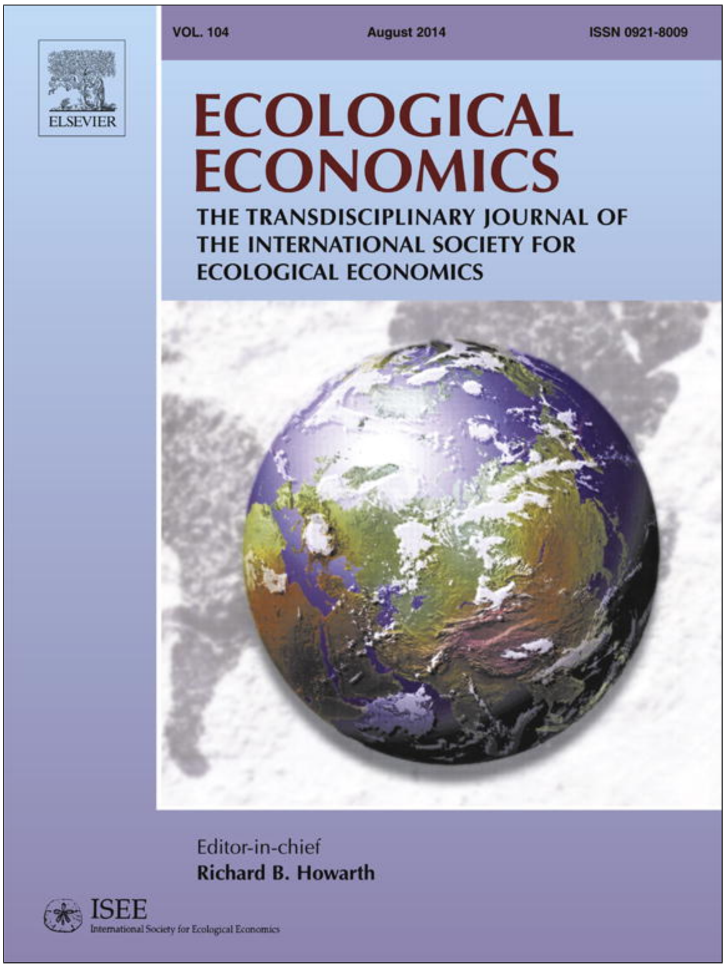
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Analysis

Wildlife corridor market design: An experimental analysis of the impact of project selection criteria and bidding flexibility

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ABSTRACT

In this work we used controlled laboratory experiments to investigate the impact of project selection criteria and bidding flexibility on the economic performance of wildlife corridor auctions. Bidders coordinated their bids to form valid corridors and compete with other valid corridors to be successful. We tested the impact of bidding flexibility in terms of (a) bidders differentiating their offers for different eligible corridors and (b) bidders submitting a single offer that would automatically be considered for all eligible corridors. Within the bidding options, we compared the performance of the auctions under a net benefit and a benefit cost ratio selection criteria. We found that participants conditioned their offers in terms of corridor benefit information. As a consequence, allowing multiple offers significantly increased payment and rent extraction. On the other hand, a single offer restriction facilitated a higher proportion of valid agreements and reduced rent extraction and, as a result, the agency's payment. We could not find any significant difference between project selection criteria in terms of payment and rent extraction. These results provide important insights for policy makers engaged in conservation market design throughout the world.

1. Introduction

The ecological benefits of establishing wildlife corridors in fragmented landscapes are well documented (Niemela, 2001; Parks et al., 2013). Wildlife corridors can provide a route for daily and seasonal migrations and connectivity for species dispersal; which in turn can improve long term persistence of species in the face of climate change (Conrad et al., 2012; Sutcliffe et al., 2003). Wildlife corridors can also provide additional and complementary services such as carbon storage, provision of amenity benefits and amelioration of other environmental problems (Parris et al., 2011).

Early models of reserve and corridor selections were motivated by ecological objectives, such as minimizing the number of sites required to ensure that a set of species are preserved or minimizing the amount of unsuitable habitat in the corridor (Parks et al., 2013). Only in the last few decades have planners and policy makers started to incorporate opportunity costs and spatially heterogeneous parcel costs in the design of corridors (Sessions, 1992; Williams, 1998). Since then, many studies have incorporated opportunity costs in the form of budget constraints (Naidoo et al., 2006). For example, Conrad et al. (2012) designed corridors for grizzly bears in the US which cover maximum amount of suitable habitats subject to a budget constraint. While these studies provide valuable information on the tradeoffs involved in environmental and ecological objectives (Ando et al., 1998; Naidoo and Adamowicz, 2005; Polasky et al., 2001), in most cases these studies did not consider landholders' strategic response to the design of a corridor program.

It is necessary to design appropriate incentive mechanisms for private landholders to engage them in wildlife corridor programs (Morse et al., 2009; Rolfe et al., 2008; Windle et al., 2009). This is particularly important in fragmented landscapes, where most of the ecologically important areas are under private ownership or control (Windle et al., 2009). Parkhurst et al. (2002), Shogren et al. (2001, 2003) and Wätzold and Drechsler (2005) conducted some of the early studies of the impact of spatial incentives in the form of agglomeration bonuses. Under such schemes, landholders received financial bonuses if they retired lands adjacent to other retired lands. In many cases, agglomeration bonus was successful in securing spatially arranged environmental services. Later, Rolfe et al. (2009) and Windle et al. (2009), in a series of field experiments on multi-round auctions to improve landscape connectivity, observed that most of the cost-effectiveness benefits were captured very early in the auction. Reeson et al. (2011) tested the impact of a 'lock in' rule. Under this rule during intermediate rounds, provisional winning bidders were not allowed to increase their offers above their original offers. They observed that the 'lock in' rule improved coordination and reduced rent seeking.

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It has also been found that bidders respond to the environmental quality information of the land. For example, Cason et al. (2003), in a series of laboratory experiments exploring drivers leading to non-point source of pollution reduction, observed that bidders conditioned their offers on their projects' environmental quality when such information was available. Later, based on actual offer data submitted under the Conservation Reserve Program (CRP), Kirwan et al. (2005) observed that landholders asked for higher rental rates if the parcel has a higher environmental benefit score. Similarly, landholders with low environmental benefit scores offered higher discounts (or reduced offers) to improve their chances of selection. For example, in one particular round they observed that landholders with low quality land offered a discount more than twice as large as those in the highest quality lands (Kirwan et al., 2005). Later, Glebe (2013) provided a theoretical foundation for the Cason et al. (2003) study. They theoretically proved that bidders have an incentive to raise their offers for higher quality projects. They also observed that concealing information about conservation benefits may be the optimal strategy when entry decisions are not relevant. However, revealing quality information might be beneficial to entice reluctant or marginal landholders.

While these studies provide valuable information, they are only concentrated on individual bidder settings, where aggregate outcomes would arise from individual responses. Our paper follows on from this set of literature and studies rent seeking and strategic behavior in the context of coordinated bidding and competition in a corridor auction. We have used economic experiments to provide information on rent seeking behavior in the context of coordinated bidding when landholders could potentially be part of multiple corridors, all relevant landholders have to coordinate their bids to form valid corridors and compete with other valid corridors.[3]

Another important dimension of a wildlife corridor auction is the bid selection criteria. Traditionally, conservation auction programs have a budget constraint. As a result, the most ecologically beneficial corridor (or parcel of lands) is selected given the available budget. In order to achieve this, conservation auctions implemented in Australia and elsewhere, commonly apply a cost effectiveness approach as the project selection criteria. Benefit is measured as the expected environmental or ecological improvements (Hajkowicz et al., 2009). While cost effectiveness analysis is convenient, it suffers from several problems. It does not, for example, provide a definitive criterion for selecting a given project. Rather, it provides a measure for ranking projects. It also has a tendency of not including all the relevant benefits and costs of a project (Commonwealth of Australia, 2006).

As a result, there are potential benefits and flexibility to be gained from using a range of economic decision making tools when the environmental benefits and costs can be objectively evaluated (Boardman et al., 2011). In this article, we have studied the performance of two standard project selection criteria: net benefit (NB) and benefit cost ratio (BCR) in our experimental setting. While there is a large body of literature on the relative merits of these criteria, we are not aware of any study which has used experimental economic techniques to compare these two approaches.

In our experiment, subjects were asked to make offers for incorporating a parcel of land that they manage into a wildlife corridor. In each experiment session there were six subjects that represent agricultural landholders. Each landholder was assigned an opportunity cost for their unique parcel if it is selected to become a part of the corridor (as presumably it cannot then be used for agricultural production). The first treatment variable explored the effect of allowing participants to submit multiple offers per round (conditional on which corridor they would be a part of) or restricting them to making only one offer. The second treatment variable varied whether the "winning" corridor is selected based on the highest net benefits or the highest benefit to cost ratio. We posed two research questions: (1) Does flexibility in offer submission influence aggregate outcomes of a corridor auction? and (2) Does the project selection criteria influence bidding behavior and aggregate outcomes?

We describe the auction model in the following section. Then, we discuss the details of our experiments followed by results and discussion.

2. Auction Model

We have implemented a repeated open bidding auction design.[4] There are several reasons behind selecting such a design. It has been observed in previous experimental studies on landscape auctions with individual bidding that a repeated design was necessary to achieve coordinated outcomes, as it provides an opportunity for the landholders to identify potential ecological and economic synergies (Parkhurst and Shogren, 2007; Reeson et al., 2011). Rolfe et al. (2009) and Windle et al. (2009) in their field experiments found that multiple bidding round auctions can improve auction performances. They observed that the auction efficiency improved by 66% between the first and the final rounds (Rolfe et al., 2009; Windle et al., 2009). Similar results have been observed in a number of laboratory experimental studies (Davis and Reilly, 1998; Gneezy and Smorodinsky, 2006; Kagel and Levin, 1993; Kagel et al., 1987; Shogren et al., 2000). Studying multiple bidding rounds is important as (a) any new market based instrument takes time to evolve and understanding the relative time it takes to achieve optimal outcomes is important, (b) while there would not be annual renegotiations of existing contracts, there are often a series of tenders involved in the implementation of a conservation strategy, and (c) finally, in some cases there might be requirement for annual re-negotiations. For example, if the corridor project involves maintaining certain land use for a particular season of the year (e.g., maintaining fallow land for seasonal migration of birds and animals) then instead of a multi-year contract the agency might want to re-negotiate the contracts frequently through repeated auction.

In our corridor auction setting, bidders share their offers with other potential bidders to form viable corridors. This necessitated the open auction format as individual bidders could see their potential partners and competitors' bids. This format might occur informally in the field as landholders live in local well-connected communities and be useful in situations where landholders are relatively inexperienced in these types of landscape scale auctions. It might be beneficial to them to gain some experience in this market before making a final offer[5] (Cummings et al., 2004).

In our experiment, the notion behind open repeated bidding is that once the round starts individual bidders enter offers for their eligible corridors. They can see what other bidders are doing in terms of offers and corridor choices. They also see the current status (such as validity of the corridor and net worth of the proposed offer) of all corridors. Bidders can respond to the information by revising their offers (prices and/or corridor choices). Groups become valid when all bidders

[3] A potential extension would be to test the market when it is regulated by the competition of multiple corridors in different locations within the landscape.

[4] In traditional iterative bidding, allocations are made at the end of series of iterations. In our experiments, earnings for successful participants are calculated after every round and they were paid their aggregated earnings at the end of the session. This was done to comply with the fairness principle that participants earn income based on their overall performance in the session. In our experiments, participants were assigned properties randomly before the start of a session and only a sub-set of properties were in the optimal allocation. Therefore, if we conditioned participants' earning based on their winning condition in the final round and the auction efficiently allocates the contracts, only participants assigned to the optimal corridor would receive payments and the rest of the participants would earn no income for their effort.

[5] We recognize that conservation tenders focusing on individual projects often work by offering limited opportunities for individual bidders to learn. However, in the case of a corridor auction, bidders need to know about the relative standing of their neighbors' bids and projects to form a viable corridor. While allowing for this flexibility, in our experiments, coordination happened only through bid revision and learning from previous outcomes. We did not allow any informal or direct communication (such as chat) before or during the auction. In the future experiments, it would be useful to test the impact of learning and direct interactions on corridor auction outcomes.

necessary to form an eligible corridor submit offers on that corridor and the total offer is not greater than its maximum benefit. A single bidder could be part of multiple valid groups. At the end of a round, the auctioneer solves the winner determination problem to select the winning corridor. Bidders in the winning group receive their offers. The auctioneer also calculates feedback information (such as winning bid, its worth, and individual bidders' experimental and actual income). Bidders use this information to revise their offers in the following round. The process continues until the maximum number of rounds is reached. The winner determination problem is formally presented below.

In the auction model, the auctioneer aims to maximize the environmental worth (either in terms of net benefit or benefit cost ratio) from selecting a corridor. O_g is the sum of the offers submitted by individual bidders i on corridor g (i.e., $O_g = \sum_{i \in g} o_{ig}$). V_g is the environmental benefit of the corridor. At the end of a round, the auctioneer uses this information to calculate the worth (b_g) of a corridor. Depending on the treatment conditions, it is either the net benefit of the corridor or the ratio between benefit and offer. The auctioneer's winner determination problem is to maximize the total worth (Z) from selecting a corridor.

Formally:

$$\begin{aligned} & Z = \max \sum_{g=1}^{G} b_g x_g \\ & s.t.\ b_g = V_g - O_g;\ O_g = \sum_{i \in g} o_{ig} \quad \text{for NB} \\ & b_g = V_g / O_g; O_g = \sum_{i \in g} o_{ig} \quad \text{for BCR} \\ & \sum_g x_g \leq 1 \\ & x_g \in \{0, 1\}. \end{aligned} \tag{1}$$

Here, x_g is a binary variable, indicating the winning condition of corridor g. The second constraint ensures that at most a single corridor is selected.

While a repeated auction potentially promotes better coordination and environmental outcomes, it can increase the cost of purchase. For example, Cummings et al. (2004) have observed in their discriminatory pricing auction experiments for irrigation reduction that the average price typically increased over revision rounds. Similar results have been found in simulated auctions for environmental services by Hailu and Schilizzi (2004, 2005); and by Schilizzi and Latacz-Lohmann (2007) for experiments on target constrained auctions. In a landscape auction setting, Reeson et al. (2011) observed in laboratory experiments that in repeated auctions if the participants were told the duration of auctions they start bidding high from very early in the auction. Based on these observations, Reeson et al. (2011) commented that increasing the number of rounds in an auction is unlikely to improve overall efficiency if participants had known the duration of the auction beforehand. Recently, Iftekhar et al. (2013) observed in simulated auctions that the effect of repeated rounds depended on the underlying competition structure of the market. With intense competition, rent extraction reduces with iteration (and vice versa). Therefore, it would be interesting to observe the trends in the aggregate outcomes of the auctions in our experiments.

3. Methodology

A series of experiments were conducted to explore coordinated bidding in the context of a wildlife corridor auction. The experimental market consisted of six bidders competing and coordinating for securing contracts for environmental services between two regions A and B. We describe our experimental design, environment and procedures below.

3.1. Experimental Design

We implemented a 2 × 2 design. The main treatment on bid selection allowed for multiple offers: bidders have the opportunity to condition their offers according to the qualities of their eligible corridors; and single offers whereby bidders can submit only one offer, which is automatically considered for all eligible corridors. The treatments were blocked by two project selection criteria: net benefit and benefit cost ratio criteria. Three experimental sessions were conducted for each treatment/experimental set combination. Each session consisted of 20 rounds. Each round lasted 3 min.

During a session, participants could see the position of their farmland relative to other farms and the value of each corridor. Within a round participants could revise their offers as many times as they like. Bid revision was facilitated by instantaneous feedback on all currently standing offers on each corridor, validity of corridors (formation of a corridor was valid if the aggregate of offers placed by the three (3) players was less than (or equal to) the value of the corridor) and the worth (b_g) of each corridor. This information was updated whenever any participant changed her offer within a round. As a result, if a participant wanted she could calculate the marginal contribution of her standing offer to the overall corridor offer. At the end of a round, only a single corridor with maximum worth was selected using Eq. (1).[6]

At the end of each round, a subset of historical information was provided to all participants. Participants could see their own actual and experimental income for each round. They could also see their current amount of accumulated actual income. Moreover, they received information (such as number or ID, value and payment) on successful group for each completed round. However, they did not receive any information on the opportunity costs of other participants in any stage of the experiment.

3.2. Bidder Profile

Participants represented individual landholders, who are different in terms of their opportunity costs and location (Fig. 1). Since we were interested in learning and offer revision, the opportunity costs and location of the bidders remained fixed during a session. Given constant valuations, participants were able to learn and respond to the outcomes of prior rounds, and use the information from previous rounds to revise and coordinate their offers. In each auction there were a total of 8 different alternative corridors available connecting region A and region B. In the multiple offer treatment sessions participants (bidders) could submit offers on a maximum of four corridors.

In order to generate costs for individual corridors we assumed linearity and aggregated individual bidders' opportunity costs to get the total cost for a corridor. To generate environmental benefits for each corridor we assumed a negative relationship between opportunity costs and environmental benefits. It is generally observed that more productive lands have been converted to agriculture and other uses. The remaining ecologically valuable and sensitive parcels are located on lands either not easily convertible or not very productive for agriculture (for many reasons such as rough terrain, poor quality soil).

The schematic presented in Fig. 1 is a simplified representation of a landscape context, where diagonals (such as farms 1, 2 and 6) could also form a viable corridor. Following Williams et al. (2012) we assumed that some parcels are better for corridor activity than others for many reasons such as permeability or quality of the parcels. Therefore, the benefit values of the corridors used in the experiments are a combined reflection of the distance, synergy values and connectivity between different parcels. We wanted to test the designs as a proof of concept. Therefore, we have implemented a very simple setting where we have

[6] If two corridors formed with the same worth, the first corridor formed would be selected. This selection criterion was not implemented as corridors with the same worth were not formed in any of the sessions.

Region A	1 ($4)	2 ($5)	3 ($15)	Region B
	4 ($10)	5 ($12)	6($10)	

Fig. 1. Physical location and opportunity costs of individual bidders (farms) in the hypothetical landscape.

only a single corridor with the maximum worth (Max NB and BCR). This also ensured individual bidders' incentive compatibility as bidders on the optimal corridor should submit an offer on the optimal corridor and receive maximum profit if all corridors receive offers equal to their environmental benefits. In our experimental setting, the corridor consisting of farms 1, 2 and 6 ("126") is the optimal corridor and has higher worth (net benefit and benefit cost ratio) than any other corridor (columns 5 and 6, Table 1). It should be noted that even though the optimal corridor is the same in both selection criterion treatments, the underlying competition structure is different. For example, the second highest corridors in terms of NB and BCR are "156" and "123" respectively. This results in a stronger bargaining position for bidders 1 and 6 in the NB treatment and bidders 1 and 2 in the BCR treatment. As a result, individual bidders will have different expected bidding behaviors in different treatments, which we describe below.

3.3. Estimation of Benchmark

In order to establish benchmark of expected behavior of the groups and individual bidders we assumed a risk neutral setting. We have adopted an indirect approach where we first calculated the expected profit maximizing aggregate offer on individual corridor and then divided the corridor payoff among the group members according to their estimated Shapley offer (Roth, 1988).

In our experiment participants have information on their income from farming which is the opportunity cost (c_{ig}) of their participation in the corridor. If the bidder submits an offer o_{ig} and if it is part of a successful corridor then her profit would be ($\pi_i = o_{ig} - c_{ig}$). The aggregate costs and offers on a corridor are $C_g = \sum_{i \in g} c_{ig}$ and $O_g = \sum_{i \in g} o_{ig}$ respectively. Total group profit is then ($\pi_g = O_g - C_g$). If the total benefit on the corridor is V_g the benefit captured by the agency by selecting the corridor is ($V_g - O_g$).

A common characteristic of all bidding situations is the balance between net payoffs and the acceptance probability. A higher offer increases the net payoff but reduces the probability of winning (and vice versa). Even though offers are submitted individually and not jointly, in order to be successful bidders have to coordinate their offers since the selection is made on aggregate offers on individual corridors. Each group therefore faces the problem of determining the optimal offer which maximizes their expected profit ($E(\pi_g)$) above the opportunity costs:

For net benefit treatment

$$\max E\left(\pi_g\right) = \left(O_g - C_g\right) \times \Pr\left(\left(V_g - O_g\right) > (V_h - O_h)\right); g \neq h. \quad (2)$$

For benefit cost ratio treatment

$$\max E\left(\pi_g\right) = \left(O_g - C_g\right) \times \Pr\left(\left(V_g / O_g\right) > (V_h / O_h)\right); g \neq h. \quad (3)$$

Using the cost and benefit distribution presented in Table 1 (columns 3 and 4 respectively), we numerically solved Eqs. (2) and (3) to estimate the expected profit maximizing offers (O_g^*) for individual corridors (column 7 in Table 1). Then in the second step we used these profit-maximizing offers to calculate the distribution of individual

Table 1
Aggregate costs and total benefits of individual corridors and estimated benchmark for bidding behavior and auction outcomes under different treatment combinations.

Treatment combinations	Corridor	Aggregate cost	Corridor benefit	Net Benefit (NB)	Benefit cost ratio (BCR)	Expected profit maximizing bid	Shapley offer for individual players						
							1	2	3	4	5	6	Total
Single BCR	123	24	119	95	4.96	71	23	24	24				71
	126	19	130	111	6.84	75	23	24				24	71
	153	31	85	54	2.74	58	23		24		24		72
	156	26	125	99	4.81	76	23				24	24	72
	423	30	120	90	4.00	76		24	24	25			72
	426	25	100	75	4.00	63		24		25		24	73
	453	37	123	86	3.32	81			24	25	24		73
	456	32	126	94	3.94	78				25	24	24	74
Single NB	123	24	119	95	4.96	72	24	24	24				71
	126	19	130	111	6.84	76	24	24				25	72
	153	31	85	54	2.74	58	24		24		24		72
	156	26	125	99	4.81	76	24				24	25	72
	423	30	120	90	4.00	75		24	24	25			72
	426	25	100	75	4.00	63		24		25		25	73
	453	37	123	86	3.32	80			24	25	24		73
	456	32	126	94	3.94	79				25	24	25	74
Multiple BCR	123	24	119	95	4.96	71	24	24	24				71
	126	19	130	111	6.84	75	25	25				25	75
	153	31	85	54	2.74	58	19		19		19		58
	156	26	125	99	4.81	76	25				25	25	76
	423	30	120	90	4.00	76		25	25	25			76
	426	25	100	75	4.00	63		21		21		21	63
	453	37	123	86	3.32	81			27	27	27		81
	456	32	126	94	3.94	78				26	26	26	78
Multiple NB	123	24	119	95	4.96	72	24	24	24				72
	126	19	130	111	6.84	76	25	25				25	76
	153	31	85	54	2.74	58	19		19		19		58
	156	26	125	99	4.81	76	25				25	25	76
	423	30	120	90	4.00	75		25	25	25			75
	426	25	100	75	4.00	63		21		21		21	63
	453	37	123	86	3.32	80			27	27	27		80
	456	32	126	94	3.94	79				26	26	26	79

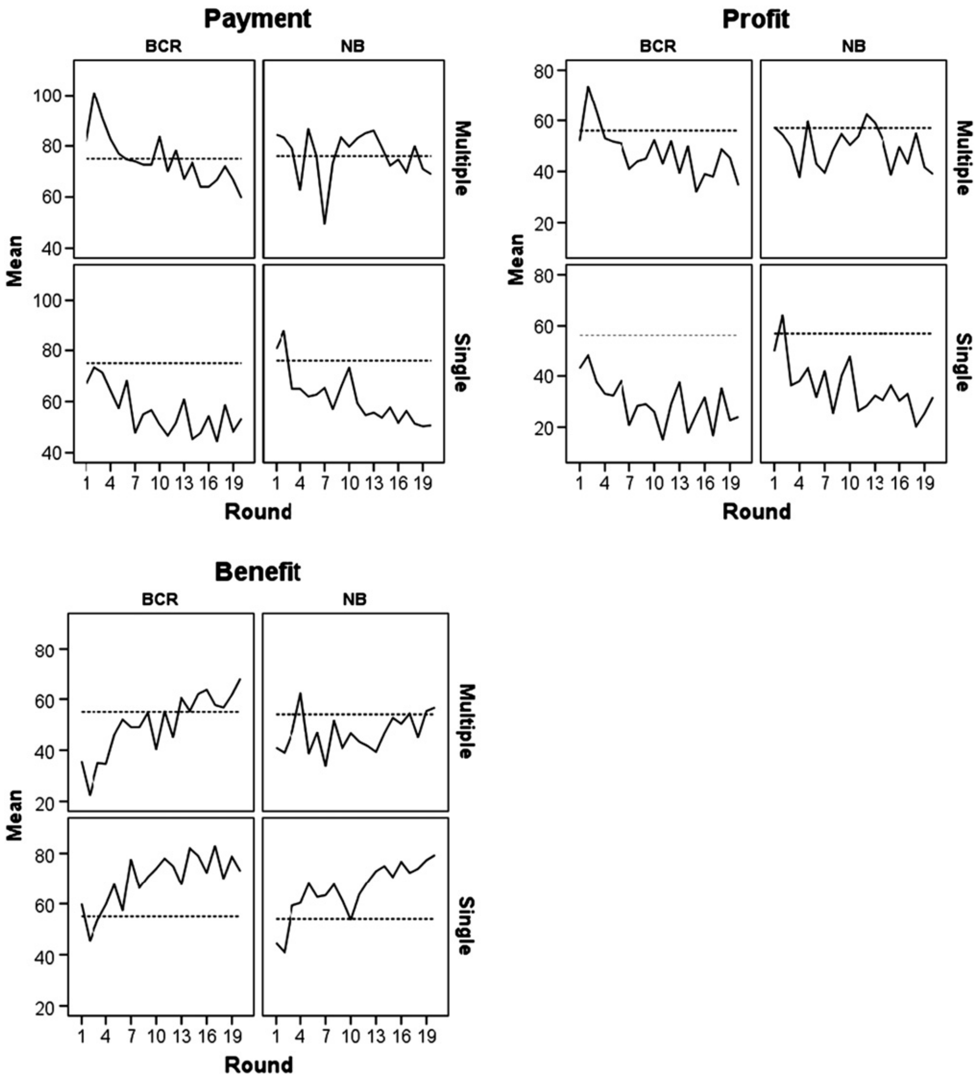

Fig. 2. Trends in group payments, group profits and government benefits captured through rounds in different treatments. The dotted line indicates benchmarks for the expected profit maximizing optimal outcomes.

offers for different corridors. We used the bidder's Shapley values to estimate the expected distribution of offers. Shapley value captures the average marginal contribution of a bidder in a feasible coalition when every coalition[7] has an equal chance of being formed. Let the marginal contribution of bidder i to coalition S in relation to corridor g with $i \notin S$ be denoted by $\Delta_{ig}O$ and defined by $\Delta_{ig}O(S) = O(S \cup \{i\}) - O(S)$. Then, the probability that bidder i will find coalition $S - \{i\}$ already formed is $(|S|-1)!(n-|S|)!\,/\,n!$. For the multiple offer treatment, bidders could vary their offers for different corridors. A bidder's Shapley value o_{ig}^* for bidder i is the average of its marginal contribution to all possible coalitions in relation to corridor g (Macho-Stadler et al., 2007):

$$o_{ig}^* = \sum_{\substack{S \subset N \\ i \in S}} \frac{(|S|-1)!(n-|S|)!}{n!} \times \Delta_{ig}O(S). \tag{4}$$

In the case of the single offer treatment, the Shapley values for individual bidders were calculated by considering the bidder's marginal contributions to all eligible corridors. In our experiment, a single bidder could be part of 24 legitimate coalitions (6 coalitions of three bidders for 4 corridors). Therefore, we calculated the total marginal contributions of a bidder to the legitimate coalitions and estimated the average to determine the Shapley offer for a bidder in the single offer treatment. Our estimated benchmark for the expected profit maximizing offers on individual corridors and individual Shapley values are presented in Table 1 (columns 8–13). Note that, the sum of the Shapley offers in each row (last column in Table 1) does not always coincide with the expected profit maximizing bid (column 7 in Table 1) for single offer treatment as in this case all eligible corridors are considered when calculating individual bidders' Shapley values.

Table 2
Spearman's rank order correlation coefficients: relationship between round and auction outcomes in different treatment combinations.

Project selection	Project offer	Payment	Profit	Government benefit
BCR	Multiple	−0.421**	−0.320*	0.499**
	Single	−0.407**	−0.312*	0.477**
NB	Multiple	−0.093	−0.113	0.120
	Single	−0.535**	−0.371**	0.629**
Overall		−0.421**	−0.320*	0.499**

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

[7] Here, we have considered that coalitions would be different for different ordering of bidders.

Table 3
Panel regression random effect models with AR1 error structure: effects of treatments on group bid, group profit and government benefit.

	Payments		Profits		Government benefit	
	Coefficient	Standard error	Coefficient	Standard error	Coefficient	Standard error
Corridor benefit	0.39*	(0.19)	0.39*	(0.19)	0.61**	(0.19)
Group cost	−0.12	(0.12)	−1.12**	(0.12)	0.12	(0.12)
Selection dummy	−3.56	(8.84)	−3.56	(8.84)	3.56	(8.84)
Offer dummy	−17.27^	(8.84)	−17.27^	(8.84)	17.27^	(8.84)
Interaction term	−1.03	(12.5)	−1.03	(12.5)	1.03	(12.5)
Constant	31.8	(25.93)	31.8	(25.93)	−31.8	(25.93)
Wald	18.15**		149.28**		20.59**	

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

3.4. Experimental Procedures

The experimental sessions were conducted in the Experimental Economics Laboratory at the University of Tasmania from January to April 2013.[8] Subjects were recruited from the University student population through a campus wide advertising campaign and on-line registration. On arrival subjects were provided with a set of instructions and quiz to test their understanding of the tasks to be undertaken during the experiment (an example set of instructions and associated quiz are provided in the Appendix). The funding for this project required high levels of external validity and as such contextualization of the experimental environment. While it is recognized that contextualization may invoke a form of historic context response, the participants in the experiments were students from a capital city state university and as such assumed have limited connection bias to the context of the experimental setting.

Overall, 12 independent computerized sessions were conducted (2 treatments × 2 blocks × 3 sessions). The total number of subjects was 3 × 6 × 4 = 72. Each session lasted approximately 1 1/2 h. In addition to their auction earnings, subjects received a show-up fee of A$10 (~U.S.$9). The average earning (including the show up fee) was A$22 (~U.S.$20).

We used specialized software to program our experiments. The experimental software collected all offers from each group, computed the final allocation and payoff[9] for each participant and sent information back to the participant's screen each round.

We use the following measures of the aggregate outcomes of the auction:

- Optimal corridor selection: whether the optimal corridor (corridor "126") was selected or not
- Payments for securing corridors: aggregate payment by the agency
- Profit earned by the group: total profit earned by the successful group
- Benefits to the agency: net benefits (benefit minus cost of acquiring the corridor) captured by the agency.

At individual bidder level, we have observed data on submitted offers and measured data on expected profits for all valid and winning corridors. These outcomes have been compared to the expected risk neutral benchmark outcomes.

4. Results

In this section we analyze and discuss our experimental data and findings. We begin by examining aggregate outcomes of the auctions in terms of optimal allocation, payment and total profits. Then in the second part of the analysis we evaluate the offers and associated expected profit of individual bidders.

4.1. Aggregate Outcomes of the Auction

4.1.1. Optimal Corridor Selection

Overall, the optimal corridor was selected in 35% of rounds. The proportion of optimal corridor selection increased as the auction progressed. There is a positive correlation between round number and optimal corridor selection ($\rho = 0.215$, $p < 0.01$). This trend is most prominent in the BCR treatment ($\rho = 0.340$, $p < 0.01$). On the other hand, with NB selection there is no clear trend in optimal corridor selection ($\rho = 0.098$, $p > 0.10$). A positive correlation could be observed for both single ($\rho = 0.208$, $p < 0.05$) and multiple ($\rho = 0.228$, $p < 0.05$) offer treatments. Overall, there is no significant difference in the number of times optimal corridor selection between two project selection criteria (Mann–Whitney U test, $Z = -1.219$, $p > 0.10$). Among the offer treatments, the frequency of selecting optimal corridor was significantly higher in the single offer treatment than in the multiple offer treatment (Mann–Whitney U test, $Z = -2.302$, $p < 0.05$).

It is important to know the number of valid corridors formed each round. Overall, in 76% of rounds participants formed a valid corridor.[10] The frequency of valid corridor formation gradually increased through rounds. For example, in the first quarter of the rounds, 72% of the times the participants have formed a valid corridor. By the last quarter of the rounds this percentage had increased on average to 79%. In aggregate, there was no significant association between number of valid corridors and project selection treatments ($\chi^2 < 0.00$, $p > 0.99$). Similar to the optimal corridor selection, bidders formed valid corridors more frequently in single offer treatment (93%) compared to multiple offer treatment (59%; $\chi^2 = 301.92$, $p < 0.01$).

4.1.2. Budgetary Outcomes

Average payment to secure corridors, group profits and government benefits under different treatment combinations have been plotted in Fig. 2. In general, average payment gradually declines as the auction progresses. The trend is most prominent in the single offer treatment with net benefit selection. However, we found no significant relationship between auction duration and payment for net benefit selection with the multiple offer treatment. We observed similar trends for profits earned by the successful groups; profits decline as the auction progresses. As expected, benefits captured by the agency shows the opposite trend; benefits to the government increases as the auction progresses. Trends under individual treatment combinations follow similar patterns (Table 2).

Table 3 provides a series of panel regression models to test different treatment effects and corridor features on auction outcomes, namely payment, group profit and government benefits. In these models, we regressed outcome variables for corridor benefit (column 4 in Table 1), group cost (column 3 in Table 1), a selection dummy variable (BCR = 1, NB = 0), an offer dummy variable (single = 1, multiple = 0) and an interaction variable between offer and selection dummy variables.

[8] http://www.utas.edu.au/business-and-economics/research/experimental-economics.
[9] Pay-off to bidders was a function of the amount of money they could earn from either being part of a successful corridor or a default income from farming.
[10] When participants were not part of a valid and successful corridor they were paid according to their farm income.

Table 4
Wilcoxon signed rank tests to compare between obtained and benchmark outcomes for different treatment combinations.

Project selection	Project offer	Payment	Profit	Government benefit
BCR	Multiple	−0.277	−2.982**	−1.491
	Single	−6.003**	−6.450**	−5.348**
NB	Multiple	−0.269	−2.880**	−2.375*
	Single	−5.510**	−6.213**	−5.243**
Overall		−6.319**	−9.763**	−3.264**

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

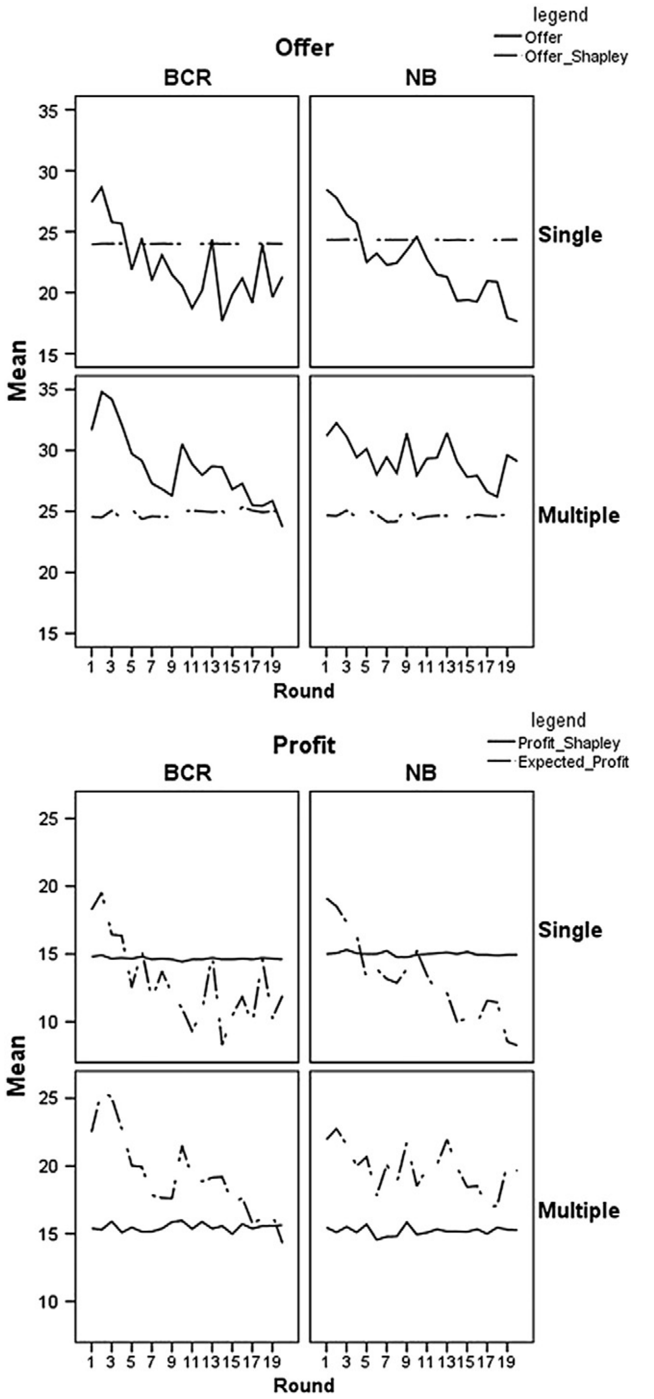

Fig. 3. Trends in individual offers and expected profits for all valid corridors through rounds in different treatments.

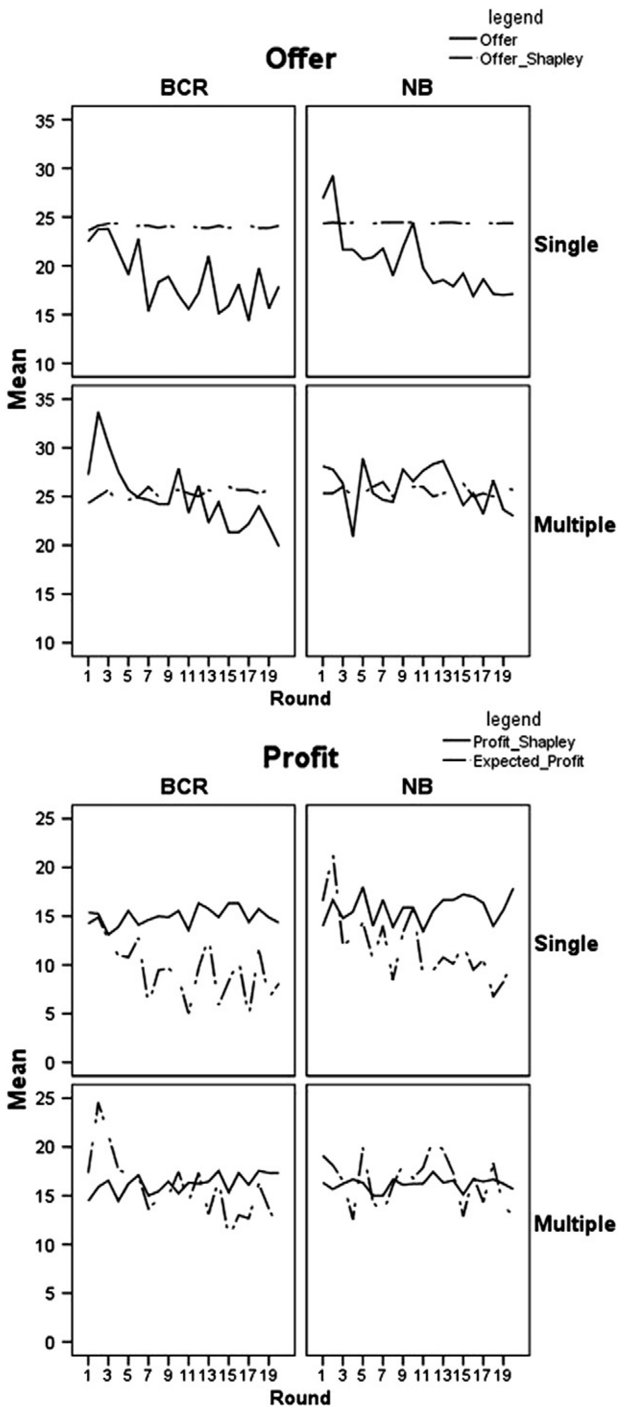

Fig. 4. Trends in individual offers and expected profits for all successful corridors through rounds in different treatments.

Table 5
Spearman's rank order correlation coefficients: relationship between round and individual bids and profits on all valid corridors and winning corridors in different treatment combinations.

Project selection	Project offer	All valid corridor		Winning corridor	
		Bid	Expected profit	Bid	Profit
BCR	Multiple	−0.205**	−0.198**	−0.194**	−0.147*
	Single	−0.229**	−0.192**	−0.225**	−0.174*
NB	Multiple	−0.078*	−0.077*	−0.083	−0.071
	Single	−0.381**	−0.302**	−0.380**	−0.269**
Overall		−0.225**	−0.197**	−0.207**	−0.156**

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

Table 6
Panel regression random effect models with AR1 error structure: effects of treatments on individual bids and profits on all valid corridors and winning corridors.

	All valid corridors				Winning corridors			
	Individual bid		Expected profit		Individual bid		Profit	
	Coefficient	Std. error	Coefficient	Std. error	Coefficient	Std. error	Coefficient	Std. error
Corridor benefit	0.05*	(0.02)	0.05*	(0.02)	0.05	(0.11)	0.05	(0.11)
Individual cost	−0.03	(0.09)	−1.03**	(0.09)	0.17	(0.17)	−0.83**	(0.17)
Selection dummy	−0.62	(0.98)	−0.62	(0.98)	−0.51	(1.64)	−0.51	(1.64)
Offer dummy	−6.92**	(0.93)	−6.92**	(0.93)	−5.41**	(1.70)	−5.41**	(1.70)
Interaction	0.37	(1.33)	0.37	(1.33)	−1.27	(2.37)	−1.27	(2.37)
Constant	23.69**	(3.13)	23.69**	(3.13)	18.71	(14.48)	18.71	(14.48)
Wald	112.67**		254.61**		28.26**		52.23**	

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

Since, the offer and selection dummy variables are static we used a random effect regression model. Moreover, present bidding behavior is likely to be influenced by past outcomes and behavior so we have imposed an AR(1) autoregressive error structure[11] (Gneezy and List, 2006).

We noted that corridor benefit has a significant positive effect on the payment received by the successful groups. The higher the corridor benefit the higher the payment received by the successful groups ($\beta = 0.39$, $p < 0.05$, Table 3); profits earned by successful groups ($\beta = 0.39$, $p < 0.05$, Table 3) and benefits captured by the agency ($\beta = 0.61$, $p < 0.01$, Table 3). As expected, group cost has significant negative impact on the profits earned by the group ($\beta = -1.12$, $p < 0.01$, Table 3). We could not, however, find any significant effect of group cost on successful group's payment and government benefit.

Among the offer treatments, single offer treatment had significantly lowered payments to successful groups ($\beta = -17.27$, $p < 0.10$, Table 3), lowered profit ($\beta = -17.27$, $p < 0.10$, Table 3) and increased benefit captured by the agency ($\beta = 17.27$, $p < 0.10$, Table 3) compared to multiple offer treatment. This suggests that payments in situations where bidders can only submit one offer tend to be lower. However, we could not find any significant difference between project selection treatments in terms of any of the auction outcomes.

Finally, we compared aggregate outcomes of the auction with the benchmark calculated using the expected profit maximizing offer formulation. Aggregate outcomes are much closer to the expected profit maximizing offer for optimal corridor in multiple offer treatments. Based on the results of a Wilcoxon signed rank test we observed no significant difference between observed and expected payments for net benefit ($z = -0.277$, $p < 0.10$, Table 4) and benefit cost ratio selection criterion ($z = -0.269$, $p < 0.10$, Table 4) treatments with multiple offers. However, in single offer treatments, the aggregate payments gradually move away from the expected profit maximizing benchmark. For example, in BCR selection criterion treatment the average distance between the payment and benchmark increased from 11% in round one to 29% in the final round. In NB selection criterion treatment the distance increased from 6% to 33%. Similar trends could be observed for profits realized by the successful groups. On the contrary, government benefits gradually increase as the auction progresses (Fig. 2).

4.2. Individual Offers

Given these aggregate outcomes of the corridor auctions in different treatment combinations, in this sub-section we explore outcomes for individual bidders in terms of submitted offers, expected and realized profits.

[11] We have assumed that learning and behavior are impacted by previous experience. So, we have used an auto-regressive error structure. The auto-regressive structure accounts for correlation between successive error terms and AR(1) takes on board possible learning from one period to the next. The rate of impact of learning through time may vary through rounds in complicated experimental designs. However, we do not have any prior assumptions on how the experience impact might be different in early and late rounds in different treatments in our experiments to include in the regression models. This is an interesting issue and worthy of further research.

4.2.1. Trends and Impact of Treatment Variables

The first notable outcome at the individual level is that bidders' reduced their offers (and expected profit) as the auctions progressed (Figs. 3 and 4). For example, from Table 5 we can see that overall, individual offers on valid corridors have a significant negative relationship with auction round. Expected profit also shows a significant negative trend. The trend is similar when we consider individual offers and realized profits for winning corridors. Among the treatment combinations, the trend is most prominent for net benefit selection criteria with single offer treatment. It is interesting to observe that when only offers on winning corridors are considered, there is no significant relationship between auction rounds and individual offers under net benefit selection criteria with multiple offer treatment (Table 5).

Similar to the analysis of group outcomes, we have used panel regression models to analyze individual offers and expected profits (Table 6). In these models, we regressed individual offers and expected profits for corridor benefit (column 4 in Table 1), individual costs (Fig. 1), a selection dummy variable (BCR = 1, NB = 0), an offer dummy variable (single = 1, multiple = 0) and an interaction variable between offer and selection dummy variables. From the regression analysis, we observe that individual bidders are strongly motivated by the benefit information as indicated by the significant impact of the corridor benefit. Consistent with the group outcomes, there is a significant impact of corridor benefit on individual bidder's offers ($\beta = 0.05$, $p < 0.05$, Table 6) and expected profit ($\beta = 0.05$, $p < 0.05$, Table 6). However, this impact disappears when offers on only winning corridors are considered ($p > 0.10$, Table 6). Opportunity costs have a significant negative impact ($p < 0.01$, Table 6) on bidders expected and realized profits for all valid and winning corridors. However, in either case, we could not find any significant difference between the selection treatments ($p > 0.10$).

Bidders submit significantly higher offers in multiple offer treatment ($\beta = -6.92$, $p < 0.10$, Table 6) compared to the single offer treatment. The difference is slightly smaller when we consider offers on winning corridors ($\beta = -5.41$, $p < 0.10$, Table 6). This result could be explained by the fact that bidders have a tendency to submit bids on corridors with high benefits when they have the option to submit corridor specific bids. For example, in multiple offer treatments, the number of times individual valid offers were submitted on corridors with high benefits such as "126", "456" and "453" were 16%, 17% and 16% respectively, whereas, only 4% of the number of times individual valid offers were submitted on corridor "153" with the lowest benefit. On the hand, in single offer treatments, the number of times valid offers submitted on individual corridors was more or less even (around 13%).

4.2.2. Profit Maximizing Offers

We observed that individual offers gradually moved towards expected profit maximizing offers and profits through rounds. For example, the average distance between offers and benchmark estimates reduced from 17% in round 1 to 10% in the final round. Similar estimates for expected profits were 33% to 15% (Fig. 3). There is a significant difference between observed offers and expected profit with the respective

Table 7
Wilcoxon signed rank tests to compare between obtained and benchmark outcomes for individual bids and profits on all valid corridors and winning corridors in different treatment combinations.

Project selection	Project offer	All valid group		Winning group	
		Bid	Expected profit	Bid	Profit
BCR	Multiple	−8.004**	−8.004**	−1.657^	−1.657^
	Single	−9.137**	−9.137**	−7.417**	−7.417**
NB	Multiple	−9.639**	−9.639**	−0.347	−0.347
	Single	−14.393**	−14.393**	−7.495**	−7.495**
Overall		−3.353**	−3.353**	−8.119**	−8.119**

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

benchmarks in all treatments on all valid corridors ($p < 0.01$, Table 7). However, when we consider only offers on winning corridors, there is no significant difference between the outcomes and benchmark for the treatment with NB selection and multiple offers ($p > 0.10$, Table 7). In all other treatment combinations, there is significant difference between observed behavior and the estimated benchmark.

In order to further understand the bidding behavior in single and multiple offer treatments, we plotted the maximum and minimum Shapley offers[12] a bidder could put on eligible corridors in a multiple offer treatment with their actual offers (see Fig. 5). In multiple offer treatments, bidders gradually reduce their offers closer to their maximum Shapley offer. The average distance between offers and maximum Shapley offers reduced from 20% in round one to 1% in the final round when we considered offers on all valid corridors. The distance is lower when we consider individual offers on winning corridors. However, in the single offer treatment, participants gradually reduced their offers closer to their minimum Shapley offers. For example, the average distance between offers and minimum Shapley offers reduced from 40% in round one to 3% in the final round when we considered offers on all valid corridors. Considering only winning corridors, bidders started bidding lower than their risk neutral minimum Shapley offer after round 10.

4.2.3. Inter-player Dynamics

Given the bids were open; the dynamics of individual bidding behavior is worth exploring. We have compared individual players' offers and expected profits on all valid corridors by different quarters of rounds of an experimental session. It is interesting to observe that players in competing locations appeared to have coordinated their bids. For example, there is no significant difference between Players 1 and 4 in terms of their submitted offers (except for third quarter, Table 8), even though their opportunity costs were substantially different. Similar trends could be observed between Players 2 and 5 and between Players 3 and 6. However, we could not find similar strong evidence that neighboring players (such as Players 1 and 2, 2 and 3, and so forth) and players part of the same corridor (such as Players 1 and 5, and 2 and 6) were coordinating their bids (Table 8). Further, we could not find any evidence of coordination in terms of players' expected profit (Table 8).

5. Discussion

We have studied the effect of two important design features of a wildlife corridor auction: bidding flexibility and project selection criteria. We postulated that landholders (or a group of landholders) might have the opportunity to strategically select a corridor. We were interested to explore whether landholders as a group would increase their offers for high benefit corridors if they get the opportunity. Moreover, we were interested to see whether the project selection criteria would influence auction outcomes.

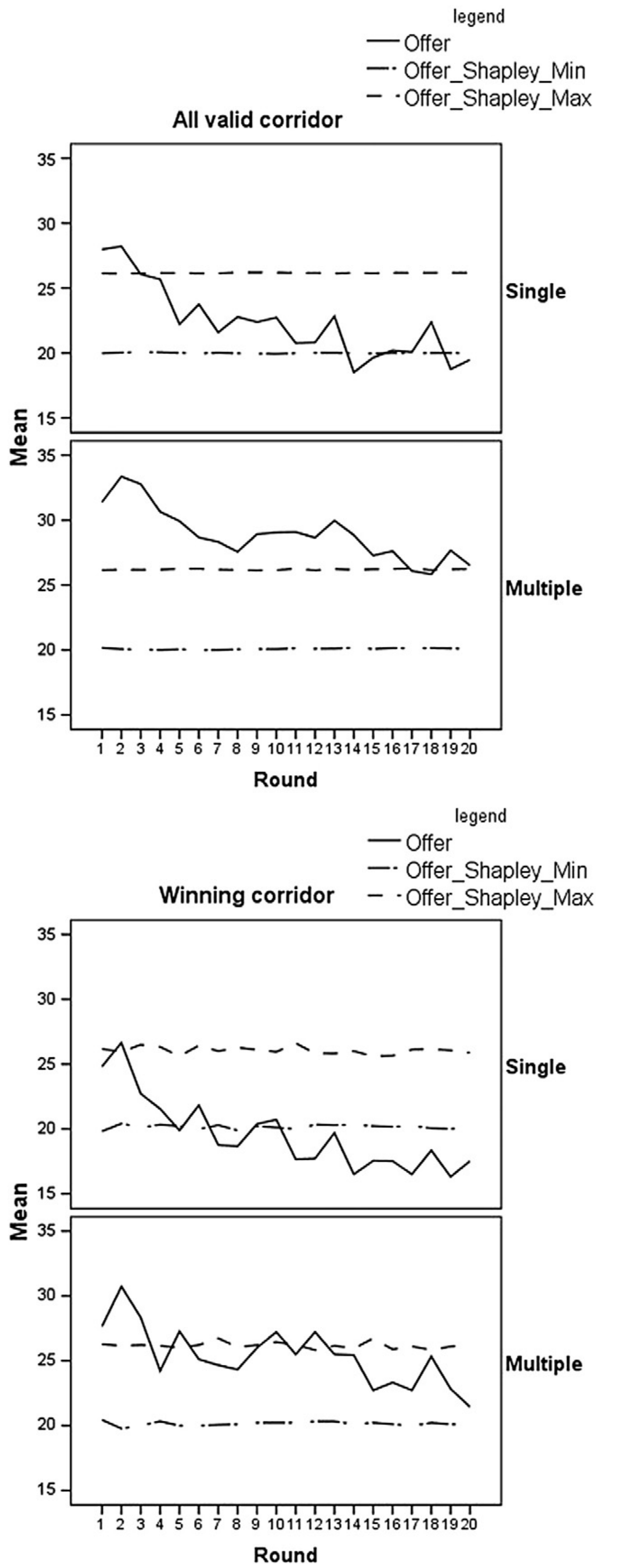

Fig. 5. Trends in individual offers and minimum and maximum Shapley offers for a bidder for all valid corridors and winning corridors.

[12] A bidder is eligible to submit offers on four corridors. Each corridor has different benefits and group composition. So, four shapely values (one for each corridor) are calculated for a single bidder. The minimum and maximum Shapley values refer to the minimum and maximum of these values for a bidder.

Table 8
Mann–Whitney U test: pair-wise comparisons between players in terms of their offers and expected profit for all valid corridors by quarters of rounds.

Player pairs	Offer				Expected profit			
	1st qrt	2nd qrt	3rd qrt	4th qrt	1st qrt	2nd qrt	3rd qrt	4th qrt
1 vs 2	−1.78^	−0.64	−4.94**	−2.63**	−0.18	−2.47	−6.29**	−0.74
1 vs 3	−0.85	−2.56**	−3.45**	−3.47**	−9.31**	−12.39**	−11.36**	−8.42**
1 vs 4	−0.13	−0.21	−2.06*	−0.82	−4.69**	−5.63**	−7.38**	−6.57**
1 vs 5	−2.16*	−1.09	−3.99**	−1.86^	−3.99**	−9.35**	−10.54**	−6.91**
1 vs 6	−0.29	−1.99*	−3.65**	−3.01**	−4.88**	−8.54**	−8.75**	−4.52**
2 vs 3	−3.06**	−1.53	−3.57**	−0.76	−9.57**	−11.25**	−8.74**	−9.85**
2 vs 4	−1.67	−0.63	−3.99**	−2.06*	−5.54**	−3.95**	−1.38	−8.08**
2 vs 5	−0.12	−0.64	−2.91**	−0.92	−5.61**	−8.03**	−5.82**	−9.55**
2 vs 6	−2.02*	−1.44	−2.62**	−0.41	−5.78**	−6.63**	−2.81**	−6.24**
3 vs 4	−0.85	−2.02*	−1.25	−2.95**	−4.99**	−7.42**	−7.03**	−3.50**
3 vs 5	−3.52**	−2.02*	−0.57	−2.16*	−6.07**	−5.37**	−4.42**	−2.84**
3 vs 6	−0.39	−0.43	−0.54	−0.22	−4.73**	−6.54**	−6.33**	−5.51**
4 vs 5	−2.02*	−1.12	−1.70^	−1.47	−0.16	−3.43**	−4.43**	−1.58
4 vs 6	−0.34	−2.10*	−1.68^	−2.36*	−0.34	−2.10*	−1.68^	−2.36*
5 vs 6	−2.38*	−1.15	−0.09	−1.41	−0.25	−1.66	−3.12**	−4.38**

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

Based on a series of laboratory experiments with students our results conform to the theoretical predictions of Glebe (2013) for individual bidders. We observed that bidders (both individually and as groups) increased their offers for high benefit corridors. It is interesting to observe that individual and group costs did not influence individual offers and group payments respectively. One possible explanation could be that in the experiments cost information was private and bidders could not see each other's opportunity costs. However, environmental benefit information of individual corridors was public knowledge and bidders could condition their bids according to the benefit information. Therefore, bidders were more motivated by public environmental benefit information compared to private opportunity cost information. Additional analysis revealed that bidders were strategically following their competitors' (in terms of landscape locations) bids. However, it would be interesting to study whether this observation holds in other scenarios such as hiding or revealing information on both corridor costs and benefits, or in markets with competition of multiple corridors in different locations within the landscape.

We also observed that the participants increased their offers when they participated in the multiple offer treatment compared to the single offer treatments. Moreover, in the multiple offer treatment bidders submitted offers closer to their expected profit maximizing offers. Further, they concentrated more on high valued corridors compared to low valued corridors (the difference in valid offer submissions between the highest and lowest valued corridors was 12 percentage points). As a result, given the flexibility on bid submission, in multiple offer treatment bidders focused their bidding efforts on high value corridors to maximize their profit. This, in part, explained the observed lower number of viable group offers but higher level of group and individual profits in multiple offer treatment.

On the other hand, in the single offer treatments, bidders did not have the flexibility to bid only on high value corridors. If a bidder set up their offers too high (close to their maximum Shapley value), they would reduce the probability of being part of viable corridors. However, if they set up the offer close to (or even lower than) their minimum Shapley value they would increase their probability of being part of viable corridors and becoming successful. As a result, under the single offer treatment higher number of group bids was viable compared to the multiple offer treatment. This in return facilitated selection of optimal corridor in higher proportion, lower payment for successful corridors and higher government benefits. Therefore, agencies might consider restricting bidders to single choice offers even when the landholders could potentially be part of multiple corridors.

We also explored the potential role of project selection criteria on the outcomes of a wildlife corridor auction. We could not find any significant difference in aggregate outcomes and individual bidders' bidding behavior between net benefit and benefit cost ratio criteria. In a simplified setting such as in our experiment where the objective was to establish a single corridor it seems that both project selection criteria would provide similar outcomes. However, we did observe that in the net benefit treatment with multiple offer flexibility bidders bid close to their Shapley value offers. Moreover, with BCR selection the benefits of having a repeated round are more prominent compared to a net benefit selection criteria. This provides scope for further research as in more complex settings (such as with multiple winning corridors or multiple equilibrium bids) the difference between these two project selection criteria could become significant.

Further, we observed significant positive effects of offer revisions and repeated rounds on optimal outcomes and rent extraction. This result is contradictory to what others have found in conservation auction experiments. There could be several reasons. First, in our experiments bidders have to be cognisant about both competition and coordination effects. Bidders could learn to bid more competitively through trials and errors. Second, in our experiment there is only a single optimal corridor, which provides an interesting contribution to previous studies which resulted in a large number of offers being accepted. As observed by Iftekhar et al. (2013) in high competitive environments, bidders are more likely to use offer revision opportunities.

In essence, our results suggest that the agency could potentially improve the cost effectiveness of corridor auctions by following a restrictive bidding format, but at the same time allowing bidders ample opportunities to revise their offers before making a final selection. Single offer option is likely to be administratively easy to operate in the real world. The real-world corridor auctions are likely to involve many relevant landholders/stakeholders. With substantially more parcels, selection of a suitable corridor becomes very difficult to calculate (since there would be many possible corridor combinations) and that would influence the extent to which landholders could attempt to condition their offers on the offers of their neighbors. If landholders have the flexibility in their corridor choices and they only submit offers to participate in a handful of potential corridors, this would severely limit the possibility of actually forming a corridor. In this case, the difference between the performance of the single offer and multiple offer scenarios is likely to be even higher.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.ecolecon.2014.04.017.

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