Under what landscape configuration, does agglomeration bonus hold great potential for boosting landscape-scale environmental outcomes?

Abstract

Based on theoretical analyses, the Agglomeration Bonus (AB) has been advocated as a pecuniary incentive mechanism to effectively boost spatially coordinated conservation efforts. However, empirical evidence has remained scant, and the results are inconclusive. Specifically, our understanding of the performance of AB in conservation auction-based programmes across different contextual conditions is still limited. To fill in the gap, this paper employs a controlled lab experiment to investigate the performance of AB in budget-constrained discriminatory-price auctions across different landscape configurations. We set up a stylized agricultural landscape, where the conservation agency aimed to connect fragmented wildlife habitats. Spatial correlations between opportunity costs and environmental benefits are uncorrelated, negatively correlated, or positively correlated. We found that auction performance was sensitive to cost-benefit correlations. The benefits of AB in improving landscape-scale environmental outcomes became apparent in the positive landscape type. However, the AB resulted in worse outcomes in the uncorrelated or negative landscape types. Insights from the budget effect of bonus payment versus procurement payment could partly explain the variation in bonus performance. The results suggest that in the presence of a budget constraint, policy makers should consider adopting AB with great caution.

Key words: Conservation auctions, spatial correlation, spatial coordination, agglomeration, wildlife corridors

1. Introduction

Agri-Environmental Schemes (AES) have increasingly gained prominence in agri-environmental policy as a means to financially incentivize 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 (Kleijn, Rundlöf, Scheper, Smith, & Tscharntke, 2011; Pe'er et al., 2014). Recent AES-evaluation studies warn that despite the enormous public budget spending on AES over the past decades, AES have disproportionately generated environmental improvements and that the degradation of farmland biodiversity is still continuing at an alarming rate (Ait Sidhoum, Canessa, & Sauer, 2022; Cullen, Hynes, Ryan, & O'Donoghue, 2021; Pannell & Rogers, 2022). Attempts to understand the barriers to effective AES design and implementation are essential to reconcile agricultural production and nature conservation.

One of the main critiques against the design of conventional AES is that incentive mechanisms do not reward the contiguity of conserved farm lands (Emery & Franks, 2012; Groeneveld, Peerlings, Bakker, Polman, & Heijman, 2019; Westerink, Melman, & Schrijver, 2015). Farm-scale environmental targeting approach leads to individual and fragmented conservation actions. This inhibits AES from exploiting the full potential of environmental gains obtained by spatial coordination across landholdings. It is well-documented that the more fragmented the conserved habitats are, the less biological usefulness in sustaining wildlife populations (Naidoo et al., 2018; Wünscher, Engel, & Wunder, 2008). When spatial coordination of conservation efforts is a prerequisite for achieving environmental targets, such as for establishing wildlife corridors, failing to spatially target conservation actions at the landscape scale would likely result in a high risk of achieving low environmental outcomes (Leventon et al., 2017)

To overcome such spatial scale issue of AES design, landscape-scale oriented AES has been highlighted as the way forward for the next generation of AES (Franks, 2019; McKenzie, Emery, Franks, & Whittingham, 2013). Accordingly, economists have proposed two novel incentive mechanisms for achieving landscape-scale environmental outcomes. They include spatially-targeted conservation auctions and Agglomeration Bonus. The former ranks the bids according to environmental scoring rules which take into account the additional environmental benefits of spatial contiguity of conservation efforts (Banerjee, Kwasnica, & Shortle, 2015; Reeson et al., 2011). The latter is a pecuniary incentive for adjacent conserved farmlands.

The idea of Agglomeration Bonus was first introduced by Smith and Shogren (2001). Parkhurst et al. (2002) conducted the first experimental study demonstrating the potential effectiveness of AB in enhancing spatial coordination. Since then, there has been a burgeoning strain of the literature examining AB performance within auction mechanisms. Most of the works adopted experimental approaches. A systematic review of the driving factors affecting the performance of AB was provided by Nguyen, Latacz-Lohmann, Hanley, Schilizzi, and Iftekhar (2022). To date, the effect of AB on spatial coordination and auction cost-effectiveness have been the subject of debate. Liu et al. (2019) suggests that bidders were likely to 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 payment made to contiguous farm parcels. Low level of bonus capitalization in bids would likely erode AB performance (Banerjee, Cason, de Vries, & Hanley, 2019; Dijk, Ansink, & van Soest, 2017; Fooks et al., 2016). These findings are contrary to those of another stream of the literature, which suggests the improvements in spatial coordination and cost-effectiveness brought about by the AB (see e.g., Parkhurst et al. (2002); Parkhurst and Shogren (2007); Parkhurst and Shogren (2008); Banerjee, De Vries, Hanley, and van Soest (2014); and Kuhfuss, Préget, Thoyer, de Vries, and Hanley (2022)). The conflicting results about the performance of AB require more research to identify the conditions under which the positive or negative outcomes of AB are likely to occur.

The literature identifies the driving factors affecting the performance of AB, such as network size (Banerjee, Kwasnica, & Shortle, 2012), transaction costs (Banerjee, Cason, de Vries, & Hanley, 2017), type and amount information provided to bidders before bid submission (Banerjee et al., 2015), and spatial autocorrelation of the opportunity costs (Bareille, Zavalloni, & Viaggi, 2023). However, much less is known about how spatial correlations of opportunity costs and environmental values affect the performance of AB. Spatial distribution of these two contextual factors is often assumed to be uncorrelated in existing literature. Empirical evidence suggests that opportunity costs and environmental benefits could be either negatively correlated (i.e. the high-benefit parcels tend to be the low-cost parcels), or positively correlated (i.e. the low-benefit parcels tend to also be the low-cost parcels) (Babcock, Lakshminarayan, Wu, & Zilberman, 1996; Heimlich, 1989). For instance, the native forest protection program in the southern coast of Bahia in Brazil operated in the landscape where there was a strong negative correlation between forest cover and land value. This was because deforestation enabled land to be more accessible, thereby having higher values (Chomitz et al., 2006). Similarly, the state of Georgia ran an auction to compensate farmers who voluntarily stop irrigating their crops during times of drought. The parcels that experienced the greatest water use were also the low-cost parcels, reflecting the negative correlation between opportunity costs and environmental benefits (Ferraro, 2003). By contrast, Moore, Balmford, Allnutt, and Burgess (2004) found positive correlations between conservation costs and environmental benefits for ecoregion conservation across Africa. A positive correlation has also observed in endangered species recovery program in the US (Ferraro, 2003).

In the theoretical paper, Banerjee, Shortle, and Kwasnica (2009) demonstrated that the nature of spatial correlations of opportunity costs and environmental benefits (cost-benefit correlations) would affect the likelihood of achieving the desired spatial configuration of selected bids in spatially-targeted conservation auctions. In the following works, Lundberg, Persson, Alpizar, and Lindgren (2018) and Sharma, Cho, and Yu (2019) used agent-based simulation modelling indicated the significant impacts of cost-benefit correlations on the relative cost-effectiveness of the cost-ranked and cost-benefit-ranked discriminatory auctions. Note that both of these studies looked at the performance of non-spatially targeted auctions. However, as far as the authors are aware, to date, no empirical work has been conducted on the effect of cost-benefit correlations on auction performance.

Building upon the literature, this paper aims to systematically examine the effect of cost-benefit correlations on the performance of spatially-targeted and budget-constrained auctions with the inclusion of Agglomeration Bonus. We consider two types of Agglomeration Bonus: bonus for connected parcels within the farm (within-farm bonus) and bonus for connected parcels between neighbouring farms (between-farm bonus). We hypothesize that (1) The Agglomeration Bonus would promote more connected parcels to be offered, thereby induce 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; (3) The performance of AB in achieving spatial coordination and improving auction cost-effectiveness will vary depending on cost-benefit correlations.

We conducted a series of controlled lab experiments with agriculture students at Kiel University, Germany. Specifically, the students participated in a stylized discriminatory pricing conservation auction where the government, with a limited budget, selected offers of land retirement from six potential landholders to establish wildlife corridors and/or stepping stones. The offers were ranked based on the ratio of procurement costs and environmental values. The environmental scoring rule 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 Agglomeration Bonus (with and without bonus) in a stylized agricultural landscape. In the experiment, the subjects could communicate at a cost with their neighbors to negotiate/coordinate their conservation activities and bidding strategies. This mimics the private transaction costs incurred by landholders prior to bid submission in conservation auctions (Mettepenningen, Verspecht, & Van Huylenbroeck, 2009). To date, there have been no controlled studies allowing communication to be endogenously chosen by landholders. Our paper adds value to the experimental literature by allowing communication to be optional, which better reflects reality.

We found experimental support to the positive effect of Agglomeration Bonus in boosting willingness to coordinate contiguous habitats across landholders. However, the extent to which bidders capitalize the bonus in their bidding decisions varied across landscape types. The results support the adoption of AB in landscapes where opportunity costs and environmental benefits are positively correlated to enhance spatial coordination. However, the costs incurred by the AB payment were likely to weaken the positive effects of AB on cost-effectiveness in this landscape type. By contrast, the results warned against using AB in landscapes where opportunity costs and environmental benefits are uncorrelated or negatively correlated. Lessons learnt from this study would be a useful proof-of-concept for ongoing reform of AES.

The rest of this paper proceeds as follows. Section 2 describes landscape structure, auction design, and the metrics used to evaluate auction performance. Section 3 sets out the experimental procedures. Section 4 presents the results. Discussion and Concluding remarks for the adoption of AB are discussed in Section 5.

2. Landscape structure and conservation auction design

Landscape structure and environmental management goal

We set up a stylized agricultural landscape with six landholders each owning six parcels of land, for example landholder ID1 owns parcels 1-6 (see Figure 1). Suppose we have two habitats, namely A and B (black areas), which are separated from each other by intensively used agricultural land owned by the six landholders. The landscape in Figure 1 is made visible to all landholders. The government aims to reduce the fragmentation between the two habitats A and B by establishing corridors and stepping stones that enable wildlife migration between the two habitats. A corridor is formed only when four parcels are connected horizontally. Conversely, stepping stones are formed when a single parcel 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, while 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].

[Figure 1 here]

The government formalizes its management goal of improving the connectiviy between the two habitats by computing Total Environmental Value (TEV_j) generated by the *j*th corridor/stepping stone as follows:

$$TEV_j = \sum_{i=1}^{n_j} EV_i + (n_j - 1)^2 * K \qquad (1)$$

Where EV_i denotes environmental value of parcel *i*, and n_j represents the number of horizontally connected parcels that are set aside for conservation in the *j*th corridor/stepping stone. *K* is a constant increment in environmental value that is obtained due to spatial

[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, Haynes, Dillemuth, & Cronin, 2004; Kramer-Schadt, S Kaiser, Frank, & Wiegand, 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. While stepping stones are unable to allow the movement of some species as corridors, such as land mammals and crawling insects, they facilitate the movement of other species, such as birds and flying insects. Ecological benefit of corridor is therefore greater than that of 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 than revealing the parcels' absolute EVs.

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, $(n_j - 1)^2 * K$ represents "*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:

$$TEV = \sum_{j=1}^{m} TEV_j \quad (2)$$

Where m is the number of corridors/stepping stones obtained from a conservation program.

Auction design

We employed the format of a multiple-round, discriminatory-price auction with a budget constraint and unknown end-points[3]. Six rounds of auctions were run. However, landholders were only informed that they will participate in a multiple-round auction, in which one of the rounds will be randomly chosen for payment. Multiple-round auctions facilitate landholders to identify connectivity between farms and learn how to bids (Krawczyk, Bartczak, Hanley, & Stenger, 2016). The OC and EV values associated with each plot were the same for all 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. The specified total budget (B=1500) was unknown to landholders. However, they were informed that not all bids can be accommodated within the budget[5].

Details of the environmental objective function (1) were not revealed to the landholders (Banerjee et al., 2015). The landholders were unware of the existence of ecological gain from

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[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, List, & Hayes, 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)

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

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

spatial coordination in the selection process of winning bids. They were simply 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. They incurred a submission fee of 10 Experimental Dollars for each offered parcel. This reflects transaction costs for preparing and submitting bids. The submission fee would prevent the subjects from offering parcels with a lower probability of being chosen (Messer et al., 2017). Landholders were informed that a benefit-cost ratio (BCR) is used to select successful bidders[6].

The government's optimization problem entails selecting corridors/stepping stones that generate the highest environmental value per dollar spent (i.e., max BCR_j)) until the budget (B) was exhausted.

$$Max_{j \in M}\ BCR_j = \frac{TEV_j}{\sum_{i=1}^{n_j} bid_i + within\_farm\_AB_j + between\_farm\_AB_j}$$

$$TEV_j = \sum_{i=1}^{n_j} EV_i + (n_j - 1)^2 * K$$

$$within\_farm\_AB_j = \alpha * k_j \ \ (0 \le k_j \le 2) \qquad (3)$$

$$between\_farm\_AB_j = \beta * l_j \ \ (l_j = 0,1) \qquad (4)$$

$$s.t. \sum_{j \in M} (\sum_{i=1}^{n_j} bid_i + \alpha * k_j + \beta * l_j) \le B$$

where i is a parcel ith 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 neighboring farms[7]. 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

[6] Fooks et al (2016) also examined the performance of Agglomeration Bonus in the spatially-targeted and budget-constrained auctions where the spatial correlation between opportunity costs and environmental values are uncorrelated. However, in their study, environmental benefit values are homogenous across parcels and bids were ranked based on total environmental benefit, rather than benefit-cost ratio.

[7] For a corridor, k_j and l_j are equal to 2 and 1, respectively. For a three-parcel stepping stones, 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.

the between-farm bonus payment amount for the *j*th corridor/stepping stone (*between_farm_AB*$_j$). The cost of buying the *j*th corridor/stepping stone comprises of two components: the bid payment (i.e., the procurement payment $\sum_{i=1}^{n_j} bid_i$) and the bonus payment (within-farm bonus payment and between-farm bonus payment).

In the treatments without Agglomeration Bonus, the bonus payment is zero (α and β were set at 0) and the landholders were paid their bid price. In the treatments with the Agglomeration Bonus, the landholders could receive a within-farm bonus of 30 Experimental Dollars for each horizontal connection within their farm that was selected by the government (α =30). They could also earn a between-farm bonus of 40 Experimental Dollars for each horizontal connection between their farm and their neighbouring farm that was selected by the government (β=40)[8]. In all treatments, the landholders were told that if their offered parcels are not selected, they will receive the payments, which are equal to their parcels' production values (opportunity costs). 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.

To evaluate and compare auction performance across different treatments, we use the performance metrics as shown in Table 1.

[Table 1 here]

3. Experimental procedures

The lab experiments were conducted with 180 students at Kiel University, Germany from November 2021 to March 2022 via Ztree-Unleashed (Duch, Grossmann, & Lauer, 2020; Fischbacher, 2007). The experiments were framed in the context of agricultural landscape where two habitats are fragmented from each other due to agricultural intensification on privately-owned land[9]. Specifically, the students participated in a stylized conservation auction,

[8] 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 are about 34% and 45% of the average opportunity costs.

[9] Using context-free approach is commonly considered as a way to achieve experimental control. However, the literature also suggests that neutral instructions are still subject to construal in which people might interpret the instructions in subjective ways (Voors, Turley, Kontoleon, Bulte, & List, 2012). By contrast, contextualized experiments, which provides more realistic (life-like) situation would help improve people's understanding and reduce confusion about instructions, especially in the

a lottery game, and a questionnaire survey. They were randomly assigned into six treatment groups (see Table 2).

[Table 2 here]

Each treatment consisted of five sessions with six subjects per session (i.e., 30 subjects per treatment)[10]. Before the sessions started, we presented the experimental instructions to the subjects via Zoom (see **Appendix A.1.** for the details of the experimental instructions). The students received their earnings in the form of cash payments. The experiments followed a three-by-two design varying by: (i) spatial correlation of opportunity costs and environmental values (uncorrelated, positive, and negative) and (ii) Agglomeration Bonus (with and without agglomeration bonus). The between-subject design allowed us to avoid the confounds caused by order effects across the treatments.

The degree of correlation between opportunity costs and environmental 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 type, and zero for the uncorrelated landscape. 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 bidding stage in each round. However, communication was costly (15 Experimental Dollars per neighbor contacted). Given the landscape set-up shown in Figure 1, each subject had either one or two direct neighbors with whom they could communicate to coordinate their offers. Direct neighbours are those whose parcels are horizontally adjacent to each other. For instance, subject ID1 has one direct neighbour that is subject ID4, while subject ID4 has two direct neighbours including subject ID1 and subject ID2. Communication was conducted via a chat room with a limited time duration of 3 minutes 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. A summary of the auction procedure is presented in Figure 2.

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relatively complex experimental design (Krawczyk et al., 2016). This would help people make their choices more consistent and strategic. By reviewing the evidence from the literature, Alekseev, Charness, and Gneezy (2017) found that contextualized experiments are either useful or produce no change in behaviour and that contextualized experiments increase external validity of the results in coordination games and common-pool public good games.

[10] 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 markup rate ($\frac{\sum bids}{\sum OCs}$) from the treatments. The sample size was determined via sample size calculation given by Canavari, Drichoutis, Lusk, and Nayga Jr (2019) to ensure 80% chance of correctly rejecting the null hypothesis (i.e. a power (1-β) = 0.8).

[Figure 2 here]

4. Experimental Results

This section presents the key findings on the interplay effect between the agglomeration bonus (AB) and the spatial correlations of OCs and EVs on auction performance. The data was analyzed at the auction level, individual bidder level, and parcel level.

It can be seen from the summary statistics in Table 3, in the absence of AB, the average submitted bid value per round for the positive landscape type was the highest ($116.519), while those of the uncorrelated and negative landscape types were $113.671, and $104.474, respectively. However, when AB was present, bidders were likely to bid less aggressively in the positive landscape. We also observed a similar pattern on the average accepted bid value per round in the presence of an AB. Each bidder offered an average of 4.027 out of 6 parcels and about 2.352 parcels were selected, approximately 59.51% of offered parcels. Furthermore, in the presence of an AB, we found an increased number of offered parcels per bidder per round across three landscape types. However, it is worth noting that although AB promoted more offered parcels, AB lowered number of selected parcels. On average, nine connected parcels were selected in each round. Depending on the nature of the cost-benefit correlation, AB affects the degree of spatial coordination differently. Specifically, a reduced spatial coordination was reported in the uncorrelated and negative landscape types, while an increased spatial coordination was observed in the positive landscape types.

[Table 3 here]

In order to further examine if the effects of AB on auction performance were statistically significant and how spatial configuration of offered/selected parcels would change in the presence of AB, we conducted Mann-Whitney U tests using the auction-level data (see Table 4). As shown in Table 4, AB led to a significant increase in participation rate at 10% significance level. By closely examining the spatial configuration of offered parcels, we found that AB promoted a greater number of corridors and three-parcel stepping stones offered. Bidders significantly lowered their bids on the offered parcels (i.e., reducing from 1.425 to 1.238) in the expectation of earning the bonus. These findings are consistent with those of Liu et al (2019). However, we found AB reduced spatial coordination at 5% significant level (P-value = 0.045). AB also reduced auction cost-effectiveness from 2.938 to 2.552. This is partly because the presence of AB promoted participation rate, but it significantly reduced the selection rate at 10% significance level (P-value = 0.054). 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 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.

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 AB was introduced and incorporated into the payment mechanism, the mark-up rate on the selected parcels was significantly higher, increasing from 1.428 to 1.495. This reveals that bidders did not substantially include the bonus as part of their bid formulation with a significant rent reduction to enhance their bids' competitiveness in tendering. The presence of bonus payment has correspondingly tightened the remaining budget for conservation procurement. However, rent reduction was relatively lower than the bonus payment paid to adjacent conserved parcels. As a result, AB reduced selection rate from 64.2% to 59.4% at 10 % significance level (P=0.054). Spatial configuration of selected parcels depends not only on spatial configuration of offered parcels but also the extent to which landholders lower their bids in budget-constrained auctions.

[Table 4 here]

Table 5 shows the results of the 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, and cost-effectiveness were regressed on the following: the number of rounds, the availability of bonus, two dummies regarding landscape type (NEGATIVE LANDCAPE and POSITIVE LANDSCAPE in which the uncorrelated landscape type was chosen as a baseline), and the interaction between landscape types and Agglomeration Bonus. The negative and significant coefficient associated with the variable AGGLOMERATION BONUS in the regression of mark-up revealed that the bonus significantly attenuated rent-seeking behaviour. However, we also found a negative but insignificant coefficient associated with AGGLOMERATION BONUS in the regression of spatial coordination. This reflects a counter effect of agglomeration bonus on the degree of spatial coordination, although such an effect was not robust.

When it comes to the effect of landscape type, we observe a significant reduction in mark-ups on the offered parcels in the positive landscape relative to the uncorrelated landscape at 10% significance level (P-value = 0.094) when AB was present. Landscape type was found to be a driving factor that caused the variation in spatial coordination. Particularly, in the regression of spatial coordination, the negative and significant coefficient associated with the variable NEGATIVE LANDSCAPE suggests that spatial coordination could be better achieved in the uncorrelated landscape than in the negative landscape. By contrast, the positive and significant coefficient associated with the variable POSITIVE LANDSCAPE at 5% significant level (P-value = 0.03) revealed that the positive landscape was likely to generate higher degree of spatial coordination than the uncorrelated landscape. Interestingly, when we interact NEGATIVE LANDSCAPE with AGGLOMERATION BONUS, we found that the associated coefficient was positive and insignificant. This suggests that in the presence of AB, the degrees of spatial coordination became non-significant difference between the uncorrelated and negative landscape types. Conversely, the positive and significant coefficient associated with the interaction between POSITIVE LANDSCAPE and AGGLOMERATION BONUS reveals that the presence of AB significantly increases spatial coordination in the positive landscape type, relative to the uncorrelated landscape type.

The results derived from the regression of cost-effectiveness with the presence/absence of AB indicate that the coefficient associated with AGGLOMERATION BONUS is negative and significant at 1% significance level (P-value = 0.001). AB significantly reduces auction cost-effectiveness. However, when we interact AGGLOMERATION BONUS with POSITIVE LANDSCAPE, we observe a positive sign of the associated coefficient. This suggests that the presence of an AB results in a more cost-effective auction in the positive landscape than in the uncorrelated landscape. Conversely, the presence of AB did not significantly affect the differences in cost-effectiveness between the negative and uncorrelated landscapes (P-value = 0.348)

[Table 5 here]

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 6). The results suggest that AB reduced the markup rates on the offered parcels by 27% (from 40.8% to 12.9%) in the positive landscape, while only by 13.9% (from 39.7% to 25.8%) and

14.2% (from 47% to 32.8%) in the uncorrelated and negative landscapes, respectively. When the bonus payment was taken account as a part of the final payment on the selected parcels, the results show that the markups on the selected parcels increased by 17.2% in the uncorrelated and by 8.4% in the positive landscape type at 1% significance level. By contrast, no statistically significant difference in the mark-ups on the selected parcels was found in the negative landscape type when AB was present (P-value = 0.944). The results revealed that the bonus payment effect on bidding behaviour varied across landscape types.

[Table 6 here]

Table 6 reports that the AB did not have any significant effect on participation rates across the three landscape types. AB reduced the selection rate in the uncorrelated and positive landscapes, although the effects were not salient. Conversely, the negative effect of AB on the selection rate was significant in the negative landscape at 5% significance level (P-value = 0.013). AB increased, decreased, and had no effect on spatial coordination in the positive, uncorrelated, and negative landscapes, respectively. In the presence of AB, the auction cost-effectiveness deteriorated in the uncorrelated and negative landscape types. By contrast, no effect of AB on auction cost-effectiveness was found in the positive landscape type.

Table 7 shows that the presence of AB attracted high quality offers (more contiguous conserved habitats)[11]. The number of offered corridors increased sharply in the positive landscape type at 1% significance level (P-value = 0.000). Similarly, a significant increase in the number of offered three-parcel stepping stones was observed in the negative landscape type at 1% significance level (P-value = 0.005). As a result, the government procured more corridors in the positive landscape. However, except for a slight increase in two-parcel stepping stones, AB did not affect spatial configuration of selected parcels in the negative landscape. We found that AB reduced the number of selected corridors in the uncorrelated landscape.

[Table 7 here]

[11] In our experiment, offering interior parcels located in Zones 2&3 could help bidders earn the between-farm bonus, while contributing to an increased number of offered corridors or three-parcel stepping stones to the government. We employed a random effects probit model to test if the probability of offering the interior parcels would increase when AB was introduced (see **Appendix A.2.**). The results show that the coefficient associated with ENVIRONMENTAL ZONES (Dummy variable, which equals 1 if parcels located in Zones 1&4 (exterior parcels), otherwise it equals 0) was found to be positive and significant at 1% significance level (P-value = 0.000). 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 agglomeration bonus was likely to increase the probability of offering interior parcels, which is needed for enhancing conservation connectivity between farms.

Interior parcels (located in Zones 2 & 3) have a chance to receive both within-farm and between-farm bonuses, whereas exterior parcels (located in Zones 1 & 4) could obtain only within-farm bonus. In other words, the location will determine the potential maximum amount of bonus payment at parcel level. We computed the ratio of the differences in average bid per parcel between non-AB and AB treatments and the maximum amount of bonus payment at parcel level (See Table 8). This gives an indication of the extent to which bidders adjust their bid shading relative to the bonus payment when they were informed of the presence of AB. On average, bidders reduced their bids by approximately 18.93% and 14.94 % of the maximum bonus payment on the interior and exterior parcels, respectively. We found that bonus capitalization in the bids was at the highest level in the positive landscapes (i.e., 34.66% on the interior parcels and 52.19% on the exterior parcels). This is followed by the degree of bonus capitalization in the uncorrelated landscape (i.e., 17.17% on the interior parcels and 20.99% on the exterior parcels). By contrast, a very small degree of bonus was found to be capitalized in the bids on the interior parcels in the negative landscape (2.87%). Additionally, we observed aggressive rent-seeking behaviour on the exterior parcels in the negative landscape. AB did not reduce rents on the exterior parcels in the negative landscape type, which are also likely to be the low-OC and high-EV ones in this landscape type.

[Table 8 here]

Since bidders did not substantially capture the bonus in their bids, we are interested in examining if collusive bidding exists in the presence of AB. A random effects regression model was employed in which observations were clustered at individual bidder level (see Table 9). We particularly looked at the effect of communication frequency of individual bidders and its interaction with agglomeration bonus on mark-up rate on the offered parcels. Table 9 shows that the coefficient associated with AGGLOMERATION BONUS is negative and significant at 1% significance level. This suggests that AB significantly mitigate rent-seeking behaviour. However, when AGGLOMERATION BONUS was interacted with COMMUNICATION, the associated coefficient became non-significant. It signals that when bidders communicated with each other more frequently, the effect of AB in mitigating aggressive bidding was no longer salient. There might be a possibility that communication facilitates collusion, which in turn partly keeps bid shading at a relatively high level. These findings further support those of Krawczyk et al. (2016) and Fooks et al. (2016), suggesting that communication encourages collusion, thereby accelerating rent-seeking rates. The positive and non-significant coefficient associated with ROUND indicates that markup rates tend to increase over time. However, our results did not strongly support the existence of the learning effect. The significant coefficients associated with NEGATIVE LANDSCAPE and POSITIVE LANDSCAPE suggest significant differences in markup rates between landscape types. However, these differences tend to be attenuated in the presence of an AB as the coefficients associated with the interactions between landscape type and agglomeration bonus became non-significant. We did not find the significant effect of number of direct neighbours, number of neighbouring parcels selected in the previous round, own farm's section rate in the previous round, and risk attitude[12] on markup rates.

[Table 9 here]

5. Discussion and concluding remarks

Agglomeration Bonus (AB) is explicitly designed to reward spatial coordination of conservation efforts among landholders. To date, the real-world applications of AB are rare, and the effectiveness of AB is still ongoing debate (Nguyen et al., 2022). The experimental literature suggests that AB is not a panacea mechanism for achieving desirable spatial patterns of conservation habitats. 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 AB. Particularly, using a systematic laboratory-experimental approach, the aim of this paper is to examine the effect of spatial correlations of opportunity costs and environmental benefits (positive, negative, no correlation) on AB performance in budget-constrained and spatially-targeted auctions. We set up a stylized agricultural landscape where the environmental goal is to establish corridors and/or stepping stones to facilitate the movement of wildlife species.

First, AB significantly mitigated rent-seeking and effectively promoted willingness to coordinate among landholders. We found an improved spatial configuration of offered parcels. Unfortunately, AB reduced the selection rate. Contrary to expectations, an improved spatial configuration of offered parcels did not lead to an improved spatial configuration of selected parcels. AB decreased the degree of spatial coordination. The likely cause for these results is

[12] We ran lottery-based experiments using the Eckel and Grossman method (Eckel & Grossman, 2002). The subjects were presented with 6 gambles and asked to select one that they would like to play. One of the gambles involves a certain payoff, while the other five gambles involve the expected payoff that increases linearly with risk. The subjects are incentivized with the real payment if they win in the lottery game.

that with a fixed total budget, the increased AB payment also means a shrinking budget for conservation procurement. This budget tightening did not enhance bidding competitiveness. We found that although the bonus was captured in the bids, the extent to which bidders capitalize the bonus in their bids was modest. We did not find supportive evidence that AB could improve auction cost-effectiveness. These findings differs from the previous research suggesting that a reduced procurement budget could potentially improve auction competitiveness, thus cost-effectiveness by mitigating rent-seeking rates (Duke, Messer, Lynch, & Li, 2016; Messer et al., 2017). However, it is worth noting that the information about the budget allocation between procurement and bonus payments was not highlighted to the subjects in our experimental design. This could partly explain why the presence of AB did not substantially enhance competitiveness among bidders. Our results alerted the likelihood of collusive bidding among landholders. Future work should be undertaken to examine whether conveying the information about the fixed total budget which will be allocated between the two sub-budgets (i.e., procurement and bonus) could foster more competitive bidding among landholders and boost a higher degree of coordination. Another possible reason for the modest level of bonus capitalization in the bids could be that the interdependencies between neighbouring landholders' bidding decisions might give rise to uncertainty on the chance of obtaining the bonus (Grout, 2009). Therefore, landholders still significantly elevate their bids above their true opportunity costs to secure rent premiums (23.8%).

Second, when the participation rate was examined closely in each landscape type, we found that AB did not induce a higher participation rate. However, 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 AB reduced the selection rate in all landscape types. Especially, the reduction in selection rate was statistically significant in the negative landscape. Our results suggest that an improved spatial configuration of offered parcels does not necessarily guarantee that AB would improve the spatial configuration of selected parcels. 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 capitalized 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 remains 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 capitalized about 34.66% 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 the 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), which 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 landscape type, although the budget effect of the bonus could result in no improvement in cost-effectiveness. Adopting a spatial agent-based simulation, Drechsler and Grimm (2022) suggest 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 permeance of conservation coordination among landholders. This would achieve cost-effectiveness in the long term than to offer a small bonus throughout the contract. A future experimental study could further test if the positive effect of AB on spatial coordination is still maintained, while improving auction cost-effectiveness in the positive landscape type if we reduce the bonus size in the long-term. The findings of our study may be an artefact of the experimental design. Therefore, external validity of the results should be further tested with real farmers.

In sum, this paper provides fresh insights into the important role of the spatial correlation of opportunity costs and environmental values in determining the likelihood that AB succeeds/fails in achieving spatial coordination. Given stringent budget constraints, AB would be likely do more harm than good on spatial coordination in the landscapes where opportunity costs and environmental values are uncorrelated and negative. However, the adoption of AB would be highly recommended to achieve desirable spatial configuration of conservation habitats in the positive landscape type. These findings would be useful to inform refinements in the design of agri-environmental schemes for better landscape-scale environmental outcomes.

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TABLES

Table 1: Conservation auction performance criteria

Criteria	Definition	Formula
1. Mark-up rate		
Mark-up rate on the offered parcels	The ratio of sum of submitted bids and opportunity costs	$\frac{\sum submitted\ bids}{\sum OCs}$
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	$\frac{\sum (selected\ bids + bonus)}{\sum OCs}$
2. Participation rate	The percentage of eligible parcels offered in the conservation program	$\frac{Number\ of\ offered\ parcels}{Number\ of\ eligible\ parcels}$
3. Spatial configuration of offered parcels	Pattern of offered parcels in the conservation program	• 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 program	$\frac{Number\ of\ selected\ parcels}{Number\ of\ offered\ parcels}$
5. Spatial configuration of selected parcels	Pattern of selected parcels in the conservation program	• 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	$\frac{\sum TEV}{\sum winners'bids + bonus}$

Table 2: 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)

Table 3: 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	107.035 (36.232)	113.671 (39.030)	104.474 (33.097)	116.519 (42.411)	104.367 (30.969)	107.835 (39.981)	96.014 (25.895)
Average accepted bid value per round	97.850 (29-193)	103.8 (28.837)	93.857 (29.653)	111.359 (29.099)	96.463 (28.568)	93.155 (28.722)	89.530 (24.411)
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 (1.360)	3.986 (1.443)	3.78 (1.152)	3.856 (1.334)	4.017 (1.404)	4.072 (1.210)	4.372 (1.506)
Average number of selected parcels per bidder per round	2.352 (1.323)	2.432 (1.517)	2.547 (1.040)	2.260 (1.271)	2.267 (1.409)	2.444 (1.084)	2.194 (1.510)
Average number of selected and connected parcels	9 (3.109)	10.433 (1.906)	6.633 (3.124)	11.233 (1.716)	8.267 (1.721)	5.6 (2.127)	11.833 (1.392)

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

Table 4: Auction-level treatment effects of the agglomeration bonus

		Without AB	With AB	Mann-Whitney test results: Prob > |z|
Participation rate		0.626	0.658	0.092*
		(0.101)	(0.098)	
Spatial configuration of offered parcels				
	Corridors	3.067	3.678	0.002***
		(1.279)	(1.293)	
	Three-parcel stepping stones	0.356	0.589	0.024**
		(0.567)	(0.726)	
	Two-parcel stepping stones	2.578	2.411	0.133
		(1.406)	(1.591)	
	Single parcel	4.033	2.389	0.000***
		(2.372)	(2.023)	
Selection rate		0.642	0.596	0.054*
		(0.121)	(0.104)	
Spatial configuration of selected parcels				
	Corridors	2.122	1.889	0.061*
		(0.805)	(0.847)	
	Three-parcel stepping stones	0.167	0.011	0.000***
		(0.404)	(0.105)	
	Two-parcel stepping stones	0.222	0.489	0.032**
		(0.418)	(0.797)	
	Single parcel	4.689	5.278	0.359
		(3.527)	(3.663)	
Mark-up rate on the offered parcels		1.425	1.238	0.000***
		(0.185)	(0.189)	
Mark-up rate on the selected parcels		1.428	1.495	0.004***
		(0.199)	(0.218)	
Spatial coordination		9.433	8.567	0.045**
		(3.065)	(3.043)	
Cost-effectiveness		2.938	2.552	0.000***
		(0.388)	(0.309)	

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

Table 5: Parameters estimates for random effects regression on auction performance (at auction-level)

	Mark-up on the offered parcels			Spatial coordination			Cost-effectiveness		
	Coeff	Robust Std. Err.	P-value	Coeff	Robust Std. Err.	P-value	Coeff	Robust Std. Err.	P-value
Round	-0.007	0.011	0.511	0.019	0.185	0.185	0.019	0.020	0.355
Agglomeration Bonus	-0.211***	0.064	0.001	-0.022	0.045	0.628	-0.269***	0.079	0.001
Negative landscape	0.072	0.073	0.328	-0.323***	0.055	0.000	-0.108	0.108	0.321
Positive landscape	-0.059	0.042	0.162	0.218***	0.043	0.000	0.184**	0.085	0.030
Negative landscape x Agglomeration Bonus	-0.004	0.146	0.979	0.299	0.109	0.299	0.204	0.217	0.348
Positive landscape x Agglomeration Bonus	-0.140*	0.084	0.094	0.001***	0.086	0.001	0.495***	0.169	0.004
Constant	1.458	0.068	0.000	0.000***	0.000	0.000	2.789***	0.097	0.000
Wald Chi^2	106.71			447.31			68.69		

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

Table 6: Effect of Agglomeration Bonus on auction performance across different types of landscape (at auction level)

	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
1. Mark-up rate									
Mark-up rate on the offered parcels	1.397 (0.161)	1.258 (0.119)	1.470 (0.183)	1.328 (0.268)	1.408 (0.206)	1.129 (0.078)	0.000***	0.023**	0.000***
Mark-up rate on the selected parcels	1.338 (0.114)	1.510 (0.136)	1.587 (0.240)	1.533 (0.339)	1.359 (0.109)	1.443 (0.089)	0.000***	0.944	0.001***
2. Participation rate	0.626 (0.110)	0.657 (0.086)	0.640 (0.116)	0.675 (0.093)	0.611 (0.073)	0.642 (0.115)	0.364	0.281	0.649
3. Selection rate	0.645 (0.153)	0.581 (0.103)	0.688 (0.114)	0.614 (0.093)	0.594 (0.064)	0.593 (0.114)	0.157	0.013**	0.548
4. Spatial coordination	10.433 (1.906)	8.267 (1.721)	6.633 (3.124)	5.6 (0.388)	11.233 (1.716)	11.833 (1.813)	0.000***	0.225	0.096*
5. Cost-effectiveness	3.029 (0.368)	2.411 (0.248)	2.819 (0.463)	2.405 (0.285)	2.966 (0.297)	2.842 (0.209)	0.000***	0.000***	0.133

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

Table 7: 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 (1.094)	3.3 (1.557)	3.167 (1.704)	3.533 (1.106)	2.93 (0.944)	4.2 (0.980)	0.541	0.570	0.000***
Three-plot stepping stones	0.5 (0.682)	0.667 (0.922)	0.133 (0.434)	0.467 (0.571)	0.433 (0.504)	0.633 (0.626)	0.667	0.005***	0.219
Two-plot stepping stones	2.3 (1.685)	3.033 (1.884)	2.233 (1.304)	2.267 (1.660)	3.2 (0.961)	1.933 (0.860)	0.178	0.771	0.000***
Single parcels	4.033 (1.903)	2.4 (1.652)	5.5 (2.432)	4.233 (1.633)	2.567 (1.813)	0.533 (0.837)	0.008***	0.024**	0.000***
Spatial configuration of selected parcels									
Corridors	2.4 (0.563)	1.7 (0.651)	1.5 (0.900)	1.167 (0.592)	2.467 (0.507)	2.8 (0.479)	0.000***	0.116	0.015**
Three-plot stepping stones	0.1 (0.305)	0 (0.000)	0.1 (0.305)	0 (0.000)	0.3 (0.535)	0.033 (0.183)	0.237	0.237	0.023**
Two-plot stepping stones	0.267 (0.450)	0.733 (1.015)	0.167 (0.379)	0.467 (0.681)	0.233 (0.430)	0.267 (0.606)	0.087*	0.069*	1.000
Single parcels	3.567 (1.569)	5.267 (2.288)	8.767 (2.635)	9.067 (2.477)	1.733 (1.112)	1.5 (1.921)	0.003***	0.769	0.177

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

Table 8: Level of bonus capitalization in the bids on the parcels located at different environmental zones

	Low-EV zones			High-EV zones		
	Average bid per parcel		Bonus capitalization (%)	Average bid per parcel		Bonus capitalization (%)
	No bonus	Bonus		No bonus	Bonus	
Uncorrelated landscape	107.00	94.983	17.17	119.82	113.52	20.99
Negative landscape	117.38	115.37	2.87	96.09	101.98	-19.63
Positive landscape	105.81	81.55	34.66	127.14	111.48	52.19
All landscapes	109.60	96.35	18.93	113.09	108.61	14.94

Table 9: Parameters estimates for random effects regression on the mark-up rate at individual bidder level

	Coefficient	**Robust Std.Err**	**P-value**
Round	0.007	1.17	0.241
Agglomeration Bonus (1= Yes; 0 = No)	-0.188***	0.061	0.002
Negative landscape	0.099*	0.056	0.076
Positive landscape	-0.062*	-1.77	0.076
Negative landscape x Agglomeration Bonus	-0.074	0.115	0.518
Positive landscape x Agglomeration Bonus	-0.045	0.069	0.522
Communication	0.011	0.014	0.430
Communication x Agglomeration Bonus	-0.023	0.027	0.380
Number of direct neighbors	0.011	0.044	0.804
Number of neighboring parcels selected in the previous round	-0.003	0.007	0.662
Own farm's selection rate in the previous round	-0.039	0.033	0.248
Risk	0.003	0.011	0.805
Constant	1.438***	0.088	0.000
Wald Chi^2	49.53 Prob > Chi^2 = 0.000		
Obs	888		

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

FIGURES

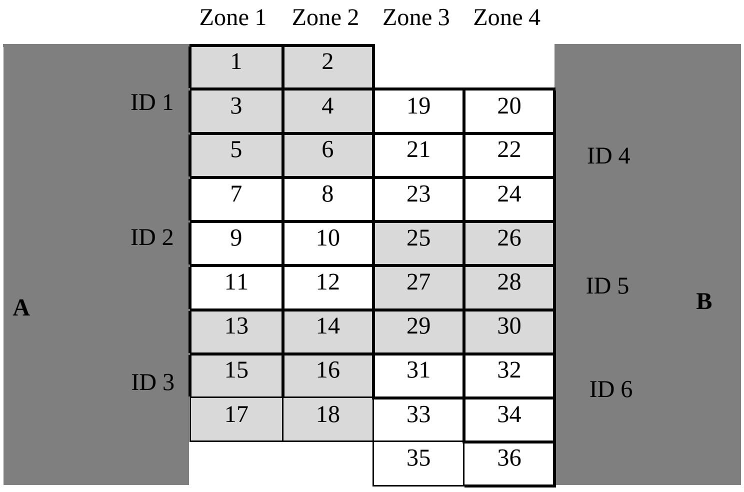


Figure 1: Stylized agricultural landscape set-up

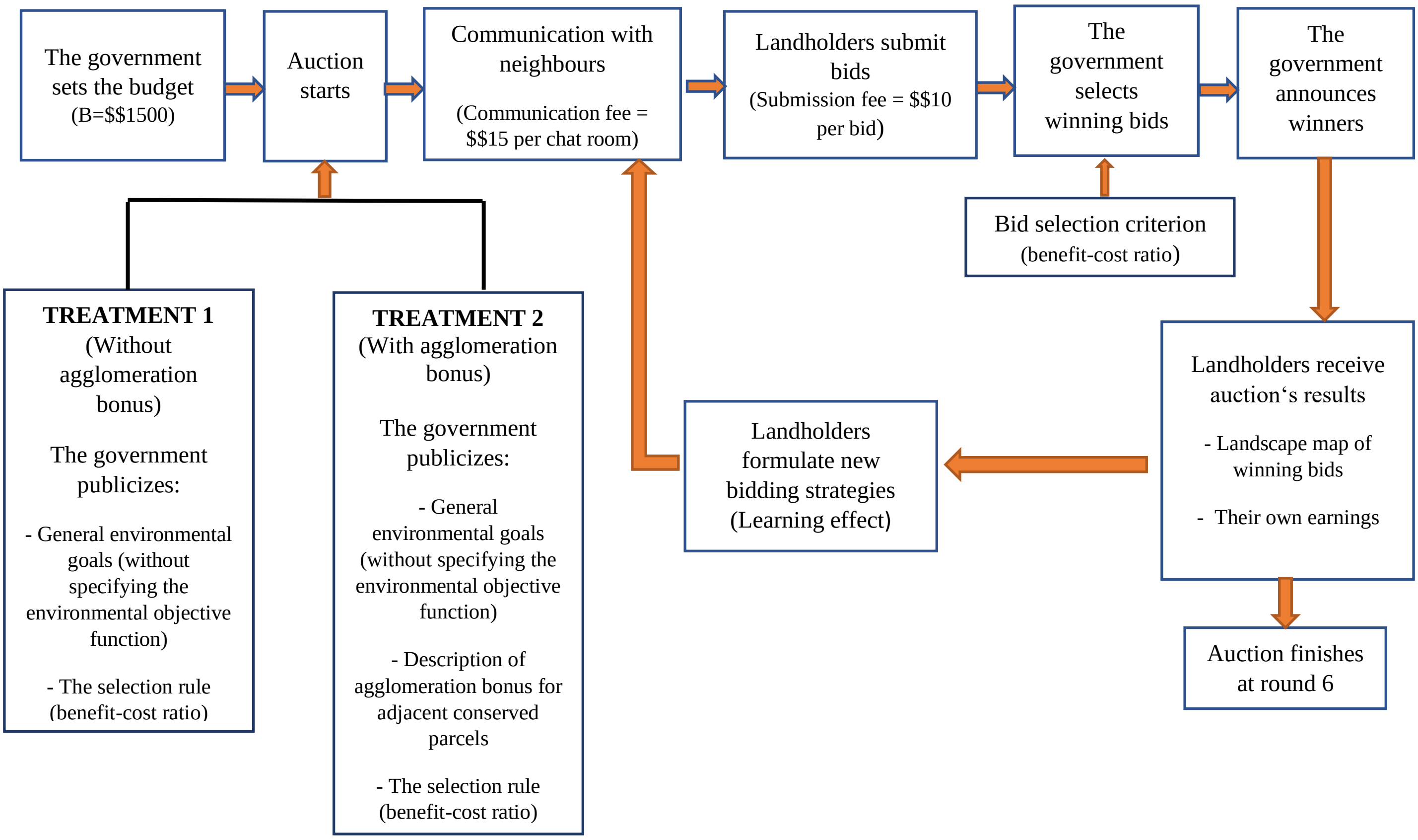


Figure 2: The procedure of the auctions

APPENDIX

"Assessing the performance of agglomeration bonus in budget-constrained conservation auctions"

Appendix A.1. Experimental instructions

General information

Thank you for your interest in our experiment! It is an experiment about economic decision making. In addition to a €10 show up fee, you will be able to earn Experimental Dollars during the experiment, which will be described to you in a moment. At the end of the experiment, experimental dollars will be converted to Euro at the rate of 1 Euro for 20 Experimental Dollars. The experiment will take up to 120 minutes and consists of three tasks:

- Task 1: Lottery Choice
- Task 2: Conservation Auction
- Task 3: Survey

You need to complete all three tasks for our results to be valid, and to receive your payment. There will be separate instructions for each task. If you read the instructions carefully, you can earn a significant amount of money. Your earnings will depend on your decisions and the decisions of others, and will be paid to you privately in cash at the end of the experiment.

During the experiment, any kind of communication between you and other participants is not permitted. Participants intentionally violating the rules may be asked to leave the experiment and may not be paid. Your subject ID will be privately provided via the Zoom chat box. It is critical that you enter your subject ID correctly. We will check whether you have entered your subject ID correctly before commencing the tasks.

During the experiment, you will be asked to make many decisions. Often everyone must click OK/CONTINUE before the task can continue. There is no need to rush your decisions/review of results. However, be aware that other participants may have to wait for you if you regularly forget to click OK and wait for the time-out.

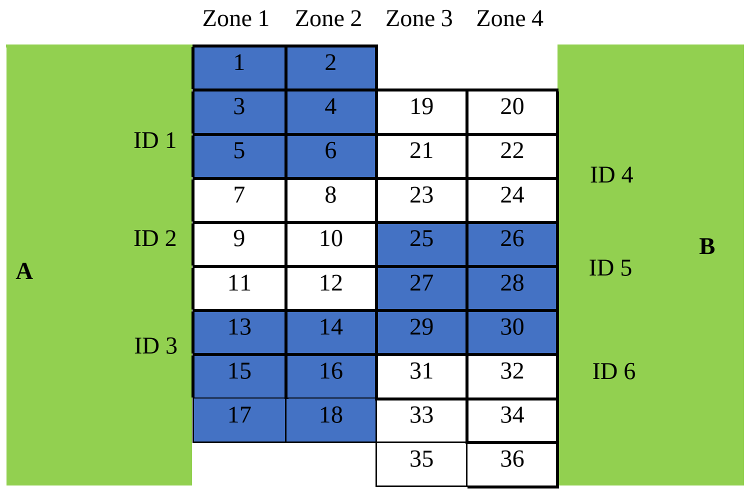
Please listen carefully to all instructions and let us know if you do not understand something. Once you are ready, please press Continue.

Task1: Lottery Choice

In this game, you will be given 6 lotteries. Each lottery involves a 50/50 chance of two payoff levels (high versus low). You will be asked to choose the lottery that you prefer the most. You may change your mind up until you click OK. Given your chosen lottery, the computer will draw a random number between 0 and 100, with the rule that for any number greater than 50, you will receive the higher payoff. Otherwise, you will receive the lower payoff.

Task 2: Conservation Game

In this experiment, you will make a decision to participate/not participate in a conservation auction program. This program is run by the government. Participation means you will need to set your land aside for conservation (stop agricultural activities on your registered farm parcels) and receive the payment from the government in return. You will play this game in a group of 6 participants. Each member of the group will own 6 arable land parcels. These parcels are located between the two habitat areas A and B. For example, Subject ID1 owns 6 parcels from P1-P6.



An AUCTION will take place during the experiment, during which you will have the possibility to offer some or all of your parcels to the GOVERMENT. The government buys the parcels to establish corridors or stepping stones that enable the migration of wildlife species between the two high conservation value habitats, namely A and B (green areas).

A corridor is formed only if four horizontally connected parcels are offered to the government. A single parcel or any horizontal combination of two or three parcels that are offered to the government serve as stepping stones for wildlife.

Here are examples of corridors and stepping stones:

Horizontal connectivity of parcels 9,10, 25, and 26 forms a corridor

Horizontal connectivity of parcels 9,10, and 25 forms a three-parcel stepping stone

Horizontal connectivity of parcels 10 and 25 forms a two-parcel stepping stone

Parcel 25 is a single stepping stone

Each parcel has its own PRODUCTION VALUE (PV), that is the income received from agricultural production on each parcel. The production values will vary across the parcels. You only know the production values of your parcels, not those of other participants.

Each parcel has its own ENVIRONMENTAL VALUE (EV). Parcels in Zone 1 and Zone 4 generate the same units of Environmental Values (EV1). Parcels in Zone 2 and Zone 3 generate the same units of Environmental Values (EV2). Parcels in Zone 1 and Zone 4 have greater Environmental Values than those on Zone 2 and Zone 3. This means EV1>EV2.

The government has a limited budget. They cannot accommodate all the bids. They will only buy corridors or stepping stones that can generate the highest environmental values per dollar spent.

The auction will have multiple rounds. The budget and the Production Value (PV) and Environmental Value (EV) associated with your parcels are the same for all rounds. In each round, you will submit offers to put up for conservation any number of the 6 parcels that you own. These offers indicate the amounts (BIDs) you wish to receive for the parcels that you are willing to offer. Each offer you make will cost you $$10 Experimental Dollars for submission fee. After each round, you will be informed of your offered parcels were selected by the government. And you are also provided the information about the selected parcels of other group members. You can choose not to submit any offers and receive the production values of your parcels. Your decisions in the current round are independent with those in the previous rounds. You can change the BIDs and/or the parcels you wish to set aside for conservation in each round. Finally, one of the rounds will be randomly chosen for payment. You will get paid the amount equal your BIDs if your BIDs are selected by the government. In addition to your bids, you could receive a bonus of $$30 (i.e., within-farm bonus) if your two selected parcels are horizontally connected. You could also receive a bonus of $$40 (between-farm bonus) if your selected parcel and your neighbour's selected parcel are horizontally connected.

For your unselected BIDs, you will earn the amount equal to the parcels' production values. For your unsold parcels, you will also receive the amount equal to their production values.

Each of you can have ONE or TWO direct neighbours whose parcels are horizontally adjacent to yours.

Your Subject ID	**Your direct neighbors' ID**
1	4
2	4 and 5
3	5 and 6
4	1 and 2
5	2 and 3
6	3

Before making your own decisions, you can communicate with your direct neighbours via the chat box if you wish. You can decide with whom you want to communicate. Communication is costly to you. It will cost 15 Experimental Dollars per each neighbour. You have 3 minutes for communication per round. When choosing communication option, your messages can be delivered to your neighbour even when your neighbour did not choose to communicate in the first place. For those, who do not choose communication option, please wait for the time to pass before we turn to the decision stage.

Your earnings in each round will be calculated according to the formula:

Earning ($$) = Sum of BIDs for sold and selected parcels + Sum of PRODUCTION VALUES of unsold or unselected parcels – Number of sold parcels * submission fee - Number of communicating neighbour * chat fee + within-farm bonus + between-farm bonus

<u>Task 3: Survey</u>

You will now complete a survey. This survey collects some background information about you.

Appendix A.2.

Table A2: Marginal effect estimates for random effects probit model: Probability of offering parcels located in different environmental zones (using parcel-level data)

	Coefficient	Delta-method Std.Error	P value
Round	-0.008***	0.003	0.007
Environmental Zone (1=High; 0 = Low)	0.100***	0.026	0.000
Negative landscape	0.014	0.027	0.607
Positive landscape	-0.026	0.026	0.312
Negative landscape x Environmental Zone	0.198***	0.054	0.000
Positive landscape x Environmental Zone	-0.086*	0.051	0.094
Agglomeration Bonus (1= Yes; 0 = No)	0.035	0.026	0.185
Environmental Zone x Agglomeration Bonus	-0.047	0.053	0.371
Negative landscape x Agglomeration Bonus	0.004	0.054	0.936
Positive landscape x Agglomeration Bonus	0.009	0.052	0.855
Negative landscape x Environmental Zone x Agglomeration Bonus	-0.020	0.109	0.853
Positive landscape x Environmental Zone x Agglomeration Bonus	0.013	0.103	0.898
Log Likelihood	-3069.377		
Obs	6480		

Note: *, **, *** indicate significance at 1%, 5% and 10% levels of significance, respectively. Data was clustered at parcel level.