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Exploring the cost effectiveness of land conservation auctions and payment policies*

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This article evaluates the cost-effectiveness of the Catchment Care Australian conservation auction. It provides evidence of auction cost effectiveness, and estimates cost savings from two discrete components: (i) the opportunity cost revelation incentive provided by the auction mechanism, and (ii) the improved environmental targeting capacity that results from development of a scientifically based environmental benefits assessment capacity. Results show that there are potentially very large returns associated with the latter component that have been overlooked in the literature.

Additionally, transaction costs involved with administering the case study conservation auction and the prior non-auction payment policy are compared. We find that the administration costs for the auction were greater than or equal to those associated with the prior policy. Estimates of relative cost effectiveness across policies are shown to be sensitive to the methods of comparison. In this case study, there is inelastic supply of the last units of environmental benefit. This inelasticity results in large estimated auction comparative cost advantage when the benefit metric is the estimated cost required to achieve auction aggregate environmental benefit. Estimated benefit of the auction is much less when measured as environmental benefits attainable with alternative payment policies subject to the auction budget constraint.

Key words: auctions, biodiversity, cost effectiveness, environmental economics, environmental policy.

1. Introduction

Until recently, public efforts to encourage conservation on private land in many countries have been primarily through uniform payment policies. For example, a significant portion of the three billion dollar Australian National Heritage Trust (NHT) fund is to be used to pay landholders for conservation efforts (NHT 2005). Typically this involves paying willing landholders at uniform rates per unit of input or practice. Payment approaches involving

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uniform payments also have been an important feature of agro-environmental policy in Europe and the USA (Latacz-Lohmann and Hodge 2003).

Auctions, meanwhile, are increasingly being used as a payment mechanism to provide environmental improvements on private land. One of the most cited examples in the literature is the US Conservation Reserve Program (CRP) (Reichelderfer and Boggess 1988). The common practice in conservation auctions involves landholders offering sealed bids describing actions they are willing to take and the associated payment they are willing to accept. Agencies subsequently rank and select bids for funding based on some measure of cost effectiveness until a fixed budget is exhausted or a preset reserve price is reached.

In Australia, there have been a number of instances where carefully designed auctions have been implemented within a conservation plan. Two such auctions include the BushTender programme, analysed by Stoneham *et al*. (2003), and the World Wildlife Fund auction, analysed by White and Burton (2005). These auctions have introduced two unique features not present in previous policies that pay for conservation on private lands: (i) the incentive for bidders to truthfully reveal their opportunity costs, and (ii) the ability to target the highest valued environmental projects using a scientifically based bid assessment method.

The objective of this article is to evaluate the cost-effectiveness of a more recent real-world conservation payment plan – the Catchment Care Australian conservation auction implemented in 2004. The Catchment Care auction was developed to help fund watercourse and riparian zone restoration and protection activities in the Onkaparinga catchment in South Australia. Stoneham *et al*. (2003) and White and Burton (2005), both find considerable cost savings from implementing auctions relative to uniform/fixed plans. In addition to providing further evidence of the potential cost-effectiveness of auctions vs. uniform payments, we expand upon the previous studies by identifying more specifically where and how these cost savings might arise. In particular, we disaggregate the cost savings into two discrete components: (i) the opportunity cost revelation incentive provided by the auction mechanism, and (ii) the improved environmental targeting capacity that results from development of a scientifically based environmental benefits assessment capacity. We show that there are potentially very large returns associated with the latter component that have been overlooked in the literature.

Prior studies have found that estimated level of benefits diverged significantly depending on method of assessment. For comparative purposes our analysis of the benefits of using a discriminant price auction was consistent with the same two approaches found in both Stoneham *et al*. (2003) and White and Burton (2005). In particular, the gains are estimated as (i) the environmental benefit attainable with an alternative payment policy holding expenditure constant at the auction level; and (ii) the level of expenditure required with an alternative payment policy to attain the level of environmental benefit achieved by the auction.

It should be emphasised that the level of cost savings we identify in our analysis is not simply a function of offering a tiered payment scheme. Indeed, there are policy options other than discriminant price auctions that involve price differentiation. The payment policy in place in the case study area considered here will allow us to illustrate this point. In particular, the prior policy used in this catchment area involved implicit price differentiation through negotiated levels of in-kind labour contribution. We compare the relative cost per unit of environmental benefit of this prior policy approach to encourage true opportunity cost revelation to the incentives the discriminant price auction policy provided.

Finally, the analysis contributes to the literature as one of the few published studies providing an evidence-based estimate of the transaction costs of alternative conservation policies. Transaction costs involved with administering the case study conservation auction are compared to the transaction costs of administering the prior non-auction payment policy.

2. Literature review

Agencies implementing both uniform payment and auction policies face asymmetric information challenges. They have limited information about the opportunity costs incurred by participants. Setting a uniform payment level is a key challenge to achieving cost effective environmental goals when agencies must contend with conditions of asymmetric information. If the price is set too high, inefficiency results because landholders with opportunity costs less than the payment rates will receive payments in excess of their true opportunity costs. When the price is set too low, low rates of participation can occur. Groth (2005) notes that low participation rates are likely to result in high program administration costs per unit of conservation action.

The economic rationale for the use of auctions is that they create decentralised incentives to offer bids close to landholder opportunity cost, even when the implementing agency holds little information about these opportunity costs (Mcafee and McMillan 1987). There is a growing theoretical literature on the relative efficiency of various formats of auctions and other payment instruments (Milgrom 2000). Most of this literature is underpinned by a set of 'benchmark model' assumptions, including: (i) bidders are risk neutral; (ii) bidders have independent private values; (iii) there is symmetry among bidders; (iv) payment is a function of bid alone; and (v) there are no costs associated with bid construction and implementation (Mcafee and McMillan 1987). These assumptions provide a theoretical foundation for the evaluation of auction efficiency. Violation of one or more of the assumptions is often observed in field implementations. As such, these theoretical assumptions provide little guidance to policy analysts in their efforts to determine the relative efficiency of different auction specifications in real world environments (Rothkopf and Harstad 1994).

Consequently, a growing simulation and experimental economics literature is analysing the efficiency of hypothetical auctions subject to the controlled manipulation of theoretical assumptions. For example, Latacz-Lohmann and van der Hamsvoort (1997) use a utility theoretical simulation model to compare the optimal bid response of auctions to uniform payment policies. They conclude that as bidder uncertainty regarding auction reservation price converges to zero, the optimal responses of the auction and the uniform payment policy converge. Hailu and Schillizzi (2004), meanwhile, suggest that the convergence of auction and uniform payment policy outcomes can occur in repeated auctions when agencies treat information in ways that allow for bidder learning about agency reservation price. A real world example of such convergence is the US CRP: over successive rounds bidder uncertainty regarding the agency reservation price decreased with a simultaneous convergence of the average bid to the agency reservation price (Cooper 1997).

Latacz-Lohmann and van der Hamsvoort (1997, p. 416) argue that when the level of uncertainty regarding agency reservation price is high, a discriminant price auction can lead to inefficient outcomes. In particular, they state that 'performance measures [of auctions] may even fall below the level of the offer [fixed payment] system.' The potential for reduced efficiency arises because the optimal bid level is an increasing function of agency reservation price uncertainty. This result is consistent with the findings in experimental economics (i.e. Cummings *et al.* 2004; Ward *et al.* 2007) which suggest that when discriminant price auction formats are associated with considerable price signal uncertainty, strategic rent-seeking behaviour can arise.

Non-auction based real-world payment policies that involve payment level differentiation among participants also exist. Latacz-Lohmann and van der Hamsvoort (1997) investigate the relative efficiency of such policies relative to auctions. They show that auctions tend to provide the greatest reductions in costs relative to payment policies that involve little use of *a priori* information regarding bidder opportunity costs to differentiate payment levels. In contrast, only moderate savings were identified when the auction was compared to a payment policy that involves setting differing payment levels for groups of landholders with observable attributes correlated with their opportunity costs.

Finally, while the importance of transaction costs as a factor influencing efficiency of auctions and other incentive based policies such as cap and trade is widely discussed in the literature, there are few evidence based assessments of transaction costs involved in incentive based policy. One exception is Fang and Easter's (2003) analysis of a Minnesota river nutrient trading program. They found that when the transaction costs of participating in the nutrient trading program are included, the net benefits of such a program may be negative.

3. The Catchment Care auction

Catchment Care (Bryan *et al.* 2005a,b) was developed in the Onkaparinga catchment in South Australia and administered by the Onkaparinga Catchment Water Management Board (or the *Board*). Catchment Care was a sealed bid, first price, discriminant price auction. Landholders submitted sell offers (referred to as bids) to the Board proposing a suite of conservation actions and a price. Bids were then assessed based on price and an environmental benefits index (EBI) score. The EBI developed for the auction is based on a risk analysis

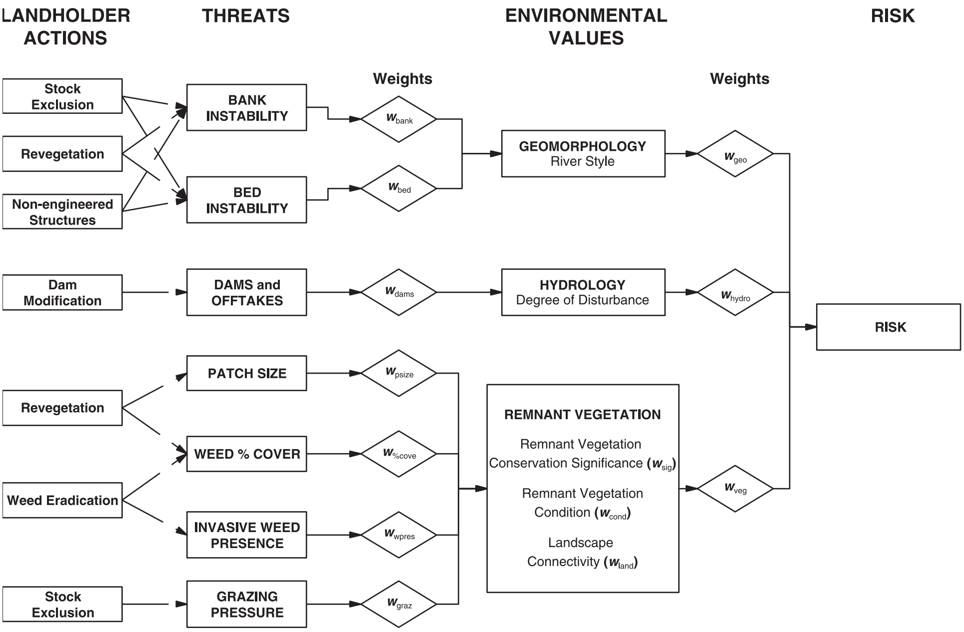

Figure 1 Structure of Catchment Care risk analysis framework.

framework (Standards Australia 2006). In this framework, the EBI is a function of the inherent environmental value of the site, threats active at the site, the expected amount of threat reduction that would be achieved by the proposed landholder actions, and the size of the area targeted for action. The EBI framework is explained in full detail in Bryan *et al*. (2005a).

Figure 1 illustrates the relationships among the environmental values, threats, and landholder actions, and the construction of a weighted index to assess the environmental benefits of bids in the risk analysis framework. The dashed lines between actions and threats indicate that actions can reduce specific threats.

The four steps in the environmental benefits assessment and bid selection process are summarised as follows and discussed below.

1. Assess site environmental values, threats, and risk at a site of proposed action;
2. Score the amount of threat reduction expected from proposed actions;
3. Calculate an environmental benefits index score for each bid; and
4. Rank and select bids based on cost-effectiveness.

3.1 Assess site environmental values, threats, and risks

This step involved the assessment of the environmental values, threats, and risk scores for each site proposed for conservation action by employing a field-based site assessment procedure specifically designed for this study. Environmental value scores were calculated for each site for each of three criteria: (i) rarity and significance of geomorphological type; (ii) the degree of hydrological disturbance and; (iii) the condition, landscape connectivity, and conservation significance of remnant vegetation (Figure 1). For each criterion, relevant threats were assessed (Figure 1). In total, seven threats were considered across the three criteria: threats acting upon the geomorphology value include bed and bank instability; threats acting upon hydrology include the existence of dams and off-takes; and threats to remnant vegetation include habitat patch size, weed presence and proportional cover, and grazing pressure.

An environmental risk score was then calculated for each site by summing the product of each appropriately weighted threat score by the relevant environmental value scores over all seven threats. In calculating the risk score, sites of high environmental value subject to more severe threats were given higher scores (Bryan *et al.* 2005a).

3.2 Score the amount of threat reduction expected from proposed actions

In the Catchment Care framework, landholder actions as proposed in the bids can be expected to reduce the level of threats operating at a site. The expected level of threat reduction from each action was scored by an expert panel, comprised of field officers and researchers, using standardised procedures developed for the project.

3.3 Calculate an environmental benefits index score for each bid

First, the impact of the bid was calculated as the sum of the product of the threat reduction score and the risk score of the bid over all threats. Bids offering higher levels of threat reduction at higher risk sites received higher impact scores. Second, the EBI score for a bid was calculated by summing the product of the impact score by the area of proposed actions over all threats in recogni-tion that actions taken over a larger area are more valuable, ceteris paribus.

3.4 Rank and select bids based on cost-effectiveness

The cost-effectiveness of bids was calculated by dividing the environmental benefits index score by the bid price. Finally, bids were ranked and selected for funding in order of cost-effectiveness until the available funds were exhausted.

Low participation can result from uncertainty regarding the land management options and bid preparation. To ensure adequate participation rates and minimise the potential for strategic behaviour, the agency in charge of designing the auction initiated two actions. The Board mitigated against bid preparation uncertainty through agency site visits, providing information and materials about the auction, environmental values, threats and potential solutions relevant to the property. Secondly, the Board withheld the environmental benefit index scores of bids and the methods of calculating environmental benefits, thereby reducing the potential for strategic rent seeking.

Prior to implementation of the auction, the policy to encourage conservation on private land in the area was in place and consisted of an input payment scheme. A unique feature of this pre-existing policy was that, while payment rates for commercially purchased inputs were uniform, differential payments for in-kind labour contributions were determined through bilateral negotiation between agency officers and landholders. Bids were considered and accepted as they arose; hence, a systematic evaluation and subsequent ranking to select a subset of the most cost effective bids was precluded. This 'as they arise' policy is in contrast to the typical conservation auction process in which all bids are compiled and a subset is systematically selected on the basis of cost effectiveness using an environmental benefits index and bid price as prioritisation criteria.

4. Auction outcome

Conceptually, the bid selection process involves an agency attempting to minimise the cost of paying landholders for conservation actions on private land. A subset of a population of eligible participants submit bids. Each bidder *i* offers a package of conservation actions and an associated price, B_i. Each bid can be thought of as having an environmental benefits index value, E_i. For auctions such as Catchment Care, E_i is known to the agency and is used to evaluate the bids. With other possible auction or payment policies, however, the agency does not use and EBI to evaluate bids and thus the values of E_i associated with bids are unknown.

The bid selection algorithm used in the Catchment Care auction can be written as:

$$\max \sum_i I_i E_i \quad \text{subject to} \quad \sum_i I_i B_i \leq \text{CB}, \tag{1}$$

where I_i is a set of binary choice variables taking a value of 1 for each bid that is selected and 0 for each bid that is not, and CB is the agency conservation budget.

This problem can be solved with several algorithms including the approach used in this case study, funding bids in ascending order of cost utility ($/EB) until a budgetary constraint is met. Hajkowicz *et al*. (2007) concludes that slightly higher level of environmental benefit are attainable with an algorithm capable of finding a global optima. The benefits are attained because packages of lower priority bids can be substituted for the lowest EB/$ bid in ways that increase total benefit and total expenditure within the budget constraint. In this case study the Board preferred the ascending order cost utility ranking. Given that excess budget can be carried over, they viewed the opportunity cost of funding the last bid as a potentially higher EB/$ project next year.

Twenty-nine bids were submitted and ranked according to the environmental benefits per dollar (EB/$) selection criterion. Seventeen bids were funded. The bid offer curve resulting from the auction is shown in Figure 2. The actual expenditure level of $139 278 did not exactly meet the budget constraint as

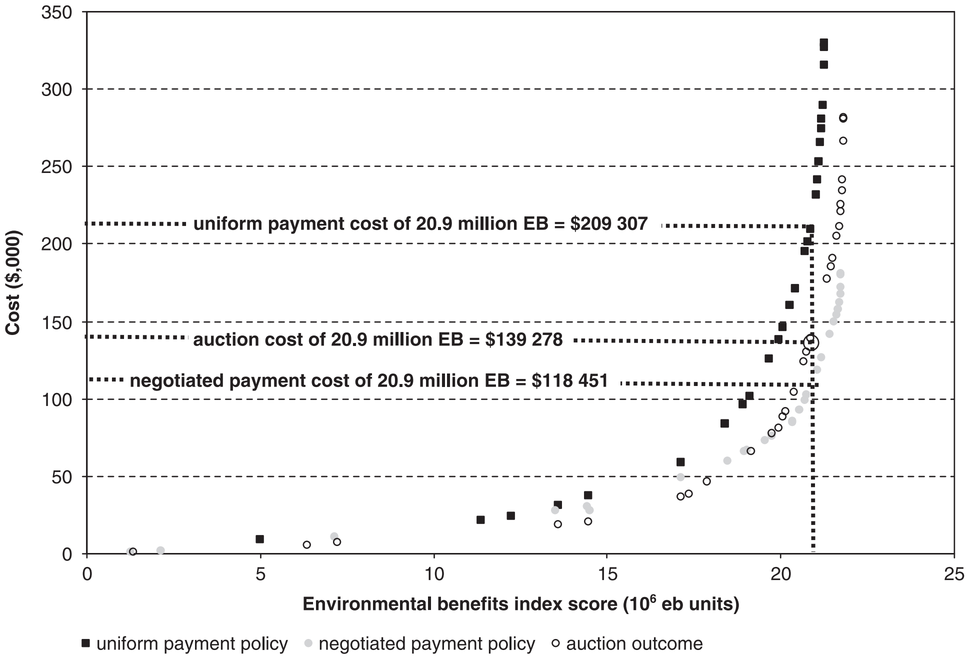

Figure 2 Outcome of auction, uniform and negotiated payment with EBI based bid selection.

a result of the discreet or 'lumpy' nature of the bids. The total estimated environmental benefit associated with this expenditure was 20.9 million environmental benefit units (EB).

5. Comparing auction and uniform payment policy cost effectiveness

Ideally, a comparison of auction and other policies would be based on the environmental benefits and costs of their actual implementation. Such comparison would require information on actions taken, payments made and an environmental benefit index score for each policy. In this case and prior Australian conservation auction evaluations (Stoneham *et al.* 2003; White and Burton 2005), no EBI scores existed; hence, an EBI evaluation process was also absent in prior payment policies. Given the lack of EBI data for observed responses to past payment programs, previous auction evaluations have constructed estimates of behavioural responses to alternative policies using existing auction data. The same approach is taken here; we compare actual auction outcomes to estimated responses to alternative policies.

Here the auction outcome is compared to estimated outcomes from four comparison payment policies: (a) a uniform payment; (b) a negotiated payment; (c) a uniform payment policy with selection of projects based on EB/$; and (d) a negotiated payment policy with projects chosen selectively based on EB/$.

The rational for including a uniform payment policy is that it has served as the benchmark for comparison with the estimates of the cost savings from auctions in all past Australian auction evaluations. The negotiated payment policy is included, alternatively, as an estimate of the cost of the negotiated input prices payment policy in the study area prior to the auction.

Policies (c) and (d) involve the systematic selection of projects based on the EBI used in the actual auction, excluding the price determination mechanism used in the auction. Rather, prices are assumed to be set at either uniform or negotiated per unit input levels and estimated with data from the payment policy in the study area prior to the auction. These policies are included to compare the results of the actual auction with estimates of the savings attributable to the opportunity cost revelation incentive created by the auction.

5.1 Monte Carlo simulation of payment policies without environmental targeting

Conceptually, the uniform payment policy modelled represents an agency setting a price per unit input at a uniform level, P, for all potential participants. No attempt is assumed to price discriminate based on differences in either the opportunity costs or environmental benefits among bids. Participant i who can offer conservation action at an opportunity cost (OC_i) less than the uniform payment level ($OC_i \leq P$) is assumed to be willing to accept the payment. Projects were selected based on the order that they arose. It is assumed that this does not result in systematically selecting bids based on differences in opportunity cost or environmental benefit. Given the further assumption that there is a budget constraint (CB) such that not all bids can be accepted, bid selection can essentially be considered using a random draw from the population for whom $OC_i \leq P$ up to the budget limit CB. For these assumptions, the expected environmental benefit is E (E_i) for all I_i such that $OC_i \leq P$.

The cost of this uniform input payment policy was estimated with Monte Carlo simulation by randomly drawing 100 samples from the population of the 29 bids submitted to the actual auction. Bids exceeding the costs of inputs used in the prior payment program were rejected and other bids were assumed to be paid at the prior payment program rates per unit input, even if bids were for less than this cost. The average cost and the environmental benefit level for the 100 samples were computed. These averages were then used to compute the expected EB/$ expenditure of the uniform input payment program.

The payment program in place prior to the auction involved bilateral negotiation between the agency and landholders regarding the level of in-kind labour contributions. Rather than offering all bidders a uniform price P, a different price $C_i \leq P$ was negotiated by the agency with each bidder. To estimate the cost of the policy, it is assumed that all potential auction bidders participate in the negotiated payment policy if their opportunity cost is less than the negotiated payment level, or $OC_i \leq NP$, where NP is the average prior policy negotiated input payment level. To model this policy, we assume that bids are funded in the order that they arise without efforts to differentiate based on expected opportunity cost or environmental benefit. It is further assumed that there is a budget constraint such that not all bids can be accepted; this allows us to represent the bid selection as a random draw from the subpopulation for whom $OC_i \leq NP$ up to a budget limit *CB*. As with the uniform payment policy Monte Carlo simulation involving 100 random draws was used to estimate the cost of the negotiated input payment policy.

The validity of these estimators of the cost effectiveness of a uniform and negotiated input payment policy were predicated on several assumptions. The first is that the population of individuals who would self-select to participate in the payment policies is the same as the population that self-selected to offer bids to participate in the auction. The second is that the process of selecting program participants can be simulated as a random selection from the population of those who submitted auction bids. The third is that those who offered to participate in the auction would also be willing to participate in the payment program as long as the payment offered is greater than or equal to the auction bid offered. Implications of violations of these assumptions are considered in the results discussion section below.

5.2 Estimating cost of uniform and negotiated payment environmental targeting

The uniform payment policy with bids chosen selectively based on environmental value (comparison policy c) essentially involves funding bids in order of their estimated EB/\$ at uniform input payment rates until allocated funds are exhausted.

Conceptually, this policy is similar to the UK Conservation Stewardship Scheme (Groth 2005) in that systematic selection of bids to participate in a uniform rate per unit input payment scheme is assumed. This policy is modelled mathematically with a bid selection algorithm:

$$\max \sum_i I_i E_i \quad \text{subject to} \quad \sum_i I_i L_i P \leq \text{CB}. \tag{2}$$

As above, I_i is a set of binary variables taking a value of 1 for each bid that is selected and 0 for each bid that is not. L_i is the input level associated with the bid. As in the auction, the goal of the agency is to choose the combination of bids that offer the greatest EB/\$ expenditure. The main difference between this policy and the auction is that all bids would be funded at a standard and uniform payment level per unit input *P* whereas in the auction each participant chooses a bid level B_i. The cost of this policy was modelled by costing all 29 bids submitted to the auction at the uniform input prices used in the prior payment policy. Bids were then selected in order of cost effectiveness up to a budget constraint equal to the level of actual auction expenditure.

The final counterfactual policy considered also assumes a systematic selection of bids to participate in a payment scheme, yet assumes negotiated input prices. This policy is modelled mathematically with a bid selection algorithm that looks similar to the actual auction bid selection algorithm:

$$\max \sum_i I_i E_i \quad \text{subject to} \quad \sum_i I_i L_i \mathrm{NP}_i \leq \mathrm{CB}. \tag{3}$$

The main difference between this policy and the auction is that the payment level of the former depends on the input level L_i and a negotiated payment level per unit input NP_i. The cost of this policy is modelled by costing all 29 bids submitted to the auction at the average negotiated price per unit input in the prior negotiated payment policy and selecting bids in order of cost effectiveness up to a budget constraint equal to the level of actual auction expenditure.

6. Results

Results based on the uniform and negotiated payment policies (without systematic selection of bids based on environmental value) are summarised in Table 1. In comparison to the auction policy, the estimated average environmental benefit of the uniform payment policy was 11.7 million EB ($\sigma = 3.9$ million) or 56 per cent of the benefits attained through the auction with the same level of overall expenditure. As can be seen in Table 2, the level of environmental benefit estimated to result from this policy varied substantially across Monte Carlo draws. For example, the estimated benefit for the draw with the greatest EB (20.4 million) was very near to the level achieved by the actual auction, while the draw with the least EB (3.7 million) resulted in less than 0.33 of the average estimated environmental benefit.

The negotiated input policy considered here is similar to the payment policy that was implemented prior to the auction. Estimated average environmental

Table 1 Uniform and negotiated payment policy Monte Carlo simulation results

	Uniform payment policy		
	Cost ($)	EBI score	Bids funded
Mean	143 208	11 741 967	16.53
Standard deviation	5 789	3 961 244	2.15
Maximum	149 955	20 425 584	22
Minimum	123 628	3 682 668	12
95th percentile	149 733	18 749 576	21
5th percentile	130 306	5 487 230	14
	Negotiated payment policy		
	Cost ($)	EBI score	Bids funded
Mean	144 413	14 096 114	19.13
Standard deviation	4 751	3 669 635	2.01
Maximum	149 984	21 104 881	24
Minimum	128 777	6 873 143	13
95th percentile	149 587	19 702 339	22
5th percentile	132 306	7 240 119	16

Table 2 A summary of estimates of the cost effectiveness of the auction and various payment policies in the Onkaparinga Catchment

Policy	Cost ($) of achieving the auction level of environmental benefits	Level of EB (millions) achievable with auction level of expenditure	$/1000EB	Percent of auction environmental attained for the auction expenditure level (%)
Discriminant price auction (Catchment Care)	139 278	20.9	6.6	
Uniform input payment policy selection of projects on an as they arise basis	N/A	11.7	11.9	56
Negotiated input payment policy selection of projects on an as they arise basis	N/A	14.3	10.3	68
Uniform input payment policy with selection of projects based on EB/$	209 307	19.9	7.0	95
Negotiated input payment policy with selection of projects based on EB/$	118 451	21.4	6.48	102

benefit of this policy was 14.3 million EB ($\sigma = 3.67$ million) or approximately 68 per cent of the benefits attained through the auction. Again as shown in Table 2, the level of environmental benefit estimated to result from this policy varied substantially across Monte Carlo draws. Not surprisingly, on average a greater number of bids could be expected to be funded with the negotiated payment policy.

The finding that, with a constant expenditure level, a uniform payment scheme achieved an estimated 56 per cent of the environmental benefit level achieved with the auction is in accord with Stoneham *et al.* (2003) and White and Burton (2005). Both estimated substantial savings from discriminant auctions when compared to uniform payment policies. A randomly drawn negotiated payment policy similar to that implemented in the study area prior to the auction policy reduces the savings attributable to the auction by 12 per cent. This finding corroborates the conclusions of Latacz-Lohmann and van der Hamsvoort (1997) that auction savings are reduced when compared to policy alternatives that discriminate bids based on observable factors correlated with differences in landholder opportunity costs.

The results associated with the environmental benefit of the uniform and negotiated input payment policies subject to the systematic selection of bids based on cost effectiveness are summarised in Table 2. The estimated benefit of the uniform payment policy with systematic EB/$ based selection of bids was 19.9 million EB or approximately 95 per cent of the benefits attained through the auction. The estimated environmental benefit of the negotiated payment with systematic selection of bids based on EB/$ is 21.4 million EB, or 102 per cent of the benefits attained through the auction assuming the same level of overall expenditure.

Contingent on the capacity to target the most cost effective projects, our results suggest that the alternative (uniform and negotiated) payment schemes can achieve approximately the same aggregate EB (95 and 102 per cent, respectively) observed with the auction approach. In the absence of the capacity to evaluate and prioritise projects based on EB/$, the uniform and negotiated pricing schemes were estimated to achieve 56 and 68 per cent, respectively, of the auction aggregate EB. This finding provides evidence that the costs savings accruing to the auction may arise primarily from the ability to assess and prioritise the EB/$ attributable to each project.

Previous evaluations of Australian conservation auctions (Stoneham *et al.* 2003; White and Burton 2005) have estimated the level of benefits resulting from auction implementation using two methods: (i) by estimating the level of benefits attainable with alternative payment policies constrained by the auction expenditure; and (ii) by estimating the expenditure necessary with alternative payment approaches to attain the same level of environmental benefit observed in the auction. The results from both studies suggest substantially greater benefits attributable to the auction using the latter method.

Results presented in Tables 1 and 2 are based on method 1. Sensitivity of the conclusions was also assessed by estimating the benefits of alternate policies with method 2. Results are shown graphically in Figure 2 in addition to the actual auction outcome. The figure illustrates that, assuming equal levels of expenditure (auction = $139 278), there is a negligible difference in the estimated benefits achieved by the auction and the other payment policies when the EBI-based bid selection criteria is used.

In contrast, the relative cost effectiveness of the auction mechanism varies considerably when the basis of comparison is the cost of achieving the same aggregate EB as the auction. Figure 2 shows that the estimated cost of achieving the auction outcome of 20.9 million EB with a negotiated payment policy and EB/$ based project selection is $118 451; this is 85 per cent of the actual auction cost. The cost of achieving the auction EB outcome with a uniform payment policy and EB/$ based project selection is estimated at $209 307, or 150 per cent of the actual auction cost. Thus, significantly greater benefit can be attributed to auction implementation compared to the uniform payment policy with this benefits assessment methodology.

Careful inspection of Figure 2 provides insight as to why there is greater variation in estimated auction benefit. In the comparison of the uniform payment with EB/$ project selection, 50 per cent of the total expenditure is required to procure the last 5 per cent of EB. The potential for high marginal costs may be an artefact of the EBI specification. Alternative functional representation of the EBI that maintains the ordinal ranking of bids could lead to a much less steeply sloped function, especially for the least cost effective bids or projects. This could, for example, be the case if the EBI function included fewer multiplicative and more additive terms. The implication here is that the much larger estimated auction benefit attained by measuring the cost of attaining the auction-related benefits with alternative payment policies may be an anomaly of the benefits index functional form; such an issue should be the subject of future investigation.

One interpretation of the results of this study is that the main efficiency gain from implementation of the Catchment Care auction resulted from our ability to assess and prioritise projects based on conservation value. A further interpretation could be that, for the case study at hand, the incentive to reveal true opportunity cost may not be much different for a discriminant auction, a uniform and a negotiated input payment policy. These conclusions support findings summarised in the literature review suggesting that the efficiencies of discriminant auctions relative to alternative payment policies is dependent on several factors.

The conclusions give rise to the question: are there other reasons to choose a discriminant auction over another payment policy? One obvious consideration is the magnitude of transaction costs. Intuitively, the pre-auction policy involving case-by-case individual negotiation of in-kind labour contributions would involve high transaction costs. However, auctions such as Catchment Care also involve considerable efforts to visit landholders, provide them information about conservation options, provide tutoring regarding the bidding process, and to score and rank bids.

One objective of the Catchment Care trial was to carefully document all administrative costs incurred by the auction process and compare these to the costs involved with administering the prior negotiated payment policy. These administrative costs are one component of total transaction costs. Over the course of the trial, all time and operating costs were carefully recorded for comparison with records that had been kept from the prior program. This included observations of the time required to establish landholder contact, produce custom site maps for landholders, visit sites, write plans, enter data into databases, write contracts, and assess and rank bids. Additionally, the cost of production and distribution to landholders of printed materials in both the auction and prior program were recorded.

Results of this analysis are summarised in Table 3. The results presented in Table 3 show that while the cost of the two programs on a per property funded basis are very similar, the administrative cost per dollar of total conservation works funding incurred for the auction is 24 per cent more expensive than the prior program.

The finding that the auction has administrative costs equal to or greater than the prior negotiated payment policy may, at first glance, seem counter intuitive. However, it points to the fact that conservation auctions, as they have been implemented in Australia recently, are actually a mix of instruments with considerable education, suasion and extension effort involved.

Table 3 Administrative cost of the Catchment Care Auction and prior negotiated payment policy

	Catchment Care auction	Negotiated payment policy
Hours of administrative effort per funded contract	26.03	29.69
Total labour cost for $139 278 of funded conservation work at the rate of $30/h	$13 275	$12 471
Cost of office materials for $139 278 of funded conservation work	$2 789	$458
Total cost for $139 278 of funded conservation work	$16 064	$12 929
Cost per property	$945	$923
Ratio of administrative cost to cost of funded conservation work	0.107	0.086

7. Conclusion

We have evaluated the Catchment Care Australian conservation auction implemented in 2004 with four objectives: (i) Compare the cost effectiveness of the auction with the existing payment policy characterised by implicit price differentiation through negotiation of levels of in-kind labour contribution; (ii) Produce disaggregated estimates of auction savings attributable to (a) auction incentive for opportunity cost revelation, and (b) enhanced ability to target high conservation value projects; (iii) Estimate and compare the transaction costs involved with administering the case study conservation auction and the prior non-auction payment policy; and (iv) Test the sensitivity of auction cost savings estimates due to estimation methodology.

The results of this analysis suggest that the estimated cost savings achievable with the discriminant price auction for conservation contracts depend on a number of factors. Similar to other studies analysing conservation payment plans in Australia, auctions can produce significant savings compared to the costs of a uniform input payment policy. Specifically, reduced but substantial auction cost savings were estimated when compared to a uniform payment policy with opportunity costs revelation but without the benefit of systematic bid selection based on EB/$.

The potential for cost savings under an auction may be dampened slightly when the transaction costs associated with auction implementation are considered. We found that the administration costs for the auction were greater than or equal to those associated with the negotiated payment policy that was previously used.

We conclude that the benefits of the auction are gained primarily through the EBI bid prioritisation rather than the incentive for truthful revelation of opportunity costs intrinsic to the auction mechanism. The evidence presented indicates that when the selection of bids was based on an 'as they arise' basis, the uniform payment policy only achieved 56 per cent of the environmental benefits the auction process produced when both policies were subject to the same budget constraint. Similarly, a negotiated price payment policy without the advantage of prioritising bids based on knowledge of the environmental benefits provided achieved 68 per cent of the environmental benefits produced by the auction.

Alternatively, when the capacity to prioritise projects based on EB/$ was introduced, the uniform payment policy produced 95 per cent of the benefits accrued under the auction, subject to the same budget constraint. The negotiated price payment policy achieved 102 per cent of the environmental benefits produced by the auction when knowledge of the environmental benefits was used to prioritise bids.

Estimates of relative cost effectiveness across policies are shown to be sensitive to the methods and metrics of comparison. One metric used by Stoneham *et al.* (2003) and White and Burton (2005) is the estimated cost required to achieve auction aggregate environmental benefit with alternative payment policies. Comparisons relying on this metric are sensitive to the shape of the environmental benefits supply curve. In this case study, as well as the Stoneham *et al.* (2003) and White and Burton (2005) there is inelastic supply of the last units of environmental benefit. When this is the case the estimated cost required to achieve auction aggregate environmental benefit metric results in large estimated auction comparative cost advantage. In this and previous studies, estimated benefits of auctions are much less when measured as environmental benefits attainable with alternative payment policies subject to the auction budget constraint.

We suspect that the highly inelastic benefits supply characterising this and previous studies may be an artefact of the environmental benefits index specification. A recommendation for further research is an investigation of the sensitivity of auction cost benefits to specification and functional form of the environmental benefits index and measure of cost effectiveness.

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