Received: 28 June 2023 | Revised: 15 January 2024 | Accepted: 15 February 2024

DOI: 10.1111/1477-9552.12576

ORIGINAL ARTICLE

JAE Journal of Agricultural Economics

Landscape-level determinants of the performance of an agglomeration bonus in conservation auctions

Chi Nguyen[1,2] | Uwe Latacz-Lohmann[1,2] | Nick Hanley[3]

[1]Department of Agricultural Economics, Kiel University, Kiel, Germany

[2]Department of Agriculture and Resource Economics, School of Agriculture and Environment, The University of Western Australia, Perth, Western Australia, Australia

[3]Institute of Biodiversity, Animal Health and Comparative Medicine, University of Glasgow, Glasgow, UK

Correspondence
Chi Nguyen, Department of Agricultural Economics, Kiel University, Olshausenstraße 40, Kiel D-24098, Germany.
Email: cnguyen@ae.uni-kiel.de and chi.nguyen@uwa.edu.au

Funding information
HORIZON EUROPE European Innovation Council, Grant/Award Number: 817903

Abstract

The agglomeration bonus (AB) has been advocated as an incentive mechanism to boost spatially coordinated conservation efforts, where such coordination is thought to be beneficial to achieving biodiversity or other ecological outcomes. Specifically, an AB is paid to individual landholders if their conserved habitats are spatially connected to the conserved habitats of adjacent neighbours. This paper employs a series of controlled lab experiments with agriculture students to investigate the performance of AB in budget-constrained discriminatory-price auctions across different landscape types. We focus on the spatial correlation of opportunity costs and environmental benefits as one potentially important aspect of the landscape. We set up a stylised agricultural landscape where the conservation agency aims to connect fragmented wildlife habitats by incentivising farmers to enrol land in a conservation programme. We investigate the effects of an AB in landscapes where opportunity costs and environmental benefits are uncorrelated, negatively correlated or positively correlated over space. We found that the benefits of an AB in improving landscape-scale environmental outcomes were significant in the positive correlation landscape. However, the AB resulted in worse outcomes in the uncorrelated and negative landscapes.

KEYWORDS

agglomeration bonus, conservation auctions, spatial coordination, spatial correlation, wildlife corridors

JEL CLASSIFICATION

Q18, Q38, Q57

1 | INTRODUCTION

Agri-environmental schemes (AES) have gained increasing prominence in agri-environmental policy as a means to financially incentivise farmers to provide biodiversity and ecosystem services on private farmland (de Vries & Hanley, 2016; Hasler et al., 2022). However, the success of AES at achieving environmental targets has been questionable. Recent AES evaluation studies warn that AES have often failed to generate environmental improvements and that the degradation of farmland biodiversity continues at an alarming rate (Ait Sidhoum et al., 2022; Cullen et al., 2021). Attempts to understand the barriers to effective AES design and implementation are essential to reconcile agricultural production and nature conservation.

One of the critiques of conventional AES is that incentive mechanisms do not reward higher connectivity of conserved farmland (Groeneveld et al., 2019; Westerink et al., 2015). Farmers usually select their least productive parcels for conservation, typically leading to spatially fragmented conservation patterns. This inhibits AES from exploiting the full potential of environmental gains obtained by spatial coordination across landholdings in many settings. In many situations, the more fragmented the conserved habitats are, the less their contribution to sustaining wildlife populations (Naidoo et al., 2018; Wünscher et al., 2008). When spatial coordination of conservation efforts is a prerequisite for achieving environmental targets, such as for establishing wildlife corridors, failing to spatially coordinate conservation actions at the landscape scale would likely result in a high risk of not achieving the environmental targets (Leventon et al., 2017).

To overcome such spatial scale issue of AES design, landscape-scale oriented AES have been promoted as the way forward for the next generation of AES (Barral & Detang-Dessendre, 2023). Economists have proposed two incentive mechanisms for achieving landscape-scale environmental outcomes. These are spatially targeted conservation auctions and the agglomeration bonus (AB). The former ranks bids in a conservation auction according to environmental scoring rules which take into account the additional environmental benefits of spatial contiguity of conservation efforts (Banerjee et al., 2015; Krawczyk et al., 2016). The latter is a two-part subsidy scheme. Farmers earn a bonus for enrolling land that is adjacent to other conserved farmlands. This bonus is paid on top of the standard payment in fixed-payment schemes or on top of the winning bid amounts in conservation auctions (Drechsler, 2023b; Liu et al., 2023; Nguyen et al., 2022).

Experimental analyses suggest that spatially targeted conservation auctions are effective in promoting spatial coordination of conservation auctions (Banerjee et al., 2015; Fooks et al., 2016; Iftekhar & Tisdell, 2014). Although the real-world applications of spatially targeted auctions are scant, few existing schemes have provided the evidence base confirming the positive results obtained from experimental studies. For instance, the spatially targeted auctions in the Southern Desert Uplands and the Eastern Mount Lofty, Australia, successfully incentivise the creation of corridors of protected native vegetation for which conservation actions occurring on neighbouring farmlands are required for the environmental outcomes to be achievable (Bond et al., 2019; Rolfe et al., 2008; Windle et al., 2009).

The AB was first introduced by Smith and Shogren (2001). Parkhurst et al. (2002) conducted the first experimental study demonstrating the potential effectiveness of AB in achieving spatial coordination. Since then, there has been an increasing number of studies examining AB performance, both outside of and within auction mechanisms. Most of these papers use experimental approaches. It is worth noting that the discussion of the AB in auctions for spatial coordination is still in its infancy (Liu et al., 2019). In particular, there is very limited empirical evidence regarding the performance of AB in spatially targeted conservation auctions (e.g., Banerjee et al., 2021; Fooks et al., 2016; Liu et al., 2023). As yet, no real-world scheme has incorporated AB in a spatially targeted conservation auction.

To date, the performance of AB has been the subject of debate. Liu et al. (2019) suggests that bidders reduce their rent seeking to earn the bonus. However, it is not always the case that the average reduction in bid amount significantly offsets the bonus payments. A low level of bonus capitalisation in bids would likely erode AB performance (Banerjee et al., 2021; Dijk et al., 2017; Fooks et al., 2016). These findings are contrary to those of another stream of the literature, which suggests that AB can improve spatial coordination and auction cost-effectiveness (see e.g., Banerjee et al., 2014; Kuhfuss et al., 2022; Parkhurst et al., 2002; Parkhurst & Shogren, 2007, 2008). These conflicting results imply that more research is needed to identify the conditions under which positive or negative outcomes of AB are likely to occur.

Driving factors affecting the performance of AB such as network size (Banerjee et al., 2012), transaction costs (Banerjee et al., 2017), type and amount of information provided to bidders before bid submission (Banerjee et al., 2015), and the spatial autocorrelation of opportunity costs (Bareille et al., 2023) have been investigated. However, much less is known about how spatial correlations of opportunity costs and environmental values affect the performance of AB. This seems a significant gap in the literature (Drechsler, 2023a; Nguyen et al., 2022), since a priori we might expect such spatial correlation to be an important factor determining both farmers' willingness to participate in an AES scheme, and the bid they enter in a conservation auction.

The spatial distribution of these two contextual factors is often assumed to be uncorrelated in the existing literature. Yet, the empirical evidence suggests that opportunity costs and environmental benefits could be either negatively correlated (i.e., the high environmental benefit parcels tend to be the low-cost parcels), or positively correlated (i.e., the low environmental benefit parcels tend to also be the low-cost parcels; Babcock et al., 1996). Simpson et al. (2022) find that opportunity costs of creating conservation offsets on farmland and two different indicators of farmland biodiversity are negatively correlated across a case study landscape in central Scotland. Armsworth et al. (2017) find that opportunity costs for forest conservation and a range of ecological quality indicators are predominantly negatively spatially correlated for eastern US forest sites. By contrast, Moore et al. (2004) found positive spatial correlations between conservation costs and environmental benefits for ecoregion conservation across Africa. Sarker et al. (2008) found that the opportunity costs of setting aside arable land for riparian vegetation are positively correlated with indicators for water quality in the Lockyer catchment in southeast Queensland, Australia.

In a seminal work, Ferraro (2003) demonstrated how ignoring spatial correlations between opportunity costs and environmental values in designing mechanisms for selecting participating landholders could reduce the effectiveness of agri-environmental schemes. Specifically, when benefits and costs are positively correlated, a selection mechanism based solely on the environmental benefit index, ignoring the costs of enrolled farmland, produces less than 50% of the maximum potential benefits that could be achieved. Conversely, this effect would be only minor (approximately 10%) when benefits and costs are negatively correlated.

Along a similar line, Banerjee et al. (2009), in their theoretical work, demonstrated for the first time how the nature of spatial correlations between opportunity costs and environmental values (cost–benefit correlations) would affect the likelihood of achieving the desired spatial configuration of selected bids in the context of spatially targeted conservation auctions. The results suggest that in the landscapes where similar parcel types (i.e., similar magnitudes of environmental benefits) are situated adjacent to each other and costs of land management for habitat protection are positively correlated with the environmental benefits from land preservation, spatially targeted conservation auctions would better promote spatial connectivity of conservation efforts than non-spatially targeted (conventional) auctions. By contrast, when similar parcel types share common borders and costs and benefits are negatively correlated, non-spatially targeted auctions could perform as well as spatially targeted auctions in terms of spatial coordination of conservation efforts.

The contribution of this paper is to systematically examine the effect of cost–benefit correlations on the performance of budget-constrained, spatially targeted auctions where an AB is paid to connected plots. We consider two types of AB: a bonus for connected parcels within the farm (within-farm bonus) and a bonus for connected parcels between neighbouring farms (between-farm bonus). Whereas most prior theoretical and experimental studies focused on the effectiveness of either spatially targeted conservation auctions or the AB in promoting landscape-scale environmental outcomes, this article considers both of these coordination mechanisms. It sets out, for the first time, to overlay the different spatial configurations of landscape with and without AB in a spatially targeted conservation auction. We hypothesise that: (1) AB would promote more connected parcels to be offered because it increases the monetary reward to winning bidders with connected parcels, and thereby induces the desired contiguous spatial pattern of conservation efforts; (2) In the presence of AB, bidders would reduce their bids at different levels depending on the nature of cost–benefit correlations (since reducing their bid increases the competitiveness of their offer); and (3) The performance of AB in achieving spatial coordination and improving auction cost-effectiveness and social welfare will vary depending on cost–benefit correlations. We refer to (1) as a connectivity effect, (2) as a bid shading effect, and (3) as a performance metric effect.

We found experimental support to the positive effect of the AB in boosting willingness to coordinate contiguous habitats across landholders (the connectivity effect). However, the extent to which bidders capitalise the bonus in their bidding decisions—the bid-shading effect—varied across landscape types. The costs incurred by the AB payment were likely to weaken the positive effects of AB on cost-effectiveness. The presence of AB also leads to a decrease in social welfare (the performance metric effect). The results support the adoption of AB in landscapes where opportunity costs and environmental benefits are positively correlated to enhance spatial coordination. However, the results warned against using AB in landscapes where opportunity costs and environmental benefits are uncorrelated or negatively correlated.

2 | EXPERIMENTAL SET-UP

We conducted a series of controlled lab experiments with agriculture students at Kiel University, Germany. The students participated in a stylised discriminatory-price conservation auction where the government, with a limited budget, selected offers of land retirement to establish wildlife corridors and/or stepping stones. Offers (auction bids) were ranked based on the ratio of environmental values to procurement costs. The scoring rule that generated this environmental value incorporated weights associated with different degrees of spatial coordination of conserved farmlands. The experiments followed a three-by-two design with varying spatial correlations of opportunity costs and environmental values (uncorrelated, positive and negative), and the presence or absence of an AB (with and without bonus) in a stylised agricultural landscape. In the experiment, the subjects could choose to communicate at a cost with their neighbours to negotiate/coordinate their conservation activities and bidding strategies. Table 1 summarises the experimental design.

2.1 | Landscape structure and environmental management goal

We set up a stylised agricultural landscape with six landholders each owning six parcels of land, for example landholder ID1 owns parcels 1–6 (see Figure 1). There are two wildlife habitats, A and B (black areas), which are separated from each other by intensively used farmland owned

TABLE 1 Experimental design.

Design elements	Descriptions
Participants	• 180 participants
Sessions	• 30 sessions
Landscape set-up	• A grid stylised landscape of 36 parcels • 6 participants (landholders) per group. Each possesses 6 parcels of land. • Each parcel is assigned an opportunity cost (OC) and an environmental value (EV) • Heterogeneous OCs • Heterogeneous EVs (similar magnitudes of environmental benefits are not horizontally situated adjacent to each other)
Auction mechanism	• A multiple-round discriminatory auction with a budget constraint and unknown end-points (6 rounds and a limited budget of $$1500 each round) (Note: $$ signifies Experimental Dollars)
Submission fee	• $$10 per each offered parcel
Communication	• Optional (yes/no) • Costly ($$15 per each neighbour)
Private information	• Each participant knows absolute OC values and relative EV values associated with their own parcels
Public information	• The general environmental management goal: establish corridors and/or stepping stones to reduce habitat fragmentation. • High and low environmental zones across landscape
Agglomeration bonus	• Within-farm bonus ($$30) • Between-farm bonus ($$40)
Average earnings	• €23.50 per participant
Average time	• 2 h per session

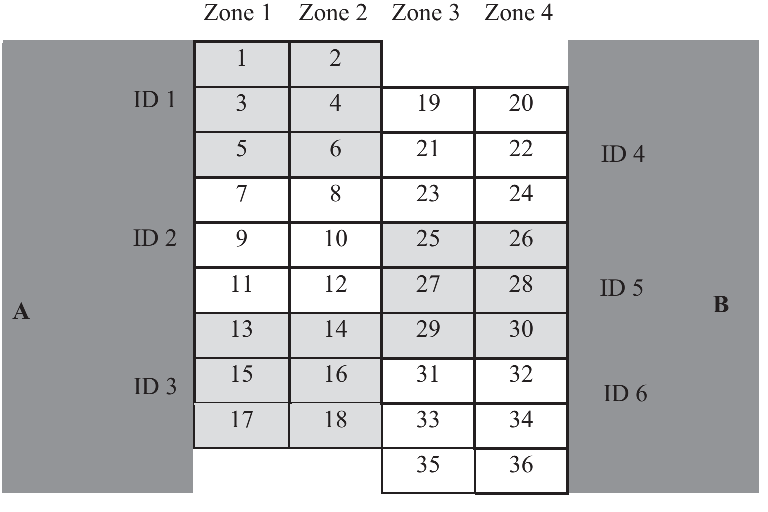

FIGURE 1 Stylized agricultural landscape set-up.

by the six landholders. The landscape in Figure 1 is made visible to all participants. The government aims to reduce fragmentation between the two wildlife habitats by establishing corridors and stepping stones for wildlife migration between the two habitats. A corridor is formed only when four parcels are connected horizontally. Stepping stones are formed when a single parcel is offered or a horizontal combination of two or three parcels are connected.[1] For instance, as shown in Figure 1, horizontal connection of parcels 9, 10, 25 and 26 forms a corridor, whereas horizontal connection of parcels 9, 10 and 25 is counted as a three-parcel stepping stone.

Each parcel is assigned an opportunity cost (OC) and an environmental value (EV). The OC values in Experimental Dollars ($$) reflect the income forgone from taking land out of production. Landholders know their own individual cost per parcel, but not that of other landholders' parcels. Environmental value (EV) indicates units of environmental benefit generated when a parcel is retired from production. We assume that the parcels close to the habitats generate higher environmental benefits than those further from the habitat. Specifically, as shown in Figure 1, the parcels located in Zones 1 and 4 have higher environmental values than those in Zones 2 and 3. Within a zone, EVs are the same for all parcels. In the experiment, subjects were provided with a map of the landscape with colour-coded parcels depicting the relative EVs between zones.[2]

The government formalises its management goal of improving the connectivity between the two habitats by computing total environmental value (TEV_j) generated by the jth corridor/stepping stone as follows:

$$\mathrm{TEV}_j = \sum_{i=1}^{n_j} \mathrm{EV}_i + \left(n_j - 1\right)^2 * K \tag{1}$$

EV_i denotes the environmental value of parcel i, and n_j represents the number of horizontally connected parcels that are set aside for conservation in the jth corridor/stepping stone. K is a constant increment in environmental value that is obtained due to spatial connectivity (i.e., we assume the value of $K = 100$). The objective function (1) indicates that habitat fragmentation could be mitigated by having longer horizontal connectivity between the two habitats leading to higher environmental value. In the TEV_j formula (1), while $(n_j - 1)^2$ reflects an increasing marginal environmental value, $\left(n_j - 1\right)^2 * K$ represents a 'connectivity value' or ecological gain of spatial coordination. In case the offer is a single parcel ($n_j = 1$), there will be zero connectivity value. Total environmental value derived from the conservation auction is computed as follows:

$$\mathrm{TEV} = \sum_{j=1}^{m} \mathrm{TEV}_j \tag{2}$$

where m is the number of corridors/stepping stones obtained from a conservation programme.

2.2 | Auction design

We employed multiple-round, discriminatory-price auctions with a budget constraint and unknown end-points.[3] Six rounds of auctions were run with one of the rounds being randomly chosen for payment. The OC and EV values associated with each plot were the same for all

[1]Wildlife corridors and stepping stones in our experiments were formulated based on the definitions of wildlife corridors/stepping stones provided in the conservation literature (Baum et al., 2004; Kramer-Schadt et al., 2011). Accordingly, wildlife corridors are connections across the landscape that link up areas of habitat to allow movement of species. Stepping stones are relatively small patches connecting to each other. Although stepping stones are unable to allow the movement of some species, such as land mammals and crawling insects, they facilitate the movement of other species, such as birds and flying insects. The ecological benefit of a corridor is therefore greater than that of a stepping stone.

[2]Banerjee and Conte (2018) suggested that revealing the relative form of environmental benefit information reduces rent premiums sought by landholders and improves auction cost-effectiveness more than revealing the parcels' absolute EVs.

[3]The use of multiple-round auctions over single-round auction could generate efficiency gains where participants are not familiar with the auction process, and uncertainty accelerates rent seeking (Rolfe & Windle, 2006; Shogren et al., 2000). Multiple-round auctions without unknown ending point (i.e., the number of rounds is unknown to the bidders in advance) reduce rent-seeking rates and deliver more cost-effective environmental outcomes than those with known ending point (Reeson et al., 2011).

rounds. The OC values were drawn from a uniform distribution on (20,150).[4] The OC values were heterogeneous as the parcels have different crop gross margins due to different crops being grown and farmers' management skills being heterogeneous. Similarly, the EV value for Zones 1 and 4 was 200, while that of Zone 2 and 3 was 100.[5] The pairwise values of OC and EV for each landscape type (positively correlated, negatively correlated, uncorrelated) were derived through a process of shuffling opportunity costs and environmental values to generate the expected degree of correlation between them. The degree of correlation between OC and EV values was calibrated in such a way that Spearman correlation coefficients equal 0.5 for the positive landscape type, −0.5 for the negative landscape and zero for the uncorrelated landscape.

The specified total budget (B = $$1500), which the agency uses to pay for contracts, was unknown to landholders. However, they were informed that not all bids could be accommodated within the budget. [6] Details of the environmental objective function (1) were not revealed to the landholders (Banerjee et al., 2015). The landholders were asked to retire their parcels to establish corridors or stepping stones to provide landscape connectivity between the wildlife habitats A and B. Each landholder could choose to opt out or offer any number of parcels from 1 to 6. Landholders freely chose which parcels they were willing to offer for conservation. The endogenous entry feature acknowledges the fact that landholders choose to participate in agri-environmental schemes voluntarily, rather than being compelled (de Vries & Hanley, 2016). Landholders incurred a submission fee of $$10 Experimental Dollars for each offered parcel. This reflects the transaction costs for preparing and submitting bids. Landholders were informed that a benefit–cost ratio (BCR) is used to select successful bidders.[7]

The government's optimisation problem entailed selecting bids that generate the highest environmental value per dollar spent (i.e., max BCR_j) until the budget (B) was exhausted. To solve this optimisation problem, we implemented a computer algorithm which computes the benefit–cost ratios of all offers, ranks these ratios in descending order, and finally accepts the offers with the highest benefit–cost ratios, subject to the budget constrainst. In the case that multiple corridors/stepping stones had equal benefit–cost ratios and the budget was insufficient to acquire all of them, the agency randomly selected one from among those.

$$\text{Max}_{j\in M}\text{BCR}_j = \frac{\text{TEV}_j}{\sum_{i=1}^{n_j}\text{bid}_i + \text{within\_farm\_AB}_j + \text{between\_farm\_AB}_j}$$
$$\text{TEV}_j = \sum_{i=1}^{n_j}\text{EV}_i + \left(n_j - 1\right)^2 * K \tag{3}$$
$$\text{within\_farm\_AB}_j = \alpha^* k_j \left(0 \le k_j \le 2\right)$$

$$\text{between\_farm\_AB}_j = \beta * l_j \left(l_j = 0, 1\right)$$
$$s.t. \sum_{j\in M}\left(\sum_{i=1}^{n_j}\text{bid}_i + \alpha * k_j + \beta^* l_j\right) \le B \tag{4}$$

[4]Gross margins of arable crops in Germany range between €200 and €1500 per hectare.

[5]Landscapes are often characterised by uneven distribution of environmental values and costs of supplying environmental services (Thomson et al., 2020). Banerjee et al. (2009) in their theoretical study introduced heterogeneity in EVs and indicated that spatial location of parcels with similar magnitudes of environmental benefits influences the likelihood of achieving desirable spatial configuration of conserved parcels. In our study, we focus on the landscapes where parcels with similar magnitudes of environmental values are geographically dispersed (i.e., similar types of parcels are not horizontally situated to each other).

[6]Bidding behaviour was found to be sensitive to budget information (Banerjee et al., 2015; Messer et al., 2014, 2017). However, little is known about the optimal budget information disclosure strategy. This could be an interesting area for future work.

[7]Fooks et al. (2016) also examined the performance of AB in a spatially targeted, budget-constrained conservation auction where the spatial correlation between opportunity costs and environmental values were uncorrelated. However, in their study, environmental benefit values were homogeneous across parcels and bids were ranked based on total environmental benefit, rather than benefit–cost ratio.

where i is a parcel in the jth corridor/stepping stone. M is a set of offered corridors/stepping stones ($j \in M$). k_j represents the number of horizontal connections within the farms which belong to the jth corridor/stepping stone. l_j indicates if the jth corridor/stepping stone has a horizontal connection between neighbouring farms.[8] α and β are within-farm bonus and between-farm bonus payment rate parameters. Equation (3) computes the within-farm bonus payment amount for the jth corridor/stepping stone (within_farm_AB$_j$), whereas Equation (4) calculates the between-farm bonus payment amount for the jth corridor/stepping stone (between_farm_AB$_j$). The cost of buying the jth corridor/stepping stone comprises two components: the bid payment (i.e., the procurement payment $\sum_{i=1}^{n_j} \text{bid}_i$) and the bonus payment (within-farm bonus payment and between-farm bonus payment).

In the treatments without an AB, the bonus payment is zero (α and β were set at 0) and the winning landholders were paid their bid price. In the treatments with the AB, the landholders could receive a within-farm bonus of $$30 Experimental Dollars for each horizontal connection within their farm if their bid was selected ($\alpha = 30$). They could also earn a between-farm bonus of $$40 Experimental Dollars for each horizontal connection between their farm and their neighbouring farm for winning bids ($\beta = 40$).[9] In all treatments, landholders were told that if their offered parcels are not selected, they will receive the payments that are equal to their parcels' production values (opportunity costs). This mimics land staying in farming and farmers earning an agricultural return and receiving no AES payment. At the end of each round, landholders were informed of the winning parcels across the landscape and how much they earned from the auction. Information about their neighbours' earnings was not revealed.

2.3 | Auction performance criteria

To evaluate and compare auction performance across different treatments, we use the performance metrics shown in Table 2.[10] The 'mark-up rate' on the offered parcels indicates how much bidders inflate their bids relative to their true opportunity costs. When the bonus is present, mark-up rate on the selected parcels is computed as the ratio of the total payment made to winners (i.e., sum of the selected bids and any bonus payments made) and opportunity costs. 'Participation rate' reflects the percentage of eligible parcels offered in the auction, whereas selection rate represents the percentage of offered parcels that are selected in the

[8]For a corridor, k_j and l_j are equal to 2 and 1, respectively. For a three-parcel stepping stone, k_j and l_j are both equal to 1. For a two-parcel stepping stone, if the two parcels belong to one farm, k_j and l_j are equal to 1 and 0, respectively. If each of the two parcels belongs to each farm, k_j and l_j are equal to 0 and 1, respectively. For a single-parcel stepping stone, k_j and l_j are both equal to 0.

[9]The challenges arising from strategic uncertainty and transaction costs in coordinating conservation efforts among farmers contribute to difficulties in achieving cross-farm coordination (Drechsler, 2022). In contrast, when it comes to coordinating conservation efforts within individual farms, where decisions are made at an individual decision-making level rather than being contingent on multiple decision-makers, these challenges tend to be more cognitively manageable. In other words, opting for differential bonus rates is not expected to significantly increase the cognitive burden on landholders compared to using uniform bonus rates. In both scenarios, the primary source of cognitive burden for landholders mainly stems from the uncertainty associated with obtaining the between-farm bonus, rather than the within-farm bonus. The experiment conducted by Parkhurst and Shogren (2007) involved the implementation of differential bonus rates within farms and between farms. Bareille et al. (2023) suggest that when agglomeration bonus is high enough to cover the coordination costs incurred in cooperation, it would facilitate conservation coordination among landholders. In our experiment, the between-farm bonus was set to be greater than the within-farm bonus as between-farm coordination on conservation actions requires higher coordination costs (transaction costs) than within-farm coordination. The experimental literature suggests a huge variation (i.e., 2%–100%) in bonus size relative to land values (opportunity costs) (Banerjee et al., 2017; Nguyen et al., 2022). In our experiment, we set the within-farm bonus and between-farm bonus at about 34% and 45% of the average opportunity costs, respectively.

[10]There are other potential performance criteria for evaluating auction performance, such as Payment-Budget ratio (sum of payments/budget), Ask-payment ratio (sum of bids / sum of payments), and Percentage of Optimal Cost-effectiveness Realised (the quantity of environmental benefits procured per dollar / the maximum possible at the optimal allocation where landholders' bids are equal to the opportunity costs). We have also analysed auction performance using these criteria; however, we found no further insights to be added to our current results.

TABLE 2 Auction performance criteria.

Criteria	Definition	Formula
1. Mark-up rate		
Mark-up rate on the offered parcels	The ratio of the sum of submitted bids and opportunity costs	$\frac{\sum \text{submittedbids}}{\sum OCs}$
Mark-up rate on the selected parcels	The ratio of the payment made to winners (sum of the selected bids and any bonus payments made) and the opportunity costs	$\frac{\sum (\text{selectedbids} + \text{bonus})}{\sum \text{OCs}}$
2. Participation rate	The percentage of eligible parcels offered in the conservation programme	$\frac{\text{Number of offered parcels}}{\text{Number of eligible parcels}}$
3. Spatial configuration of offered parcels	Pattern of offered parcels in the conservation programme	• Number of offered corridors • Number of offered three-parcel stepping stones • Number of offered two-parcel stepping stones • Number of offered single parcels
4. Selection rate	The percentage of offered parcels selected in the conservation programme	$\frac{\text{Number of selected parcels}}{\text{Number of offered parcels}}$
5. Spatial configuration of selected parcels	Pattern of selected parcels in the conservation programme	• Number of selected corridors • Number of selected three-parcel stepping stones • Number of selected two-parcel stepping stones • Number of selected single parcels
6. Spatial coordination	Number of selected and connected parcels	Number of selected corridors * 4 + Number of selected three-parcel stepping stones * 3 + Number of selected two-parcel stepping stones * 2
7. Cost-effectiveness	Average quantity of environmental benefits procured per dollar spent	$\frac{\sum \text{TEV}}{\sum \text{winners' bids} + \text{bonus}}$
8. Net welfare	Net impact of the conservation programme on both conservation and agricultural production outcomes	Total environmental value from all selected offers – total income forgone from agricultural production – total submission fee – total communication fee

auction. We also observe spatial configuration of offered parcels and of selected parcels across the landscapes. These spatial configurations are measured in terms of the number of corridors and stepping stones offered or selected. The number of selected and connected parcels is used as a proxy to measure the degree of spatial coordination. Cost-effectiveness is measured as the average quantity of environmental benefits procured per Experimental Dollar spent. The welfare effect of the conservation programme reflects the net economic impact of the conservation auction. It is calculated by deducting from the total environmental value generated (1) total income forgone from agricultural production, (2) total submission fee of all offered parcels, and (3) total communication fee.[11]

[11]The submission fee and communication fee were incurred by landholders and not transferred to the conservation agency; they represent welfare loss.

TABLE 3 Experimental treatments.

Treatments (between-subject design)	Spatial correlation of opportunity costs and environmental benefits: Uncorrelated	Negative	Positive
Without agglomeration bonus	5 sessions (Treatment T1)	5 sessions (Treatment T2)	5 sessions (Treatment T3)
With agglomeration bonus	5 sessions (Treatment T4)	5 sessions (Treatment T5)	5 sessions (Treatment T6)

3 | EXPERIMENTAL PROCEDURES

The lab experiments were conducted with 180 agriculture students at Kiel University, Germany from November 2021 to March 2022 via Ztree-Unleashed (Duch et al., 2020; Fischbacher, 2007). We used a contextualised setting, as recommended in Alekseev et al. (2017). We employed the block randomisation method (Suresh, 2011) to randomly assign subjects into six treatment groups that result in equal sample sizes (see Table 3).

Each treatment consisted of five sessions with six subjects per session.[12] Before the sessions started, we presented the experimental instructions to the subjects via Zoom (see Online Appendix A1 for details of the experimental instructions). After the instructions were explained, the students took part in a quiz to confirm their understanding of the instructions before proceeding to the main experiments. The experiments followed a three-by-two design varying by: (1) the spatial correlation of opportunity costs and environmental values (uncorrelated, positive and negative) and (2) whether an AB was paid to winning bids. The between-subject design allowed us to avoid the confounds caused by order effects across the treatments. The students received their earnings in the form of cash payments. Average earnings per student were €23.50.

In all treatments, the subjects were provided with a communication option in which they could freely choose with whom they wanted to communicate before entering the bidding stage in each round. However, communication was costly ($$15 Experimental Dollars per neighbour contacted). Given the landscape set-up shown in Figure 1, each subject had either one or two direct neighbours with whom they could communicate to coordinate their offers. Direct neighbours are those whose parcels are horizontally adjacent to each other. Communication was conducted via a chat room with a limited time duration of 3 min in each round. We allowed one-way communication between the subjects. That is, the messages could still be delivered to direct neighbours with whom the subject wanted to communicate, even when direct neighbours did not select the communication option in the first place. Figure 2 presents a summary of the auction procedure.

4 | HYPOTHESES

Table 4 presents the main hypotheses that will be tested in our study. See the Online Appendix A2 for a discussion of these hypotheses.

[12]We conducted two pilot experiments to test the experimental design and the results from the pilot testing were used as priors for means and standard deviations of mark-up rate ($\frac{\sum \text{bids}}{\sum \text{OCs}}$) from the treatments. The sample size was determined via sample size calculation given by Canavari et al. (2019) to ensure 80% chance of correctly rejecting the null hypothesis (i.e., a power ($1-\beta$) = 0.8).

Journal of Agricultural Economics

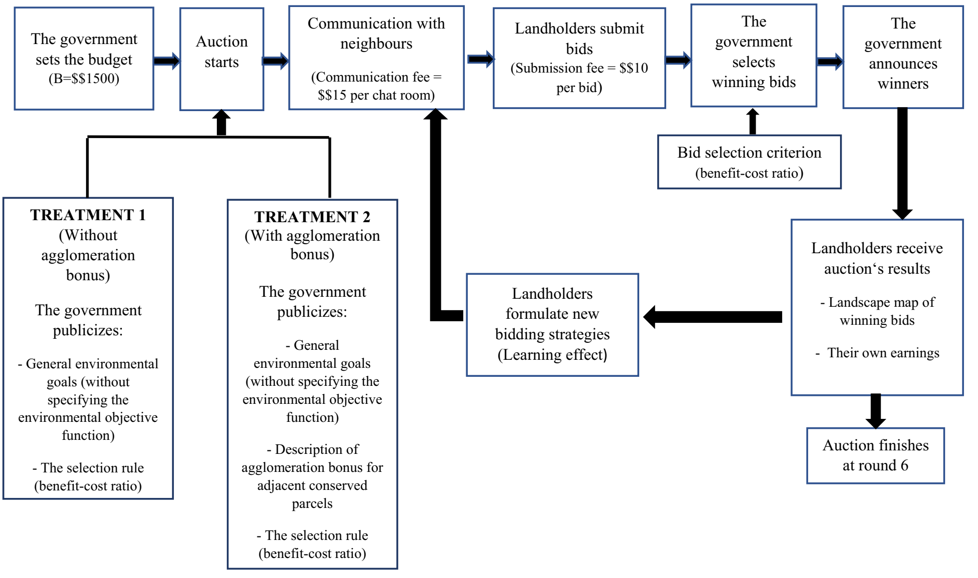

FIGURE 2 The procedure of the auctions.

5 | RESULTS

5.1 | Descriptive statistics

The descriptive statistics in Table 5 show that in the absence of AB, the average submitted bid value per round for the positive landscape type was the highest (S$116.51), while those of the uncorrelated and negative landscape types were S$113.67, and S$104.47, respectively. We also observe a similar pattern on the average accepted bid value per round in the presence of an AB. Each bidder offered an average of 4.02 out of 6 parcels and 2.35 parcels were selected, constituting 59% of offered parcels. Furthermore, in the presence of an AB, we found an increase in the number of offered parcels and a decrease in the number of selected parcels per bidder per round across three landscape types. Figure 3, which depicts bid distributions across the treatments, illustrates that when an AB was introduced, bidders tended to adjust their bids downward in the uncorrelated and positive landscapes. However, this trend is not as clearly observed in the negative landscape type.

In the following sections, we evaluate the performance of AB using the experimental data at the auction level, individual bidder level and parcel level.

5.2 | Analysis of auction performance

5.2.1 | Effects of the agglomeration bonus

In order to examine the effects of AB on auction performance, we conducted Mann–Whitney U tests using the auction-level data. As shown in Table 6, AB led to a significant increase in participation rate at the 10% significance level.[13] By closely examining the spa-

[13]The probability of a parcel being selected in a given round is conditional on the offer decision. We employed a Heckman random effects probit model to test if AB leads to more parcels offered, subsequently reducing the probability of a parcel being selected in the budget-constrained auctions (the 'participation effect' of AB; see Online Appendix A3). We found that the AB reduces the probability of a parcel being selected in the auctions.

TABLE 4 Hypotheses.

Treatment	Benchmark treatment	Hypothesis
Agglomeration Bonus	No agglomeration bonus	**Hypothesis 1:** The AB will: • Reduce the mark-up rate on offered parcels • Foster a high level of spatial coordination of conservation efforts • And improve the cost-effectiveness and social welfare of conservation programmes
Uncorrelated landscape + Agglomeration Bonus Negative landscape + Agglomeration Bonus Positive landscape + Agglomeration Bonus	Uncorrelated landscape + No agglomeration bonus Negative landscape + No agglomeration bonus Positive landscape + No agglomeration bonus	**Hypothesis 2:** The impact of AB on the degree to which landholders reduce their bids should vary significantly depending on the specific landscape types. • The AB will attenuate rent seeking behaviour in the negative landscape. However, the effect is not as pronounced as it is in the uncorrelated landscape. • The AB should reduce overbidding in the positive landscape. The effect is as pronounced as it is in the uncorrelated landscape. **Hypothesis 3:** In the presence of AB, the degree to which landholders coordinate conservation efforts will vary significantly depending on the specific landscape types. • The AB will improve the quality of spatial configuration of offered parcels in all three landscape types. • The AB enhances spatial coordination in all three landscape types. The improved degree of spatial coordination in the negative landscape type is not as high as those in other landscape types. **Hypothesis 4:** The AB will improve cost-effectiveness and social welfare outcomes in all three landscape types. However, due to the variability in bidding behaviour across landscape types, the performance of AB in terms of cost-effectiveness and social welfare outcomes also vary across landscape types.

tial configuration of offered parcels, we found that AB promoted a greater number of corridors and three-parcel stepping stones to be offered. Bidders significantly lowered their bids on the offered parcels (i.e., reducing from 1.42 to 1.23) in the expectation of earning the bonus. However, we found that the AB reduced spatial coordination at the 5% significant level. AB also reduced auction cost-effectiveness from 2.93 to 2.55. This is partly because the presence of AB promoted a higher participation rate, but it also significantly reduced the selection rate at the 5% significance level. The results on the spatial configuration of selected parcels reveal that AB significantly reduced the number of selected corridors and three-parcel stepping stones at the 10% and 1% significance level, respectively. By contrast, more two-parcel stepping stones were selected, while no effect of AB was found on the number of selected single parcels.

TABLE 5 Summary statistics.

	All	Without agglomeration bonus			With agglomeration bonus		
		Uncorrelated landscape	Negative landscape	Positive landscape	Uncorrelated landscape	Negative landscape	Positive landscape
Average submitted bid value per round	107.03 (36.23)	113.67 (39.03)	104.47 (33.09)	116.51 (42.41)	104.36 (30.96)	107.83 (39.98)	96.01 (25.89)
Average accepted bid value per round	97.85 (29.19)	103.8 (28.83)	93.85 (29.65)	111.35 (29.09)	96.46 (28.56)	93.15 (28.72)	89.53 (24.41)
Average fraction of selected bids per round (%)	59.51 (30.92)	59.88 (32.31)	70.07 (27.04)	59.34 (30.34)	56.57 (31.70)	62.63 (28.07)	50.34 (32.40)
Average number of offered parcels per bidder per round	4.027 (1.36)	3.98 (1.44)	3.78 (1.15)	3.856 (1.33)	4.017 (1.40)	4.07 (1.21)	4.37 (1.50)
Average number of selected parcels per bidder per round	2.352 (1.32)	2.43 (1.51)	2.54 (1.04)	2.260 (1.27)	2.26 (1.40)	2.44 (1.08)	2.19 (1.51)

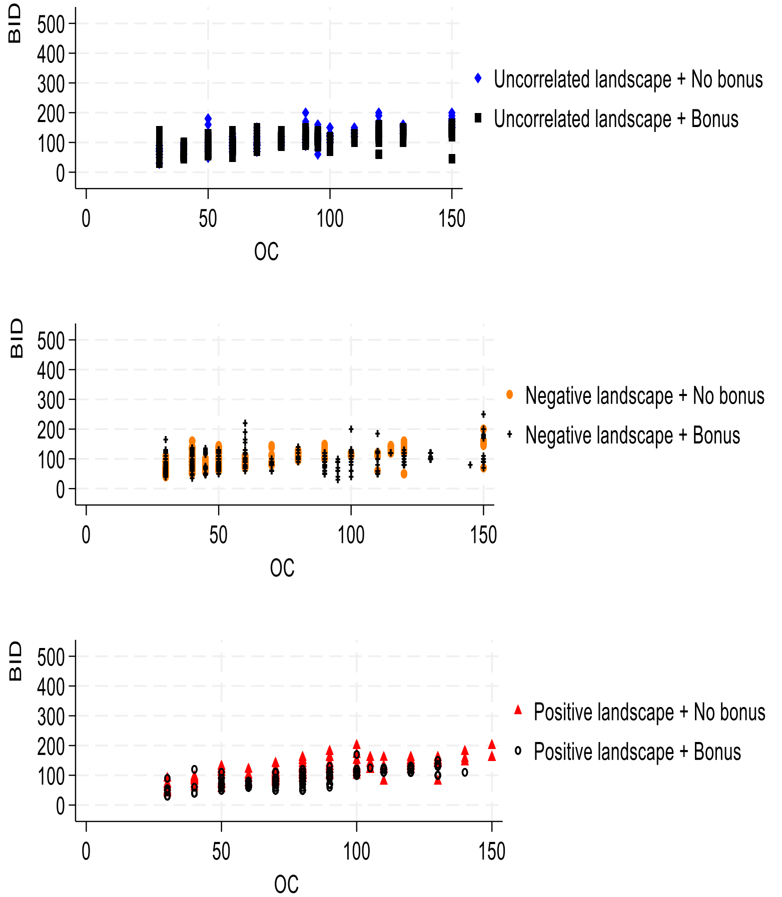

FIGURE 3 Comparisons of bid distributions across treatments.

The results suggest that AB could be effective in achieving the desirable spatial configuration of *offered* parcels, but it does not necessarily translate into improved spatial configuration of *selected* parcels. We found that when the AB was incorporated into the payment mechanism, the mark-up rate on the selected parcels (i.e., $\frac{\sum(\text{selectedbids}+\text{bonus})}{\sum \text{OCs}}$) was significantly higher, rising from 1.42 to 1.49. This suggests that bidders did not substantially include the bonus in their bid formulation with a significant rent reduction to enhance their bids' competitiveness in the auction: the reduction in the bids was lower than the bonus paid to adjacent conserved parcels. The presence of the AB thus makes paying for contracts more expensive for the auctioneer. As a result, the AB reduced the selection rate from 64% to 59% at the 5% significance level. The spatial configuration of selected parcels depends not only on spatial configuration of offered parcels, but also on the extent to which landholders lower their bids in budget-constrained auctions. The AB was also found to lead to a welfare loss at the 1% significance level.

These results taken together suggest:

Result 1: The presence of AB increases participation rate and enhances the spatial connectivity of offered parcels. However, due to a tight budget constraint and the fact that bid reduction is lower than the bonus payment, the AB has a negative impact on the spatial connectivity of selected parcels and the cost-effectiveness of the auction compared to the baseline treatment when the AB is not offered. A significant welfare loss is likely to arise from the AB programme.

TABLE 6 Auction-level treatment effects of the agglomeration bonus.

	Without AB	With AB	Mann–Whitney test results: Prob > |z|
Participation rate	0.62 (0.10)	0.65 (0.09)	0.09*
Spatial configuration of offered parcels			
Corridors	3.06 (1.27)	3.67 (1.29)	0.00***
Three-parcel stepping stones	0.35 (0.56)	0.58 (0.72)	0.02**
Two-parcel stepping stones	2.57 (1.40)	2.41 (1.59)	0.13
Single parcel	4.03 (2.37)	2.38 (2.02)	0.00***
Selection rate	0.64 (0.12)	0.59 (0.10)	0.05**
Spatial configuration of selected parcels			
Corridors	2.12 (0.80)	1.88 (0.84)	0.06*
Three-parcel stepping stones	0.16 (0.40)	0.01 (0.10)	0.00***
Two-parcel stepping stones	0.22 (0.41)	0.48 (0.79)	0.03**
Single parcel	4.68 (3.52)	5.27 (3.66)	0.35
Mark-up rate on the offered parcels	1.42 (0.18)	1.23 (0.18)	0.00***
Mark-up rate on the selected parcels	1.42 (0.19)	1.49 (0.21)	0.00***
Spatial coordination	9.43 (3.06)	8.56 (3.04)	0.04**
Cost-effectiveness	2.93 (0.38)	2.55 (0.30)	0.00***
Net welfare	3004.67 (58.02)	2619.4 (61.09)	0.00***

Note: *, **, *** indicate significance at 1%, 5% and 10% levels, respectively. Standard deviations are provided in parentheses.

5.2.2 | Landscape type and its influence on the performance of agglomeration bonus

To assess whether the aforementioned result (Result 1) holds true consistently across all three landscape types, we conducted a comprehensive analysis to investigate the influence of landscape type on the performance of AB.

Mark-up rates

Using the data at auction level, we computed the performance metrics, including average values of mark-up rate, spatial coordination, cost-effectiveness, and net welfare across six rounds for all the treatments. As shown in Figure 4, the introduction of AB leads to a reduction in mark-up rates on offered parcels in all landscape types. We conducted Cuzick's tests to investigate whether mark-up rates displayed a consistent tendency to either increase or decrease over time. These results suggest a likelihood of bidders aiming for higher mark-ups over successive rounds in the negative landscape type, with a statistical significance of 5%. For the other landscape types, no noticeable trends in mark-ups were observed.

Table 7 shows the results of a random effects regression model in which the observations were clustered at the auction level. Auction outcomes including mark-up on the offered parcels, spatial coordination, cost-effectiveness, and net welfare were regressed on the following variables: number of rounds, presence of AB, two dummies regarding landscape type (the uncorrelated landscape type was chosen as a baseline), and the interaction between landscape types and AB. The results derived from the regression of mark-up rates suggest a significant reduction in mark-ups on the offered parcels in the positive landscape relative to the uncorrelated

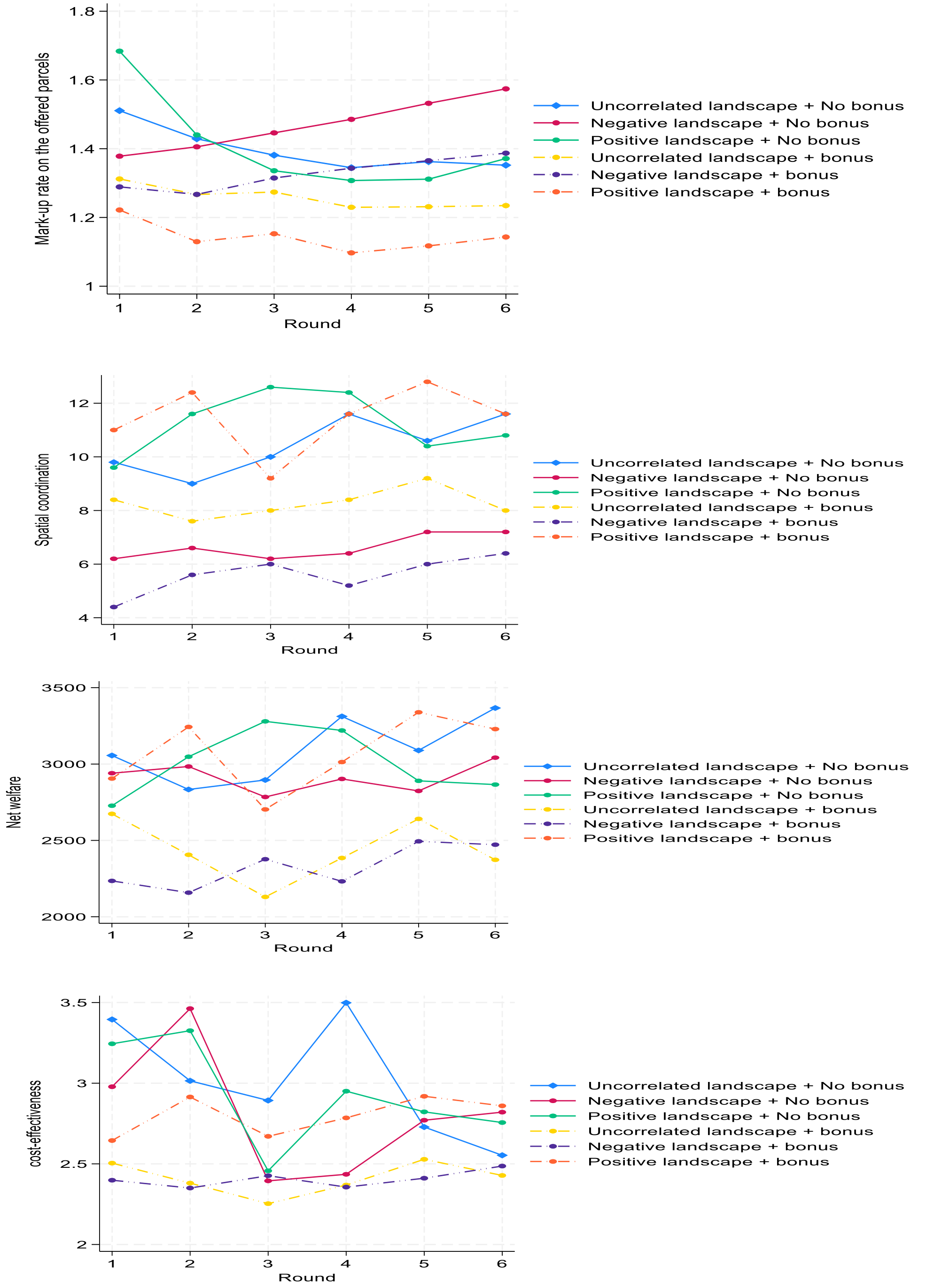

FIGURE 4 Average mark-up rates, spatial coordination, cost-effectiveness, and net welfare over 6 auction rounds in the different treatments.

landscape at the 10% significance level when AB was present. By contrast, there are no significant differences in mark-up rates on the offered parcels between the negative and uncorrelated landscape, both in the absence and presence of AB.

Together with the direction of the effects, we are also interested in the magnitude of the AB effects on auction performance across landscape types. We thus conducted Mann–Whitney

U tests comparing auction performance with and without bonus in each landscape type (see Table 8). Table 8 shows that AB reduced the mark-up rates on the offered parcels by 28 percentage points (from 40% to 12%) in the positive landscape, while only by 14 percentage points (from 39% to 25%) and 15 percentage points (from 47% to 32%) in the uncorrelated and negative landscapes, respectively. When the bonus payment was included in the final payment on the selected parcels, the results show that the mark-ups on the selected parcels increased by 18 percentage points in the uncorrelated and by 9 percentage points in the positive landscape at the 1% significance level. By contrast, no statistically significant difference in the mark-ups on the selected parcels was found in the negative landscape when AB was present. These results clearly show that the bonus payment effect on bidding behaviour varied across landscape types.

We thus have Result 2 summarising the 'bid shading effect':

Result 2: The AB mitigates rent-seeking behaviour to varying degrees, contingent on landscape type. The effect of AB in reducing mark-up rates on the offered parcels was most pronounced in the positive landscape type, followed by the uncorrelated and negative landscape types, respectively. By contrast, the AB significantly increases the mark-up rates on selected parcels in the uncorrelated and the positive landscapes.

Spatial coordination

Table 8 shows increased participation rates in each landscape type in the presence of AB. However, these effects were not found to be statistically significant. In terms of the quality of offers, Table 9 shows that the presence of AB attracted more contiguous conserved habitats.[14] The number of offered corridors increased sharply in the positive landscape at the 1% significance level. Similarly, a significant increase in the number of offered three-parcel stepping stones was observed in the negative landscape at the 1% significance level. The number of single parcels offered significantly decreases in all three landscape types. The government procured more corridors in the positive landscape. However, the AB did not affect the spatial connectivity of selected parcels in the negative landscape. We found that AB reduced the number of selected corridors in the uncorrelated landscape.

Table 7 suggests that landscape type plays a role in explaining the variation in spatial coordination. Particularly, spatial coordination could be better achieved in the uncorrelated landscape than in the negative landscape. In contrast, the positive landscape was likely to generate a higher degree of spatial coordination than the uncorrelated landscape. The presence of AB did not significantly affect the difference in spatial coordination between the uncorrelated and negative landscapes. Conversely, the presence of AB significantly enhanced spatial coordination in the positive landscape, relative to the uncorrelated landscape type.

When we specifically examine the effect of AB within each landscape type, the results in Table 8 indicate an increase in spatial coordination in the positive landscape at the 10% significance level, a decrease in the uncorrelated landscape at the 1% significance level, and no significant effect in the negative landscape. Regardless of the presence or absence of AB, spatial coordination achieved through the auctions was highest in the positive landscape, followed by

[14]In our experiment, offering interior parcels located in Zones 2 and 3 could help bidders earn the between-farm bonus, while contributing to an increased number of offered corridors or three-parcel stepping stones. We employed a random effects probit model to test if the probability of offering the interior parcels would increase when AB was introduced (see Online Appendix A4). The results show that the coefficient associated with ENVIRONMENTAL ZONES (Dummy variable, which equals 1 if parcels located in Zones 1 and 4 [exterior parcels], otherwise it equals 0) was found to be positive and significant at the 1% significance level (p-value = 0.00). This suggests that the interior parcels were less likely to be offered than the exterior parcels. However, when the variable ENVIRONMENTAL ZONES was interacted with the variable AGGLOMERATION BONUS, the associated coefficient became negative. This implies that the presence of an AB was likely to increase the probability of offering interior parcels, which is needed for enhancing conservation connectivity between farms.

TABLE 7 Parameters estimates for random effects regression on auction performance (at auction-level).

	Mark-up on the offered parcels			Spatial coordination			Cost-effectiveness			Net welfare		
	Coeff.	Robust std. err.	*p*-value	Coeff.	Robust std. err.	*p*-value	Coeff.	Robust std. err.	*p*-value	Coeff.	Robust std. err.	*p*-value
Round	−0.01	0.01	0.51	0.01	0.18	0.18	0.01	0.02	0.35	47.36	30.84	0.13
Agglomeration bonus	−0.21***	0.06	0.00	−0.02	0.04	0.62	−0.26***	0.07	0.00	−234.80*	123.30	0.06
Negative landscape[a]	0.07	0.07	0.32	−0.32***	0.05	0.00	−0.10	0.10	0.32	−108.30	156.15	0.49
Positive landscape[a]	−0.05	0.04	0.16	0.21***	0.04	0.00	0.18**	0.08	0.03	339.70***	125.86	0.00
Negative landscape × Agglomeration bonus	−0.01	0.14	0.97	0.29	0.10	0.29	0.20	0.21	0.34	146.60	312.31	0.64
Positive landscape × Agglomeration bonus	−0.14*	0.08	0.09	0.00***	0.08	0.00	0.49***	0.16	0.00	756.20***	251.72	0.00
Constant	1.45***	0.06	0.00	0.00***	0.00	0.00	2.78***	0.09	0.00	2662.83***	156.83	0.00
Wald Chi^2	106.71			447.31			68.69			47.25		

Note: *, **, *** indicate significance at 1%, 5% and 10% levels, respectively.

[a]Baseline: Uncorrelated landscape.

TABLE 8 Effect of agglomeration bonus on auction performance across different types of landscape (at auction level).

	Mean value (standard deviation)						Mann–Whitney test results: Prob > $\lvert z \rvert$		
	Uncorrelated landscape + No AB (T1)	Uncorrelated landscape + AB (T4)	Negative landscape + No AB (T2)	Negative landscape + AB (T5)	Positive landscape + No AB (T3)	Positive landscape + AB (T6)	T1 vs T4	T2 vs T5	T3 vs T6
1. Mark-up rate									
Mark-up rate on the offered parcels	1.39 (0.16)	1.25 (0.11)	1.47 (0.18)	1.32 (0.26)	1.40 (0.20)	1.12 (0.07)	0.00***	0.02**	0.00***
Mark-up rate on the selected parcels	1.33 (0.11)	1.51 (0.13)	1.58 (0.24)	1.53 (0.33)	1.35 (0.10)	1.44 (0.08)	0.00***	0.94	0.00***
2. Participation rate	0.62 (0.11)	0.65 (0.08)	0.64 (0.11)	0.67 (0.09)	0.61 (0.07)	0.64 (0.11)	0.36	0.28	0.64
3. Selection rate	0.64 (0.15)	0.58 (0.10)	0.68 (0.11)	0.61 (0.09)	0.59 (0.06)	0.59 (0.11)	0.15	0.01**	0.54
4. Spatial coordination	10.43 (1.90)	8.26 (1.72)	6.63 (3.12)	5.6 (0.38)	11.23 (1.71)	11.83 (1.81)	0.00***	0.22	0.09*
5. Cost-effectiveness	3.02 (0.36)	2.41 (0.24)	2.81 (0.46)	2.40 (0.28)	2.96 (0.29)	2.84 (0.20)	0.00***	0.00***	0.13
6. Net welfare	3078 (97.72)	2391.8 (91.88)	2896.4 (122.01)	2356.8 (76.32)	3039.6 (77.08)	3109.6 (72.23)	0.00***	0.00***	0.40

Note: *, **, *** indicate significance at 1%, 5% and 10% levels, respectively. Please refer to Table 2 for the definitions of auction performance criteria.

TABLE 9 Spatial configuration of offered and selected parcels across landscape types.

	Mean value (standard deviation)						Mann–Whitney test results: Prob > |z|		
	Uncorrelated landscape + No AB (T1)	Uncorrelated landscape + AB (T4)	Negative landscape + No AB (T2)	Negative landscape + AB (T5)	Positive landscape + No AB (T3)	Positive landscape + AB (T6)	T1 vs T4	T2 vs T5	T3 vs T6
Spatial configuration of offered parcels									
Corridors	3.1 (1.09)	3.3 (1.55)	3.16 (1.70)	3.53 (1.10)	2.93 (0.94)	4.2 (0.98)	0.54	0.57	0.00***
Three-plot stepping stones	0.5 (0.68)	0.66 (0.92)	0.13 (0.43)	0.46 (0.57)	0.43 (0.50)	0.63 (0.62)	0.66	0.00***	0.21
Two-plot stepping stones	2.3 (1.68)	3.03 (1.88)	2.23 (1.30)	2.26 (1.66)	3.2 (0.96)	1.93 (0.86)	0.17	0.77	0.00***
Single parcels	4.03 (1.90)	2.4 (1.65)	5.5 (2.43)	4.23 (1.63)	2.56 (1.81)	0.53 (0.83)	0.00***	0.02**	0.00***
Spatial configuration of selected parcels									
Corridors	2.4 (0.56)	1.7 (0.65)	1.5 (0.90)	1.16 (0.59)	2.46 (0.50)	2.8 (0.47)	0.00***	0.11	0.01**
Three-plot stepping stones	0.1 (0.30)	0 (0.00)	0.1 (0.30)	0 (0.00)	0.3 (0.53)	0.03 (0.18)	0.23	0.23	0.02**
Two-plot stepping stones	0.26 (0.45)	0.73 (1.01)	0.16 (0.37)	0.46 (0.68)	0.23 (0.43)	0.26 (0.60)	0.08*	0.06*	1.00
Single parcels	3.56 (1.56)	5.26 (2.28)	8.76 (2.63)	9.06 (2.47)	1.73 (1.11)	1.5 (1.92)	0.00***	0.76	0.17

Note: *, **, *** indicate significance at 1%, 5% and 10% levels, respectively.

the uncorrelated and negative landscapes. Figure 4 shows a positive trend in spatial coordination over the rounds in the treatments of the negative landscape type and in the treatment of the uncorrelated landscape without the bonus at the 10% significance level (according to Cuzick's tests for trend). Landholders seem to coordinate their conservation efforts more effectively over time in these landscape types.

Taken together we thus have Result 3 summarising the 'connectivity effect':

Result 3: The AB holds the potential for promoting spatially coordinated conservation efforts in the positive landscape. By contrast, it is likely to be detrimental to spatial coordination in the uncorrelated landscape, with no observed effect in the negative landscape. However, interactions among landholders over time could lead to an improvement in their coordination.

Cost-effectiveness and net welfare

Table 7 suggest that the presence of AB enhances the cost-effectiveness of the auctions and the resulting social welfare in the positive landscape compared to the uncorrelated landscape. Conversely, the presence of AB did not significantly affect the differences in cost-effectiveness and net welfare between the negative and uncorrelated landscapes. Considering the effect of AB on cost-effectiveness and net welfare within each landscape type, the results in Table 8 show reductions on these two outcomes in the uncorrelated and negative landscape types. By contrast, no effects of AB on auction cost-effectiveness and net welfare were found in the positive landscape. The results derived from Cuzick's test indicate a lack of clear trends in cost-effectiveness and social welfare over time across the treatments (see Figure 4).

Taken together we have Result 4 summarising the 'performance metric effect':

Result 4: The AB adversely affects cost-effectiveness and social welfare in the uncorrelated and negative landscape types, with no significant impact observed in the positive landscape.

In Online Appendix A5 we provide further results from an analysis of bidding behaviour, in terms of how the reduction in bids compares to expected AB payments, and how communication affects bidding behaviour. We found that bidders do not fully incorporate the AB into their bids, which tightens the budget for procurement (the 'budget effect' of AB). Bidders tend to internalise the bonus payments into their bids at a greater extent in the positive landscape than in the other landscape types. We also found that communication could potentially result in the emergence of collusive bidding.

6 | DISCUSSION AND CONCLUDING REMARKS

The AB is designed to reward spatial coordination of conservation efforts among landholders. To date, real-world applications of AB are rare, and the best design of AB is still a matter of ongoing debate (Nguyen et al., 2022), since identifying the facilitating contextual conditions for AB success is critical (Bareille et al., 2023). This paper demonstrates the importance of taking spatial correlations between opportunity costs and environmental benefits into account when policy-makers consider adopting an AB incentive within the context of a conservation auction. Our paper examined the effect of differing spatial correlations of opportunity costs and environmental benefits (positive, negative, no correlation) on AB performance in budget-constrained and spatially targeted conservation auctions.

Our main results were as follows. First, the AB significantly mitigated rent-seeking and effectively promoted willingness to coordinate among landholders. We found an improved spatial configuration of offered parcels. However, AB payments reduced the number of contracts actually offered to 'farmers' to enrol land in the conservation scheme. Contrary to expectations, an improved spatial configuration of offered parcels did not translate into an improved spatial configuration of selected parcels. The AB lowered the degree of spatial coordination.

With a fixed total budget, offering an AB payment means fewer contracts can be awarded, ceteris paribus. This effect was also found in Banerjee et al. (2021). However, this budget tightening did not sufficiently enhance bidding competitiveness. We found that the extent to which bidders capitalise the bonus in their bids was modest. As a result, we did not find supportive evidence that AB could improve auction cost-effectiveness. These findings differ from previous research suggesting that a reduced procurement budget could potentially improve auction competitiveness by mitigating rent-seeking rates (Duke et al., 2016; Messer et al., 2017). Our results are in line with Fooks et al. (2016), suggesting that AB could result in welfare loss.

Second, the performance of an AB is contingent on landscape type. The AB improved the spatial configuration of offered parcels in three landscape types at different degrees. The effect was most salient in the positive landscape, with a significant increase in the number of offered corridors. However, the results suggest that the AB reduced the selection rate in all landscape types. This reduction in selection rate was statistically significant in the negative landscape. These results are likely to be related to the bonus payment effect on the remaining budget for procurement. The extent to which the bonus was capitalised in the bids greatly varied across landscape types. Bid reduction was largest in the positive landscape, followed by those in the uncorrelated and negative landscapes, respectively. This discrepancy could be attributed to the fact that in the negative landscape, rent-seeking on the low-OC parcels remained aggressive even in the presence of AB, as these parcels are also the high-EV ones. By contrast, in the positive landscape, the AB was capitalised about 35% on the low-OC parcels. Lowering rents on these low-OC parcels (also low-EV ones) would increase the chance for the parcels to be selected and rewarded a bonus.

In our experimental design, the within-farm and between-farm bonuses were set at 34% and 45% of average opportunity costs. We found these bonuses had an unanticipated effect on spatial coordination in the uncorrelated landscape. The results reflect those of Fooks et al. (2016), who found that spatially targeted conservation auctions with a smaller agglomeration bonus (10% of the opportunity costs) reduced spatial coordination and auction efficiency in the uncorrelated landscape. However, our study adds to the findings of Fooks et al. (2016) by pointing out that AB could be an effective incentive mechanism to foster coordination in positive landscapes. Adopting a spatial agent-based simulation, Drechsler and Grimm (2022) suggested that it is more cost-effective to first offer a large bonus in the short term to trigger a high amount of spatially agglomerated conservation efforts, and then lower the bonus to exploit the stickiness of conservation coordination among landholders. A future experimental study could test whether the positive effect of AB on spatial coordination is maintained when the bonus is lowered in the long term.

In sum, this paper provides fresh insights into the role of the spatial correlation of opportunity costs and environmental values in determining the likelihood that AB succeeds or fails in achieving spatial coordination when included as part of a conservation auction. Given stringent budget constraints, AB would likely do more harm than good for spatial coordination in the landscapes where opportunity costs and environmental values are uncorrelated or negatively correlated. Given our results, adoption of AB can only be recommended to achieve a desirable spatial configuration of conservation habitats in the positive landscape type. These findings could be useful to inform refinements in the design of agri-environmental schemes for better landscape-scale environmental outcomes. Finding out what type of spatial correlation exists between environmental values and opportunity costs in different landscapes is thus important for conservation policy designers; yet we know that opportunity costs are often private information, meaning that the regulator has poor data on one half of this important policy design parameter.

ACKNOWLEDGEMENTS

This research was funded by the European Commission via the EFFECT project (Environmental public goods From Farming through Effective Contract Targeting) under grant agreement

N°817903. We would like to thank the anonymous reviewers and the editor for their constructive and helpful comments to improve the manuscript. Open access publishing facilitated by The University of Western Australia, as part of the Wiley - The University of Western Australia agreement via the Council of Australian University Librarians.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

REFERENCES

Ait Sidhoum, A., Canessa, C., & Sauer, J. (2022). Effects of agri-environment schemes on farm-level eco-efficiency measures: Empirical evidence from EU countries. *Journal of Agricultural Economics*, 74, 551–569.

Alekseev, A., Charness, G., & Gneezy, U. (2017). Experimental methods: When and why contextual instructions are important. *Journal of Economic Behavior & Organization*, 134, 48–59.

Armsworth, P. R., Jackson, H. B., Cho, S.-H., Clark, M., Fargione, J. E., Iacona, G. D., Kim, T., Larson, E. R., Minney, T., & Sutton, N. A. (2017). Factoring economic costs into conservation planning may not improve agreement over priorities for protection. *Nature Communications*, 8(1), 2253.

Babcock, B. A., Lakshminarayan, P., Wu, J., & Zilberman, D. (1996). The economics of a public fund for environmental amenities: A study of CRP contracts. *American Journal of Agricultural Economics*, 78(4), 961–971.

Banerjee, S., Cason, T. N., de Vries, F. P., & Hanley, N. (2017). Transaction costs, communication and spatial coordination in payment for ecosystem services schemes. *Journal of Environmental Economics and Management*, 83, 68–89.

Banerjee, S., Cason, T. N., de Vries, F. P., & Hanley, N. (2021). Spatial coordination and joint bidding in conservation auctions. *Journal of the Association of Environmental and Resource Economists*, 8(5), 1013–1049.

Banerjee, S., & Conte, M. N. (2018). *Information access, conservation practice choice, and rent seeking in conservation procurement auctions: Evidence from a laboratory experiment*. Wiley Online Library.

Banerjee, S., de Vries, F. P., Hanley, N., & van Soest, D. P. (2014). The impact of information provision on agglomeration bonus performance: An experimental study on local networks. *American Journal of Agricultural Economics*, 96(4), 1009–1029.

Banerjee, S., Kwasnica, A. M., & Shortle, J. S. (2012). Agglomeration bonus in small and large local networks: A laboratory examination of spatial coordination. *Ecological Economics*, 84, 142–152.

Banerjee, S., Kwasnica, A. M., & Shortle, J. S. (2015). Information and auction performance: A laboratory study of conservation auctions for spatially contiguous land management. *Environmental and Resource Economics*, 61(3), 409–431.

Banerjee, S., Shortle, J. S., & Kwasnica, A. M. (2009). The Agglomeration Vickrey Auction for the promotion of spatially contiguous habitat management: Theoretical foundations and numerical illustrations. *Agricultural and Applied Economics Association (AAEA)*, 49337.

Bareille, F., Zavalloni, M., & Viaggi, D. (2023). Agglomeration bonus and endogenous group formation. *American Journal of Agricultural Economics*, 105, 76–98.

Barral, S., & Detang-Dessendre, C. (2023). Reforming the common agricultural policy (2023–2027): Multidisciplinary views. *Review of Agricultural, Food and Environmental Studies*, 104(1), 47–50.

Baum, K. A., Haynes, K. J., Dillemuth, F. P., & Cronin, J. T. (2004). The matrix enhances the effectiveness of corridors and stepping stones. *Ecology*, 85(10), 2671–2676.

Bond, A. J., O'Connor, P. J., & Cavagnaro, T. R. (2019). Remnant woodland biodiversity gains under 10 years of revealed-price incentive payments. *Journal of Applied Ecology*, 56(7), 1827–1838.

Canavari, M., Drichoutis, A. C., Lusk, J. L., & Nayga, R. M., Jr. (2019). How to run an experimental auction: A review of recent advances. *European Review of Agricultural Economics*, 46(5), 862–922.

Cullen, P., Hynes, S., Ryan, M., & O'Donoghue, C. (2021). More than two decades of Agri-environment schemes: Has the profile of participating farms changed? *Journal of Environmental Management*, 292, 112826.

de Vries, F. P., & Hanley, N. (2016). Incentive-based policy design for pollution control and biodiversity conservation: A review. *Environmental and Resource Economics*, 63(4), 687–702.

Dijk, J., Ansink, E., & van Soest, D. (2017). Buyouts and agglomeration bonuses in wildlife corridor auctions. *Tinbergen Institute Discussion Paper*, TI 2017-036/VIII.

Drechsler, M. (2022). Improving models of coordination incentives for biodiversity conservation by fitting a multi-agent simulation model to a lab experiment. *Journal of Behavioral and Experimental Economics*, 102, 101967.

Drechsler, M. (2023a). Ecological and economic trade-offs between amount and spatial aggregation of conservation and the cost-effective design of coordination incentives. *Ecological Economics*, 213, 107948.

Drechsler, M. (2023b). Insights from Ising models of land-use under economic coordination incentives. *Physica A: Statistical Mechanics and its Applications*, 625, 128987.

Drechsler, M., & Grimm, V. (2022). Land-use hysteresis triggered by staggered payment schemes for more permanent biodiversity conservation. *Munich Personal REPEc Archieve, MPRA Paper*, 110361.

Duch, M. L., Grossmann, M. R., & Lauer, T. (2020). Z-tree unleashed: A novel client-integrating architecture for conducting z-tree experiments over the internet. *Journal of Behavioral and Experimental Finance*, 28, 100400.

Duke, J. M., Messer, K. D., Lynch, L., & Li, T. (2016). *Reverse auctions for purchases of ecosystem services: The effect of information on auction structure performance. Applied Economics & Statistics Research Report*, University of Delaware, RR16-05.

Ferraro, P. J. (2003). Assigning priority to environmental policy interventions in a heterogeneous world. *Journal of Policy Analysis and Management*, 22(1), 27–43.

Fischbacher, U. (2007). Z-tree: Zurich toolbox for ready-made economic experiments. *Experimental Economics*, 10(2), 171–178.

Fooks, J. R., Higgins, N., Messer, K. D., Duke, J. M., Hellerstein, D., & Lynch, L. (2016). Conserving spatially explicit benefits in ecosystem service markets: Experimental tests of network bonuses and spatial targeting. *American Journal of Agricultural Economics*, 98(2), 468–488.

Groeneveld, A., Peerlings, J. H., Bakker, M. M., Polman, N., & Heijman, W. J. (2019). Effects on participation and biodiversity of reforming the implementation of agri-environmental schemes in The Netherlands. *Ecological Complexity*, 40, 100726.

Hasler, B., Termansen, M., Nielsen, H. Ø., Daugbjerg, C., Wunder, S., & Latacz-Lohmann, U. (2022). European agri-environmental policy: Evolution, effectiveness, and challenges. *Review of Environmental Economics and Policy*, 16(1), 105–125.

Iftekhar, M. S., & Tisdell, J. (2014). Wildlife corridor market design: An experimental analysis of the impact of project selection criteria and bidding flexibility. *Ecological Economics*, 104, 50–60.

Kramer-Schadt, S., Kaiser, S. T., Frank, K., & Wiegand, T. (2011). Analyzing the effect of stepping stones on target patch colonisation in structured landscapes for Eurasian lynx. *Landscape Ecology*, 26, 501–513.

Krawczyk, M., Bartczak, A., Hanley, N., & Stenger, A. (2016). Buying spatially-coordinated ecosystem services: An experiment on the role of auction format and communication. *Ecological Economics*, 124, 36–48.

Kuhfuss, L., Préget, R., Thoyer, S., de Vries, F. P., & Hanley, N. (2022). Enhancing spatial coordination in payment for ecosystem services schemes with non-pecuniary preferences. *Ecological Economics*, 192, 107271.

Leventon, J., Schaal, T., Velten, S., Dänhardt, J., Fischer, J., Abson, D. J., & Newig, J. (2017). Collaboration or fragmentation? Biodiversity management through the common agricultural policy. *Land Use Policy*, 64, 1–12.

Liu, Z., Banerjee, S., Cason, T. N., Hanley, N., Liu, Q., Xu, J., & Kontoleon, A. (2023). *Spatially coordinated conservation auctions: a framed field experiment focusing on farmland wildlife conservation in China. Agricultural Economis Society (AES)*, Conference Paper, 334572.

Liu, Z., Xu, J., Yang, X., Tu, Q., Hanley, N., & Kontoleon, A. (2019). Performance of agglomeration bonuses in conservation auctions: Lessons from a framed field experiment. *Environmental and Resource Economics*, 73, 1–27.

Messer, K. D., Duke, J. M., & Lynch, L. (2014). Applying experiments to land economics: Public information and auction efficiency in ecosystem service markets. *The Oxford Hanbook of Land Economics*, Chapter 19, 481–510.

Messer, K. D., Duke, J. M., Lynch, L., & Li, T. (2017). When does public information undermine the efficiency of reverse auctions for the purchase of ecosystem services? *Ecological Economics*, 134, 212–226.

Moore, J., Balmford, A., Allnutt, T., & Burgess, N. (2004). Integrating costs into conservation planning across Africa. *Biological Conservation*, 117(3), 343–350.

Naidoo, R., Kilian, J., Du Preez, P., Beytell, P., Aschenborn, O., Taylor, R., & Stuart-Hill, G. (2018). Evaluating the effectiveness of local-and regional-scale wildlife corridors using quantitative metrics of functional connectivity. *Biological Conservation*, 217, 96–103.

Nguyen, C., Latacz-Lohmann, U., Hanley, N., Schilizzi, S., & Iftekhar, S. (2022). Spatial coordination incentives for landscape-scale environmental management: A systematic review. *Land Use Policy*, 114, 105936.

Parkhurst, G. M., & Shogren, J. F. (2007). Spatial incentives to coordinate contiguous habitat. *Ecological Economics*, 64(2), 344–355.

Parkhurst, G. M., & Shogren, J. F. (2008). Smart subsidies for conservation. *American Journal of Agricultural Economics*, 90(5), 1192–1200.

Parkhurst, G. M., Shogren, J. F., Bastian, C., Kivi, P., Donner, J., & Smith, R. B. (2002). Agglomeration bonus: An incentive mechanism to reunite fragmented habitat for biodiversity conservation. *Ecological Economics*, 41(2), 305–328.

Reeson, A. F., Rodriguez, L. C., Whitten, S. M., Williams, K., Nolles, K., Windle, J.,& Rolfe, J. (2011). Adapting auctions for the provision of ecosystem services at the landscape scale. *Ecological economics*, 70(9), 1621–1627.

Rolfe, J., McCosker, J., & Windle, J. (2008). Identifying the incentives that graziers in central-western Queensland need to manage land for conservation outcomes. *The Rangeland Journal*, 30(3), 297–303.

Rolfe, J., & Windle, J. (2006). *Using field experiments to explore the use of multiple bidding rounds in conservation auctions*. *Internationalal Association of Agricultural Economists*, Discussion Papers 25801.

Sarker, A., Ross, H., & Shrestha, K. K. (2008). A common-pool resource approach for water quality management: An Australian case study. *Ecological Economics*, 68(1–2), 461–471.

Shogren, J. F., List, J. A., & Hayes, D. J. (2000). Preference learning in consecutive experimental auctions. *American Journal of Agricultural Economics*, 82(4), 1016–1021.

Simpson, K. H., de Vries, F. P., Dallimer, M., Armsworth, P. R., & Hanley, N. (2022). Ecological and economic implications of alternative metrics in biodiversity offset markets. *Conservation Biology*, 36(5), e13906.

Smith, R. B., & Shogren, J. F. (2001). *Protecting species on private land. Protecting endangered species in the united states: Biological needs, political realities, and economic choices*. Cambridge University Press, pp 326–343.

Suresh, K. (2011). An overview of randomization techniques: An unbiased assessment of outcome in clinical research. *Journal of Human Reproductive Sciences*, 4(1), 8–11.

Thomson, J., Regan, T. J., Hollings, T., Amos, N., Geary, W. L., Parkes, D., Hauser, C. E., & White, M. (2020). Spatial conservation action planning in heterogeneous landscapes. *Biological Conservation*, 250, 108735.

Westerink, J., Melman, D. C., & Schrijver, R. A. (2015). Scale and self-governance in agri-environment schemes: Experiences with two alternative approaches in The Netherlands. *Journal of Environmental Planning and Management*, 58(8), 1490–1508.

Windle, J., Rolfe, J., McCosker, J., & Lingard, A. (2009). A conservation auction for landscape linkage in the southern desert uplands, Queensland. *The Rangeland Journal*, 31(1), 127–135.

Wünscher, T., Engel, S., & Wunder, S. (2008). Spatial targeting of payments for environmental services: A tool for boosting conservation benefits. *Ecological Economics*, 65(4), 822–833.

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Nguyen, C., Latacz-Lohmann, U. & Hanley, N. (2024) Landscape-level determinants of the performance of an agglomeration bonus in conservation auctions. *Journal of Agricultural Economics*, 00, 1–25. Available from: https://doi.org/10.1111/1477-9552.12576