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Analysis

Adapting auctions for the provision of ecosystem services at the landscape scale

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ABSTRACT

Auctions, or competitive tenders, can overcome information asymmetries to efficiently allocate limited funding for ecosystem services. Most auctions focus on ecosystem services on individual properties to maximise the total amount provided. However, for many services it is not just the total quantity but their location in the landscape relative to other sites that matters. For example, biodiversity conservation may be much more effective if conserved sites are connected. Adapting auctions to address ecosystem services at the landscape scale requires an auction mechanism which can promote coordination while maintaining competition. Multi-round auctions, in which bidding is spread over a number of rounds with information provided between rounds on the location of other bids in the landscape, offer an approach to cost effectively deliver landscape-scale ecosystem services. Experimental economic testing shows these auctions deliver the most cost effective environmental outcomes when the number of rounds is unknown in advance, which minimises rent-seeking behaviour. It also shows that a form of bid-improvement rule facilitates coordination and reduces rent seeking. Where the biophysical science is well developed, such auctions should be relatively straightforward to implement and participate in, and have the potential to provide significantly better outcomes than standard 'one-shot' tenders.

1. Introduction

Payments for ecosystem services (ES) are increasingly being applied to promote biodiversity conservation and other environmental policy goals. Auctions, or competitive tenders, are a proven method of overcoming information asymmetries concerning landholders' private costs and ensuring the efficient allocation of limited ES payments (Latacz-Lohmann and Van der Hamsvoort, 1997; Stoneham et al., 2003). In an ES auction (which is a form of procurement auction), landholders submit bids to provide ES in return for a payment. Landholders are free to choose the level of their payment. However the auction mechanism is competitive, with only those that offer the best value for money (quantity of ES provided per dollar requested) likely to be successful. Most ES auctions adopt a sealed bid, discriminatory price mechanism, in which successful landholders are paid their bid price (e.g. Stoneham et al., 2003; Windle et al., 2009).

In order to rank the bids made by landholders in an auction, a metric is required to measure and compare the level of ES provided by alternative bids. A number of metrics have been developed for conservation auctions, such as habitat hectares and the biodiversity benefits index (e.g. Chomitz et al., 2006; Oliver et al., 2005; Parkes et al., 2003; Wünscher et al., 2008). These calculate the value of each bid in terms of ecological outcomes, and express it as a single unit. This means the auction mechanism can select the individual projects which provide the best value for money. However, by focussing on individual bids this approach will not necessarily select the optimal spatial configuration of conservation projects across a landscape (Gole et al., 2005).

In many cases the effective provision of ecosystem services requires a landscape-scale approach, rather than a focus on individual properties (Goldman et al., 2007). For example, connectivity between biodiversity conservation sites facilitates dispersal of biota, potentially increasing the contribution that individual management actions make toward the goal of viable populations. Although different species respond to connectivity in different ways (e.g. Hostetler, 1999; Lindborg and Eriksson, 2004), the spatial configuration of sites is often critical to the biological success of conservation efforts (e.g. Drielsma and Ferrier, 2009; Jiang et al., 2007; McAlpine et al., 2006) and the selection of projects should be considered at a landscape scale in order to achieve lasting biodiversity outcomes. Some ecological metrics do assign a value to connectivity. For example, a conservation auction in Australia's Desert Uplands region had connectivity as a major focus, and applied a metric which included a significant weighting for proximity to conserved patches of remnant vegetation

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within the landscape and proximity to other bids (Windle et al., 2009).

The relative value of connectivity or permeability compared to other ecological attributes such as habitat area and condition will depend on the characteristics of the target species or community, such as dispersal ability and range requirements. Species which are poor dispersers may require connected habitat, while others may be able to make use of stepping stones across a fragmented landscape. Some degree of habitat connectivity is required for most conservation outcomes in the short term. In the medium and long term it is likely to be of even greater importance, allowing species and communities to progressively adjust their ranges in response to climate change (Mawdsley et al., 2009). The highly modified and fragmented nature of agricultural landscapes means that adapting to climate change may be particularly problematic for many species and communities.

Where there are landscape-scale objectives such as habitat connectivity the ecological metric required to prioritise proposed conservation projects becomes more complex. As the value of any one bid depends on which other bids end up in the final package, it is not possible to come up with a meaningful independent biodiversity value for an individual bid. Rather it is necessary to consider each possible combination of bids, and work out which combination provides the best biodiversity outcomes within the budget constraint. That is, an effective metric should provide a measure of combined value rather than individual value. An alternative, less computationally intensive, approach is to select projects iteratively, incorporating each newly selected site into the landscape context within which the remaining proposed sites are assessed (Barton et al., 2009). This interdependency between sites is not new to conservation biologists who have long worked within the principle of biodiversity complementarity, a calculus for the marginal contribution each site makes toward global biodiversity values (Faith, 1994; Sarkar et al., 2006).

This paper considers how ES auction mechanisms may be modified to address the combinatorial values inherent in landscape-scale biodiversity conservation. The following section considers the design of incentive mechanisms which can cost effectively deliver the coordination required for landscape-scale outcomes. Section 3 describes the experimental testing of some proposed alternative auction mechanisms, with the results presented in Section 4, followed by discussion of the policy implications in Section 5.

2. Auction Mechanisms

To address landscape-scale objectives in conservation auctions it is necessary to have a mechanism for coordinating the actions of individual landholders in order to maximise landscape synergies, for example by offering adjoining parcels of land to form a wildlife corridor. Coordinating the actions of autonomous agents is difficult as it requires them to have both information about the actions of others and an incentive to coordinate with them. A series of studies by Parkhurst, Shogren and others investigate the use of a 'smart subsidy', which is a fixed payment with an agglomeration bonus, to provide an incentive for neighbouring landholders to coordinate their bids (Parkhurst et al., 2002; Parkhurst and Shogren, 2005, 2007). In laboratory experiments the bonus mechanism was successful in prompting experimental participants to coordinate their actions for a number of simple spatial configurations. These approaches build on game theory in which the complete payoff matrix is known and/or private information of other agents' costs and benefits is available. With complete information, coordination may occur if it is a clear Nash equilibrium.

In more complex and realistic coordination experiments the bonus mechanism proved less effective (Parkhurst and Shogren, 2007). Where there is no clear equilibrium, agents will require an additional mechanism in order to coordinate their actions. In experimental games, iteration can promote coordination as agents acquire information on the strategies of others. For example, in diverse experimental designs subjects generally fail to attain the desired outcome in a one-shot game, but are successful in achieving the goal as the game is repeated (e.g. Clark and Sefton, 2001). Iteration has been shown to promote coordination by neighbouring landholders in economic experiments; coordination was more likely in later rounds of the experiment, when participants were able to use their experience from previous rounds (Parkhurst and Shogren, 2007). Iteration combined with incentives for coordination therefore has the potential to facilitate coordination among autonomous agents.

A conservation auction with multiple bidding rounds, in which landholders are provided with information on the location of bids from the previous round, offers a mechanism through which landholders can identify potential synergies with other bids and adjust their own bids accordingly (Rolfe et al., 2009; Windle et al., 2009). It could allow landholders to converge on a coordinated solution without having advance knowledge of each others' costs and likely strategies. In an auction setting, as opposed to a fixed payment scheme, landholders have an incentive to coordinate their bids even in the absence of a bonus. Provided the bid assessment process places a positive value on connectivity, bids which coordinate with others will have a greater chance of success. All things being equal, landholders should therefore attempt to submit bids which align with those of their neighbours.

However, auctions work by compelling landholders to compete, thereby revealing their costs and enabling the purchaser to select those projects with the lowest cost per unit of biodiversity. In a discriminatory price auction, bidders have incentives to inflate their bid prices above their true costs, depending on their expectations of their costs relative to other bidders, in order to seek a surplus (Abbink et al., 2006; Latacz-Lohmann and Van der Hamsvoort, 1997). If an auction is repeated, bidders' expectations will become more accurate and those with low costs may increase their surplus request. Experimental studies show that bidders' prices tend to rise over repeated discriminatory price auctions (Cason and Gangadharan, 2005; Cummings et al., 2004; Schilizzi and Latacz-Lohmann, 2007). This will compromise the ability of the auction to reveal low cost providers, eroding the efficiency benefits. There is evidence of this occurring in the US Conservation Reserve Program (Kirwan et al., 2005; Reichelderfer and Boggess, 1988).

There is also a danger that a mechanism intended to promote coordination among landholders may at the same time promote strategic behaviour. As information on other bids is revealed, some individuals will learn that their bid has particularly high value, for example by virtue of being integral to a potential corridor. This is likely to result in such bidders raising their prices and extracting more rent based on this information (Cason et al., 2003). The multi-round auction format also increases the likelihood of collusion among bidders (e.g. Burtraw et al., 2009; Fabra 2003). Therefore while multi-round auctions may overcome the coordination problem inherent in landscape-scale conservation, they also offer greater potential for collusion and rent seeking by bidders. As bidders inflate their prices the auction becomes less effective at identifying low cost suppliers and a budget-constrained buyer is able to secure fewer ES. There may therefore be a trade-off between promoting coordination over multiple rounds and minimising collusion and learned strategic behaviour. The more rounds the better the coordination of bids across the landscape, but the greater the learning (both of equilibrium prices and one's value in the landscape) and potential for collusion.

It is well established that relatively minor details in the design of auctions and other market institutions can have a major impact on market performance (e.g. Klemperer, 2002). The limited theoretical guidance on the design of multi-round auctions for conservation necessitates an experimental approach. Economic experiments allow alternative auction formats to be tested and compared. We set out to experimentally test this trade-off between coordination and collusion