (0.4704)	7.19 (0.16)	6.85 (0.17)	5.77 (0.23)	0.803 (0.4217)	1.684 (0.0921)
Average of Number of Pairs of Joint Bids Confirmed and used for Winner Determination (Maximum possible = 8 pairs per period per session)	5.98 (0.16)	6.13 (0.19)	5.46 (0.23)	-0.402 (0.6874)	1.363 (0.1727)	6.05 (0.17)	5.76 (0.21)	4.68 (0.28)	0.565 (0.5718)	2.038 (0.0416)
Number of Observations	54	53	52	12	12	54	53	53	12	12

Note: Statistical comparisons of treatment effects using Wilcoxon Mann-Whitney tests (with p-values in parenthesis) consider data from 12 experimental sessions.

higher super-bonus in the Joint-2.5 treatments does not lead to a significantly greater expressions of interest in submitting joint bids relative to the Joint-1.5 treatment, nor does it lead to any significant difference in actual pairs of joint bids submitted for both the SINGLE and MULTI treatments (contrary to the final part of Expected Effect 2). Finally, eliminating the agglomeration bonus for adjacent individual bids in the MULTI-Joint-1.5-Ind0 treatment actually results in a significant reduction (at the 5% level of significance) in the number of confirmed bids used for final winner determination.

Analysis of the Relationship of Joint Bids to Individual Bids

In our experiment all subjects submit individual bids and, as just documented, most of them communicate and coordinate with their neighbors on their joint and individual bid submissions. Given the prospect of earning super-bonus payments, in accordance with Expected Effect 2 outlined in Section 2, we consider the relationship between individual and joint bid markups across the different joint bidding treatments. For this we compute bid markups using the mandatory individual bids and confirmed joint bids.[29] Table 7 presents the average values of individual and confirmed joint bid markups over cost, defined as (*Offer* – *Cost*)/*Cost*, across all sessions and periods for all joint treatments.[30] Similar to results presented in Table 5, both higher individual and joint bids are submitted for the Joint-1.5-Ind0 treatments. Also, average individual bid markups are always positive and greater than the corresponding joint bid markup values in all treatments, which offers support for Expected Effect 2. Additionally, the average joint bid markups for the MULTI-Joint-2.5 and MULTI-Joint-1.5 treatments are negative. This reflects aggressive, below-cost bids that bidders submit to earn profits from the joint bid super-bonuses. Moreover, bid markups are higher without bid revision opportunities for both individual and joint bids. Statistical tests indicate significant differences between individual and joint bid markups for all except the SINGLE-Joint-2.5 treatment. Subjects submit significantly lower joint bid markups close to costs or less than costs relative to individual bid markups. These lower markups can increase the likelihood that neighboring subjects are selected via joint bids so that they can earn super-bonus payments.

[29] Since there are more individual bids than confirmed joint bids, we compare across these two types of bids for only those bidders whose joint and individual bids were ultimately used for auction winner determination in a period, after eliminating the observations corresponding to periods where some subjects clearly had comprehension difficulties.

[30] We compare the joint bid markups to the individual bid markups of the joint bidding treatments only and not the individual treatments, since the strategic incentives faced by subjects when they can win via individual or a joint bid is different from when they can win only via individual bids.

However as noted already, lower markups do not necessarily mean that more joint bids are winners, since the overall procurement cost is higher. As noted above, this result provides some support for Expected Effect 2.

Result 7: Bidders submit bid markups above cost by a greater amount for individual bids than for joint bids, indicating their propensity to submit more competitive joint bids relative to individual bids in order to increase their likelihood of earning super-bonus payments.

Table 7: Summary Statistics for Individual Offer and Joint Offer Markup & Within-Session treatment Comparisons

Treatments	Single-Round			Multi-Round		
	Column 1s	Column 2s	Column 3s	Column 1m	Column 2m	Column 3m
	Individual Offer Markup	Joint Offer Markup	Treatment Comparison	Individual Offer Markup	Joint Offer Markup	Treatment Comparison
Joint-2.5	0.138 (0.01)	0.133 (0.01)	0.943 (0.3454)	0.08 (0.01)	-0.028 (0.01)	2.201 (0.0277)
Joint-1.5	0.141 (0.01)	0.075 (0.01)	2.201 (0.0277)	0.063 (0.02)	-0.022 (0.004)	2.201 (0.0277)
Joint-1.5-Ind0	0.224 (0.03)	0.107 (0.01)	2.201 (0.0277)	0.115 (0.01)	0.026 (0.004)	2.201 (0.0277)

Note: Columns 1 and 2 in both panels report mean and standard errors. Statistical comparisons using Sign-Rank tests (with p-values in parenthesis) for Within-Session treatment effects consider data from 6 experimental sessions for each comparison

5 Discussion and Conclusions

This paper studies a conservation auction that allows for 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 AES: (*i*) the desire to encourage specific kinds of spatial configurations between producers enrolling in the scheme; and (*ii*) recent moves in several countries to encourage participation by groups of producers, in addition to or instead of 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.

Since no conservation procurement auctions with financial incentives for joint bidding exist in practice, we used a laboratory experiment to test-bed the auction in both a single-round and multi-round setting. Due to multi-dimensional complexities and interdependencies across adjacent participants, theoretical insight to guide auction design and predict auction performance is limited. This paper therefore focuses on some specific conjectures ("expected effects") only. The only source of empirical evidence for joint bidding in conservation auctions at this pre-policy stage is experimental data of the type presented in this paper.[31] We did not attempt to calibrate the experiment to a specific geographic landscape, opportunity costs or agglomeration benefits in any particular setting. Instead, our experiment is intended to study the empirical implications of variation in potential design features of conservation auctions. Such design features include whether to pay individual and joint bidding bonuses, the implications of setting higher or lower joint bidding bonuses, and the impact of multiple-round bidding. There is nothing special about the particular parameter choices, such as the variation of the joint bonus from 1.5 to 2.5, for example. In this test-bedding study we could have easily chosen other bonus parameters, as well as other distributions for costs and benefits.

We also acknowledge that in reality, the opportunity costs of setting agricultural land aside for conservation will likely be spatially correlated, due for example to neighboring farms sharing the same soil type or elevation, whereas we assume that costs are spatially uncorrelated. What the experiment allows us to evaluate is the *qualitative* impact of an increase in the bonus size, since *quantitative* effects will depend on specific conditions (and auction design features) that differ from one application to another. Our experimental design is set up to capture important features of a range of conservation contexts, while being as simple as possible. Ecological benefits from switching to a conservation land use vary across space, as is the case for bird conservation on farmland, or flood risk alleviation through wetland restoration, for example. Many real-world conservation auctions recognize this kind of variation in ecological benefits through an Environmental Benefits Index used to score bids, as in the CRP (Hellerstein, 2017). Additionally, ecological benefits can increase when a switch to conservation land use occurs on neighboring plots, as is the case, for example, in creating wildlife or native vegetation corridors (Rolfe et al., 2008), or woodland restoration (Bond et al., 2019).

[31] We are aware of conservation policies only in the Netherlands that allow farmer collectives to submit joint funding applications. However, these policies do not have an auction format and the people who are permitted to submit joint applications are pre-determined based on their landscape location (Ministry of Economic Affairs, 2016).

We find that auction efficiency is high in all treatments (at least 90%). When an individual level Agglomeration Bonus (AB) is offered to participants, allowing for joint bidding does not enhance auction efficiency, nor does it generate significantly larger environmental benefits. Indeed, individual bidding can produce the same level – or an even higher degree – of spatial coordination and environmental benefits, depending upon the presence or absence of bid revision opportunities. This finding, though, changes once the individual-level AB payment is removed with the AB payment for winning joint bids still available. In this case, joint bidding results in higher environmental benefits and spatial coordination but comes at the expense of a reduction in cost-effectiveness. This reflects the strategic bidding of neighbors who submit substantially lower joint bid markups, leading to selection of many joint projects but also disbursal of super-bonus payments that lower cost-effectiveness.

In nearly all cases the average environmental benefits, level of agglomeration and cost-effectiveness is greater, and the amount of seller rents lower, with multi-round bidding compared to single round bidding. The size of the bonus which determines payments made for winning adjacent individual and joint bids has an effect on the size of bids as well, with higher bonus values leading to lower joint bids. However, higher bonus values also raise the cost to the regulator of paying for successful joint bids, and thus reduce the number of contracts that can be awarded given a fixed budget. Finally, notwithstanding the presence or absence of bonus payments for individual adjacent winning bids, participants submit higher markups for individual bids than for joint bids. In fact, in multi-round settings where rewards for individual adjacent bids are possible, we observe negative markups on joint bids as neighboring bidder pairs make bid submissions to win the super-bonuses offered for successful joint bids.

In sum, our overall conclusion on whether allowing for joint bidding in conservation auctions is a viable policy lever turns on three issues. The first is whether an individual-level AB is offered to participants to encourage spatial coordination amongst individual bids. The second is whether the regulator prioritizes environmental gains over cost-effectiveness in auction design. The third is to what extent the regulator is able to absorb the public transaction costs of auction implementation to run a multi-round auction, as opposed to single-round auctions that are more common in practice. In real-world settings, regulators will need to consider how high to set the super-bonus offered for joint bids. As we show, this has conflicting effects on auction performance: a higher bonus can encourage moderation of bids, increasing auction competitiveness, but it also increases the total cost to the regulator of paying bonuses for winning joint bids, thus reducing the number of contracts that can be awarded. Where spatial coordination between neighboring landowners is especially important for delivering environmental benefits (such as where the positive ecological or environmental spillovers between farms are high), this would encourage regulators to offer a higher super-bonus. The size of these ecological spatial spillovers can be estimated in specific settings using landscape-level ecological models (e.g., Hodgson et al., 2011; Dallimer et al., 2010). When the transactions costs of assembling joint bids between farmers are relatively large, then this also argues for a high super-bonus to offset these transactions costs if joint bidding is to be encouraged.

A number of qualifications are in order for the results presented here. First, we analyzed behavior of subjects on a circular networked landscape structure where everyone communicated and chose whether (or not) to submit joint bids with their left and right neighbors. A different spatial setup involving an asymmetric neighborhood profile will cause different people at different locations to have different communication profiles (since they communicate to different numbers 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. Future experiments can consider asymmetric spatial neighborhood structures and heterogeneous communication profiles, and these can be compared to this symmetric setting. Moreover, Chwe (2000) indicates that different network communication profiles can impact strategic behavior (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 allows subjects 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 experiment is based on decisions on the extensive margin since every participant has one item (project), acceptance of which in the auction leads to greater environmental benefits on that parcel of land. In practice, however, the conservation agency acting as the buyer may focus only on acreage under a particular land use and not care whether spatial coordination of pro-environment actions occurs within single properties or between multiple properties. If the identity of the farmer does not matter and each farmer has a varying number of plots to offer in the auction (e.g., Reeson et al., 2011), the strategic setting of the joint-bidding auctions will be very different from that considered in this paper. In this case, there could be opportunities for holdouts, and for varying magnitudes of bid markup submissions for different plots depending on their location vis-à-vis other plots. We are obviously unable to investigate these issues in our current design, but identify these features as subject matter for future research on conservation auctions.

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