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Spatially Coordinated Conservation Auctions: A Framed Field Experiment Focusing on Farmland Wildlife Conservation in China

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Abstract

This paper presents a framed field experiment from China studying a spatially coordinated (SC) auction mechanism for the allocation of agri-environmental contracts, which pay farmers to change their agricultural practices to provide environmental benefits. The SC auction is designed to maximise a metric of environmental benefit that depends both on site-specific environmental values and benefits due to spatial coordination of conserved patches, subject to a budget constraint. We investigate whether auction performance can be improved by the introduction of agglomeration bonus (AB) and joint bidding (JB) mechanisms. The AB is a bonus payment awarded to neighbouring farmers who bid individually but receive agri-environmental contracts simultaneously. The JB mechanism allows neighbouring farmers to bid jointly and provides a bonus payment for successful joint bids. We conducted experimental SC auctions with a total of 432 Chinese farmers randomly assigned to one of four treatments which differed in whether the AB and JB mechanisms were adopted, following a two-by-two full factorial experimental design. Our empirical results suggest that the SC auction has similar environmental performance regardless of whether an AB is provided, although cost-effectiveness is slightly higher when AB is not provided. Moreover, introducing the JB mechanism into the SC auction leads to lower environmental performance and lower cost-effectiveness. Finally, the AB mechanism achieves higher environmental performance than the JB mechanism but has similar cost-effectiveness.

Keywords: Agglomeration bonus, joint bidding, agri-environmental schemes, Payments for Ecosystem Services, framed field experiment.

JEL codes: C72, C93, D44, Q15, Q57.

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I. Introduction

The past few decades have witnessed a rapid global proliferation of agriculture-related Payments for Ecosystem Services (PES) programmes, which provide payments for farmers to incentivise them to voluntarily undertake environmentally friendly land-use activities (Hanley et al., 2012; Wunder et al., 2020). In many countries, agricultural PES programmes account for a substantial proportion of total public spending on agriculture (Hanley et al., 2012; Nguyen et al., 2022). The scientific and policymaking communities have been actively considering novel design features of PES programmes in an attempt to achieve higher levels of conservation efficacy and cost-effectiveness. This study focuses on PES programmes intended to change agricultural practices to provide more favourable living environments for wildlife living near agricultural lands. One important consideration is to allocate PES contracts to better account for supplementary ecological benefits arising from the spatial coordination of changing agricultural practices on multiple farms ('edge' benefits), in addition to benefits of changing agricultural practices on each farm individually ('node' benefits). Conventional PES programmes typically provide individual contracts at the farm level, thus focussing on node benefits rather than edge benefits. However, many species benefit more from having a favourable living environment at the landscape level (than at the farm level); whilst ecosystem service supply can also be increasing in connectivity (Engel, 2016; Haddad et al., 2015; Hanley et al., 2012; Nguyen et al., 2022; Reeling et al., 2019; Saura et al., 2018).

The PES literature has placed increasing emphasis on spatially coordinated conservation, with the more commonly explored mechanism involving providing agglomeration bonuses (AB) to reward farmers for the provision of edge benefits, in addition to the basic PES payments intended for node benefits (e.g. Banerjee, 2018; Banerjee et al., 2017;

Parkhurst and Shogren, 2007, 2008; Reeling et al., 2019; Ward et al., 2021. Another approach to incentivise increased connectivity on conservation is through a spatially coordinated (SC) conservation auction, which aims to allocate PES contracts in such a way that achieves the highest total environmental benefits consisting of both node and edge benefits (Banerjee et al., 2015; Krawczyk et al., 2016; Reeson et al., 2011). Conservation auctions can enhance the environmental performance and cost-effectiveness of PES by allocating PES contracts preferentially to farmers who offer to provide more environmental benefits and/or ask for lower payments (Engel, 2016; Ferraro, 2008; Hanley et al., 2012). In a conservation auction, each participating farmer offers to provide certain environmental benefits, and bids for a PES payment to compensate for the opportunity costs of providing the environmental benefits by switching to a more conservation friendly land use. Previous studies have explored various design features of conservation auctions using laboratory experiments (e.g. Cason and Gangadharan, 2004; Cramton et al., 2021; Liu, 2021; Schilizzi and Latacz-Lohmann, 2007, 2016), although most do not explicitly involve spatial coordination issues. Finally, another mechanism is to consider neighbouring farms collectively for a joint PES contract (Engel, 2016). This could be incorporated into conservation auctions through joint bidding (JB), where neighbouring farmers bid together for a joint PES contract and receive additional bonus payments reflecting the higher costs of bid preparation in this context (Banerjee et al., 2021; Nguyen et al., 2022).

Only a few experimental studies on the design of SC conservation auctions explicitly account for edge benefits as part of the optimisation objective in allocating PES contracts (e.g. Banerjee et al., 2015; Krawczyk et al., 2016; Reeson et al., 2011). These studies focused on whether the performance of the SC conservation auction might be affected by auction rules other than AB and JB. For instance, Reeson et al. (2011) tested in a multiple bidding round setting the effects of allowing provisional winners in previous rounds to update their bids in later rounds, and the effects of announcing the final round of the auction. Banerjee et al. (2015) investigated whether bidders would increase rent seeking if they are aware of the auctioneer's spatial objective. Krawczyk et al. (2016) looked at the effects of communication among bidders and whether accepted bids receive uniform- or differentiated-rate payments. Fooks et al. (2016) and Liu et al. (2019) explored conservation auctions that provide AB, and the main findings are mixed. Fooks et al. (2016) found that combining AB and spatial targeting in conservation auctions leads to better performance than providing AB alone. Liu et al. (2019) found no statistical evidence that AB can improve the performance of target-constrained conservation auctions that aim to conserve a fixed number of land plots at the lowest costs. None of these studies sought to formally assess whether the performance of SC conservation auctions can be improved by the introduction of AB.

Another promising yet under-explored approach to facilitate spatially coordinated conservation in PES auctions is to allow joint bidding, which refers to neighbouring farmers tendering a joint bid and being considered as a group for a joint PES contract (Banerjee et al., 2021; Nguyen et al., 2022). Existing evidence on the performance of joint bidding in PES auctions has been considerably limited. Due to the novelty of this design feature, real-world PES auctions that allow joint bidding have been rare and limited in scale, which has precluded formal *ex post* quasi-experimental statistical assessments. For instance, the Tiffin Watershed BMP (Best Management Practice) auctions in the US only had a total of 10 bidders, and none of them bid jointly although they were allowed to do so (Palm-Forster et al., 2016). To the best of our knowledge, Banerjee et al. (2021) is the only laboratory experiment to study joint bidding in PES auctions. Other experimental studies on joint bidding, such as Chernomaz (2012) and Rondeau et al. (2016), did not concern PES and did not involve any spatial relations among bidders. Several other studies have investigated the performance of joint bidding in PES auctions, such as Calel (2012), Iftekhar and Latacz-Lohmann (2017), and Iftekhar and Tisdell (2016), but these are simulation-based studies.

This paper focuses on SC conservation auctions and uses a framed field experiment with Chinese farmers to investigate the extent to which auction cost-effectiveness and environmental performance specifically can be improved by including an AB and/or JB mechanism. Our study makes three key contributions. First, this study is the first to compare auction performance with AB and/or JB to a baseline SC conservation auction that neither provides AB nor allows JB. This gap is important to address since current SC conservation auctions in practice rarely involve AB and JB, and any potential performance improvement (both economic and environmental) from including JB and/or AB requires comparing auction performance to this current auction baseline. The theoretical analysis in Appendix A shows that it is possible to improve the environmental performance of the SC conservation by introducing AB or JB. However, this potential improvement is not guaranteed theoretically and thus needs to be investigated empirically.

Second, policymakers are interested in findings drawn from the policy's target population, such as farmers in the case of our study, since it is the behaviour of these agents that the policymaker is trying to influence (Cason and Wu, 2019; List, 2011). Herein, our experiment employs farmer subjects who represent the target population potentially participating in real-world conservation auctions. This is a crucial next step to assess the

[1] Banerjee et al. (2021) also tested other design features of SC conservation auctions, such as whether an auction session concludes after one or multiple bidding rounds.

performance and policy relevance of the SC conservation auctions with AB and JB.

Third, the experimental PES auctions in this study were set in the context of China, using Chinese farmers as bidders. Exploring spatial coordination issues in PES auctions is highly relevant to PES design in China. The country has been investing heavily in large-scale conservation programmes that involve biodiversity hotspots and make financial transfers in various forms to local communities (Busch et al., 2021; Tuanmu et al., 2016). These conservation programmes have a strong preference to enrol more contiguous land plots in pursuit of enhanced ecological benefits (and savings in administrative costs) that this offers. However, these programmes often attempt to achieve contiguous conservation by forcibly enrolling all local communities that live in target areas. This approach likely leads to compromised environmental efficacy and/or adverse impacts on local livelihoods. Moreover, conservation auctions are cognitively demanding in general (Howard et al., 2022), especially for farmers in developing regions who typically have lower levels of education, numeracy skills and market experience. Thus, even if a more theoretically preferrable approach were to be taken with targeted enrolment through an auction, it is upfront not clear whether a voluntary PES auction that favours spatial coordination can be a viable alternative to the conventional mandatory approach adopted in China which is more familiar to farmers.

The remainder of this paper proceeds as follows. Section II describes the design and procedures of our experiment which empirically assesses the effects of introducing AB and JB in SC conservation auctions. Section III reports the data, analytical methods and empirical results. Section IV summarises the main findings and concludes.

II. Experimental Design and Fieldwork Procedures

This section details the design and procedures of our experimental auctions. We adopted a balanced two-by-two full factorial experimental design (as shown in Table 1). Participating farmers bid in auction groups, which were randomly divided into four treatments: 1) Treatment SC is the basic SC conservation auction which only allows individual bids and does not provide AB payments; 2) Treatment SC_AB only allows individual bids but provides AB payments; 3) Treatment SC_JB allows both individual and joint bids but does not provide AB payments; 4) Treatment SC_AB_JB allows both individual and joint bids, and provides AB payments.

Table 1. Experimental Design

		Agglomeration Bonus	
		No	**Yes**
Joint Bidding	**No**	Treatment SC	Treatment SC_AB
	Yes	Treatment SC_JB	Treatment SC_AB_JB

The experimental auctions in this study were set in the context of a hypothetical PES programme.[2] Our subjects were told explicitly that they were in a study about a hypothetical PES programme which had no connection to their actual land-use activities but would affect their payoffs from participation in the experiment. In all treatments, the experimental auction was a budget-constrained sealed-bid PES auction which provided differentiated payments equal to winning farmers' bids. Additionally in the treatments with AB and/or JB, winning participants received bonus payments under certain conditions, which will be further described below. The auctions were repeated for multiple independent periods. Each auction period consisted of multiple bidding rounds and the results of the last round determined farmers' payoffs in that auction period. (Both Windle et al., 2009 and Banerjee et al., 2021 found that the multiple auction rounds had a positive impact on SC auction performance.) All monetary values in the experiment (i.e. bids, bonus payments and cost parameters) had a one-for-one exchange rate with the local currency (CNY). In addition, upon the completion of their experimental session, each farmer i received a fixed show-up fee. All auction sessions were run in farmers' villages with paper and pen. Each farmer received two handouts: an information sheet that contained the position and parameters of their own hypothetical farm, and a bid sheet for each farmer to specify their bid.

A. Auction Features Common to All Treatments

Each auction group consisted of six farmers. At the beginning of each auction session, the six participating farmers were seated randomly in a circle, at least one metre apart from each other and facing the outside of the circle.[3] The farmers remained in the same seats (and thus had the same neighbours) throughout the auction session.

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[2]Economics experiments conventionally employ context-free framing. Despite that, it is not uncommon in the conservation auction literature to conduct contextualised experiments (e.g. Krawczyk et al., 2016; Kits et al., 2014; Liu et al., 2019; Fooks et al., 2016; Reeson et al., 2011. Alekseev et al. (2017) argue that although context is likely to affect behaviour, such influence is not always undesirable. For example, findings from a contextualised experiment can be more relevant if the research question focuses on a situation that involves specific context, which is the case of our study, where the research question is in the context of PES auctions. Moreover, contextualised instructions can help subjects better understand the experiment, which is particularly important in this study because our subjects are farmers who live in less developed regions and have limited education and market experience. Based on these considerations, we opted to provide context in our experimental auctions.

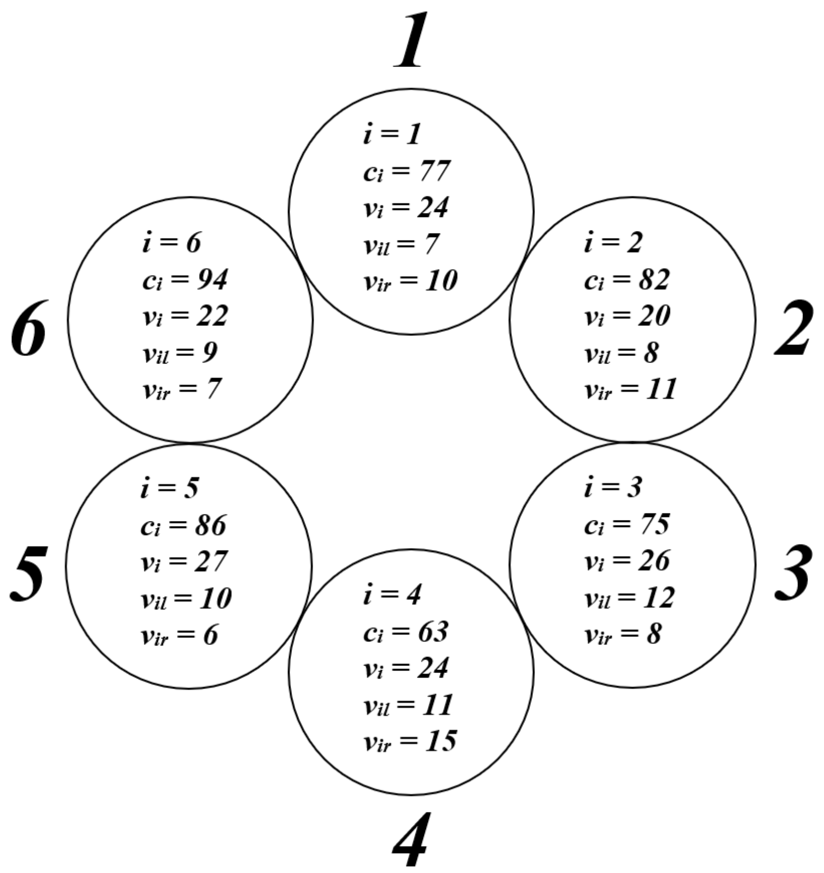

Figure 1. Spatial Layout of Farms and an Example Configuration of Parameters in the Experimental Auction

[3]Laboratory auctions often prefer to keep bidders anonymous to each other because bidders' behaviour is likely to change if they are aware of each other's identities (Lusk and Shogren, 2007). Some field experiment researchers argue that it can be helpful to investigate people's behaviour in a less anonymous environment, because findings from a completely anonymous environment may be less applicable to those real-world situations that feature lower degrees of anonymity (Levitt and List, 2007). Our study focuses on a particular type of PES auction which targets neighbouring farmers, who are likely to know each other. We therefore opted for a non-anonymous setting which resembles that situation in reality. Another reason behind this decision was that the vast majority of our subjects have extremely low levels of computer literacy and would not be able to independently complete the experiment (especially the communication process) in private on a computer or tablet, which adds to the logistical difficulty of ensuring anonymity.

The experimenter read the instructions aloud to the farmers. Each farmer was assumed to own one of the six farms on a circular network (as shown in Figure 1), and farmers' seats represented the spatial layout of their farms. Each farmer was assumed to grow fruit trees on their own farm using chemical pesticides which were harmful to birds and bees. The farmers were informed that there was a hypothetical PES intended to protect birds and bees. This programme sought to select a subgroup of the six farmers as participants. If a farmer was selected into this programme, they would be required to switch from using chemical pesticides to biological pesticides, which are less toxic to birds and bees, but equally effective in terms of pest control and would therefore ensure the same fruit yield. Biological pesticides are commercially available in our study area but are more expensive than chemical pesticides. Switching from chemical to biological pesticides incurs an additional cost c_i for each farmer i. The PES programme would provide a farmer-specific payment b_i for each selected farmer to compensate for the additional cost of switching. The farmers' task in the experiment was to specify the amount of the payment they would be willing to accept to adopt this new pesticide. In Treatment SC, farmer i's net payoff from the experimental auction can be expressed as:

$$\Pi_i = w_i(b_i - c_i), \tag{1}$$

where w_i is a binary variable which takes the value one if farmer i is selected into the PES programme, and zero otherwise. (In the experiment, all rules were explained to farmers in a non-mathematical way accompanied by numerical examples.)

The experimenter then explained the selection rules of the PES auction. The six farmers were told that only a subgroup of them would be selected into the PES programme, due to budget constraints. The programme would select participants in such a way that would achieve the highest benefits for birds and bees. If farmer i 'wins' the auction and enters a PES contract, they would switch to biological pesticides on their own farm, which provides an environmental benefit v_i (node benefit). If at least one of their neighbours also wins the auction and switches to biological pesticides, supplementary edge benefits v_{il} and/or v_{ir} would also be realised. The environmental benefit provided by each farmer i can be expressed as:

$$V_i = w_i(v_i + w_{il}v_{il} + w_{ir}v_{ir}), \tag{2}$$

where w_{il} (or w_{ir}) is a binary variable which indicates whether the left (or right) neighbour is selected. The amount of the budget was not announced to farmers.

At the beginning of each bidding round, farmers had a total of 3 minutes to communicate freely in private with the left and right neighbours separately.[4] Farmers then wrote their own bid on the bid sheet. The experimenter then came to each farmer to enter the bid into an Excel Solver algorithm, worked out the (provisional) winners and net payoffs, announced the winners to the entire group, and returned to each farmer to write in private their own net payoff on the bid sheet. This process (from farmers' pre-bidding communication with neighbours to the experimenter communicating the results to farmers) was then repeated for a minimum of three and a maximum of six rounds.[5] In each new bidding round, farmers were allowed to freely revise their bids upwards or downwards on the basis of their bids in the previous round. The results of the final bidding round constituted the results of the auction period and determined farmers' payoffs. Following the third bidding round, the auction period concluded if the current bidding round had the same winners as in the previous round. If this stopping rule was not satisfied, the next round was conducted till the sixth round was conducted at which point the auction ended. This stopping rule was not communicated to farmers.[6]

Each auction group undertook a total of three auction periods. In each period, farmers remained in the same seats but the parameters of their farms were reshuffled. As can be seen in Figure 1, the four parameters (c_i, v_i, v_{il} and v_{ir}) for one farm were always grouped as a single set of parameters. The reshuffling process maintained the relative positions of the six sets of parameters.[7] We did not tell farmers how we reshuffled the parameters. At the beginning of each auction period, each farmer simply received a new information sheet that contained a new set of parameters. The parameters were adapted from Banerjee et al. (2021), although we reduced the auction group size to six and rescaled the parameters so that the costs approximate the actual price difference between chemical and biological pesticides (CNY per litre). The parameters and the budget were chosen such that if the PES programme (the auctioneer) has perfect information about the parameters, it

[4]In the experiment, allowing neighbouring farmers to communicate in Treatments SC_JB and SC_AB_JB (where joint bidding is allowed) would be better in line with reality – if an actual PES auction allows joint bidding, it would be difficult to imagine farmers bidding jointly without any communication or coordination because the formation of joint bids requires mutual agreement among joint bidding partners. Moreover, one of the reasons that allowing joint bidding may help auctions achieve additional efficiency gains is that joint bidders are better positioned to utilise their private information and harness the complementarities among them to coordinate a joint bid which may materialise certain efficiency gains which could not be achieved by individual bids (Latacz-Lohmann and Schilizzi, 2005; Rondeau et al., 2016). Such efficiency gains may not be achieved if joint bidders are not allowed to communicate. However, allowing communication has direct implications for the performance of auctions, through, for example, facilitating collusion (Krawczyk et al., 2016; Schilizzi, 2017), regardless of whether farmers bid jointly or individually. If communication is allowed only for joint bidding but not for individual bidding, the treatment effects of joint bidding would be confounded by the effects of allowing communication (Rondeau et al., 2016). Therefore, we allowed communication in all four treatments.

would allocate PES contracts to three contiguous farms (which would be farms 3–5 if the parameters are assigned as in Figure 1. The three farms are hereafter referred to as the first best farms.

At the end of each auction period, each farmer learnt their own net payoff, although we did not make the actual payments until the completion of the last auction period (and a post-experiment questionnaire survey, which will be further described in the Fieldwork subsection).

Prior to the three formal auction periods, there was a practice auction period to

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[5]We adopted multiple bidding rounds to allow bidders to learn and gain experience with the auction rules (Banerjee et al., 2015; Lusk and Shogren, 2007; Rolfe et al., 2009). This is particularly important in our study area, since an earlier study (Liu et al., 2019) that ran single-round experimental auctions on Chinese farmers found that a non-trivial proportion of the subjects had difficulty understanding the auction rules. Admittedly, multiple bidding rounds may lead to efficiency losses (compared to the single-round setting) for several reasons. For instance, bidders may become better positioned for rent-seeking due to the information and experience they have gained over multiple bidding rounds (Hellerstein, 2017; Schilizzi and Latacz-Lohmann, 2007). This study does not formally compare the performance of multiple- and single-round conservation auctions, which has been explored by several previous studies (e.g. Banerjee et al., 2021; Rolfe et al., 2009).

[6]If the last round was known to farmers in advance, there could be higher rent-seeking (Reeson et al., 2011) and/or other changes in bidding behaviour in the last round due to endgame effects (Banerjee et al., 2021). We thus chose not to inform our subjects about the stopping rule, following Banerjee et al. (2021).

[7]For instance, in one auction period, farms 1–6 could take parameter sets 1, 2, 3, 4, 5 and 6, respectively. In the next period, farms 1–6 could take parameter sets 4, 5, 6, 1, 2 and 3. In that case, the parameter sets are reshuffled in a way that maintains their relative positions, because the six farms are on a circular network.

improve farmers' understanding of the auction rules. The rules of the practice period were mostly the same as in the formal periods, except that, 1) the practice period had only two bidding rounds which both needed to be completed, 2) farmers had 5 minutes to communicate before bidding in each practice round, and 3) the practice period did not provide real payments for winning farmers.

B. The Agglomeration Bonus and Joint Bidding Treatments

Treatment SC_AB introduced AB payments into the SC conservation auction described above. Each farmer i was required to tender an individual bid b_i for their own farm. If farmer i and at least one of their neighbours were simultaneously selected into the hypothetical PES programme, farmer i would receive the basic PES payment they bid for (b_i), and an AB payment equal to the edge benefits (the additional connectivity-derived benefits to birds and bees when neighbouring farms switch simultaneously to biological pesticides). For farmer i, the AB payment would be 1) v_{il} if farmer i and the left neighbour were both selected, 2) v_{ir} if farmer i and the right neighbour were both selected, or 3) $v_{il} + v_{ir}$ if farmer i and both neighbours were all selected. Farmer i's net payoff from the experimental auction can be expressed as:

$$\hat{\Pi}_i = w_i(b_i + w_{il}v_{il} + w_{ir}v_{ir} - c_i), \tag{3}$$

where w_i, w_{il} and w_{ir} are binary variables indicating whether farmer i and their left and right neighbours are selected or not, respectively.

In Treatment SC_JB, each farmer could either bid individually, or bid jointly with one or both neighbours. Each farmer needed to specify on the bid sheet whether they would like to bid jointly, and if so, with which neighbour. In addition, each farmer i needed to specify the basic PES payment they would like to have for their own farm (b_i), regardless of whether they were bidding individually or jointly. If farmer i chose to bid individually, their situation would be the same as in Treatment SC. If farmer i chose to bid jointly, they and their joint bidding partner(s) would be considered by the PES programme as one single bidder. The PES programme still sought to select a subgroup of the six farmers to maximise the total environmental benefit, although there was one additional restriction that farmers in a joint bid needed to be jointly selected or rejected. If farmer i was selected through a joint bid, they would receive the basic PES payment they asked for (b_i), plus a JBB payment equal to 1.5 times the edge benefits achieved.[8] Farmer i's net payoff from the experimental auction can be expressed as:

$$\tilde{\Pi}_i = w_i(b_i + 1.5x_{ijl}v_{il} + 1.5x_{ijr}v_{ir} - c_i), \tag{4}$$

where x_{ijl} (or x_{ijr}) is a binary variable which indicates whether farmer i bids jointly with the left (or right) neighbour.

Treatment SC_AB_JB combined the incentive mechanisms in Treatments SC_AB and SC_JB: AB payments were provided for neighbouring farmers selected simultaneously through individual bids, and JBB payments were provided for successful joint bids. This implies that a farmer could have their joint bid accepted with one neighbour and have their other neighbour selected as well so would receive the AB as well as the JBB. Farmer i's net payoff from the experimental auction can be expressed as:

$$\bar{\Pi}_i = w_i[(b_i + 1.5x_{ijl}v_{il} + (1 - x_{ijl})w_{il}v_{il} + 1.5x_{ijr}v_{ir} + (1 - x_{ijr})w_{ir}v_{ir} - c_i)]. \tag{5}$$

It is worth noting that for a particular pair of farms, AB and JBB payments were mutually

[8] The payment rate of JBB was set higher than that of AB, because joint bidding is likely to incur higher coordination/transaction costs (Banerjee et al., 2021).

exclusive, because one farm could be selected only once, through either an individual or a joint bid.

C. Power Analysis

We conducted experimental auctions with a total of 432 Chinese farmers divided equally into 72 auction groups. Each auction group was randomly assigned to one of the four treatments, giving rise to 108 farmers (18 groups) per treatment. We prepared a pre-registration report which included power calculations that helped us determine the sample size at the auction group level, because the effects of the AB and JB treatments were planned to be estimated at this level. The power calculations considered the six auction outcome variables listed in Table 2. The power calculations required reference values for the means and standard deviations of the auction outcome variables, which were derived from the data of the laboratory experiment of Banerjee et al. (2021). We attempted to find a sample size which would provide adequate statistical power (at the 80% level or higher) for the estimation of the treatment effects if they are at least 10% of the reference level means of the auction outcome variables, following the recommendations of Ferraro and Shukla (2020), and Ioannidis et al. (2017). We performed two sets of power calculations. One set adopted the formula recommended by Moffatt (2021), assuming that the treatment effects would be estimated using standard t-tests. The other set followed the simulation-based approach of Bellemare et al. (2016), assuming that the treatment effects would be estimated using non-parametric rank-sum tests. Both sets of power calculations corrected for the familywise false positive error rate (associated with multiple hypothesis testing) using the Holm-Šidák procedure as described in Dinno (2015). Figure B1 in Appendix B presents the results of the power calculations. It can be seen that our sample size (18 auction groups per treatment) achieves the target statistical power for the two key variables of most interest ('total benefit' and 'cost effectiveness'), and for another indicator 'farms conserved'. Our research budget did not allow for a sample size that would achieve the target statistical power for the other three variables.

D. Fieldwork

Our subjects were recruited from 28 villages in 3 counties in Huangshan municipality, Anhui province, China. Figure 2 shows the locations. The municipality is mostly covered by Mount Huangshan, a conservation hotspot recognised as a UNESCO World Heritage Site and Biosphere Reserve for its unique landscape and extremely rich biodiversity. Mount Huangshan provides habitats for many endangered species on the IUCN red list, such as the oriental stork (Osipova et al., 2020). Moreover, the municipality's rural population is mostly farming actively and is familiar with PES programmes such as the Sloping Land Conversion Programme (SLCP), China's flagship PES programme which pays farmers to plant trees on highly sloped farmland. The municipality thus provides an ideal setting for our fieldwork.

Table B1 in Appendix B summarises the demographic characteristics of the subjects (at the bidder level). It also presents the results of cross-treatment balance tests for these 12 covariates, which were selected on the basis of previous studies that involved the determinants of bidding behaviour in conservation auctions (e.g. Jack, 2013; Liu et al., 2019).[9] The covariate balance tests were performed at both the bidder and the auction group levels. The p-values of the covariate balance tests were derived from permutation tests, which is preferrable when the sample size is not large enough to justify strong distributional assumptions (Holt and Sullivan, 2021). As can be seen in Table B1, the p-

values of the balance tests for the 12 covariates are all above 0.30. The magnitudes of the means are highly comparable across treatments for nearly all the covariates, except for 'cattle', which contains two outlying bidders in Treatment SC_JB and one in Treatment SC_AB_JB who had large numbers of cattle.[10]

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[9]We first included three standard demographic variables 'age', 'gender' and 'education'. In addition, we sought to proxy bidders' income levels using four variables about bidders' assets and household size ('cattle', 'land', 'household size' and 'rooms'). In less developed rural areas such as our study area, it can be difficult to accurately measure income levels without asking a large number of detailed questions about the input and output of a wide range of production activities, because most local households tend to be self-employed and engaged in various production activities. By comparison, data on assets and household size can better capture household income levels (Haughton and Khandker, 2009). The two variables 'household head' and 'market experience' account for the heterogeneity in bidders' experience in land-related decision making and market activities. Moreover, we measured bidders' risk preferences using a 5-level self-rating question and constructed the variable 'risk averse', because risk preferences have been frequently found relevant to bidding behaviour in conservation auctions (Banerjee et al., 2021) and other types of experimental auctions (Lusk and Shogren, 2007). Furthermore, Sheremet et al. (2018) found that forest owners' willingness to participate in spatially coordinated PES programmes depends positively on pre-existing experiences of collaborative forest management activities. We thus included the variable 'collaboration', which indicates whether a bidder had real-life agricultural collaboration experiences with neighbours. Lastly, we accounted for bidders' within-village social status using the variable 'leader', because higher-status people may intentionally behave in a less self-interested way in economic experiments as a means to invest in their social capital in real life (Bulte et al., 2017).

[10]Aside from three outlier farmers, the mean of 'cattle' is 2.57 in SC_JB and 1.72 in SC_AB_JB, which are highly comparable to the other two treatments. We did not observe any indication that the three outliers (out of a total of 432 bidders) might have been systematically assigned to SC_JB and SC_AB_JB. Therefore, the outlying values of 'cattle' in those two treatments were likely caused by random sampling variability.

In preparation for the formal fieldwork, we tested the procedures and parameters of the experiment in five rounds of pilots, two with university students in Beijing, and three with farmers in Beijing and Huangshan. The formal fieldwork was conducted in Huangshan in 2021. Winning bidders earned CNY 58.90 (∼USD 9.13) per person on average from the experimental auctions. In addition, each bidder received CNY 50 (∼USD 7.75) as a show-up fee regardless of the results of the experimental auctions. The typical duration of an auction session (consisting of one practice period and three formal periods) was 2–3 hours, depending on the treatment. Upon the completion of the experiment, each bidder completed a face-to-face questionnaire which asked about their demographic and socioeconomic details, risk attitudes, and social connections with other bidders in the same auction group. All payments were made in cash after the completion of the experiment and the questionnaire.

III. Data Analysis and Results

Our data analysis starts with assessing the effects of the AB and JB treatments on the performance of the experimental auctions. This part of the analysis was conducted at the auction group level. After that, we proceed to an analysis on how bidding behaviour is affected by auction parameters (farm-specific costs and benefits of conservation), auction periods, and farmers' demographic and socioeconomic characteristics. Throughout this analysis we focus on data from the last bidding round of each auction period, because those data are directly associated with the final results of the auction period which determined farmers' payoffs.

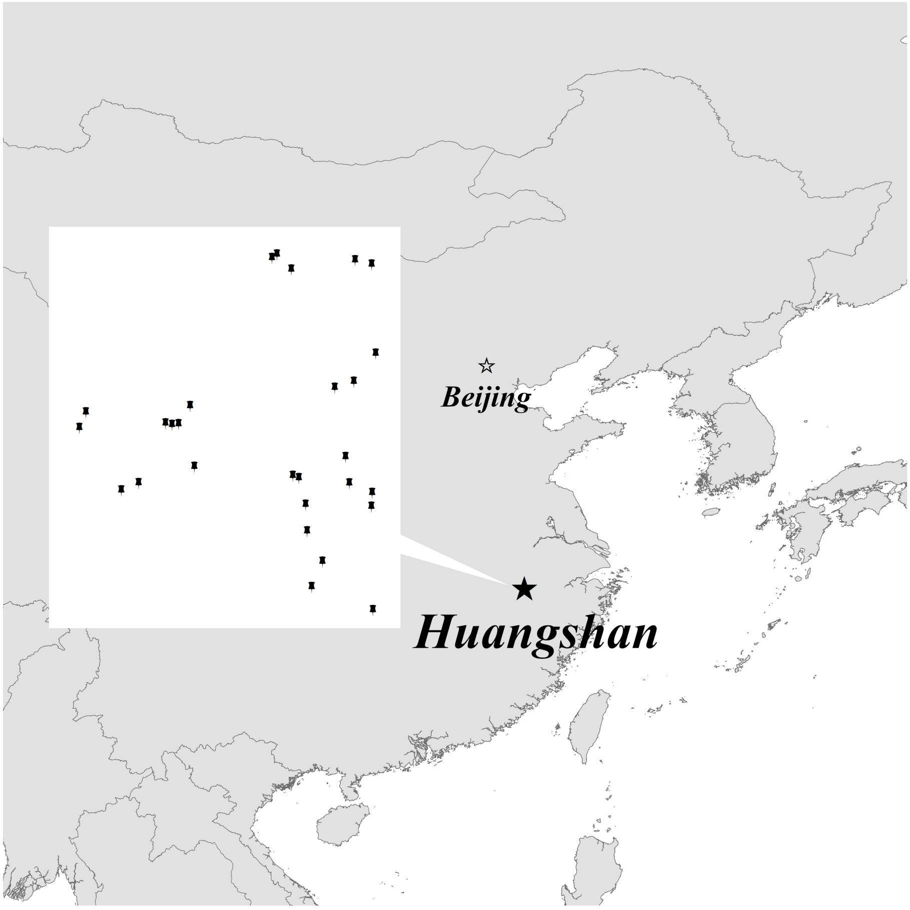

Figure 2. Fieldwork Locations

Note: We intentionally removed the boundaries of the three counties for statistical disclosure control purposes.

A. Effects of the Agglomeration Bonus and Joint Bidding Treatments

We start with analysing the effects of the AB and JB treatments on the performance of the experimental auctions. Auction outcomes are characterised by the six variables listed in Table 2. The two environmental benefit variables refer to the total and edge environmental benefits achieved, respectively, with edge benefits reflecting the degree of connectivity achieved in patches switching to biopesticide use. The variables 'cost effectiveness' and 'net payment' indicate the economic performance of the auctions, where the former refers to the environmental benefit procured per unit of payment, and the latter represents the level of rent-seeking by bidders (including bonus payments). The

Table 2. Auction Outcome Variables: Definition and Descriptive Statistics

Variable	Definition	Descriptive statistics: Mean (SD)			
		SC	**SC_AB**	**SC_JB**	**SC_AB_JB**
Total benefit	Sum of node and edge environmental benefits achieved	123.02	119.37	103.37	108.44
		(10.09)	(12.75)	(20.93)	(10.40)
Edge benefit	Sum of edge environmental benefits achieved	44.52	42.13	35.67	38.11
		(5.03)	(6.88)	(8.71)	(6.14)
Bid cost difference	Sum of bid-cost differences for all winning bidders	41.85	24.80	18.00	9.62
		(19.03)	(26.38)	(37.63)	(24.07)
Net payment	Sum of net payments (bids plus bonuses minus costs) for all winning bidders	41.85	66.93	54.76	62.61
		(19.03)	(21.66)	(31.50)	(18.23)
Cost effectiveness	Environmental benefit procured per unit of payment	0.45	0.40	0.41	0.39
		(0.04)	(0.04)	(0.07)	(0.05)
Farms conserved	Number of farms conserved	3.11	3.06	2.67	2.87
		(0.26)	(0.31)	(0.43)	(0.17)
	Obs. (independent groups):	18	18	18	18

Note: The variables above were measured for each auction period and then averaged over the three auction periods conducted for each auction group.

remaining two variables, 'bid cost difference' and 'farms conserved' measure bid markups and the total number of farms conserved, which help explain the reasons for the observed effects of the AB and JB treatments.

The treatment effects were first estimated as differences in means using standard t-tests. In addition, we estimated another set of treatment effects as differences in the rank sums of the outcome variables, using Wilcoxon rank-sum tests, which do not rely on distributional assumptions and are less affected by outliers (Athey and Imbens, 2017; Moffatt, 2021). Moreover, we corrected the p-values for the family-wise false positive error rate using the Holm-Šidák procedure as per Dinno (2015). This is because the comparison of each pair of treatments involves the comparison of multiple outcome variables, or multiple hypothesis testing, which, if not accounted for, is likely to increase the probability of falsely rejecting true null hypotheses (Ferraro and Shukla, 2020; Ioannidis et al., 2017).

Tables 3A and 3B present the treatment effect estimates. The first three columns of Table 3A suggest that the SC conservation auction has similar environmental performance no matter whether AB is provided (Treatment SC_AB) or not (Treatment SC). The two treatments' environmental benefit indicators are statistically indistinguishable, and the magnitudes of the differences in means are well below 10%. However, the cost effectiveness of the SC conservation auction is decreased by the introduction of AB, although the magnitude of the decrease is less than 10% (the p-values from both the t- and rank-sum tests are at most 0.01). This decrease is largely owning to a sizeable and statistically significant increase in the total net payment for winning bidders in the presence of AB (Treatment SC_AB), which is nearly 60% higher than that in the absence of AB (Treatment SC). Despite that, the two treatments' difference in 'bid cost difference' suggests that farmers in SC_AB bid lower, due to potential AB payments, compared to farmers in SC.[11] The p-values of the difference are above the conventional threshold level of statistical significance (0.10), yet the size of the difference (41%) is considerable. These results suggest that some winning bidders in SC_AB bid lower in anticipation of receiving AB payments, although the decrease in their bids tended to be smaller in size than the AB payments they received, which led to a higher total net payment. Also, Treatments SC and SC_AB are statistically similar in terms of the number of farms conserved, which suggests that it was affordable for SC_AB to conserve a similar number of farms despite the increase in the total net payment. The average number of the three target (first best) farms conserved is also similar in SC_AB (2.76) and SC (2.78).

[11] This was also found by Liu et al. (2019) who had Chinese farmers participate in experimental conservation auctions with and without AB. Their conservation auctions did not directly account for edge benefits when selecting winning bidders and therefore differed from the SC auction in this study.

Our results so far suggest that SC conservation auctions with and without AB have similar environmental performance. Nonetheless, it might be worth considering whether such similarity is attributable to the spatial configuration of the first best farms (which are three neighbouring farms). We investigated this question using simulated auctions where we randomly reshuffled the six sets of parameters and thus allowed the possibility that the first best farms to be conserved might be disconnected from each other. The simulated bids were predicted values from treatment-specific regressions of bid values on the cost, node benefit and edge benefit parameters, two auction period dummies and bidder fixed effects. The simulated bids were predicted by replacing the actual values of auction parameters with randomly reshuffled parameters. We next compared the simulated outcomes between Treatments SC and SC_AB, using the same methods as described above. The results are reported in Table B2 in Appendix B, and they show that the main findings are almost identical no matter whether the target farms are connected or not. In the simulated auctions, the total environmental benefit in SC_AB is lower than that in SC. This difference has a p-value close to the conventional threshold level of statistical significance (0.10), although the magnitude of the difference remains rather limited (4%).[12]

[12] We assessed whether our simulation procedure can generate auction outcomes that are comparable to the actual experimental auctions if the auction parameters are reshuffled in the same way (which maintains the relative positions of the six sets of parameters, so that the three target farms are always next to each other). The results of this assessment are presented in Table B3 in Appendix B. It can be seen that the means of the six auction outcome variables are almost identical between the simulated and actual auctions, and the p-values from rank-sum tests are nearly all greater than 0.50, which cannot reject the null hypothesis that the means of the six outcome variables are statistically equal between the simulated and actual auctions.

These results taken together suggest:

Result 1. *The presence of the AB to further reward spatial coordination in the SC conservation auction has no impact on environmental performance and negatively impacts economic performance relative to the baseline when this payment is not offered.*

The next three columns of results in Table 3A concern the effects of introducing the JB mechanism into the SC conservation auction. The SC conservation auction has lower environmental performance under the JB mechanism. The differences in the two environmental benefit indicators are both sizeable (between 15% and 20%) and statistically significant (p-values ¡ 0.01). This is largely because most bidders in SC_JB chose to bid jointly in pursuit of higher JBB payments, and joint bids were less affordable to the PES programme under the fixed budget constraint. The data reveals that 74% of the bids in SC_JB are joint bids (93% of these involve two bidders). Thus, the fact that most bidders in SC_JB chose to bid jointly rather than individually, and these were more expensive bids reduced the number of farms affordable to the budget.[13] Further evidence is provided by the fact that the average number of farms conserved in SC_JB is 14% lower than that in SC, which is statistically significant at the 1% level. Moreover, SC_JB also conserved a smaller number of first-best farms (2.28 on average), compared to that in SC (2.78 on average), and this difference is statistically distinguishable at the 1% level based on a rank-sum and a t-test.

[13]For example, if one auction group tenders three joint bids from three pairs of bidders, the JBB mechanism would need to select or reject farms pair by pair, because the two farms in each joint bid need to be selected or rejected simultaneously. In that case, it is likely that the budget can afford only one of the three joint bids, or in other words, only two farms would be conserved, which would likely provide

That said, it is worth noting that bidders in SC_JB bid substantially lower than those in SC, as shown by the difference in the variable 'bid cost difference', and fewer bidders bid jointly in the last auction period than in the first two. Many bidders attempted to increase their probability of winning the auction by reducing their bids and switching between bidding jointly and individually. It is possible that the JB mechanism could have achieved better environmental performance and cost-effectiveness if the bidders had undertaken more auction periods, which could have allowed them to further update their bidding strategies through adaptive learning. Lastly, the JB mechanism slightly decreased the cost effectiveness of the experimental auctions (less than 10%) with the reduction be significant (p-value = 0.06). These findings are largely stable in the simulated auctions[14] which allowed disconnected first-best farms, as shown in Table B2 in Appendix B.

These findings can be summarised as:

Result 2. *Introducing the JB mechanism into the SC conservation auction leads to lower environmental performance and marginally lower cost effectiveness.*

Adding both the AB and JB mechanisms to the SC conservation auction leads to systematically lower performance, as shown in the last three columns of Table 3A, for similar reasons as discussed above. In addition, the two treatments' notable difference

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lower environmental benefits compared to a typical auction group in Treatment SC where the PES programme is more likely to conserve three farms because all bidders bid individually.

[14]In the simulated auctions, the choice between bidding jointly or individually was simulated using treatment-specific binary logit models which explain the choice between bidding individually or jointly using the period-specific auction parameters, the averages of the auction parameters over the three auction periods, and the bidder-specific covariates listed in Table B1.

in 'bid cost difference' suggests that winning bidders in Treatment SC_AB_JB bid considerably lower than those in Treatment SC, although this difference was outweighed by the bonus payments received by winning bidders in SC_AB_JB. This explains the overall higher level of rent-seeking in SC_AB_JB, as suggested by the large difference in 'net payment' between Treatments SC_AB_JB and SC. The higher level of rent-seeking in SC_AB_JB translated into lower cost effectiveness, which is roughly 13% lower than in SC. The simulated auctions with randomly reshuffled auction parameters have similar findings. We thus have:

Result 3. *The SC conservation auction provides lower environmental benefits and is less cost effective in the presence of both the AB and JB mechanisms.*

Table 3B compares the performance of Treatments SC_AB, SC_JB and SC_AB_JB. SC_AB outperforms SC_JB and SC_AB_JB in terms of both the two environmental benefit indicators, by 10–18%, and the p-values of the differences are mostly lower than 0.10. This is because most bidders in SC_JB and SC_AB_JB chose to bid jointly (74% in SC_JB and 68% in SC_AB_JB), and joint bids tended to be less affordable to the fixed budget than individual bids. This is evidenced by the differences in the variable 'farms conserved', which suggests that SC_AB was able to afford a higher number of farms on average, 15% higher than that in SC_JB and 7% higher than in SC_AB_JB. Overall, the three treatments achieved similar levels of environmental benefits per unit of payment, as shown by the levels of 'cost-effectiveness' of the three treatments which have no statistically discernible difference.

Comparing SC_JB and SC_AB_JB, the last three columns of Table 3B show that if an SC conservation auction has already adopted the JB mechanism designed in this study, providing AB for individual bids may slightly improve the environmental performance, although such improvement in our results is insignificant in terms of both the p-value and the size.

Overall, the analyses in Table 3B find evidence for:

Result 4. *In the SC conservation auction setting, providing AB for individual bids leads to higher environmental performance and similar cost-effectiveness, compared to allowing JB and providing JBB.*

B. Analysis of Bidding Behaviour

We next consider the factors potentially influencing farmers' bidding behaviour. Model 1 in Table 4 reports the bid function regression, controlling for village and experimenter fixed effects and clustering standard errors by auction group.

The estimates of Model 1 suggest that farmers bid lower if AB was provided (about 10% lower than the average bid of all treatments) or if they chose to bid jointly with JBB being provided (about 7% lower than average). This is qualitatively in line with what we found from the cross-treatment comparison of bid markups as discussed above. On the one hand, the possibility of earning AB or JBB allowed farmers to bid lower while achieving the same expected payoff as in Treatment SC (in the absence of AB and JBB). On the other hand, farmers who could potentially earn AB or JBB needed to lower their bids to make them affordable to the fixed auction budget which may be partly spent on bonus payments. Therefore, these farmers were likely to bid lower than those in Treatment SC, as formally discussed in the theoretical analysis in Appendix A. This resembles the finding of Liu et al. (2019) which compared the bid levels of non-SC PES auctions with and without AB.

Regarding the auction parameters (c_i, v_i, v_{il} and v_{ir}), Model 1 shows that the estimate

Table 3A. Effects of the Agglomeration Bonus and Joint Bidding Treatments (Part I)

	SC_AB *minus* SC			SC_JB *minus* SC			SC_AB_JB *minus* SC		
	Mean diff. (SE)	***p*-value (*t*-test)**	***p*-value (rank-sum)**	**Mean diff. (SE)**	***p*-value (*t*-test)**	***p*-value (rank-sum)**	**Mean diff. (SE)**	***p*-value (*t*-test)**	***p*-value (rank-sum)**
Total benefit	–3.65	0.57	0.46	**–19.65**	**<0.01**	**<0.01**	**–14.57**	**<0.01**	**<0.01**
	(3.83)			**(5.48)**			**(3.42)**		
Edge benefit	–2.39	0.57	0.46	**–8.85**	**<0.01**	**<0.01**	**–6.41**	**<0.01**	**<0.01**
	(2.01)			**(2.37)**			**(1.87)**		
Bid cost difference	–17.06	0.13	0.28	**–23.85**	**0.06**	**0.07**	**–32.23**	**<0.01**	**<0.01**
	(7.67)			**(9.94)**			**(7.23)**		
Net payment	**25.07**	**<0.01**	**<0.01**	12.91	0.15	0.16	**20.76**	**<0.01**	**<0.01**
	(6.80)			(8.67)			**(6.21)**		
Cost effectiveness	**–0.04**	**0.01**	**0.01**	**–0.04**	**0.06**	0.11	**–0.06**	**<0.01**	**<0.01**
	(0.01)			**(0.02)**			**(0.01)**		
Farms conserved	–0.06	0.57	0.51	**–0.44**	**<0.01**	**<0.01**	**–0.24**	**<0.01**	**<0.01**
	(0.09)			**(0.12)**			**(0.07)**		
Obs.		36			36			36	

Table 3B. Effects of the Agglomeration Bonus and Joint Bidding Treatments (Part II)

	SC_JB *minus* SC_AB			SC_AB_JB *minus* SC_AB			SC_AB_JB *minus* SC_JB		
	Mean diff. (SE)	***p*-value (*t*-test)**	***p*-value (rank-sum)**	**Mean diff. (SE)**	***p*-value (*t*-test)**	***p*-value (rank-sum)**	**Mean diff. (SE)**	***p*-value (*t*-test)**	***p*-value (rank-sum)**
Total benefit	**–16.00**	**0.04**	**0.03**	**–10.93**	**0.05**	**<0.01**	5.07	0.87	0.86
	(5.78)			**(3.88)**			(5.51)		
Edge benefit	**–6.46**	**0.07**	**0.03**	**–4.02**	0.26	**0.03**	2.44	0.87	0.86
	(2.62)			**(2.17)**			(2.51)		
Bid cost difference	–6.80	0.78	0.75	–15.18	0.26	0.18	–8.38	0.87	0.86
	(10.83)			(8.42)			(10.53)		
Net payment	–12.17	0.46	0.30	–4.31	0.64	0.52	7.85	0.87	0.76
	(9.01)			(6.67)			(8.58)		
Cost effectiveness	0.004	0.83	0.89	–0.01	0.64	0.52	–0.02	0.87	0.83
	(0.02)			(0.01)			(0.02)		
Farms conserved	**–0.39**	**0.02**	**0.03**	**–0.19**	0.15	**0.04**	0.20	0.35	0.76
	(0.12)			**(0.08)**			(0.11)		
Obs.		36			36			36	

on ‘cost’ is positive and statistically significant. This finding is stable if we control for bidder fixed effects and estimate treatment-specific bid function models for individual and joint bids separately, as shown in Tables B4 and B5 in Appendix B. This suggests that farmers bid for a lower PES payment when faced with lower opportunity costs for providing the environmental benefits, other conditions being equal, consistent with standard auction theory. The conservation auction mechanism is usually believed to be able to allow for differentiated payments for farmers with different opportunity costs, and thereby to achieve higher levels of cost-effectiveness (Engel, 2016; Ferraro, 2008; Hanley et al., 2012). Our finding lends support to that postulation.

Moreover, we find that farmers tended to bid higher if they were able to provide higher environmental benefits, as shown by the positive and statistically significant estimates on ‘node benefit’ and ‘edge benefit’ in Model 1. This finding is consistent with a rent-seeking strategy. For farmers able to provide higher environmental benefits, the multiple bidding round setting might have allowed them to learn that their farms were prioritised by the PES programme and were thus more likely to be selected. If so, those farmers may exploit that advantage and bid higher in an attempt to obtain higher payoffs. This echoes findings from previous studies on experimental and real-world conservation auctions (e.g. Banerjee et al., 2021; Hellerstein, 2017). As shown in Tables B4 and B5, this finding is particularly evident in Models B2 and B6 which were estimated using the bids in Treatment SC and the individual bids in Treatment SC_JB. This is likely because, for the bids in Models B2 and B6, the payoff of winning the auction depended entirely on the value of the bid (aside from the opportunity cost), because no bonus payments were provided for these bids. In those cases, bidding higher was the only possible way to further capitalise on the advantage of being able to provide higher environmental benefits. For the bids involved in the other models in Tables B4 and B5, the payoff of winning the auction depended on both the bid and bonus payments, where the rent-seeking strategy could be more complex and noisier.

In addition, the estimates on the two auction period dummies are negative and sizeable, although the p-value of the estimate on 'Period 3' (0.13) is slightly above the conventional threshold of statistical significance. This suggests that farmers tended to bid lower in Periods 2 and 3 than in Period 1, indicating an improvement in auction cost-effectiveness with increasing auction experience.

Furthermore, the positive and statistically significant estimate on the variable 'risk averse' suggests that risk averse farmers bid slightly higher (about 3% higher than average), which resembles qualitatively the finding of Banerjee et al. (2021). In conservation auctions without AB and JBB, risk averse bidders are typically expected to bid lower in an attempt to reduce the uncertainty of the expected payoff (Latacz-Lohmann and der Hamsvoort, 1997). However, the conservation auctions in this study provided bidders the opportunity of earning AB and/or JBB. In that case, risk-seeking bidders could obtain higher utility from the potential bonus payments which had higher uncertainty, compared to risk averse bidders. Risk-seeking bidders could bid lower so as to enhance the probability of winning the auction and eventually to increase their overall expected payoff (Banerjee et al., 2021). This could explain our finding that more risk averse farmers bid a bit higher than risk-seeking farmers.[15]

The findings discussed above can be summarised as:

[15] That said, the estimate on 'risk averse' could be confounded by unobserved factors that correlate with both bid values and bidders' risk preference, which implies the possibility that the observed effect of 'risk averse' on bid values could be correlational rather than causal.

Result 5. *A farmer is likely to bid lower in an SC conservation auction in the following circumstances (other conditions being equal): 1) AB is provided; 2) the farmer chooses to bid jointly under the JB mechanism; 3) the conservation activity incurs lower opportunity costs or provides lower environmental benefits; 4) the farmer has greater auction experience; or 5) the farmer is more risk-seeking.*

Finally, we estimated a binary logit regression (Model 2 in Table 4) using data from Treatments SC_JB and SC_AB_JB to explore the determinants of the choice between bidding individually or jointly. The negative and statistically significant estimate on 'AB provided' implies that farmers in SC_AB_JB were less likely to bid jointly than in SC_JB (11% less likely in absolute terms), because the provision of AB made joint bids less affordable to the fixed auction budget. Furthermore, farmers able to provide higher edge benefits were more likely to bid jointly (3% more likely in absolute terms for a one-unit increase in edge benefits), which may represent another type of rent-seeking strategy to exploit advantageous environmental endowments. In addition, fewer farmers bid jointly in the last auction period, perhaps because they learnt from the previous periods that large joint bids would not win the auction. We also find that farmers who won the previous auction period were more likely to bid jointly. Moreover, farmers were more likely to bid jointly if they had real-life agricultural collaboration experiences with their neighbours in the experiment (15% more likely in absolute terms), which might imply that they were able to coordinate a joint bid more easily (with lower transaction costs). Note that the regressor 'collaboration' has some degree of exogenous variation, because farmers in each auction group were seated randomly and therefore had random neighbours within the group, although 'collaboration' could potentially correlate with unobserved confounders specific to the auction group. Lastly, farmers with more cattle were more likely to bid jointly, although to a very limited extent (less than 1% more likely in absolute terms for a one-unit increase in cattle). It is possible that these farmers are more likely to herd cattle in different locations and thus tend to be more proactive in developing new collaborative relationships (Thomson et al., 2018). However, the variable 'cattle' is likely correlated with unobserved confounders. Thus, it is more difficult to conclude whether the observed difference in the propensity to bid jointly is indeed caused by the stock of cattle per se, or by some other unobserved confounders that correlate with whether a bidder chose to bid jointly and their stock of cattle.

These findings lend support to:

Result 6. *In an SC conservation auction with the JB mechanism, a farmer is more likely to bid jointly rather than individually if, 1) AB is not provided, 2) the conservation activity could generate higher edge benefits, 3) the farmer has less auction experience, 4) the farmer won the previous auction period, 5) the farmer has pre-existing agricultural collaboration experiences with their neighbours, or 6) the farmer owns more cattle, ceteris paribus.*

Table 4. Analysis of Bidding Behaviour

Explanatory variable:	**Model 1** **Dep. var.: bid amount;** **Model: linear;** **Data: all Treatments**		**Model 2** **Dep. var.: bid jointly;** **Model: binary logit;** **Data: SC_JB, SC_AB_JB**	
AB provided	**–8.69**	**	**–0.67**	*
	(4.37)		**(0.39)**	
JB allowed	–2.23			
	(4.47)			
JB allowed × Bid jointly	**–6.44**	***		
	(2.22)			
AB provided × JB allowed	2.63			
	(5.34)			

Cost	**0.91**	***	0.03	
	(0.12)		(0.02)	
Node benefit	**0.51**	*	0.07	
	(0.26)		(0.05)	
Edge benefit	**0.93**	**	**0.19**	***
	(0.46)		**(0.07)**	
Period 2	**–2.68**	***	–0.22	
	(0.96)		(0.21)	
Period 3	–2.50		**–0.75**	**
	(1.62)		**(0.32)**	
Won previous period	–1.97		**0.96**	**
	(2.28)		**(0.43)**	
Age	0.07		–0.01	
	(0.25)		(0.02)	
Cattle	0.02		**0.02**	**
	(0.04)		**(0.01)**	
Collaboration	–3.02		**1.00**	**
	(3.19)		**(0.48)**	
Education	0.76		–0.03	
	(0.89)		(0.07)	
Gender	–0.40		–0.31	
	(2.80)		(0.48)	
Household head	0.82		0.08	
	(1.52)		(0.37)	
Household size	–0.77		0.02	
	(0.94)		(0.06)	
Land	0.63		–0.02	
	(0.41)		(0.05)	
Leader/CCP	0.47		0.38	
	(4.55)		(0.39)	
Market experience	–0.53		0.34	
	(2.50)		(0.31)	
Risk averse	**3.08**	**	–0.38	
	(1.29)		(0.33)	
Rooms	–0.26		0.01	
	(0.22)		(0.05)	
Village dummies	Yes		Yes	
Experimenter dummies	Yes		Yes	
Clustered std. error	By auction group		By auction group	

Model sig. (p-value)	<0.01	<0.01
(Pseudo) R^2	0.22	0.20
Number of bids	1,296	612
Number of bidders	432	204

Note: Asterisks indicate statistical significance: * p-value < 0.10, ** p-value < 0.05, *** p-value < 0.01. Standard errors are in parentheses.

IV. Conclusion

This paper presents the first framed field experiment study that investigates whether the performance of the spatially coordinated (SC) conservation auction can be further improved by the introduction of agglomeration bonuses (AB) and joint bidding (JB) separately and jointly. Moreover, this study conducted experimental conservation auctions in field settings using farmer subjects, which enriches the evidence base of the wider experimental literature on conservation auctions which has been dominated by laboratory experiments run on student subjects. The SC conservation auction accounts for the spatial coordination of conservation actions by allocating PES contracts in such a way that maximises not only node environmental benefits, but rather, the total environmental benefits comprised of both node and edge benefits. Despite that, our theoretical analysis suggests that the AB and JB mechanisms could, under general conditions, further improve the environmental performance of the SC conservation auction, although this potential improvement is not guaranteed theoretically, which warrants empirical investigation.

Our empirical results suggest that the SC conservation auction has similar environmental performance no matter whether AB is provided or not, although the cost-effectiveness is slightly higher when AB is not provided. Moreover, introducing the

JB mechanism into the SC auction leads to lower environmental performance and cost-effectiveness. The performance of the AB and JB mechanisms was similar in terms of cost-effectiveness, but the AB mechanism had higher environmental performance. This is largely because a joint bid involves multiple farms, which are considered jointly by the PES programme and are thus either accepted or rejected all together. Therefore, joint bids tend to be less affordable to a fixed budget, compared to individual bids which only involve a single farm.

Focusing on bidding behaviour, we find that farmers tend to bid lower in SC conservation auctions if AB is provided, or if the JB mechanism is adopted and farmers choose to bid jointly. By contrast, farmers are likely to bid higher if the conservation activity incurs higher opportunity costs or provides higher environmental benefits. In SC conservation auctions with the JB mechanism, farmers are more likely to bid jointly rather than individually if AB is not provided or if the conservation activity could generate higher edge benefits. In addition, we found that farmers typically bid lower and become less likely to bid jointly in later than in earlier auction periods.

Moreover, the subjects of our experimental auctions are real farmers, who not only better represent the target population of the type of PES programme we focus on, but also have more diverse demographic and socioeconomic characteristics (compared to student subjects), which has allowed us to assess the impacts of those characteristics on farmers' bidding behaviour. We found that risk-averse farmers tend to bid higher. Under the JB mechanism, farmers are more likely to bid jointly rather than individually if they have pre-existing agricultural collaboration experiences with their neighbours, or if they own more cattle. These findings provide useful insights for PES policymakers and can help them formulate expectations of farmers' bidding behaviour according to their demographic and socioeconomic characteristics.

Our findings on auction performance and bidding behaviour suggest that the efficacy of auction mechanisms (JB) and pecuniary incentives (AB and JBB) to promote spatially coordinated land uses will depend upon the budget available to procure projects. Rewarding spatial coordination because it generates benefits for society ultimately takes the form of a transfer of payments from the regulator to the farmer. However, this transfer can only be funded with an increase in budget. If budgets are the same regardless of whether pecuniary incentives exist or not, environmental benefits procured might be the same but auction cost-effectiveness will be lower. With scarce policy budgets, this outcome might be difficult to justify. Yet in real contexts, such as in China where dominant social norms do not discourage collaboration, auctions promoting and rewarding joint bidding with and without AB, despite reducing cost-effectiveness, may have other spill-over benefits. These include maintaining and improving community social capital (which we cannot capture with our data) which have been known to positively influence ecosystem services provision (Bodin and Crona, 2008).

Appendix A. Theoretical Analysis

This section first outlines the rules of the SC conservation auction used in this study to facilitate the theoretical discussion. The theoretical model of this study was adapted from Liu et al. (2019), Fooks et al. (2016), and Latacz-Lohmann and der Hamsvoort (1997).

A. Spatially Coordinated Conservation Auction

The baseline scenario is a budget-constrained SC conservation auction (without AB and JB) which aims to allocate PES contracts to a subset of bidding farmers to achieve the highest total environmental benefits aggregated across all farmers, including both node and edge benefits. This discussion presents each auction group consisting of six farmers, and each of them is assumed to own one of the six farms on a circular network as shown in Figure 1 in the main text. Each farmer i thus has a left and a right neighbour. Each farmer i bids individually for a PES payment b_i to undertake conservation actions at a private opportunity cost c_i which is exogenously given. If farmer i 'wins' the auction and enters a PES contract, they receive the payment they have bid for (b_i), bear the opportunity cost of changing agricultural practices (c_i) and provide an environmental benefit v_i (node benefit). If at least one of their neighbours also wins the auction, supplementary edge benefits v_{il} and/or v_{ir} would also be realised.[1] If farmer i 'loses' the auction and does not receive a PES contract, they remain in business-as-usual agricultural practices, and the net payoff is zero. Farmer i's perceived probability of winning the auction can be written as $p_i(b_i, v_i, v_{il}, v_{ir})$, which depends negatively on their bid b_i, and positively on the three environmental benefit parameters. Thus, $p'_i(b_i) = \frac{\partial p_i(b_i)}{\partial b_i} < 0$. Farmer i is assumed to be risk-neutral,[2] and they choose the level of b_i to maximise their expected payoff:

$$\pi_i(b_i) = p_i(b_i)(b_i - c_i) + [1 - p_i(b_i)] \times 0 = p_i(b_i)(b_i - c_i). \tag{A6}$$

The optimal bid b_i^* satisfies simultaneously the first and second order conditions, where the first order condition can be written as:

$$\pi_i'(b_i^*) = p_i'(b_i^*)(b_i^* - c_i) + p_i(b_i^*) = 0, \tag{A7}$$

and the second order condition requires that

$$\pi_i''(b_i^*) < 0. \tag{A8}$$

In addition, the optimal bid b_i^* needs to be greater than c_i to satisfy the participation constraint – so that the bidder can obtain a positive payoff from winning the auction.

The PES programme manager (the auctioneer) aims to maximise the total environmental benefit V, by choosing which farmers win the auction and receive a PES contract under a fixed budget constraint M. If we use W to represent the set of winning farmers (which is a subset of the six bidding farmers), that optimisation problem can be written as:

$$\begin{aligned} &\max_{W} V(W), \\ &s.t. \sum_{i \in W} b_i^* \leq M. \end{aligned} \tag{A9}$$

We use W^* to denote the solution to that optimisation problem in the baseline scenario.

We next discuss whether the environmental performance of the SC conservation auc-

[1] We assume that farmers' utility levels are not directly affected by the environmental benefits they provide.

[2] We repeated the theoretical analysis assuming risk-averse bidders. The main findings are qualitatively similar.

tion can be improved by the introduction of AB or JB. This question can be converted to whether the total payment for farmers in W^* in the AB or JB scenario is likely to be higher or lower than that in the baseline scenario. Suppose one auction group consists of farmers 1, 2, 3, 4, 5 and 6. W^* denotes winning farmers specifically in the baseline scenario (hereafter referred to as Treatment SC), which could be, for example, farmers 1, 2 and 3. The bid selection algorithm described above suggests that farmers in W^* (farmers 1, 2 and 3 in this example) provide the highest affordable total environmental benefit conditional on farmers' optimal bids (b_i^*) in Treatment SC. Some other combinations of farmers (e.g. farmers 4, 5 and 6) can provide a higher total environmental benefit, but these combinations are not affordable. Some other combinations (e.g. farmers 1, 2 and 4) are affordable, but these combinations provide a lower total environmental benefit. Farmers' optimal bids are likely to change when the AB or JB mechanism is introduced (hereafter referred to as Treatments SC_AB and SC_JB, respectively), as will be discussed shortly. If such changes in optimal bids translate into a higher payment (bid plus bonus if any) for a representative farmer, this suggests the possibility that the environmental benefits offered by farmers 1, 2 and 3 may have become unaffordable (assuming the same budget constraint across different treatments). In that case, the PES programme manager would need to turn to another set of farmers (e.g. farmers 1, 2 and 4) for an affordable but lower total environmental benefit. On the contrary, if Treatment SC_AB or SC_JB has a lower payment (bid plus bonus if any) for a representative farmer than Treatment SC, this guarantees that the environmental benefits offered by farmers 1, 2 and 3 are affordable. Moreover, the PES programme manager may be able to switch to another set of farmers (e.g. farmers 4, 5 and 6) for a higher total environmental benefit which is not affordable in Treatment SC. In that case, Treatment SC_AB or SC_JB could achieve a higher total environmental benefit than Treatment SC.

B. Agglomeration Bonus in Spatially Coordinated Conservation Auction

In Treatment SC_AB, the auction rules are the same as in Treatment SC, except that each farmer i receives a bonus payment (in addition to b_i) if they and at least one of their neighbours win the auction simultaneously. In our experimental auctions, the AB payments are set equal to the edge environmental benefits (v_{il} and/or v_{ir} in Figure 1 in the main text). We use $a_i \geq 0$ to denote farmer i's expectation of the bonus payment they receive if they win the auction. We use $\hat{p}_i(b_i)$ to represent farmer i's perceived probability of winning the auction in Treatment SC_AB; at the same level of b_i, this is lower than that in Treatment SC: $\hat{p}_i(b_i) \leq p_i(b_i)$. This is because the auctioneer in Treatment SC_AB may spend part of the (fixed) budget on bonus payments, which makes the same level of b_i less affordable, compared to Treatment SC. This difference in the perceived probability of winning the auction can be modelled as a horizontal shift of the probability function: $\hat{p}_i(b_i - \delta_i) = p_i(b_i)$, where $\delta_i > 0$. Figure A1 shows an example of this shift where $p_i(b_i)$ takes the standard logistic form. In that case, $\hat{p}_i(b_i)$ and $p_i(b_i)$ have the same shape, and $\hat{p}'_i(b_i - \delta_i) = p'_i(b_i)$.

Farmer i's expected payoff now becomes:

$$\hat{\pi}_i(b_i) = \hat{p}_i(b_i)(b_i + a_i - c_i) + [1 - \hat{p}_i(b_i)] \times 0 = \hat{p}_i(b_i)(b_i + a_i - c_i), \qquad \text{(A10)}$$

which has the first order condition:

$$\hat{\pi}'_i(\hat{b}^*_i) = \hat{p}'_i(\hat{b}^*_i)(\hat{b}^*_i + a_i - c_i) + \hat{p}_i(\hat{b}^*_i) = 0, \qquad \text{(A11)}$$

and the second order condition:

$$\hat{\pi}''_i(\hat{b}^*_i) < 0. \qquad \text{(A12)}$$

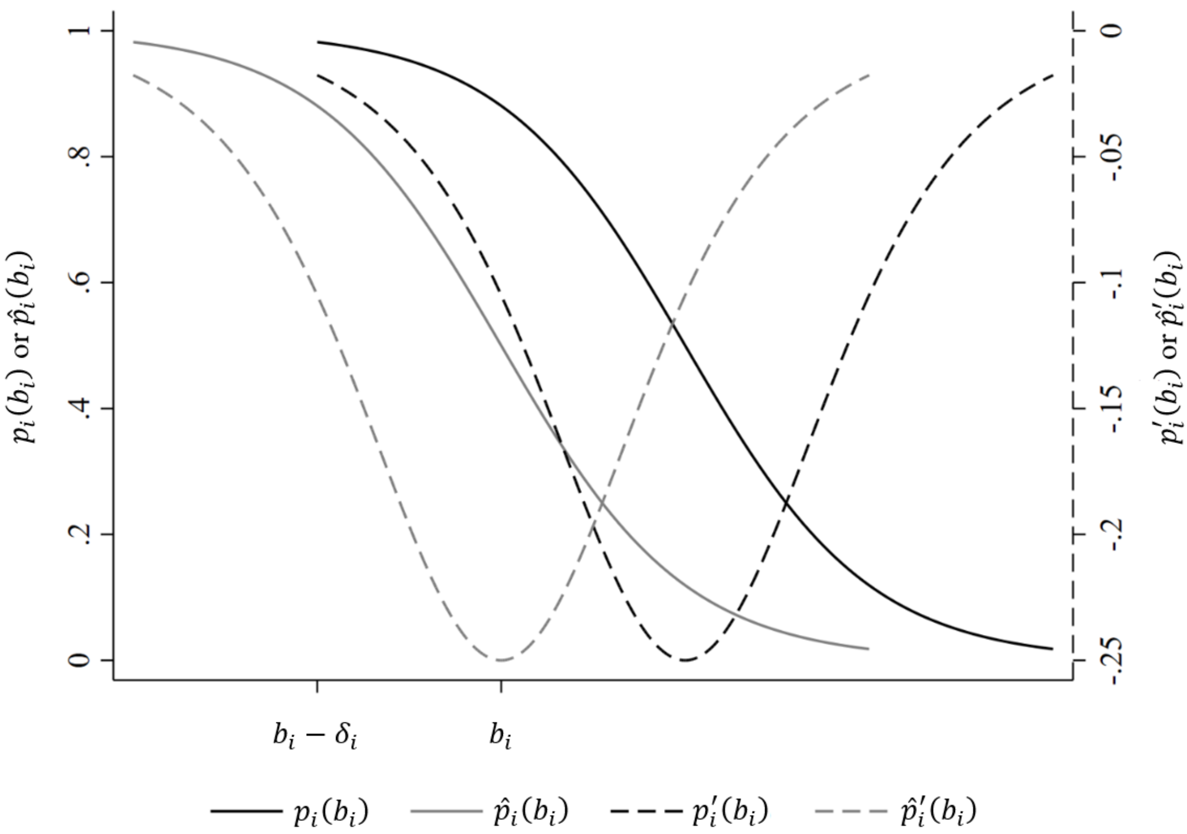

Figure A1. Example of Logistically Distributed Probability of Winning the Auction

where $\hat{b}_i^*$ is the optimal bid that maximises $\hat{\pi}_i(b_i)$. The inequality $\hat{b}_i^* + a_i - c_i > 0$ needs to be satisfied so that the bidder can obtain a positive payoff from winning the auction.

The comparison of the environmental performance of Treatment SC_AB and Treatment SC can be converted to a comparison of $\hat{b}_i^*$ and $b_i^* - a_{iW^*}$, where $i \in W^*$ and a_{iW^*} represents the AB payment that farmer i would receive if the auction winners are farmers in W^*. (Recall that W^* denotes winning farmers specifically in Treatment SC who may differ from those in Treatment SC_AB.) If $\hat{b}_i^* > b_i^* - a_{iW^*}$, the total payment for farmers in W^* in Treatment SC_AB, $\sum_{i \in W^*}(\hat{b}_i^* + a_{iW^*})$, would be higher than that in Treatment SC, $\sum_{i \in W^*} b_i^*$. This implies that the environmental benefits offered by farmers in W^* are more expensive to the PES programme in Treatment SC_AB, which may lead to a lower total environmental benefit being purchased than that in Treatment SC. Conversely, if $\hat{b}_i^* < b_i^* - a_{iW^*}$, the auction in Treatment SC_AB could potentially achieve a higher total environmental benefit than in Treatment SC.

In fact, whether $\hat{b}_i^*$ is higher or lower than $b_i^* - a_{iW^*}$ depends on how a_i, δ_i and a_{iW^*} compare to each other. For example, if $a_i > \delta_i$, we have $\hat{\pi}_i'(b_i^* - \delta_i) = \hat{p}_i'(b_i^* - \delta_i)(b_i^* - \delta_i + a_i - c_i) + \hat{p}_i(b_i^* - \delta_i) = p_i'(b_i^*)(b_i^* - c_i) + p_i'(b_i^*)(a_i - \delta_i) + p_i(b_i^*) = \pi_i'(b_i^*) + p_i'(b_i^*)(a_i - \delta_i) < 0$, because $\pi_i'(b_i^*) = 0$, $p_i'(b_i^*) < 0$ and $a_i - \delta_i > 0$. This suggests that $\hat{b}_i^* < b_i^* - \delta_i$, because $\hat{b}_i^*$ needs to satisfy the second order condition $\hat{\pi}_i''(\hat{b}_i^*) < 0$. In that case, if $\delta_i > a_{iW^*}$, we have $\hat{b}_i^* < b_i^* - a_{iW^*}$, which suggests that the introduction of AB could lead to a higher total environmental benefit than that in Treatment SC. On the contrary, if $a_i < \delta_i$, it can be proved in a similar way that $\hat{b}_i^* > b_i^* - a_{iW^*}$, in which case AB could lead to a lower total environmental benefit.

To conclude, it is possible that the environmental performance of the SC conservation auction could be improved by the introduction of AB, although this cannot be guaranteed theoretically, which warrants empirical investigation.

C. Joint Bidding in Spatially Coordinated Conservation Auction

We next proceed to describe Treatment SC_JB, which has the same auction rules as in Treatment SC, except that each farmer i is allowed to either bid jointly with their neighbour(s) or bid individually. If all farmers choose to bid individually, the situation is the same as in Treatment SC. We thus focus on the case where at least some farmers (in W^*) choose to bid jointly with at least one neighbour.

Under the JB rules designed in this study, if farmer i chooses to bid jointly with their neighbour(s), they still specify a payment b_i for their own farm, and their joint bidding partner(s) will do the same.[3] Farmer i and their partner(s) are considered by the PES programme (the auctioneer) as one single bidder, however, which suggests that they either win the auction simultaneously or lose it simultaneously. If farmer i wins the auction through joint bidding, they receive the payment they have asked for (b_i), plus a bonus payment s_i which rewards the provision of edge benefits and compensates for the private transactions costs of coordinating the joint bid, following the design of the JB mechanism in Banerjee et al. (2021). Our experimental auctions set s_i equal to 1.5 times the edge benefits v_{il} and/or v_{ir}. Therefore, the JB rules adopted in this study is a combination of allowing joint bidding and providing a joint bidding bonus (JBB).

Let $\tilde{p}_i(b_i)$ represent farmer i's perceived probability of winning the auction in Treatment SC_JB if they bid individually. We assume $\tilde{p}_i(b_i) \leq p_i(b_i)$ due to the existence of JBB, and model this difference as a horizontal shift of $p_i(b_i)$: $\tilde{p}_i(b_i - \lambda_i) = p_i(b_i)$, and $\tilde{p}'_i(b_i - \lambda_i) = p'_i(b_i)$, where $\lambda_i > 0$, similar to Treatment SC_AB. When farmer i bids jointly with their neighbour(s), farmer i's perceived probability of winning the auction can be modelled as $\tilde{p}_i(b_i)\tilde{q}_i(b_{ij})$, where $\tilde{q}_i(b_{ij})$ is a function of the joint bidding partner(s)' bid(s) b_{ij}, and $0 < \tilde{q}_i(b_{ij}) \leq 1$.[4] Farmer i's expected payoff from bidding jointly can be written as:

$$\tilde{\pi}_i(b_i) = \tilde{p}_i(b_i)\tilde{q}_i(b_{ij})(b_i + s_i - c_i) + [1 - \tilde{p}_i(b_i)\tilde{q}_i(b_{ij})] \times 0 = \tilde{p}_i(b_i)\tilde{q}_i(b_{ij})(b_i + s_i - c_i). \quad \text{(A13)}$$

The optimal bid $\tilde{b}_i^*$ that maximises $\tilde{\pi}_i(b_i)$ can be solved from the first order condition:

[3] Joint bidders are allowed to coordinate and agree on how much to bid.

[4] This in essence resembles the way that Chernomaz (2012) modelled joint bidding. Chernomaz (2012) modelled a conventional auction where three bidders bid for one single item, and the highest bidder wins the auction and buys the item at the price they bid. Therefore, an individual bidder's probability

$$\tilde{\pi}_i'(\tilde{b}_i^*) = \tilde{p}_i'(\tilde{b}_i^*)\tilde{q}_i(b_{ij})(\tilde{b}_i^* + s_i - c_i) + \tilde{p}_i(\tilde{b}_i^*)\tilde{q}_i(b_{ij}) = 0, \tag{A14}$$

and the second order condition:

$$\tilde{\pi}_i''(\tilde{b}_i^*) < 0. \tag{A15}$$

The environmental performance of Treatment SC_JB can then be discussed in a similar way to Treatment SC_AB. We use s_{iw*} to denote the JBB payment that farmer i receives if they are in W^* and win the auction through a joint bid within W^*. It can be proved that whether Treatment SC_JB achieves a higher total environmental benefit than Treatment SC depends on the relative magnitude of s_i, λ_i and s_{iw*}. If $s_i > \lambda_i > s_{iw*}$, we have $\tilde{\pi}_i'(b_i^* - \lambda_i) = \tilde{q}_i(b_{ij})[\tilde{p}_i'(b_i^* - \lambda_i)(b_i^* - \lambda_i + s_i - c_i) + \tilde{p}_i(b_i^* - \lambda_i)] = \tilde{q}_i(b_{ij})[\pi_i'(b_i^*) + p_i'(b_i^*)(s_i - \lambda_i)] < 0$. This suggests that $\tilde{b}_i^* < b_i^* - \lambda_i < b_i^* - s_{iw*}$, and Treatment SC_JB scenario could achieve a higher total environmental benefit than Treatment SC. By contrast, if $s_i < \lambda_i < s_{iw*}$, it can be proved that $\tilde{b}_i^* > b_i^* - \lambda_i > b_i^* - s_{iw*}$, which suggests that Treatment SC_JB may achieve a lower total environmental benefit than Treatment SC.

This theoretical discussion shows that it is possible to improve the environmental

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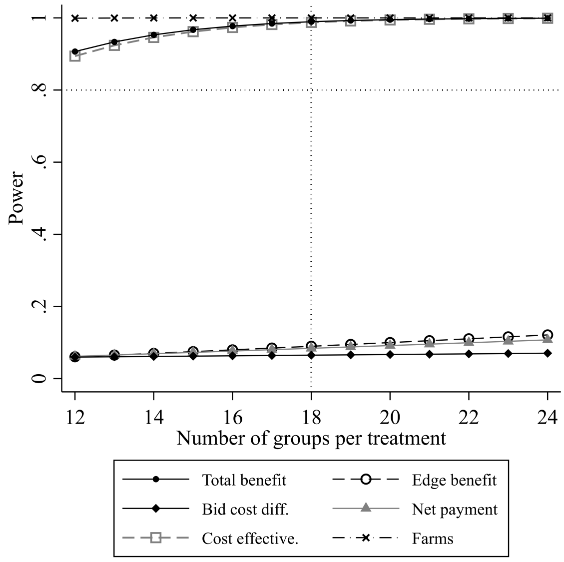
of winning the auction is $[F(b)]^2$, where $[F(b)]$ is the probability that this bidder's bid b is higher than that of another bidder, because this bidder wins the auction only if they bid higher than both the other two bidders. When two bidders bid jointly as one bidder, their probability of winning the auction becomes $F_j(b_j)$, because they win the auction as long as their joint bid b_j is higher than the bid of the third bidder. Our auction has the opposite situation: for a joint bid to win the auction, joint bidding partners all need to 'win the auction', in the sense that each of their farms offers high environmental benefits and is affordable (to the auctioneer's budget), loosely speaking. Therefore, in our auction, the probability of a joint bid winning the auction is a product of all partners' probabilities of winning the auction, whereas the probability of an individual bid winning the auction is just the probability on its own.

performance of the SC conservation by introducing AB or JB. However, this potential improvement is not guaranteed theoretically – it largely depends on how bidders update their beliefs about the relationship between their bid and the probability of winning the auction, in response to the introduction of AB or JB, as well as on how their expected bonus payments compare to those they would receive if PES contracts are allocated in the environmentally optimal way that would be achieved in the absence of AB and JB. Under some general conditions, the introduction of AB or JB could lead to a more favourable environmental outcome. This possibility is empirically explored in our framed field experiment.

Appendix B. Supplementary Tables and Figures

Panel A. Power calculations for t-tests



Panel B. Power calculations for rank-sum tests

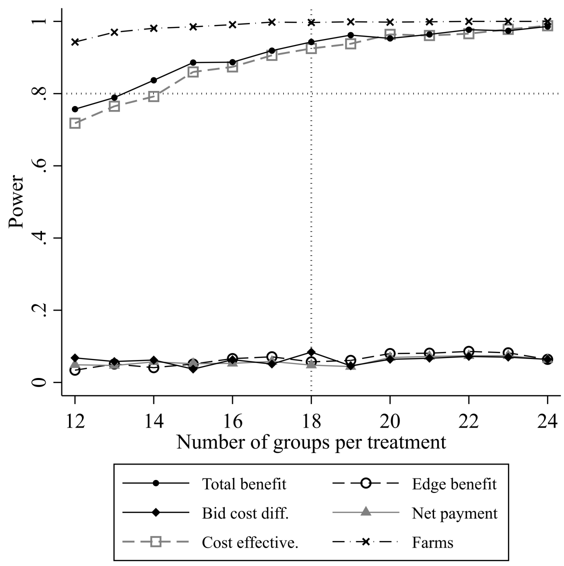


Figure B1. Power Calculations

Table B1. Demographic Variables: Definition, Description and Balance Checks

Variable	Definition	Descriptive statistics (bidder level): Mean (SD)				Balance checks (p-value)	
		SC	SC_AB	SC_JB	SC_AB_JB	Bidder level	Group level
Age	Age (years)	56.27	57.42	55.32	55.17	0.49	0.62
		(11.63)	(11.96)	(11.19)	(13.38)		
Cattle	Number of cattle in the past year	1.76	1.74	5.30	3.09	0.45	0.48
		(7.68)	(14.43)	(24.92)	(15.33)		
Collaboration	Whether a bidder had agricultural collaboration experiences with the left or right neighbour in the past three years (1 = yes, 0 = no)	0.17	0.18	0.23	0.14	0.37	0.48
		(0.37)	(0.38)	(0.42)	(0.35)		
Education	Years of education attended	6.94	6.80	7.51	7.23	0.47	0.58
		(3.79)	(3.64)	(3.60)	(3.64)		
Gender	Gender (1 = male, 0 = female)	0.61	0.73	0.66	0.63	0.35	0.53
		(0.49)	(0.45)	(0.48)	(0.49)		
Household head	Whether a bidder is the head of their household (1 = yes, 0 = no)	0.58	0.73	0.62	0.56	0.30	0.41
		(0.50)	(0.45)	(0.49)	(0.50)		
Household size	Number of household members	3.69	3.98	3.79	3.96	0.51	0.56
		(1.67)	(1.59)	(1.86)	(2.49)		
Land	Area (mu) of cropland and orchard	2.25	2.44	2.96	2.60	0.36	0.50
		(2.60)	(2.53)	(3.44)	(2.67)		
Leader/CCP	Whether a bidder is a village leader or a CCP (Chinese Communist Party) member (1 = yes, 0 = no)	0.28	0.37	0.39	0.27	0.32	0.43
		(0.45)	(0.49)	(0.49)	(0.45)		
Market experience	Whether a bidder ran businesses or had employments in urban areas in the past year (1 = yes, 0 = no)	0.48	0.51	0.52	0.55	0.60	0.65
		(0.50)	(0.50)	(0.50)	(0.50)		
Risk averse	Whether a bidder is risk averse (1 = yes, 0 = no) elicited from a 5-level self-rating question	0.57	0.54	0.53	0.60	0.48	0.60
		(0.50)	(0.50)	(0.50)	(0.49)		
Rooms	Number of rooms in a bidder's house(s)	5.17	5.18	6.01	5.19	0.51	0.56
		(3.37)	(2.96)	(3.52)	(2.69)		
	Obs.	108	108	108	108		

Note: The p-values were derived in the spirit of the Pitman Permutation Test described in Holt and Sullivan (2021). For each covariate, we first measured the differences in means between each of the six pairs of treatments using the original data. We then created 1,000 permuted datasets by randomly reassigning the treatments 1,000 times. We next used each permuted dataset to measure for each covariate the differences in means between treatments pairwise. The p-value of the permutation test was measured as the probability that the absolute value of a difference in means in the permuted data is not smaller than its counterpart in the original data.

Table B2. Treatment Effects: Simulated Auctions, Parameters Randomly Reshuffled

	SC_AB – SC		SC_JB – SC		SC_AB_JB – SC		SC_JB – SC_AB		SC_AB_JB – SC_AB		SC_AB_JB – SC_JB	
	Mean diff.	***p*-value**	**Mean diff.**	***p*-value**	**Mean diff.**	***p*-value**	**Mean diff.**	***p*-value**	**Mean diff.**	***p*-value**	**Mean diff.**	***p*-value**
Total benefit	**–4.80**	**0.10**	**–19.63**	**<0.01**	**–17.15**	**<0.01**	**–14.83**	**0.01**	**–12.35**	**<0.01**	2.48	1.00
Edge benefit	–2.91	0.56	**–9.96**	**<0.01**	**–8.76**	**<0.01**	**–7.06**	**0.10**	**–5.85**	**<0.01**	1.20	0.70
Bid cost difference	**–22.13**	**0.03**	**–30.11**	**<0.01**	**–30.91**	**<0.01**	–7.98	0.52	–8.78	0.66	–0.80	1.00
Net payment	**18.96**	**0.04**	3.64	0.77	**15.62**	**0.05**	–15.32	0.16	–3.34	0.73	11.98	0.74
Cost effectiveness	**–0.04**	**0.01**	**–0.05**	**0.03**	**–0.06**	**<0.01**	–0.005	1.00	–0.01	0.49	–0.01	0.95
Farms conserved	–0.06	0.56	**–0.35**	**0.04**	**–0.31**	**<0.01**	–0.30	0.19	–0.26	0.13	0.04	1.00
Obs.	36		36		36		36		36		36	

Note: The p-values were derived from Wilcoxon rank-sum tests and corrected for multiple hypothesis testing.

Table B3. Outcomes of Simulated and Actual Experimental Auctions, Parameters Reshuffled in the Same Way

	SC			SC_AB			SC_JB			SC_AB_JB		
	Simulated mean (SD)	**Actual mean (SD)**	***p*-value of mean diff.**	**Simulated mean (SD)**	**Actual mean (SD)**	***p*-value of mean diff.**	**Simulated mean (SD)**	**Actual mean (SD)**	***p*-value of mean diff.**	**Simulated mean (SD)**	**Actual mean (SD)**	***p*-value of mean diff.**
Total benefit	123.06	123.02	0.93	118.35	119.37	0.89	100.43	103.37	0.54	102.41	108.44	0.58
	(4.84)	(10.09)		(13.92)	(12.75)		(22.60)	(20.93)		(19.43)	(10.40)	
Edge benefit	44.89	44.52	0.80	41.94	42.13	0.87	34.83	35.67	0.38	36.04	38.11	0.58
	(2.48)	(5.03)		(6.70)	(6.88)		(10.43)	(8.71)		(9.10)	(6.14)	
Bid cost difference	46.35	41.85	0.51	28.87	24.80	0.80	18.37	18.00	0.92	13.96	9.62	0.39
	(18.16)	(19.03)		(28.72)	(26.38)		(32.38)	(37.63)		(29.11)	(24.07)	
Net payment	46.35	41.85	0.51	70.81	66.93	0.75	52.65	54.76	0.94	61.71	62.61	0.55
	(18.16)	(19.03)		(24.22)	(21.66)		(29.82)	(31.50)		(28.85)	(18.23)	
Cost effectiveness	0.45	0.45	0.77	0.40	0.40	0.74	0.39	0.41	0.63	0.38	0.39	0.58
	(0.03)	(0.04)		(0.04)	(0.04)		(0.06)	(0.07)		(0.04)	(0.05)	
Farms conserved	3.07	3.11	0.81	3.02	3.06	0.73	2.67	2.67	0.94	2.72	2.87	0.54
	(0.14)	(0.26)		(0.35)	(0.31)		(0.52)	(0.43)		(0.40)	(0.17)	
Obs.	18	18		18	18		18	18		18	18	

Note: The p-values were derived from Wilcoxon rank-sum tests, but NOT corrected for multiple hypothesis testing, so that the p-values are more likely to pick up statistical difference between the simulated and actual experimental auctions, and thus provide a conservative assessment of their statistical similarity.

Table B4. Dependence of Bid Amount on Auction Parameters and Periods (Fixed Effects Estimates)

Dependent variable: bid amount **Explanatory variables:**	**Model B1** **(All bids)**	**Model B2** **(SC,** **all bids)**	**Model B3** **(SC_AB,** **all bids)**	**Model B4** **(SC_JB,** **all bids)**	**Model B5** **(SC_AB_JB,** **all bids)**
Cost	**0.72*** **	**0.63** **	**0.73*** **	**0.90*** **	**0.57** **
	(0.10)	**(0.26)**	**(0.12)**	**(0.15)**	**(0.23)**
Node benefit	**0.35* **	**1.21*** **	0.28	0.30	–0.39
	(0.21)	**(0.35)**	(0.23)	(0.25)	(0.59)
Edge benefit	0.35	0.62	0.42	0.42	–0.18
	(0.26)	(0.46)	(0.32)	(0.39)	(0.78)
Period 2	**–2.56*** **	–2.99	–2.65	–1.62	–2.97
	(0.94)	(1.96)	(1.74)	(2.04)	(1.97)
Period 3	**–4.88** **	–7.76	**–5.68* **	–3.40	–2.61
	(2.04)	(4.86)	**(2.97)**	(3.34)	(4.84)
Won previous period	3.31	4.16	4.89	1.42	2.35
	(1.99)	(4.77)	(3.47)	(3.64)	(3.87)
Bidder fixed effects	Yes	Yes	Yes	Yes	Yes
Clustered std. error (by auction group)	Yes	Yes	Yes	Yes	Yes
Model sig. (p-value)	<0.01	<0.01	<0.01	<0.01	<0.01
R^2 (within)	0.22	0.14	0.37	0.34	0.19
Number of bids	1,296	324	324	324	324
Number of bidders	432	108	108	108	108

Note: Asterisks indicate statistical significance: * p-value < 0.10, ** p-value < 0.05, *** p-value < 0.01. Standard errors are in parentheses.

Table B5. Dependence of Bid Amount on Auction Parameters and Periods (Switching Regression Estimates)

Dependent variable: bid amount **Explanatory variables:**	**Model B6 (SC_JB, indiv. bids)**	**Model B7 (SC_JB, joint bids)**	**Model B8 (SC_AB_JB, indiv. bids)**	**Model B9 (SC_AB_JB, joint bids)**
Cost	**1.04*** **	**0.82*** **	0.22	**0.70*** **
	(0.31)	**(0.19)**	(0.56)	**(0.24)**
Node benefit	**1.72** **	–0.01	–1.06	–0.05
	(0.71)	(0.42)	(1.20)	(0.53)
Edge benefit	1.10	0.48	–1.34	0.29
	(0.99)	(0.57)	(1.97)	(0.75)
Period 2	–4.51	0.01	–5.63	–0.12
	(4.91)	(2.57)	(5.45)	(1.72)
Period 3	–1.76	–5.61	0.98	–7.15
	(4.79)	(3.93)	(9.03)	(4.43)
Won previous period	4.07	4.18	5.20	5.71
	(8.52)	(4.31)	(10.65)	(4.78)
Inverse Mills Ratio	3.27	–0.36	–6.49	**10.94** **
	(4.00)	(5.08)	(6.59)	**(4.95)**
Cost and quality parameters (bidder level averages)	Yes	Yes	Yes	Yes
Won previous period (bidder level average)	Yes	Yes	Yes	Yes
Covariates	Yes	Yes	Yes	Yes
Bidder fixed effects	No	No	No	No
Bootstrapped std. error (clustered by auction group)	Yes	Yes	Yes	Yes
Model sig. (p-value)	<0.01	<0.01	0.12	<0.01
R^2	0.53	0.32	0.26	0.30
Number of bids	84	240	104	220
Number of bidders	50	96	57	93

Note: Models B6–B9 were estimated using the generalised panel data switching regression model as in Malikov and Kumbhakar (2014) and Tesfaye et al. (2021) to formally account for the sample selection process in Treatments SC_JB and SC_AB_JB where farmers self-selected into bidding individually or jointly. The switching regression models were estimated using the two-stage procedure as in Malikov and Kumbhakar (2014) and Tesfaye et al. (2021). In the first stage, we estimated for each auction period a binary selection model which explains the choice between bidding individually or jointly using the auction parameters and the 'won previous period' variable for each auction period, the averages of the auction parameters and the 'won previous period' variable over the three auction periods, and the bidder-specific covariates listed in Table B1. The first-stage model was used to compute the inverse Mills ratio estimates for the correction of potential selection bias. In the second stage, we estimated a pooled least squares model (for individual and joint bids separately) which regressed bid values against all the regressors in the first-stage model, the inverse Mills ratio derived from the first-stage model, and the auction period dummies. Standard errors (in parentheses) were estimated using 1,000 non-parametric bootstraps. Asterisks indicate statistical significance: * p-value < 0.10, ** p-value $<$ 0.05, *** p-value < 0.01. Standard errors are in parentheses.

Appendix C. Experimental Protocol

(This is the protocol for Treatment SC_AB_JB, which is identical to that for the other three treatments aside from treatment specific rules. This protocol was translated back and forward into Chinese. The information in parentheses was added for peer review.)

[Please be noted that the information in brackets was meant to help the surveyors to implement the experiment and should NOT be read out to the subjects. This is the experimental protocol. Please precisely read out this protocol to each group of subjects in the most similar way possible. In order to ensure that the subjects thoroughly understand the rules, please remain patient and respond properly to the subjects' questions.]

[1 Greeting and General Information]

Hello! We are university students from ... (The institution's name has been removed for peer review.) We would like to invite the six of you to play a game together. This game is about managing fruit trees. The results of the game will be used for scientific research only. Your personal information will be kept strictly confidential. The game is hypothetical and has no connection with your actual situation. The whole game will take about two to three hours. If you complete the entire game, we will pay each of you at least RMB 50 in cash immediately. But if you fail to complete the whole game, we would not be able to pay you. Would you like to play this game?

[If 'yes', please continue with the following instructions; otherwise please record the reasons why the subject refuses to participate and contact your supervisor.]

Thanks for agreeing to participate! After we finish the game, we will definitely pay you RMB 50 for your time, which has nothing to do with the result of the game. In addition to this RMB 50, you may also get some extra money from the game, but whether you get this extra money and how much you get depend on the result of the game. Therefore, after finishing the game, each of you will get at least RMB 50, but whether you can get more than RMB 50 depends on the result of the game. Any questions?

Thank you. Please do not talk to each other during the game unless allowed to. If you have any questions, please raise your hand, and we will come to you to answer your questions. If you do not follow these rules, we would have to ask you to leave the game and would not be able to pay you any money. Any questions?

[2 Rules of the Game]

Thank you! We will now start explaining how to play the game. Please listen carefully. If you have any questions, please feel free to raise your hand.

[2.1 Handouts]

We will now distribute two handouts. Please look at only your own handouts and do not look at others'. *[Distribute the information and answer sheets.]* Now please look at the handout with circles. *[Show farmers the information sheet.]* This handout provides all the information you need for the game. Now please look at the other handout with tables. *[Show farmers the answer sheet.]* This is for you to fill in your answers during the game. Please look at only your own handouts and do not look at others'. Otherwise, we would have to ask you to leave the game and would not be able to pay you any money.

[2.2 Seat Number and Land]

Now please look at the handout with circles. *[Show farmers the information sheet.]* This is your seat number. *[Show farmers the seat number.]* This was randomly decided just now by drawing lots. Suppose you have a plot of land. This land plot is in this graph. Each circle represents a land plot. Your land plot has the same number as your seat. For example, if your seat number is 1, your land plot is number 1; if your seat number is 2, your land plot is number 2, and so on. Each land plot has one neighbouring plot on the left and another one on the right. The numbers of your neighbours also match your seat numbers. For example, if you are number 1, the neighbour on your left is number 6 and the neighbour on your right is number 2. *[Show farmer No.1 their neighbours.]* If you are number 3, the neighbour on your left is number 2 and the neighbour on your right is number 4. *[Show farmer No.3 their neighbours.]* If you are number 6, the neighbour on your left is number 5 and the neighbour on your right is number 1. *[Show farmer No.6 their neighbours.]*. Throughout the whole game, everyone's seat number and land plot are fixed and will not change. Any questions? *[Pause briefly to make sure all the farmers have fully understood this part before continuing. If some of them do not fully understand this part, explain it again.]*

[2.3 The PES Programme]

Suppose you have fruit trees on your land plot. Originally you would use chemical pesticides. However chemical pesticides would poison wildlife, such as birds and bees. Now there is an environmental programme which wants to protect wildlife. This programme wants to choose some of you to participate. We will tell you shortly how this programme selects participants. If you are selected into the programme, you can only use bio-pesticides. Bio-pesticides are less toxic to birds, bees and other wildlife, but are equally effective against pests and diseases, and fruit trees can grow equally well. However bio-pesticides are more expensive, which means you would spend more money buying pesticides. The amount of this extra money is here. *[Point at the additional cost on the first page of the information sheet.]* The environmental programme will give you some subsidies to compensate for the extra money you spend on bio-pesticides.

In this game, you need to do only one thing. **Please tell us how much subsidy you would like to have, by writing down a number on this answer sheet.** *[Show farmers the answer sheet.]* In addition, you could have a bonus in some situations. These situations are shown on these pages, which we will talk about shortly. *[Show farmers all possible results on the information sheet.]* Shortly we will ask the six of you to write down on this answer sheet how much subsidy you want. After that, we will work out the result and announce which of you are selected. If you are selected, your net earning from the game would be calculated like this: the subsidy you ask for, plus the bonus if any, minus the extra money spent on bio-pesticides. Therefore, from your perspective, the subsidy you ask for plus the bonus should be greater than the extra money spent on bio-pesticides. Otherwise you may lose money.

For example, suppose you are selected into the programme. If you have asked for a subsidy of 100, you get a bonus of 20, and the extra money spent on bio-pesticides is 100, then your net earning would be: the subsidy of 100 plus the bonus of 20 minus the 100 spent on bio-pesticides, and your net earning would be 20. However, if you have asked for a subsidy of 60, you get a bonus of 20, and the extra money spent on bio-pesticides is 100, then your net earning would be: the subsidy of 60 plus the bonus of 20 minus the 100 spent on bio-pesticides, and you would lose 20.

The six of you have different kinds of fruit trees which may be affected by different kinds of pests and diseases. Therefore each of you may need different kinds of bio-pesticides and the extra money you spend on bio-pesticides is also different. This means you may want different amounts of subsidy.

If you are not selected into this programme, you can use the usual chemical pesticides, in which case you would not spend additional money on pesticides and would not receive any subsidy or bonus either. This means your net earning would be zero. In other words, you will not be able to earn any money from the game unless you are selected into the environmental programme.

Any questions? *[Pause briefly to make sure all the farmers have fully understood this part before continuing. If some of them do not fully understand this part, explain it again.]*

[2.4 Selection Criteria]

Now we talk about how this environmental programme selects participants. The selection rules are as follows. First, we have a limited budget for this programme. The budget needs to cover the total amount of the subsidies and bonuses for all participants that are selected. *[DO NOT tell farmers the total budget].* Therefore, if you ask for too much subsidy which exceeds our budget, you would not be selected. This means that the less subsidy you ask for, the more likely that you will be selected and get the subsidy. However, as we said earlier, if you are selected, your net earning from the game would be, the subsidy you ask for, plus the bonus if any, minus the extra money spent on bio-pesticides. Therefore, if the subsidy you ask for is too low, you may earn less money or even lose money. In short, on the one hand, if you ask for less subsidy, you are more likely to be selected and get the subsidy; on the other hand, if the subsidy you ask for is too low, you may earn less money or even lose money. You need to consider both aspects.

In addition, the objective of this environmental programme is to protect wildlife such as birds and bees. If you join this programme and switch to bio-pesticides, this will benefit birds and bees nearby. We have provided a score for your land, which shows how much you can benefit wildlife if you switch to using bio-pesticides on your land. *[Show farmers the environmental benefit in the first possible result under the first way to apply.]*

We will call this score the environmental score. A higher environmental score means a greater benefit for wildlife if you switch to bio-pesticides. The environmental programme selects participants in such a way that gives the highest total benefit for wildlife, or the highest total environmental score, as long as the budget can cover the total amount of the subsidies and bonuses for all participants that are selected. Therefore, the higher the environmental score your land has, the more likely that you will be selected into this environmental programme. This score is provided by us and cannot be changed by yourself. In addition, if you and your neighbours are simultaneously selected into the programme and switch to bio-pesticides, the benefit for wildlife on your land will become greater. *[Point at the environmental benefit in the second possible result under the first way to apply.]* This is because wildlife is less likely to be poisoned if you and your neighbours' land plots simultaneously switch to bio-pesticides, compared to the situation where only your own land switches to bio-pesticides.

To sum up, if you ask for less subsidy, and if switching to bio-pesticides on your land has a higher benefit to wildlife, you are more likely to be selected into the programme and get the subsidy. The characteristics of your land plots are different: the extra money spent on bio-pesticides is different, and the benefits to wildlife are also different. Please DO NOT look at these details on others' information sheets. Any questions? *[Pause briefly to make sure all the farmers have fully understood this part before continuing. If some of them do not fully understand this part, explain it again.]*

[2.5 How to Apply]

Now we talk about different ways to apply to join the programme. You can apply on your own, or apply jointly with one or two of your neighbours. As we said earlier, you have one neighbour on your left and another neighbour on your right. Therefore, you have four ways to apply: if you apply on your own, please write down the amount of subsidy you want in the first column of the left half of this table. *[Show farmers this column.]* If you apply jointly with the neighbour on your left, please write down the amount of subsidy you want in the second column. *[Show farmers this column.]* If you apply jointly with the neighbour on your right, please write down the amount of subsidy you want in the third column. *[Show farmers this column.]* If you apply jointly with both neighbours, please write down the amount of subsidy you want in the fourth column. *[Show farmers this column.]*

If you apply jointly with one of your neighbours, please still write down the amount of subsidy only for you. *[Point at the columns for joint bids on the answer sheet.]* However, when the environmental programme selects participants, the two of you will be considered as one single applicant. We will consider the total amount of the subsidy you two have asked for, and the total level of the environmental benefits of you two's land. These will be compared to others' applications to see whether the joint application of you two suits the programme better than others'. In the end, either both of you are selected, or neither of you is selected. Therefore, you will need to first discuss with your neighbours whether you will apply together, and if so, how much subsidy each of you will ask for. We will tell you later when and how to discuss with your neighbours. If you tell us that you are applying together with a neighbour, but this neighbour tells us that he or she is applying on their own, then both of you will be considered as applying on your own.

The rules are similar if you apply jointly with both of your neighbours.

Any questions? *[Pause briefly to make sure all the farmers have fully understood this part before continuing. If some of them do not fully understand this part, explain it again.]*

[2.6 Bonus]

Now we will explain the last part of the rules. Please remain patient and listen carefully. Now we talk about the situations where you can get a bonus.

Suppose you apply on your own. If you and at least one of your neighbours are simultaneously selected into the programme, you will get a bonus. This is because wildlife is less likely to be poisoned if you and your neighbours' land plots simultaneously switch to bio-pesticides, compared to the situation where only your own land switches to bio-pesticides. For example, please look at the second possible result under the first way to apply. *[Point at the second possible result under the first way to apply.]* If you apply on your own and are selected into the programme, and one of your neighbours is also selected, then you can get a bonus in addition to the subsidy you have asked for, and the amount of the bonus is this much. *[Point at the bonus.]*

Alternatively, if you apply jointly with a neighbour, and you are both selected, then you will get an even higher bonus. For example, please look at the first possible result under the second way to apply. *[Point at the first possible result under the second way to apply.]* If you apply jointly with a neighbour, and you are both selected, then you will get a bonus. The amount of the bonus is this much *[pointing at the bonus]*, which is higher than that in the situation where you and your neighbours apply separately but happen to be simultaneously selected into the programme.

To sum up, as long as you and at least one of your neighbours are simultaneously selected into the programme, you will get a bonus. If you apply jointly with one or both of your neighbours and the application is successful, you will get a higher bonus. Any questions? *[Pause briefly to make sure all the farmers have fully understood this part before continuing. If some of them do not fully understand this part, explain it again.]*

[3 Trials]

Before we formally start, let us run a few trials. These trials do not count, and do not affect your earning from the game.

Now you may discuss with your left side neighbour or your right side neighbour. You could discuss anything, but you can talk to only the two people sitting next to you, one at a time. You have a maximum of 5 minutes. You can now start talking. *[Timer starts.] [Wait for 5 minutes, prepare the Excel solver function, and remind farmers of the last minute.]*

Okay. The time is up. Please stop talking. Now please turn to the answer sheet. Please write down in the first row of the left half of the answer table how you would like to apply and how much subsidy you would like to ask for. *[Show farmers this row.]* If you are applying on your own, please write down in the first column how much subsidy you would like to ask for. If you are applying jointly with your left side neighbour, please write down in the second column how much subsidy you would like to ask for. If you are applying jointly with your right side neighbour, please write down in the third column how much subsidy you would like to ask for. If you are applying jointly with both neighbours, please write down in the fourth column how much subsidy you would like to ask for. When you have finished, please raise your hand. *[Record farmers' bids and work out the result.]*

Okay. In this round, the people who are selected into the environmental programme are ... *[Announce the seat numbers of the winning bidders.]* This round is a trial. It does not count, and does not affect your earning from the game. Now we will come to you to fill in the results and explain the meaning of the results. *[Fill in the results in the right half of the answer table.]*

[Explain to each farmer in private the meaning of the results. Please spend a maximum of 3min with each farmer.]

[If the farmer was selected but did not get a bonus:]

As you can see, you are selected, which means you would get the subsidy you have asked for. *[Point at the subsidy on the answer sheet.]* However neither of your neighbours is selected. *[Point at the results of the neighbours on the answer sheet.]* Therefore you would not get a bonus. This is your result. *[Point at the corresponding result on the information sheet.]* Your net earning would be, the subsidy of ... *[the amount of the subsidy the farmer has asked for]*, minus the ... *[the amount of the farmer's extra cost on bio-pesticides]* spent on bio-pesticides, which is ... *[the amount of the net earning.]* Therefore, these are all the possible results of the game. *[Point at all possible results on the information sheet.]* However, when considering how much subsidy you would like to ask for, you do not know the result of your application. You only know that the result will be one of these. *[Point at all possible results on the information sheet.]* You need to consider all these possible results, since you do not know in advance which of these will be the final result.

[If the farmer applied on their own, and was selected and got a bonus:]

As you can see, you are selected, which means you would get the subsidy you have asked for. *[Point at the subsidy on the answer sheet.]* In addition, your neighbour(s) is (are) also selected. *[Point at the results of the neighbours on the answer sheet.]* Therefore you would get a bonus. This is your result. *[Point at the corresponding result on the information sheet.]* Your net earning would be, the subsidy of ... *[the amount of the subsidy the farmer has asked for]*, plus the bonus of ... *[the amount of the bonus]*, minus the ... *[the amount of the farmer's extra cost on bio-pesticides]* spent on bio-pesticides, which is ... *[the amount of the net earning.]* Therefore, these are all the possible results of the game. *[Point at all possible results on the information sheet.]* However, when considering how much subsidy you would like to ask for, you do not know the result of your application. You only know that the result will be one of these. *[Point at all possible results on the information sheet.]* You need to consider all these possible results, since you do not know in advance which of these will be the final result.

[If the farmer applied jointly with at least one neighbour, and was selected and got a bonus:]

As you can see, you are selected, which means you would get the subsidy you have asked for. *[Point at the subsidy on the answer sheet.]* In addition, your neighbour(s) is (are) also selected. *[Point at the results of the neighbours on the answer sheet.]* Therefore you would get a bonus. Moreover, because you applied jointly with your neighbour(s), you would get a higher bonus. This is your result. *[Point at the corresponding result on the information sheet.]* Your net earning would be, the subsidy of ... *[the amount of the subsidy the farmer has asked for]*, plus the bonus of ... *[the amount of the bonus]*, minus the ... *[the amount of the farmer's extra cost on bio-pesticides]* spent on bio-pesticides, which is ... *[the amount of the net earning.]* Therefore, these are all the possible results of the game. *[Point at all possible results on the information sheet.]* However, when considering how much subsidy you would like to ask for, you do not know the result of your application. You only know that the result will be one of these. *[Point at all possible results on the information sheet.]* You need to consider all these possible results, since you do not know in advance which of these will be the final result.

[If the farmer was not selected:]

Unfortunately you are not selected, which means your net earning is zero. *[Point at the farmer's provisional net earning on the answer sheet.]* This is likely because the subsidy you asked for is too high, or others' land plots have a greater impact on wildlife. This is your result. *[Point at the corresponding result on the information sheet.]* Therefore, these are all the possible results of the game. *[Point at all possible results on the information sheet.]* However, when considering how much subsidy you would like to ask for, you do not know the result of your application. You only know that the result will be one of these. *[Point at all possible results on the information sheet.]* You need to consider all these possible results, since you do not know in advance which of these will be the final result.

[For the entire group:]

Okay. Now you have seen the situation of this round. This round is a trial. It does not count, and does not affect your earning from the game. In this trial, some of you were selected, some of you were not. You would not be able to earn any money unless you are selected. If you ask for less subsidy, and if switching to bio-pesticides on your land has a higher benefit to wildlife, you are more likely to be selected. Among those who were selected, some of them would earn more money than others. On the one hand, if you ask for less subsidy, you are more likely to be selected and get the subsidy; on the other hand, if the subsidy you ask for is too low, you may earn less money or even lose money. You need to consider both aspects. As long as you and at least one of your neighbours are simultaneously selected into the programme, you will get a bonus. If you apply jointly with one or both of your neighbours and the application is successful, you will get a higher bonus. These are all the possible results of the game. *[Point at all possible results on the* *information sheet.]* When considering how much subsidy you would like to ask for, you need to consider all these possible results, since you do not know in advance which of these will be the final result. Any questions? *[Pause briefly to make sure all the farmers have fully understood this part before continuing. If some of them do not fully understand this part, explain it again.]*

[Run another trial and explain the result following the instructions above.]

[4 Quiz]

Before we begin the game, let us start with a quiz to see whether we have clearly explained the rules of the game. On the answer sheet, there are a few statements about the rules of the game. *[Show farmers the quiz.]* Please put a tick mark next to a statement if you think it is correct, or a cross mark if you think it is wrong. Your answers in this quiz do not affect how much money you get from the game. Once you have finished, please raise your hand. We will then come to you to go through your answers and further explain the rules of the game if needed.

[5 Auction Period 1]

Now we formally start. Now we will come to you, collect your information and answer sheets, and then give you a new set of handouts. *[Collect the old information and answer sheets, and then distribute the new ones.]*

[5.1 New Handouts]

First, please look at this new information sheet with circles on it. It contains all the information you need for playing the game. Your seat number and your neighbours are the same as in the trial. *[Show farmers the information sheet.]* But three things may have become different: the extra money you would need to spend on bio-pesticides if you are selected into the environmental programme, the environmental benefits to wildlife if you switch to bio-pesticides on your land, and the amount of bonus you would receive if you and your neighbours are simultaneously selected into the programme. *[Point at these details on the information sheet.]* Please read through these carefully. The answer sheet is the same as in the trial. *[Show farmers the answer sheet.]*

[5.2 Bidding Rounds]

The rules of the game remain the same. We will repeat the procedure for a few rounds. *[Starting from Round 3, the auction period concludes if the current round has the same winning bidders as in the previous round. Otherwise proceed to the next round. Each auction period has a maximum of 6 rounds if the winners keep changing. DO NOT tell farmers the stopping rule.]* The result of the last round will be the final result. Only the result of the last round counts and affects your earning from the game. The results of all previous rounds do not count and do not affect your earning from the game. Any questions? *[Pause briefly to make sure all the farmers have fully understood this part before continuing. If some of them do not fully understand this part, explain it again.]*

[5.3 First Round]

Now we are ready for the first round. You may discuss with your left side neighbour or your right side neighbour. You could discuss anything, but you can talk to only the two people sitting next to you, one at a time. You have a maximum of 3 minutes. You can now start talking. *[Timer starts.] [Wait for 3 minutes, prepare the Excel solver function, and remind farmers of the last minute.]*

Okay. The time is up. Please stop talking. Now please turn to the answer sheet. Please write down in the first row of the left half of the answer table how you would like to apply and how much subsidy you would like to ask for. *[Show farmers this row.]* When you have finished, please raise your hand. *[Record farmers' bids and work out the result.]* Okay. In this round, the people who are selected into the environmental programme are ... *[Announce the seat numbers of the winning bidders.]* Now we will come to you and fill in the results. *[Fill in the results in the right half of the answer table.]* Okay. Now you have seen the situation of this round. This round does not count, and does not affect your earning from the game. Let us try again.

[5.4 Subsequent Rounds]

[Repeat this bidding procedure for a minimum of 3 rounds. Starting from Round 3, the auction period concludes if the current round has the same winning bidders as in the previous round. Otherwise proceed to the next round. Each auction period has a maximum of 6 rounds if the winners keep changing.]

Now let us move on to the next round. Now you may discuss with your left side neighbour or your right side neighbour. You could discuss anything, but you cannot talk to others aside from the two people sitting next to you, one at a time. You have a maximum of 3 minutes. You can now start talking. *[Timer starts.] [Wait for 3 minutes, prepare the Excel solver function, and remind farmers of the last minute.]*

Okay. The time is up. Please stop talking. Now please turn to the answer sheet. Please write down in the ... *[the ordinal number of this round]* row of the left half of the answer table how you would like to apply and how much subsidy you would like to ask for. *[Show farmers this row.]* When you have finished, please raise your hand. *[Record farmers' bids and work out the result.]*

Okay. In this round, the people who are selected into the environmental programme are ... *[Announce the seat numbers of the winning bidders.]* Now we will come to you and fill in the results. *[Fill in the results in the right half of the answer table.]*

[If this is the last round:]

Okay. Now you have seen the situation of this round. This is the final round, and the result of this round is the final result. The result of this round counts and affects your earning from the game. We will now prepare the money for you. *[Prepare the payments for this auction period.]*

[If this is not the last round:]

Okay. Now you have seen the situation of this round. This round does not count, and does not affect your earning from the game. Let us try again.

[6 Auction Period 2]

Thanks for your participation! We have completed one game. Now let us play this game one more time. Now we will come to you, collect your information and answer sheets, and then give you a new set of handouts. *[Collect the old information and answer sheets, and then distribute the new ones.]*

[6.1 New Handouts]

First, please look at this new information sheet with circles on it. *[Show farmers the information sheet.]* It contains all the information you need for playing the game one more time. Your seat number and your neighbours are the same as in the last game. But three things may have become different for you in the new game: the extra money you would need to spend on bio-pesticides if you are selected into the environmental programme, the environmental benefits to wildlife if you switch to bio-pesticides on your land, and the amount of bonus you would receive if you and your neighbours are simultaneously selected into the programme. *[Point at these details on the information sheet.]* Please read through these carefully. The answer sheet is the same as in the last game. *[Show farmers the answer sheet.]* The rules of the game remain the same. Any questions? *[Pause briefly to make sure all the farmers have fully understood this part before continuing. If some of them do not fully understand this part, explain it again.]*

[The remaining instructions for this auction period are the same as Sections 5.2–5.4.]

[7 Auction Period 3]

[The instructions for this auction period are the same as Section 6.]

[8 Closing Remarks]

Okay. The game is now all over. Thank you very much for your participation! Please remain seated. We will come to you, collect your handouts and complete a short questionnaire with you. After that, we will give you the payments. Thank you!

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