RESEARCH PROJECT THESIS

Coordination and Strategic Behaviour in Landscape Auctions

An Economic Experiment

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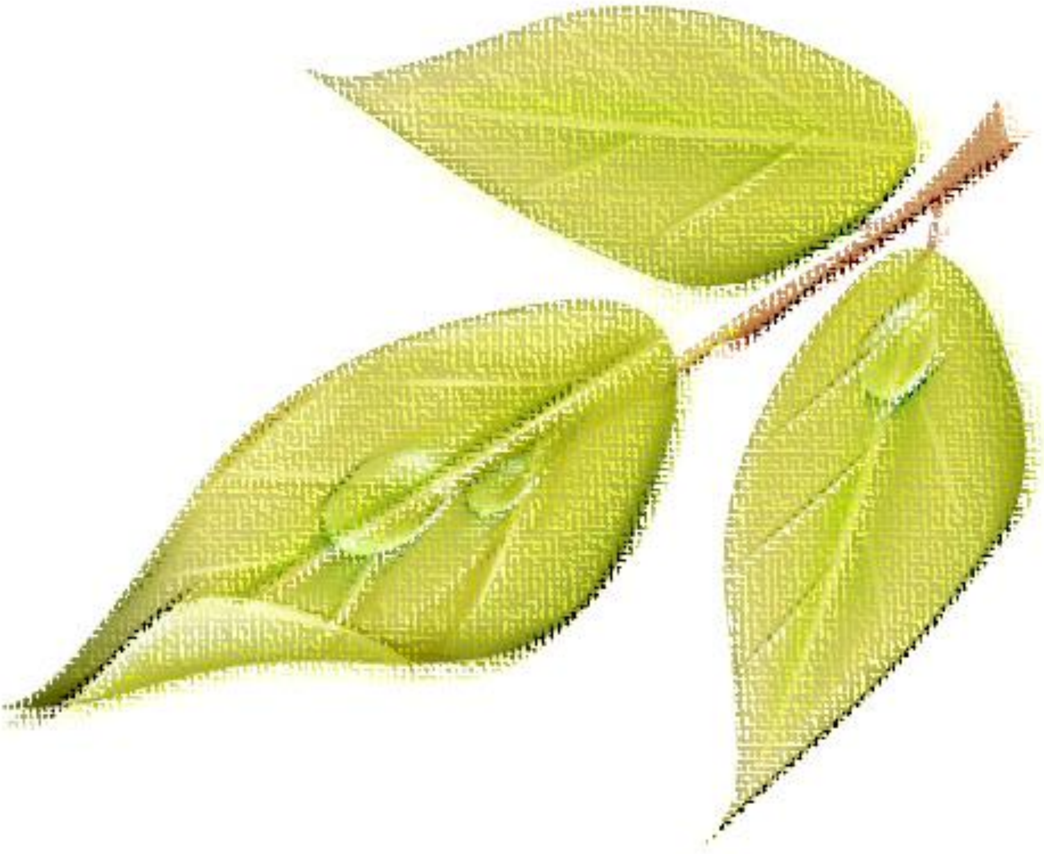

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Abstract

Designing a conservation auction where bidders know the ecological value of their land poses challenges for policy makers because bidders will tend to increase their asking price. This is known as strategic behaviour, and it is particularly prevalent in sequential auction settings. The tender process ceases to be competitive when strategic behaviour occurs, eroding the efficiency advantages of an auction. To overcome this problem, contract options can be designed such that early winners are restricted in their efforts to strategically manipulate auction outcomes. Simply offering multi-period contracts could achieve this goal if participants need to wait for their contracts to expire before they can change their asking price.

This idea was tested in a laboratory setting using computer software to simulate a simplistic multi-period auction for conservation. The results indicate that auctions offering multi-period contracts might be better equipped to constrain strategic behaviour compared to single period contracts. The treatment leads to a more efficient outcome, which supports the conclusion that given certain design intricacies, competition in an auction for conservation can be preserved with the provision of a system that works to 'lock-in' winners.

Keywords:

Conservation, Biodiversity, Auctions, Strategic Behaviour, Landscape Design, Coordination

1. Introduction

Procurement auctions for ecological services, or conservation auctions for short, involve private landholders bidding for government funding to retire areas of land from other production activities. Paying landowners to undertake conservation activities is designed to promote biodiversity through greater habitat supply, and an auction mechanism is used to encourage efficiency gains through competition. Competition in an auction setting is compromised when bidders learn that the public value of their land is worth more than their competitors' land. This affords some participants a competitive advantage, which they can capitalise on by submitting higher bids. The design intricacies of a conservation auction that endeavours to promote a contiguous landscape are such that participants are better able to ascertain the underlying value of their land, giving rise to higher bids. One strategy that can overcome this problem is a 'lock-in' mechanism which prevents auction winners from increasing their bids as the auction proceeds.

Conservation auctions can promote competitive bidding if auction participants are bidding with equally valuable parcels of land in terms of their ecological service provision. This is a key assumption underlying the revenue equivalence theorem, which specifies the potential for all auction formats to deliver the same revenue to an auctioneer, is the understanding that there is symmetry between all bidders (Latacz-Lohmann and Hamsvoort 1997). However, it is generally not the case that two parcels of land will yield the same conservation value (Vane-Wright et al. 1991). Some areas might have a higher population of the targeted endangered species, or contain a habitat type (e.g. woodland or grassland) that is better suited to the protection of that species (Church et al. 1996). Bidding in an auction with heterogeneous goods could undermine competition if participants recognise the additional value of their goods, and thus seek additional surplus (Chan et al. 2003). Economic theory refers to this phenomenon as strategic behaviour (McAfee and McMillian 1987) because it impairs the ability of an auction design to encourage efficiency gains. The design intricacies of many auctions are specifically intended to try and prevent this from occurring (McAfee and McMillan 1996; Harsha et al. 2010).

In most conservation auctions, areas of conservation are evaluated independently from one another. A relatively new consideration for conservation auctions is the importance of landscape design or connectivity, where neighbouring borders of land are treated as interdependent. There is a large body of literature that attests to the need to strive for a contiguous landscape for conservation purposes (Bennett 1999; Hostetler 1999; Jiang et al. 2007; McAlpine et al. 2006). A contiguous landscape of habitat supports species persistence by increasing resilience against disturbances, facilitating migration and in general being better suited to supporting and reproducing life (Bennett 1999; Jiang et al. 2007; Rolfe and McCosker 2003). This is particularly the case for larger mobile creatures, and less so for floral species (Lindborg and Eriksson 2004). Despite this, landowners will rarely find it is in their best interest to coordinate with their neighbours given heterogeneous costs and an inadequate incentive mechanism (Hartig and Drechsler 2010). Assuming the protection of a species is enhanced by interconnected areas of conservation, the absence of an incentive mechanism intended to bring about clustered landscapes signals a deficiency in conventional conservation auctions.

One way to encourage coordination is to use a metric that references the ecological value, land size as well as the location of a proposed area of conservation with respect to the location of other areas of conservation across the landscape (Parkhurst et al. 2002; Hartig and Drechsler 2009). If participants are told how the assessment rule works, and afforded scope to readjust the positioning of proposed areas of conservation, bidders might find it in their best interest to use the actions of their competitors to redefine their own conservation activities. This is here on referred to as a ‘spatial incentive’ or ‘landscape incentive’ because the assessment mechanism takes into account the locality of conservation, cultivating a spatially optimal configuration through coordination. In order to facilitate coordination, auction formats with spatial incentives require a repeated auction format (Shogren et al. 2000; Bernard 2005). Participants can only coordinate if they learn where other areas of conservation exist with respect to their own properties, and then allowed to adjust their bids retrospectively so that their conservation land can adjoin with their neighbours. Examples of repeated auction formats include multi-round auctions, where the auction takes place in one year, but bids can be submitted multiple times per year; and multi-period auctions, where a single round of bidding takes place each year, but the auction is repeated at different stages over some arbitrary time horizon.

Unfortunately, an unintended by-product of spatial incentives is the increased scope for strategic behaviour (Rolfe et al. 2009). Participants are better able to compare the biological value of their land compared to their neighbours because the auctioneer tells bidders that land closer together is preferred. This is diametrically opposed to the standard practice of limiting information leakage. Moreover, the repeated auction format exacerbates the problem by reinforcing learned behaviour, and allows participants to adjust their bids higher.

Reeson et al. (2011) demonstrated that a provisional ‘lock-in’ rule could preserve the advantages of a conservation auction with landscape incentives whilst preventing strategic behaviour. This approach works by allowing participants to change the location of proposed conservation areas, but restricting past winners from increasing their bids above their original asking price. A similar rationale is applied in this paper to an economic experiment of conservation with landscape incentives. The present research extends the iterative auction design of Reeson et al. (2011) by examining strategic behaviour and landscape coordination based on a multi-period auction format.

The sensitivity of auction outcomes to different designs means that it is unreasonable to extrapolate the results of a multi-round auction format to a multi-period auction format (Klemperer 2002; Shogren et al. 2002). Multi-round auctions can incur higher transaction costs compared to multi-period auctions, so there are definite policy implications if the potential extensions of a ‘lock-in’ rule can be demonstrated. The aim is to examine auction outcomes, and in particular, strategic behaviour and landscape coordination between participants in an experimental auction. The treatment offers participants an option to lock-in conservation over multiple periods in a repeated auction setting. This is then compared to the baseline scenario of single period conservation contracts.

The remainder of this paper is structured as follows. Section 2 develops the economic problem, while Section 3 details the experiment design and expectations. Section 4 discusses the results and section 5 concludes by contemplating the policy implications of this research, and identifying potential areas for future research.

2. <u>Problem Development</u>

2.1 Why Conservation for Biodiversity

Biodiversity is not only important for a healthy and resilient ecosystem, but also has implications for agricultural productivity, industry profitability, national identity, and overall social wellbeing (Murtough et al. 2002; McAlpine et al. 2006; Cork et al. 2006). Despite this, biodiversity is increasingly under threat from human pressures on natural resources both directly (e.g. land clearing and natural resource extraction) and indirectly (climate change and invasive species) (Mawdsley et al. 2009; Firbank 2005; Murtough et al. 2002). International treaties have now been established that oblige signatories to strive for measurable improvements in the protection of local level biodiversity (Hanson 1999), so the challenge now facing policy makers is to prescribe a best policy approach to achieve this goal.

2.2 Why Conservation Auctions

Generally, centralised authorities will turn to strategies such as education, regulation and grant schemes to improve biodiversity outcomes (Windle and Rolfe 2008; Earl et al. 2010). However, in the context of biodiversity promotion through conservation, regulation generally conflicts with the objectives of private landowners (Reichelderfer and Bogges 1988; Earl et al. 2010), education programs have largely failed to make tangible differences in the absence of real economic incentives**,** and fixed payment schemes are plagued by inefficiencies and nonchalant attitudes to ongoing management (Stoneham et al. 2002; Windle and Rolfe 2008). The limitations of traditional approaches have contributed to driving momentum for a market based solution.

Conservation auctions go some way to resolving the cost inefficiencies and restrictions that constrain traditional regulatory and payment schemes. The market based instrument corrects for the problem of asymmetric information between the cost of conservation provision by a private landholder, and the public benefits of biodiversity protection (Latacz-Lohmann and Hamsvoort 1998; Stoneham et al. 2002; Ferraro 2008; Chan et al. 2003). It does this by acting as a cost revelation mechanism of conservation works by encouraging competitive tenders, driving private landholders to bid closer to their underlying opportunity cost of production (Latacz-Lohmann and Hamsvoort 1998; Stoneham et al. 2002, Stoneham et al. 2003; Ferraro 2008; Chan et al. 2003).

Correcting for asymmetric information leads to a more efficient allocation of public funding, so auctions for conservations could necessarily deliver greater ecological benefits than traditional methods (Hailu and Schilizzi 2004). The inverse relation between an offer price for conservation and the success of being awarded a contract creates an incentive for landowners to reduce their bids, so the asking price of conservation is more likely to reflect the marginal value of the land (Rolfe et al. 2009). It also provides a discriminatory mechanism in the form of a cost-benefit indicator, allowing for a more efficient allocation of funding (Connor et al. 2007).

Windle and Rolfe (2008), Bryan et al. (2005), Gole et al. (2005) and Stoneham et al. (2003) evaluated 'one shot' competitive tender auctions for conservation. Each of the studies found evidence that a discriminative price auction for conservation could deliver efficiency gains relative to a fixed payment scheme, although there were significant differences in the reported magnitude of those gains. The Conservation Reserve Program in America (Murtough et al. 2002), the BushTender trials in Australia (Chan et al. 2003), and more recent examples such as the 'Landscape Recovery' and 'Catchment Care' auctions (Archer 2002; Bryan et al. 2005), have all proven relatively successful, and auctions for conservation have since emerged as the instrument of choice.

2.3 Problem of Heterogeneous Goods

The strength of the incentive mechanism to drive efficiency gains is compromised when the agency is faced with heterogeneous quality goods because the bargaining position of participants is enhanced (Latacz-Lohmann and Hamsvoort 1998).To conceptualise this idea, take two parcels of land denoted area *'A'* and area *'B,'* with respective landowners *'A'* and *'B.'* Suppose that landowner *'A'* has a lower marginal cost of providing land than landowner *'B,' in* which case (all else equal) we would expect landowner *'A'* to bid lower than participant *'B.'* Now suppose that landowner *'A'* becomes aware that their land is worth more in conservation value than landowner *'B.'* In this instance, it is no longer valid to conclude landowner *'A'* will bid lower than landowner *'B.'* Landowner *'A'* can bid higher for conservation funding, potentially even more than landowner *'B,'* and still win funding when the discriminative metric is a ratio of environmental output per unit of environmental funding (Latacz-Lohmann and Hamsvoort 1997). The problem with this scenario is not that landowner *'A'* is awarded conservation funding. Even with a higher bid, if landowner *'A'* can deliver more ecological value per dollar spent, then the auction mechanism is working as an efficient arbiter of funding. The problem is that landowner *'A'* is not being driven to submit a bid that would be lower without information regarding the value of their land. Information rents accrue to the landowner, reducing the efficiency of the auction (Ferraro 2008).

Typically, this problem is overcome by limiting the information that is conveyed to participants in the auction. Experiments run by Cason and Gangadharan (2004) and Cason et al. (2003) manipulate simulated auction environments by revealing the assessed environmental value of individual parcels of land in some experiments, and keeping this additional information hidden in others. The studies demonstrated how withholding information from landowners can achieve greater efficiency by limiting profit seeking opportunities. Other strategies that have been adopted in conservation auctions include using sealed bids, one shot auction designs, and varying the assessment metric used to evaluate conservation value (Stoneham et al. 2003; Ferraro 2008).

2.4 Inducing Contiguity

The spatial formation of conservation has an important bearing on the ecological services that conservation activities yield (Wünscher et al. 2008; Wissel and Wätzold 2008). This paper is built on the assertion that, conditional on the importance of spatial habitat configuration as a contributing facet of species protection, not incorporating a spatial determinant in the assessment of conservation will lead to suboptimal results.

Targeted areas for conservation often fall across private land boundaries (Innes et al. 1998), so that the conservation decisions of one property has a bearing on the biodiversity value of another property (Hartig and Drechsler 2010). In this scenario, conservation auctions with spatial incentives can provide an avenue for both collusion and coordination (Rolfe and McCosker 2003; Reeson et al. 2011).

'One shot' sealed bid auction formats have been prescribed as a method of overcoming the problem of collusion in an auction (Clark and Sefton 2001), but this suppresses the ability of previously developed areas of conservation to work as focal points for further conservation. Auctions with spatial incentives demand a repeated auction format, where the information revelation mechanism of a repeated game induces the learning behaviour necessary to encourage coordination (Shogren et al. 2000; Bernard 2005). Participants redefine their actions as they become more experienced because they associate past actions and their outcomes with future actions and outcomes (Morrison 2000). This is the method by which auction mechanisms can work to reinforce optimal behaviour (Rolfe et al. 2009). The purpose of spatial incentives is so that landowners align their conservation work in order to form conservation clusters (Hartig and Drechsler 2009). As past auctions give rise to conservation land, landowners can identify where to concentrate future bids in order to maximise their chance of being successful.

Parkhurst et al. (2002) found that an 'agglomeration bonus' was a viable method of inducing coordinated voluntary retirement of private land. The bonus mechanism worked by providing a financial bonus in the form of a subsidy to landowners who elected to retire land adjoining other areas of conservation. The same incentive design was extended by Parkhurst and Shogren (2005, 2007) to show it could work under more complex spatial settings, although the repeated nature of the experimental design became even more important in bringing about a coordinated outcome.

Rolfe et al. (2009) was the first to experiment with landscape incentives in an auction setting. They found evidence that conservation auctions with multiple bidding rounds could achieve efficiency gains. The workshop facilitated the auction design by Windle et al. (2009), which adapted a conservation auction with landscape incentives and a multi-round structure to the development of wildlife corridors in Queensland. The empirical application demonstrated evidence of strong cooperation between landholders.

2.5 The Problem with Spatial Incentives

The capacity of an auction with spatial incentive to constrain information is limited because bidders need to somehow be advised that conservation land closer together is preferred. This can be thought of as a form of 'cheap talk' (Hartig and Drechsler 2010). This undermines the capacity of an auctioneer to minimise informational rents. The strategic advantage of knowing how the ecological value of land is assessed is supported by the repeated structure of auctions, and the strategic advantages quickly morph into higher bids or 'profit seeking behaviour.' This is an undesirable outcome from the perspective of the auctioneer.

Gole et al. (2005) evaluated a conservation auction (without spatial incentives) over two rounds and found the cost efficiency of the auction was diminishing at the margin. Indeed, even Rolfe et al. (2009), who proposed the idea of multi-round auctions as a method of inducing coordination, found evidence that successful bidders identify they have a strategic advantage and will increase their bids in the long run. The idea is that while revision allows participants to adjust their bids as they familiarise themselves with the good and learn from market feedback, provisional winners will increase bids upwards rather than downwards (Cummings et al. 2004). In fact, Hailu and Schilizzi (2004) suggest auctions might not actually be as efficient as fixed payment schemes in the long run under a repeated auction design because the short term efficiency gains of an auction are eventually completely eroded away by the learning behaviour of participants. There is also evidence from the

American CRP that learning behaviour erodes the allocative efficiency of auctions (Reichelderfer and Bogges 1988). Evidently, as bidders become more experienced, an auction design which incorporates spatial incentives becomes vulnerable to ‘profit seeking behaviour.’

2.6 Motive of this paper

An alternative strategy proposed by Reeson et al. (2011) is a lock-in rule which induces a uni-directional amendment in bids for conservation in a repeated game scenario. Restricting landowner’s ability to use their realised strategic advantage to increase their asking price for conservation can preserve the efficiency gains achieved in an auction setting. The purpose of this study is to extend this concept to a single-round, multi-period auction format. The outcomes of auctions are sensitive to their design (Klemperer 2002; Shogren et al. 2002), so the results attained by Reeson et al. (2011) in a multi-round auction format can not be extrapolated to a multi-period auction format without additional research.

Multi-period auctions also have potential to minimise transaction costs. Efficiency gains from conservation auctions are reduced when you take into account transaction costs (Connor et al. 2007). While transaction costs are likely to vary between regions and biodiversity programs (Windle and Rolfe 2008), it is probably fair to say that auctions would have a much higher cost involved compared to fixed payment policies (Hailu and Schilizzi 2004). There are administration costs to bidders in the time taken to formulate bids, and to agency’s evaluating the environmental benefits of tenders for conservation. Assessing new conservation as a complement to existing conservation requires that every new arrangement is re-assessed (Pressey and Taffs 2001). This can be particularly unattractive if multi-round auctions are repeated over a number of periods.

Generally, conservation programs will have limited resources to be able to deliver desirable outcomes in a single year (Reeson et al. 2011). It is more realistic that the planning process is extended over a number of years, in which the development of habitat reserves takes place in stages (Cowling and Pressey 2001). Essentially, the conservation planner has to compromise between achieving the desired spatial pattern, and the time scale required to achieve that pattern, in order to minimize the transaction costs involved with running a conservation auction (Pressey et al. 2007).

3. Experiment Methodology

The aim of this experiment is to compare auction outcomes with respect to strategic behaviour and auction efficiency in a multi-period auction design under different contract length treatments. In one treatment, participants are only offered single period contracts, while the other offers participants the option of one period, two periods or three periods. In effect, the multi-period auctions simulate a quasi- lock-in rule because winners are unable to change their bids until their contract has expired.

The experiments were run in the computer laboratories at the University of Sydney, and student volunteers comprised the population of randomly selected participants. Participants were assigned a computer which included a computer screen of the auction environment and a set of instructions. After participants had finished reading the instructions, they completed a quiz intended to test their understanding. The auction began when everyone had successfully completed the quiz. As is standard in economic experiments, participants were paid based on their earnings in the auctions so that their decisions in the experiment had real financial consequences.

The auction format involved single round sealed bids, which were repeated over five periods, each period lasting three minutes. The computer optimisation algorithm took a couple of minutes to select the package of bids that maximised efficiency, and the results were projected back to participants via their computers. Limiting collusive behaviour through first price sealed bids is now fairly standard practice (Klemperer 2002; Chan et al. 2003, Rolfe and McCosker 2003; Rolfe et al. 2004, Chan et al. 2003), and the multi-period format provides scope for participants to make re-adjustments in wake of competitor's bids. As per the findings of Cason and Gangadharan (2004 ,2005), Cummings et al. (2004), and Stoneham et al. (2003) a discriminative auction rule is used instead of a uniform price because it achieves greater overall cost efficiencies**.**

The simulated auction environment adopts the same software that was used by Reeson et al. (2011). The landscape consists of a 20 by 20 gird of cells fitted with 10 properties. The properties are not identical, with some consisting of more cells than others *(see figure 1)*. Each cell has an underlying opportunity cost of $100 experimental dollars, which is intended to reflect forgone production. Participants receive this if they lose in the auction (thus the land remains in production), but not if they win. Furthermore, the opportunity cost remains constant over time, but participants are only made aware of their own production costs and not their neighbours. Since there was no cost to submitting a bid, and with perfect information regarding their present and future opportunity costs, participants faced no foreseeable risk in electing to submit a bit. This made winning contracts a particularly attractive option for participants seeking to increase their earnings in the experiment.

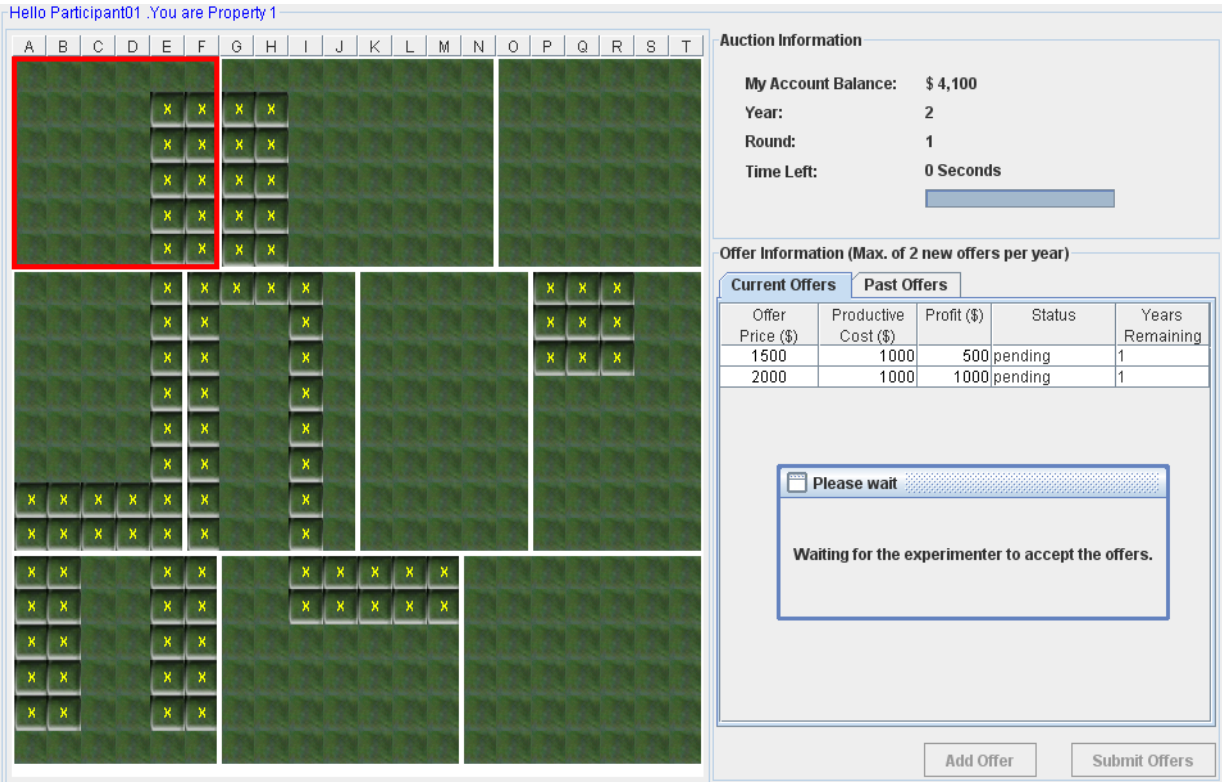

Figure 1: A screenshot of the auction environment. Between periods, participants can see the land that is in conservation, denoted by the crosses on the screen. The bold marking denote property boundaries

The ecological value of the landscape is also homogenous at the start of the auction. Each cell has a biodiversity value of one unit. As the auction evolves, land that is in a state of conservation is given a greater ecological weighting if interconnected land is also in conservation. A cell in conservation that is adjoined horizontally by another cell in conservation is given a bonus weighting of one unit. Cells in conservation that are aligned vertically are given a bonus weighting of two units, which reflects situations where forming corridors in a certain direction is desirable. Participants are instructed that conservation that adjoins other areas of conservation is preferable from the perspective of the auctioneer, including conservation that is adjoined across properties. In effect, the success of the auction mechanism in generating a contiguous landscape would be reflected by higher biodiversity scores.

The instruction set included information that was intended to familiarise participants with the auction environment. The language was kept as neutral as possible to avoid individual beliefs affecting bidding behaviour, so words such as conservation were substituted by land retirement. Participants were instructed that as land managers, they were faced with the option of leaving their land as it was and earn the production value underlying their cell, or rent it out to the government for a price that they set. Given limited funding available for government purchases of land, participants were required to reconcile the trade-off between submitting higher bids, and the reduced probability of successfully winning.

Divulging the bid assessment rule was the only information that participants were made privy to. This was the simplest way of ensuring participants were aware that the spatial incentive existed, and that the spatial formation had a bearing on the success of their bids. The number of periods, the auctioneer's budget constraint and the offer price asked by other participants were all kept hidden to encourage competitive bidding and minimise informational rents. Unlike Cason et al. (2003) and Cummings et al. (2004), no communication was allowed in this experiment because there was limited capacity for the researchers to control for the nature of interaction.

Our hypothesis is that the multi-period contracts, which serve to lock in preliminary winners of conservation contracts, will achieve greater overall efficiency because the ability of participants to seek greater levels of profit (realising their informational rents) will be undermined. Participants have a number of strategies that they could follow that can reasonably by categorised as 'aggressive or passive' (McAfee and McMillan 1996). They could bid high for conservation early, which might yield a larger return if others choose to bid conservatively, although there is less information to guide a participant's behaviour, and multi-period contracts will work to constrain the adjustment process as new information comes to light. Alternatively, participants could bid conservatively at the start to maximise their chances of winning a contract, and use new information (such as the location of other people's bids and their own successes) to guide their decision rule in each subsequent period. Ultimately, there is no dominant strategy that participants will abide by, so observing the development of bidding behaviour forms part of the discussion in the next section.

4. Results

Independent experiments were conducted, with the data collected from 4 replications of the treatment *'multi-period contracts'* (MPC) and alternate *'single period contracts'* (SPC). Table 1 provides a summary of the main variables analysed.

Table 1

The mean asking profit and auction efficiency from the eight experiments. Auction efficiency is a benefit-cost ratio of the conservation metric and money spent. Standard errors are in parentheses, and 'n' is the number of observations

	Profit (Offer Price – Opportunity Cost)		**Auction Efficiency** (Conservation Value / Money Spent)	
	First Period	Last Period	First Period	Last Period
Multi-Period Contract Options	676.3 (79.16)	838.6 (95.0)	0.55 (0.08)	0.91 (0.21)
MPC	n = 73	n = 78	n = 4	n = 4
Single Period Contract Only	766.3 (89.69)	1717.9 (193.3)	0.52 (0.17)	0.54 (0.1)
SPC	n = 73	n = 79	n = 4	n = 4

4.1 - Strategic Behaviour

Table 2 - Strategic Behaviour

Regression models comparing profit seeking in period 1 and period 5

	Model 1 Profit Seeking	Model 2 Profit Seeking
area	0.204***	0.194***
	-0.0502	-0.046
Dsingle[0]	-0.0568	0.877***
	-0.227	-0.246
two periods[1**]	-0.382	0.457*
	-0.263	-0.264
three periods[2**]	0.479*	0.126
	-0.264	-0.289
constant	4.196***	4.276***
	-0.445	-0.413
Observations	142	156

[0] 1 = single period contract only 0 = multi-period contract options

[1] 1 = two period contract chosen 0 = otherwise

[2] 1 = three period contract chosen 0 = otherwise

** base is one period contract

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

'Strategic behaviour is proxied by the profit sought from participant's newly submitted bids in each period. GLM models were run using Stata10, with the log of profit related linearly to the cell *'area'* comprising participants offer bundle, dummy variables (*'twoyears'* and *'threeyears'*) denoting whether participants asked for a two period contract or three period contract, and a dummy variable *'Dsingle'* that distinguishes if the experiment offered only single period contracts or provided options for multi-period contracts.

Table 2 shows the profit for conservations sought by the participants in the first period and last period, evaluated separately to avoid the problem of repeated measures. There was little difference in the asking price for conservation under the multi-period contract treatments and the single period contract treatments at the start of the auctions (p = 0.226). Most participants appeared to treat the start of the experiments with caution bidding closer to their opportunity cost than in other periods. This quickly dissipated by period two, and the bidding behaviour appeared to evolve as a product of the treatment effect and design intricacies of the experiment from then on.

The evolution of the mean and median asking profit between period one and five can been seen in figure 2. In both treatments there was a spike between the first and second period. This is because the relatively low bidding by participants resulted in a weakly binding budget constraint in the first period, such that almost everyone had their bids accepted (82% on average). This encouraged participants to increase their bids significantly in period 2.

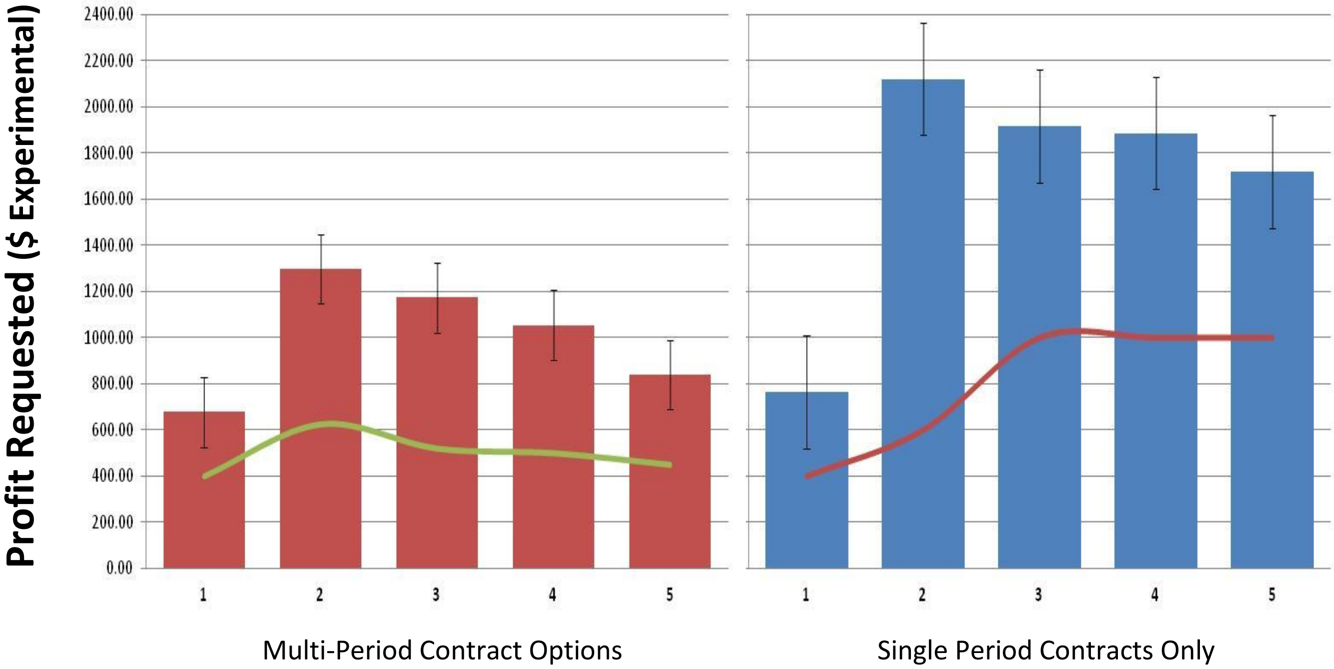

Figure 2: Average (represented by the bars) & median profit (represented by the lines) sought from newly submitted bids in each treatment across each of the 5 periods. Standard errors bars are included.

In both the MPC and the SPC experiments, the mean starts to decrease after period 2, although the single period contracts appear to ask much higher profits at each point in time. By the end of the auction, the mean profit request under the single period contract experiments was much greater than the experiment auctions that offered multi-period contracts (p = 0.000). That SPCs encourage greater asking profits is an assessment that is reinforced by the median asking profit, represented by the line series in the same figure. It never decreases in the SPC experiments, but plateaus out after period 3. This is contrary to the downward trending pattern in both the mean and median asking profit with MPCs.

What is driving this result? The most obvious explanation is that winners of multi-year contracts are 'locked in' until their contracts expire. If participants win a multi-period contract, they are automatic winners in each subsequent period until their contracts expire, but they lose the flexibility to adjust their asking price for rented land. Figure 3 shows the pooled average asking profit for one, two and three period contracts from the multi-period contract experiments and the number of accepted contracts. There is variation in the asking price between the different asking prices, although they are not statistically significant determinants of profit seeking behaviour at a 5% level. Interestingly, 2 period contracts had the lowest asking profit on average, $66 less than 1 year contracts and $520 less than 3 period contracts.

The difference between the two treatments can also be attributed to the budget constraint and its influence on winning in the auction. It is important to recognise that winning a contract for conservation tends to drive up the asking price for further conservation. There were 188 occasions in which a participant could be classified as a previous winner of conservation. On 150 occasions (79.8%), a previous winner would submit a bid asking for a higher average profit, while on only 31 occasions (16.4%) they asked for a decrease.

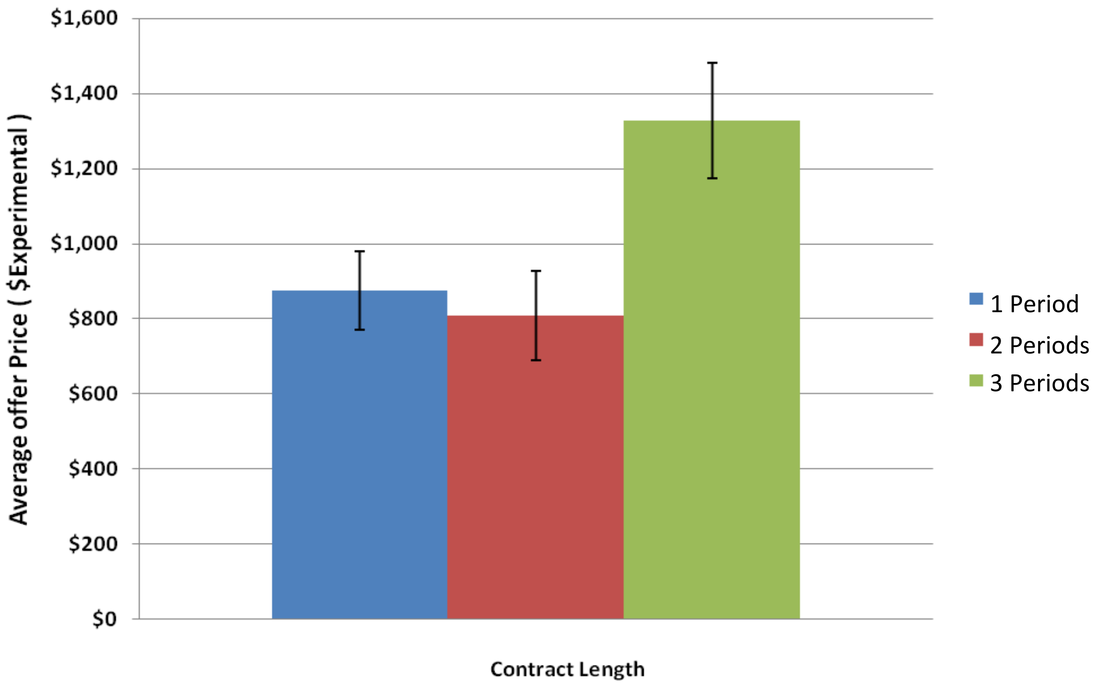

Figure 3: Average asking price for contract lengths

Table 3 shows the percentage of submitted bids that were accepted in each period. By inspection, except for period 1, the percentage of accepted bids was much lower in the MPC experiments than the SPC experiments. Therefore, given SPC experiments are more likely to accept bids than MPC experiments, and previous winners are more likely to increase their asking price for conservation in the current period, it naturally extends that MPC auctions will reveal less profit seeking behaviour. So why are bids more likely to be accepted in an SPC auction than an MPC auction?

Contracts are awarded to participants for an offer that is specified as a 'per-period payment,' and there is an underlying budget constraint of $25,000 experimental dollars per period. So, for auctions with only an SPC option, there is $25,000 experimental dollars available for new conservation contracts in each period. However, in an MPC auction, some of the $25,000 budgeted for the next period will already be set aside for the multi-period contracts awarded in the previous period. That is to say, multi-period contracts consume a portion of the budget constraint available for each new period. Take for example that only a 2 period contract was awarded in period 1. The contract requested a $1000 profit. With an underlying opportunity cost of $1000, that amounts to a total contract offer price of $2000. This means there is now only $23,000 of the $25,000 originally available for conservation in period 2. Less funding available for new conservation in each period is analogous to reducing the probability of winning a contract.

Figure 4 shows the number of accepted bids in the MPC treatment for each period and each contract type. There were substantially more bids accepted that asked for only 1 period at the start of the auction, but 40% of accepted bids did apply for 2 or more periods. This resulted in less funding available for new bids, resulting in fewer bids being accepted in the MPC treatment (193) compared to the SPC auctions (252), and correspondingly, less profit seeking behaviour.

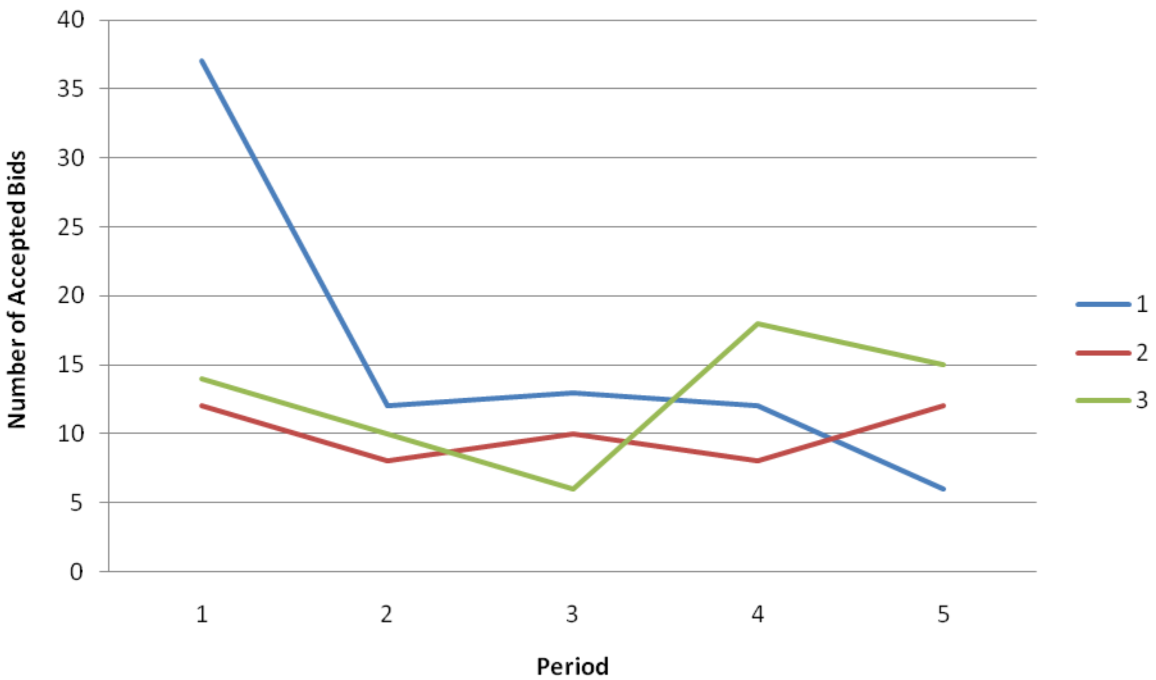

Figure 4: Number of accepted contracts from the multi-period contract trials

4.2 - Auction Efficiency

The dependent variable used to evaluate auction efficiency is a ratio of the conservation value generated, and the money spent in the auction. While the budget constraint is held constant in each period, the computer algorithm selects the package of bids that maximisise this discriminatory ratio, so the money spent in each period is not constant. Since the heterogeneity in conservation value is brought about by the bonus mechanism which rewards landscape designs that are clustered, particularly cells that are joined in a vertical orientation, we can use the conservation value achieved in the experiment as a proxy for coordination.

Table 4 indicates the regression results generated in Stata10. Model 1 is a random effects model that clusters the standard errors from each of the experiment groups. It compares the efficiency ratio to the treatment dummy *'Dsingle,'* the *'period'* and an interaction term between *'period'* and *'Dsingle'*. The treatment is strongly insignificant (p=0.944), but the period and interaction term do appear to be significant with a p-value of 0.005 and 0.021 respectively. This indicates that there is some trending behaviour in the data that is influenced by the treatment.

Table 4 - Auction Efficiency

The dependent variable is a ratio of the conservation value attained and money spent in the period

Explanatory Variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
		if period = 1	*if period = 2*	*if period = 3*	*if period = 4*	*Ifperiod = 5*
Dsingle[0]	-0.0172	-0.0300	-0.192	-0.475	0.500***	-0.370*
	(0.244)	(0.175)	(0.152)	(0.303)	(0.193)	(0.221)
Period	0.104***					
	(0.0372)					
Dsingle& Period	0.0988**					
	(0.0428)					
Constant	0.507***	0.550***	0.680***	0.960***	0.995***	0.912***
	(0.211)	(0.0761)	(0.110)	(0.294)	(0.183)	(0.199)
Observations	40	8	8	8	8	8

[0] 1 = single period contract only 0 = multi-period contract options

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Models 2 to 6 are separate GLM models of the results to try and find at which point the difference between the two auctions becomes statistically significant. This occurs in period 4 (p=0.000) and remains so in period 5 at a 10% level (p=0.094). Therefore, efficiency does appear to improve as the auction progresses, indicating that participants were using existing areas of conservation as a guide to achieve coordination.

Figure 5 illustrates path of the efficiency ratio. There is an evident upward trend in the auction efficiency achieved under MPC. There appears to be a dip in the auction efficiency achieved under the multi-period contract treatment between period 4 and period 5. The amount of strategic behaviour has already been shown to decline across all periods under a muiti-period contract setting, so coordinated bidding seems to consistently fall away by the end of the experiment.

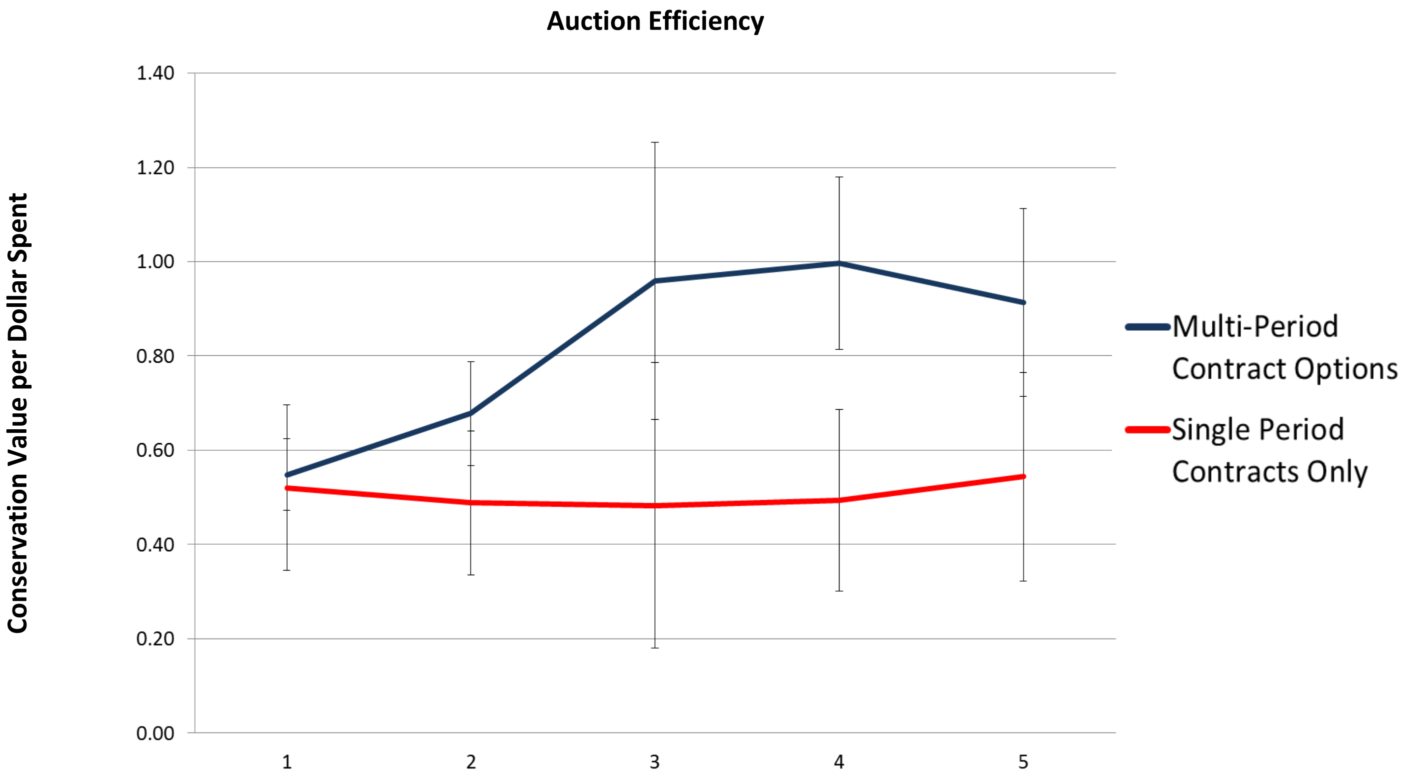

Figure 5: Auction efficiency results with 95% standard errors in each period

To try and explain this outcome a visual recreation was built from one of the experiments. Figure 6 denotes period 4 of experiment number 2, while figure 7 denotes the outcome in period 5 for the same experiment. Experiment 2 is an MPC treatment, and was chosen for this evaluation because it constituted the largest decrease in conservation value (0.18 units per dollar) of all the MPC experiments between these two periods.

Figure 6 shows there is a strong conservation network to the left of the landscape, with column A forming a completed corridor, and the participant in the top left hand corner managing to successfully fill his entire property. By the next period however, this area of conservation has broken down. Participants towards the centre have managed to win conservation bordering their properties, and some new areas of conservation have started to form to the right of the landscape. Both landscapes consists of 152 cells in conservation, but the conservation value in period 5 is 3,240 biodiversity units less, indicating a more fragmented landscape. In this instance, the fragmentation is brought about by a horizontal re-organisation of the landscape rather than vertical, which is less preferred.

It could be the case that this result is evidence of a transition or restructuring phase in the path development of auction outcomes. Landowners who were consistently denied conservation became first time winners because their bids became relatively more competitive and the participants on the right hand side of the landscape began to emerge as the dominant landholders. This re-organisation of the landscape to approach a better optimal outcome could be thought of as a path dependence problem (Liebowitz and Margolis 1995) but we do not try and embellish this proposition any further.

A1	B1	C1	D1	E1	F1	G1	H1	I1	J1	K1	L1	M1	N1	O1	P1	Q1	R1	S1	T1
A2	B2	C2	D2	E2	F2	G2	H2	I2	J2	K2	L2	M2	N2	O2	P2	Q2	R2	S2	T2
A3	B3	C3	D3	E3	F3	G3	H3	I3	J3	K3	L3	M3	N3	O3	P3	Q3	R3	S3	T3
A4	B4	C4	D4	E4	F4	G4	H4	I4	J4	K4	L4	M4	N4	O4	P4	Q4	R4	S4	T4
A5	B5	C5	D5	E5	F5	G5	H5	I5	J5	K5	L5	M5	N5	O5	P5	Q5	R5	S5	T5
A6	B6	C6	D6	E6	F6	G6	H6	I6	J6	K6	L6	M6	N6	O6	P6	Q6	R6	S6	T6
A7	B7	C7	D7	E7	F7	G7	H7	I7	J7	K7	L7	M7	N7	O7	P7	Q7	R7	S7	T7
A8	B8	C8	D8	E8	F8	G8	H8	I8	J8	K8	L8	M8	N8	O8	P8	Q8	R8	S8	T8
A9	B9	C9	D9	E9	F9	G9	H9	I9	J9	K9	L9	M9	N9	O9	P9	Q9	R9	S9	T9
A10	B10	C10	D10	E10	F10	G10	H10	I10	J10	K10	L10	M10	N10	O10	P10	Q10	R10	S10	T10
A11	B11	C11	D11	E11	F11	G11	H11	I11	J11	K11	L11	M11	N11	O11	P11	Q11	R11	S11	T11
A12	B12	C12	D12	E12	F12	G12	H12	I12	J12	K12	L12	M12	N12	O12	P12	Q12	R12	S12	T12
A13	B13	C13	D13	E13	F13	G13	H13	I13	J13	K13	L13	M13	N13	O13	P13	Q13	R13	S13	T13
A14	B14	C14	D14	E14	F14	G14	H14	I14	J14	K14	L14	M14	N14	O14	P14	Q14	R14	S14	T14
A15	B15	C15	D15	E15	F15	G15	H15	I15	J15	K15	L15	M15	N15	O15	P15	Q15	R15	S15	T15
A16	B16	C16	D16	E16	F16	G16	H16	I16	J16	K16	L16	M16	N16	O16	P16	Q16	R16	S16	T16
A17	B17	C17	D17	E17	F17	G17	H17	I17	J17	K17	L17	M17	N17	O17	P17	Q17	R17	S17	T17
A18	B18	C18	D18	E18	F18	G18	H18	I18	J18	K18	L18	M18	N18	O18	P18	Q18	R18	S18	T18
A19	B19	C19	D19	E19	F19	G19	H19	I19	J19	K19	L19	M19	N19	O19	P19	Q19	R19	S19	T19
A20	B20	C20	D20	E20	F20	G20	H20	I20	J20	K20	L20	M20	N20	O20	P20	Q20	R20	S20	T20

Figure 6: Conservation landscape for a multi-period contract experiment in period 4

A1	B1	C1	D1	E1	F1	G1	H1	I1	J1	K1	L1	M1	N1	O1	P1	Q1	R1	S1	T1
A2	B2	C2	D2	E2	F2	G2	H2	I2	J2	K2	L2	M2	N2	O2	P2	Q2	R2	S2	T2
A3	B3	C3	D3	E3	F3	G3	H3	I3	J3	K3	L3	M3	N3	O3	P3	Q3	R3	S3	T3
A4	B4	C4	D4	E4	F4	G4	H4	I4	J4	K4	L4	M4	N4	O4	P4	Q4	R4	S4	T4
A5	B5	C5	D5	E5	F5	G5	H5	I5	J5	K5	L5	M5	N5	O5	P5	Q5	R5	S5	T5
A6	B6	C6	D6	E6	F6	G6	H6	I6	J6	K6	L6	M6	N6	O6	P6	Q6	R6	S6	T6
A7	B7	C7	D7	E7	F7	G7	H7	I7	J7	K7	L7	M7	N7	O7	P7	Q7	R7	S7	T7
A8	B8	C8	D8	E8	F8	G8	H8	I8	J8	K8	L8	M8	N8	O8	P8	Q8	R8	S8	T8
A9	B9	C9	D9	E9	F9	G9	H9	I9	J9	K9	L9	M9	N9	O9	P9	Q9	R9	S9	T9
A10	B10	C10	D10	E10	F10	G10	H10	I10	J10	K10	L10	M10	N10	O10	P10	Q10	R10	S10	T10
A11	B11	C11	D11	E11	F11	G11	H11	I11	J11	K11	L11	M11	N11	O11	P11	Q11	R11	S11	T11
A12	B12	C12	D12	E12	F12	G12	H12	I12	J12	K12	L12	M12	N12	O12	P12	Q12	R12	S12	T12
A13	B13	C13	D13	E13	F13	G13	H13	I13	J13	K13	L13	M13	N13	O13	P13	Q13	R13	S13	T13
A14	B14	C14	D14	E14	F14	G14	H14	I14	J14	K14	L14	M14	N14	O14	P14	Q14	R14	S14	T14
A15	B15	C15	D15	E15	F15	G15	H15	I15	J15	K15	L15	M15	N15	O15	P15	Q15	R15	S15	T15
A16	B16	C16	D16	E16	F16	G16	H16	I16	J16	K16	L16	M16	N16	O16	P16	Q16	R16	S16	T16
A17	B17	C17	D17	E17	F17	G17	H17	I17	J17	K17	L17	M17	N17	O17	P17	Q17	R17	S17	T17
A18	B18	C18	D18	E18	F18	G18	H18	I18	J18	K18	L18	M18	N18	O18	P18	Q18	R18	S18	T18
A19	B19	C19	D19	E19	F19	G19	H19	I19	J19	K19	L19	M19	N19	O19	P19	Q19	R19	S19	T19
A20	B20	C20	D20	E20	F20	G20	H20	I20	J20	K20	L20	M20	N20	O20	P20	Q20	R20	S20	T20

Figure 7: Conservation landscape in period 5 for the same experiment as figure 6

5. Conclusion

While studies have shown conservation auctions can achieve a more efficient outcome compared to fixed payment schemes, they are susceptible to profit seeking behaviour when spatial incentives are included in the assessment of land for ecological service provision. The spatial incentives are intended to induce coordinated outcomes reflected by a clustered landscape of conservation, but learning behaviour under a repeated game scenario can also give rise to higher bids for conservation, as participants become aware of the ecological value of their land. In a multi-round auction, spatial incentives can still encourage competitive tenders using a 'lock-in rule' (Reeson et al. 2011). The same concept is extended in this paper to a multi-period auction format to examine if the same conclusions are justified under different settings.

Laboratory experiments were conducted using software to simulate a basic auction for conservation. The aim was to compare auction outcomes with respect to strategic behaviour and auction efficiency under different contract length treatments. These phenomena were proxied by the economic profit sought from participant's bids, and the aggregated conservation value generated in each period. It was hypothesised that 'Multi-Period Contracts' (MPCs), which would serve to lock in preliminary winners of conservation contracts, would achieve greater overall efficiency compared to 'Single Period Contracts' (SPCs) because the ability of participants to seek greater levels of profit would be undermined.

Data collected indicates that profit seeking behaviour declines over time when participants are offered multi-period contracts instead of just single period contracts. This is because multi-period contracts inhibit the capacity of landowners to use the information revealed in a sequential auction seeking to adjust their bids higher. The relatively modest bidding behaviour in multi-period contract settings was also attributed to a deflated budget constraint, reducing the probability of winning new contracts. With a constant annual budget constraint, some funding will need to be dedicated to existing conservation areas under contract for more than one period. In effect, the budget constraint becomes more binding, reducing the chances of winning a contract requesting excessively high profits. Participants learnt whether their previous bids were accepted or not as each new period started, and they tended to adjust their bids downwards when they were unsuccessful.

There were fewer accepted bids for conservation in MPC trials, but the auction efficiency (conservation value per dollar spent) was higher and generally increasing with each subsequent period. This result was recognized as a product of limiting profit seeking behaviour. Higher conservation value is also a reflection that participants were coordinating their activities, indicating that spatial incentives and cheap talk were effective influences on the bidding behaviour of participants.

The policy implications are relatively straight forward. The large amount of money being poured into programs to improve biodiversity outcomes (Reichelderfer and Bogges 1988; Stoneham et al. 2003) demonstrates the worth of studies that seek to improve efficiency outcomes. The results from these experiments indicate that multi-period auction formats could achieve efficiency gains over time if bidders are offered multi-period contracts for ecological service provision. In some instances, conservation programs do not even offer farmers the option of different contract lengths (Khannaa and Andoa 2009), and most certainly do not include an incentive mechanism that is designed to encourage clustered conservation outcomes. Also, multi-period auctions are preferable from the viewpoint that they incur lower transaction costs than multi-round auctions, so it is also noteworthy that the advantages that can be attained in a multi-round setting can extend to multi-period scenarios.

The external validity of economic experiments are notorious for being poor (Rolfe et al. 2009), so the results can not be extrapolated to more complex settings confidently. One caveat that would undermine the results from this experiment is if there is no variation in the choice of contract length, such that every multi-period auction only delivers single period contracts. There is evidence to suggest this might be the case in America, with almost 90% of those enrolled in the American Illinois Conservation Reserve Enhancement Program (CREP) opting for contracts that required permanent easement of production (Khannaa and Andoa 2009). All the same, experiments are still a good *ex-ante* approach to refining auction design and expectations. The aim moving forward would be to increase the complexity of this environment to confirm the robustness of these results in much the same vein as this paper.

Some interesting research that would be worth exploring is to evaluate an auction in a multi-round, multi-period format to see if any additional efficiency gains can be derived over time when opportunities to coordinate have already been exhausted. It would also be worth devising an auction setting that encourages inter-temporal stability. Land that stays in a state of conservation longer derives greater ecological benefits than land that is only conserved for a short while. It takes time for habitat to grow, and for new species to migrate and flourish. This additional ecological benefit was not attributed to those that chose a longer contract length, because the parameters of the software did not allow for such variation. Incorporating an incentive for longer term contracts on the premise that a stable environment is preferable would have implication for contract preference. This is something that requires further exploration.

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