View metadata, citation and similar papers at core.ac.uk
brought to you by CORE
provided by Research Papers in Economics

Measuring the Cost-effectiveness of Conservation Auctions Relative to Alternate Policy Mechanisms

Ben White and Michael Burton

School of Agricultural and Resource Economics,
The University of Western Australia
35 Stirling Highway
Crawley, WA 6009, Australia
E-mail address:-
benedict.white@uwa.edu.au
michael.burton@uwa.edu.au

13th December 2010
Working Paper 1006
School of Agricultural and Resource Economics
http://www.are.uwa.edu.au

THE UNIVERSITY OF WESTERN AUSTRALIA
Achieve International Excellence

Citation: White, B. and Burton, M. (2010) *Measuring the Cost-effectiveness of Conservation Auctions Relative to Alternate Policy Mechanisms*, Working Paper 1006, School of Agricultural and Resource Economics, University of Western Australia, Crawley, Australia.

© Copyright remains with the authors of this document

Abstract

The principle motivation for using price-discriminating conservation auctions is that they are expected to be significantly more cost-effective than fixed-price mechanisms. This paper measures cost effectiveness for tenders from two rounds of the Auction for Landscape Recovery in Western Australia relative to counterfactual fixed-price mechanisms. If we assume that the bid equals the compliance cost, the auction gives a significant cost saving over fixed-price mechanisms. If instead we assume that bids include an element of rent, fixed-price mechanisms can be more cost effective than the auction. The significance of these results is that a fixed price scheme may achieve a similar level of cost effectiveness to a conservation auction, when one or more of the following apply: compliance costs do not vary significantly between producers, auction bids have a significant element of rent and the auction incurs a significant additional administrative cost.

Keywords: Auctions, conservation, bio-diversity

1. Introduction[1]

Current interest in auctions as policy mechanisms is based on theoretical models (Latacz-Lohmann and van der Hamsvoort, 1997) and empirical evidence (Stoneham *et al.* 2003) that price-discriminating auctions are more cost-efficient than fixed-price mechanisms including fixed payments rates for conservation actions and environmental benefit. The

[1] This paper is derived from work for the Auction for Landscape Recovery MBI project. Particular acknowledgement is made to Cheryl Gole (WWF), Andrew Huggett and Kristen Williams (CSIRO) and Dan Faith (Australian Museum) who led the on ground assessment work and development of the ecological evaluation metrics, which provide the underlying data on which this paper is based.

estimated cost efficiency of an auction relative to a counterfactual fixed price mechanism depends upon the fixed-price mechanism selected as a comparator and the assumption made about the rent component of the bid. Stoneham *et al* (2003), used a fixed payment per unit of environmental benefit and assumed that bids did not include a rent as their counterfactual comparator mechanism. To our knowledge, there are no conservation schemes which use an environmental benefit metric as a basis for calculating fixed payments. However numerous schemes, including those run by The Department of Conservation and Land Management in Western Australia (Wallace *et al. 2003),* pay fixed amounts per unit of conservation inputs such as per kilometers of fencing and per hectare of revegetion.

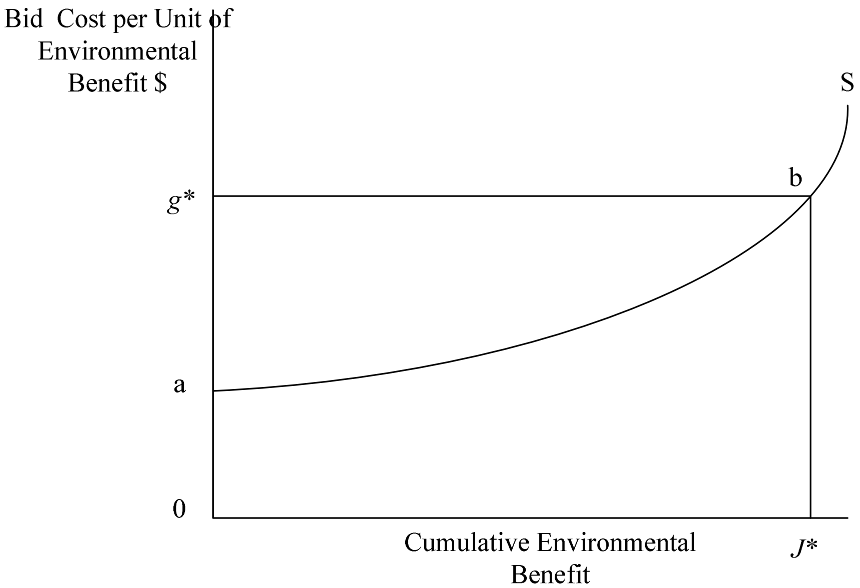
The policy significance of the analysis presented here is that it measures the cost-savings from an auction compared to a set of alternative mechanisms. In particular, there is some evidence (Stoneham, 2003; Gole *et al.* 2005) that auctions incur additional administrative costs relative to fixed-price mechanisms, if the cost-saving is greater than the additional administrative cost, the auction is efficient.

The paper is organized as follows. The next section presents a theoretical model of tender selection. Section 3 applies the model to discrete project choice using integer programming and non-linear integer programming for the auction plus five counterfactual fixed-price mechanisms. Section 4 outlines the Auction for Landscape Recovery Market Based Instrument Pilot, and Section 5 presents results on cost-efficiency and the rent component of auction bids. Section 6 concludes.

2. Theoretical Model for Selection from a Continuum of Projects

With perfect information on compliance costs, the regulator receives tenders from producers which are scored using an Environmental Benefit Index (EBI) (calculated by the regulator), bids and conservation inputs. For a continuum of very small producers tendering their compliance costs for small fixed projects the problem of selecting bids is summarized by Figure 1, where bids ranked by EBI per dollar are plotted against the cumulative EBI. Given a budget constraint, the total cumulative EBI is J^* and the total cost of the auction, the area under the 'supply curve' S, is given by $0abJ^*$. If the auction is compared to a fixed-price scheme where a fixed-amount g^* is paid per unit of the EBI. The total cost of the fixed payment is $0g^*bJ^*$ and the area ag^*b gives the efficiency gain from the auction.

Figure 1: The supply curve for Environmental Benefit



The ‘supply curve’ differs from a conventional supply curve in that it is not given as the horizontal sum of individual firm’s marginal cost curves, instead it gives the marginal cost of a sequence of projects which are ordered from the lowest marginal cost to the highest. Thus the firm is not adjusting the ‘output’ of EBI to equate the marginal cost with the fixed payment per unit of EBI. Instead, the firm’s natural capital means that each firm tenders a single project with a given marginal cost.

While the theoretical model represented in Figure 1 is for a continuum of small producers and projects, in practice projects can be ‘discrete’ that is large relative to the budget, therefore the optimal selection is a knapsack problem (Martello and Toth, 1990). Projects are selected to maximize the total EBI within the budget. The knapsack problem arises because the choice of tenders is binary and their total cost must be less than the budget constraint.

3. Optimal Project Selection under Alternative Institutional Arrangements

Once the successful tenders have been selected, the auction can be implemented by a pay-as-bid mechanism. However, the information in the tenders can also be used to estimate the costs of a set of counterfactual mechanisms. These are useful in that they measure the relative cost efficiency of the auction. A number of possible price discriminating and fixed-price mechanisms can be considered, to allow a comparison of cost efficiency the total EBI is set so that it is at least as high as for the optimal tenders for the auction.

Mechanism 1 is the auction itself where successful tenders are paid their bid. Mechanism 2, is where a fixed-price per unit of environmental benefit (EBI) is paid (Stoneham *et al,* 2003). Mechanism 3 is where fixed-prices per unit of environmental inputs are paid, these payments ensure compliance by being greater than or equal to the bid in sum.

If the regulator is restricted to fixed price mechanisms, the optimal subset of tenders selected from the price discriminating auction will be optimal. In particular, because the price paid under a fixed price scheme usually depends on one marginal bid (or a small number of bids for a multiple input based scheme), it may be optimal to drop that tender in favour of an alternative which reduces the fixed payment. Mechanism 4 is where the regulator makes an optimal selection of successful bids and pays a fixed-price per unit of EBI, Mechanism 5 is where the regulator selects bids on the basis of fixed payment rates for environmental inputs. Mechanism 6 is where the regulator optimally divides the successful bids into two groups with different payment rates based on inputs. Mechanisms 7 and 8 are environmental benefit and input based fixed-price schemes which account for the possibility that bids include an element of rent.

For Mechanism 1 the environmental benefit across the *N* firms tendering projects is identified as the integer programming (knapsack) problem

$$\max_{I_i} \sum_{i=1}^{N} I_i \{B_i(e_i, k_i)\}; \quad \text{Subject to: } \sum_{i=1}^{N} I_i b_i \le M; \quad I_i \in 0,1; \quad i = 1,...,N. \quad (1)$$

The term I_i is a binary indicator variable where a value of 1 indicates a tender is included and zero excluded, $\hat{I}_i$ is the optimal solution to (1). If bids are ‘lumpy’ then overall conservation benefits may be increased by swapping cheaper bids for higher cost ones, if the resulting solution is closer to the budget (Hajkowicz et al., 2005). In addition, $B_i(e_i, k_i)$ is the EBI for farm *i* using a (*1xL*) vector of environmental inputs e_i in return for bid b_i. The variable k_i measures 'environmental capital' and can be measured, for instance, by the existing area of bush on a farm. The benefit function is strictly increasing and concave in all element of e_i and k_i. Variations in k_i lead to differing environmental benefits from a given level of environmental inputs. The first constraint is the regulators budget constraint, whereby the sum of bids must not exceed the total budget, *M*. The solution to problem (1) is $\hat{B}$ that is the maximum total EBI.

Mechanism 2 takes the optimal subset of tenders from (1) $\hat{I}_i$, and determines a payment *g* applied to environmental benefit to minimize costs by solving the linear programming problem

$$\underset{g}{Min} \sum_{i=1}^{N} \hat{I}_i g B(e_i, k_i); \quad \text{subject to:} \quad \hat{I}_i b_i \leq g B(e_i, k_i) \qquad (2)$$

The constraint ensures, for the successful firms, the transfer payment is at least as much as the bid. This constraint approximates the individual rationality constraint and, if the bid equals the compliance cost, is the farm's individual rationality constraint. A individual rationality constraint ensures that a firm has an incentive to participate.

Mechanism 3 defines a (*1xL*) vector of fixed prices per unit of inputs *t* as:

$$\underset{t}{Min} \sum_{i=1}^{N} \hat{I}_i t e_i; \quad \text{subject to:} \quad \hat{I}_i b_i \leq t e_i \qquad (3)$$

The constraint again ensures the transfer payment is at least as much as the bids for the successful firms. The fact that the successful subset of firms are fixed and the effort is given means that the total benefit under Mechanisms 2 and 3 remains at $\hat{B}$.

Mechanism 2 and Mechanism 3 give the same cost-efficiency when:

$$t\sum_{i=1}^{N}\hat{I}_i e_i = g\sum_{i=1}^{N}\hat{I}_i B(e_i, k_i)$$

this can be interpreted further as stating that

$$t\sum_{i=1}^{N}\hat{I}_i e_i / \sum_{i=1}^{N}\hat{I}_i B(e_i, k_i) = g \qquad (4)$$

that is the average cost per unit of EBI must equal the fixed transfer from Mechanism 3. Note that g is the maximum bid per unit of EBI.

The importance of the result can be shown by considering a limiting case, where the compliance cost of effort is constant across all producers, while the EBI varies across tenders. In this case, using a fixed-price per unit of EBI mechanism will lead to a lower estimate of auction efficiency gains because those landholders who hold land of higher environmental benefits will earn rents under a fixed-price EBI mechanism. However, a fixed-price input mechanism does not give an efficiency gain from the auction because the individual rationality constraint is binding for all landholders at the fixed price. In general it is not possible to state if the fixed-price input mechanism will give higher or lower cost efficiency for the auction: it depends on the relative degree of heterogeneity in the opportunity costs, the environmental benefit, and the covariance between them.

Optimal fixed price Mechanisms

The selected set of tenders from the auction may not be the optimal set when the regulator is restricted to a fixed price Mechanisms. Mechanism 4 is EBI based, and Mechanism 5 is input based. Mechanism 4 requires the solution of the following problem:

$$\underset{I,g}{Min}\sum_{i=1}^{N} I_i gB(e_i,k_i); \quad \text{subject to:} \quad b_i I_i \leq gB(e_i,k_i); \sum_{i=1}^{N} I_i B(e_i,k_i) \geq \hat{B} \qquad (5)$$

Mechanism 4 is optimized over both the transfer payment g and the indicator variable I_i. This means that the problem is a mixed integer nonlinear programming problem. The first constraint ensures that those farms selected receive transfer payments in excess of their bids. The second constraint ensures that the total environmental benefit is at least the same as that for Mechanism 1, $\hat{B}$. Mechanism 5 is given by

$$\underset{I,t}{Min}\sum_{i=1}^{N} I_i te_i; \quad \text{subject to:} \; b_i I_i \leq te_i; \sum_{i=1}^{N} I_i B(e_i,k_i) \geq \hat{B} \qquad (6)$$

and is the environmental input-based equivalent of (5).

Price discrimination

Mechanism 6 splits the fixed-price environmental input based Mechanism Mechanism 5 into two groups. It therefore explores the gains from partial price discrimination.

$$\underset{I_i^j,t}{Min}\sum_{j=1}^{2}\ \sum_{i=1}^{N} I_i^j t^j e_i; \text{subject to: } (b_i)I_i^j \le t^j e_i; \sum_{j=1}^{2}\ \sum_{i=1}^{N} I_i^j B(e_i,k_i) \ge \hat{B}; I_i^1 + I_i^2 \le 1 \quad (7)$$

These schemes depend on the regulator having sufficient information to divide the tenders into two groups. If they depend on the farmers self-selecting this scheme may be subject to adverse selection.

Accounting for rent in bids

Producers are assumed to have an unobserved compliance cost $C(e_i)$ which is increasing and convex in elements of e_i. Bids can be decomposed as follows

$$b_i = C(e_i) + r_i \quad (8)$$

That is the bid from firm *i* equals the compliance cost plus a rent term r_i. The problem with this approach to estimating an adjusted efficiency is that the firms compliance cost function is unobserved. However, it may be possible to determine an efficient bid frontier on the basis of the environmental inputs and the bid.

Given the small size of the samples and expectation that the stochastic component of bids will be low given that actions are straightforward it was decided to establish the cost frontier using Corrected Ordinary Least Squares first proposed in the efficiency literature by Winsten (1957). This procedure involves first estimating the bid function

$$b_i = \beta_0 + f(\beta, e_i) + u_i$$

by OLS, where β_0 is the constant term, β is a vector of parameters, *f(.)* is a function and u_i is a iid residuals. In a second stage, the smallest (largest negative) residual adjust the OLS constant term by

$$\hat{\beta}_0 = \beta_0 + \min_i \{u_i\}$$

The residual is adjusted in the opposite direction and measures the distance between the cost frontier and the actual bid thus, the residual is a measure of the firms type $\theta_i = u_i - \min_i \{u_i)$. Thus (8) can be given as:

$$b_i = (\hat{\beta}_0 + f(\beta, e_i)) + \hat{r}_i$$

The term in brackets gives the compliance cost and the estimate of rent is given by

$$\hat{r}_i = u_i - \min_i \{u_i)$$

In practice the rent term may account for variations in the opportunity cost of labour and private benefits of conservation. However, it is not possible to separate these components, so the rent is treated as a single term.

Mechanisms 7 and 8 are equivalent to Mechanisms 4 and 5, but adjust bids for the rent component to determine the optimal fixed price schemes. Mechanism 7 is given by the mixed integer nonlinear programming problem:

$$\underset{I,g}{Min} \sum_{i=1}^{N} I_i gB(e_i, k_i); \quad \text{subject to: } (b_i - \hat{r}_i) I_i \leq gB(e_i, k_i); \sum_{i=1}^{N} I_i B(e_i, k_i) \geq \hat{B} \qquad (9)$$

Mechanism 8 is environmental input-based equivalent:

$$\underset{I,t}{Min}\sum_{i=1}^{N} I_i te_i; \quad \text{subject to: } (b_i - \hat{r}_i)I_i \leq te_i; \sum_{i=1}^{N} I_i B(e_i, k_i) \geq \hat{B} \tag{10}$$

4. Auction for Landscape Recovery

The Auction for Landscape Recovery (ALR) is a voluntary land and nature conservation program for landholders in the wheatbelt agricultural region of the Avon River basin (Gole *et al*. 2005). It is one of a number of pilot market based instrument schemes run in Australia (National Heritage Trust, 2004). The ALR was conducted as a sealed-bid price discriminating auction, similar to the Bushtender Program. Landholders were encouraged to submit a tender giving their proposed management activities, anticipated environmental outcomes and a bid. The process was communicated as rewarding those who deliver the greatest environmental benefit per dollar. Producers were also reminded that the scheme is competitive. In terms of auction theory the auction type is complex in that the seller sets the bid and defines the good over a multivariate set of attributes which determine the environmental benefit index. This type of procurement auction has been identified as a scoring auction (Asker and Cantillon, 2004), similar auction designs are used in road construction and electricity Mechanisms (Bushnell and Oren, 1994; Wilson, 2002)

The auction was conducted over two rounds. Round One closed at the end of April 2004: a total of 56 bids were received from 38 landholders – some landholders submitted multiple bid. Round Two closed at the end of February 2005 and generated 33 bids from 29 landholders. Here we focus exclusively on the group of tenders proposing revegetation and fencing in order to achieve some degree of homogeneity in the tenders, reducing the sample to 27 in Round One and 32 in Round Two. Tenders were evaluated using a Environmental Benefit Index which is discussed in detail in Gole *et al* (2005, p21). The Environmental Benefit Index used was predominantly a measure of biodiversity and was based on the index used in the Victorian Bushtender trial (Parkes, *et al.*, 2003).

5. Measuring the Cost-effectiveness for Auction for Landscape Recovery

In Round One, the mixed integer programming solution to the knapsack problem selects tenders with a relatively low cost per unit of environmental benefit (EBI), but as the budget constraint is approached then the solution switches to higher cost bids to satisfy the budget as closely as possible.[2] In Round One 12 tenders are selected, and the marginal tender in the selected set has a cost per EBI of $5.353. Two, relatively small tenders with lower costs are not selected. The total EBI preserved is 58,540 and the selected tenders cost $99462. In Round Two 15 tenders were selected with a total cost of $98,878 and the marginal tender had a cost per EBI of $2.403. Full results are given in Table 1.

[2] All problems were solved using GAMS solvers for linear programming, mixed integer programming and mixed integer nonlinear programming.

Table 1 Mechanisms Costs

					Transfer payments $:		
Mechanism	Round	Total Cost $	EBI	Cost Effectiveness as per cent of Mechanism 1	Per EBI	Per Fence km	Per Revegetation ha
1. Firms paid bids to maximize environmental benefit subject to budget constraint.	1	99462	58540	100	-		
	2	98878	60854	100	-		
2. Fixed payment per unit of environmental benefit	1	313368	58540	315	5.353	-	-
	2	163129	60854	165	2.680	-	-
3. Fixed payments per unit of environmental inputs	1	206197	58540	207	-	3659.87	266.;66
	2	183672	60854	186	-	1888.89	874.87
4. Optimal fixed payment per unit of environmental benefit	1	313368	58540	315	5.353	-	-
	2	142207	61584	144	2.309		
5. Optimal fixed payments per unit of inputs	1	206197	58540	207	-	3659.87	266.;66
	2	143327	60965	145	-	2329.41	198.71
6. Two-tier input pricing	1 tier 1 1 tier 2	148370	58566	149	-	3911.53 2212.92	37.88 266.67
	2 tier 1 2 tier 2	135348	60956	137	-	2207.09 1513.94	376.86 1.50
7. Efficient frontier fixed-payment per unit of environmental benefit..	1	282494	58540	284	4.826		
	2	69892	61323	71	1.139		
8. Efficient frontier fixed-payments per unit of inputs	1	86016	58540	86		2009.52	52.08
	2	85159	61160	86		1195.29	123.52

First we consider the efficiency of the auction over the two rounds relative to the output based Mechanism 2 and input based Mechanism 3. In Round One Mechanism 2 has a low level of efficiency compared to the auction while Mechanism 3 fares better. In Round Two this result is reversed.

In Figure 2 shows the relationship between the cumulative EBI and the bid per EBI ranked in ascending order for successful bids. Mechanism 1 pays each firm their bid, Mechanism 2 pays the highest Bid per EBI and Mechanism 3 pays each firm according to their inputs. From equation (4) if average cost for Mechanism 3 is less (more) than the highest Bid per EBI, Mechanism 2 (Mechanism 3) is relatively cost-effective. From Figure 2a Mechanism 3 is relatively cost-effective for Round One, thus the auction should be compared with a fixed input price scheme. From Figure 2b in Round Two, Mechanism 2 is relatively cost-effective

Mechanisms 4 and 5 show the efficiency gain to fixed price schemes of allowing a reselection of successful tenders. In Round One reselection had no effect, in Round Two it reduced costs by 40 per cent of the auction cost. Mechanism 6 gave significant cost savings over the fixed price schemes over both rounds

Figure 2a Bids Ranked by Bid per EB Round One

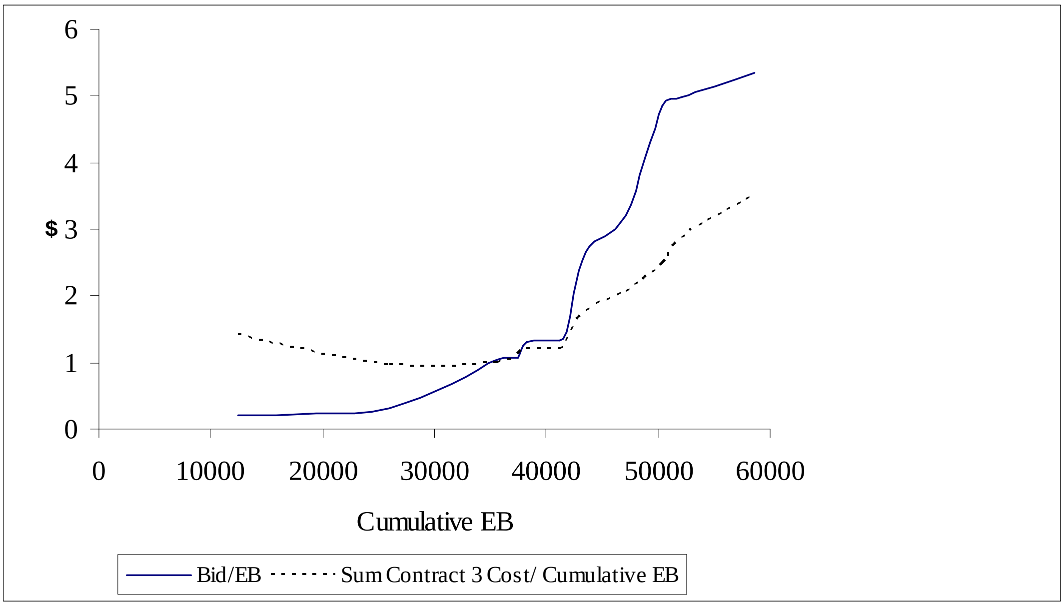
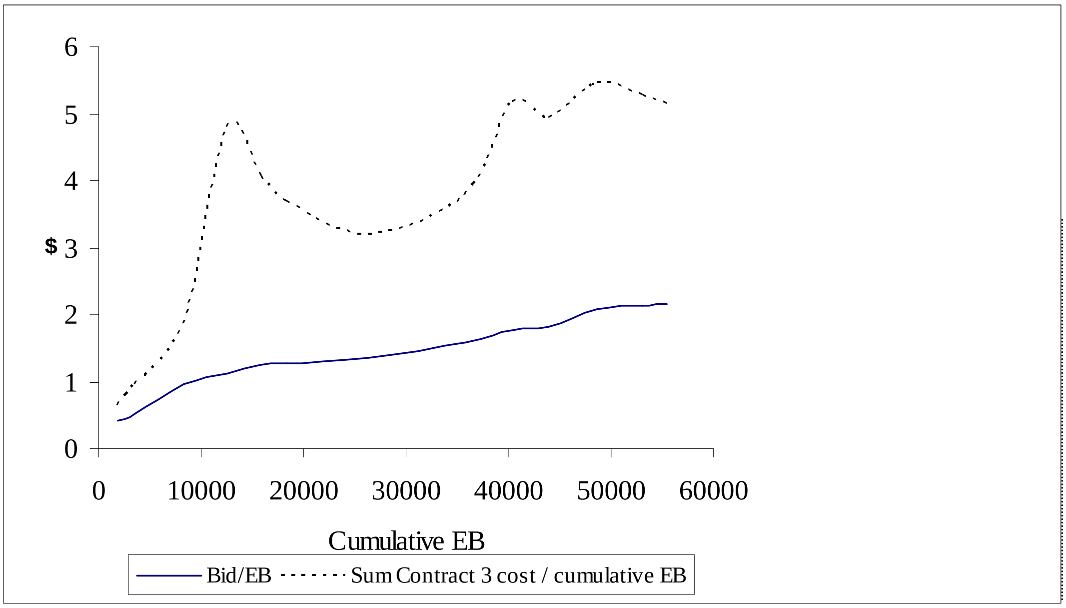


Figure 2b Bids Ranked by Bid per EB Round Two



Cost Effectiveness with Rent

Estimates for the bid cost function $C(e_i)$ are given in Table 2. The preferred functional form is a quadratic. The parameters indicate that the bid cost function is convex in both inputs. This can be explained by an increasing marginal shadow price for labour and land diverted from other productive activities.

Mechanism 7 shows a cost less than the auction for the fixed price per unit of environmental benefit scheme in round 2 and Mechanism 8 shows a cost less than the auction over both rounds. These results depend critically on the bid adjustment being a rent payment, implying that a rational producer would be willing to accept a total transfer payment which is less than their bid.

Table 2 Estimates of the bid function

	Round 1		Round 2	
Variable	Parameter	t -statistic	Parameter	T -statistic
Revegetation (squared)	0.4343	8.47	7.289843	6.13
Fence (squared)	126.7323	8.64	120.8808	3.12
Constant β_0	5014.526	6.75	6478.127	1245.13
Adjusted Constant $\hat{\beta}_0$	608.165		1667.247	
F(2, N-k)	68.44		26.98	
$\min_i\{u_i\}$	-4406.361		-4810.88	
$\bar{R}^2$	0.8384		0.626	
Observation (N)	27		32	

6. Conclusions

The choice of a comparator fixed-price scheme to measure auction efficiency should be guided by what is available as a pragmatic alternative. In Western Australia an input-based scheme is widely applied in conservation schemes but an environmental benefit basis has, to our knowledge, never been considered. The importance of this analysis is that auctions are expensive to administer, over time a regulator may decide, on the basis of the results of past auctions, to switch to a fixed-price scheme. This analysis will indicate whether an environmental benefit or input based fixed price scheme will be cost-efficient. It also indicates the extent to which bids should be discounted to eliminate the rental component.

The first conclusion from this analysis is that the data drawn from the ALR pilot auction scheme report a significant increase in efficiency over an environmental benefit-based and an input-based fixed price scheme of between 315 and 207 per cent respectively in Round One and 165 and 186 per cent in Round Two. Although not as large a gain as reported for the Bush Tender project of 700 per cent , this may reflect the pilot nature of the ALR, and the relatively small level of funding for on ground works, such that the project operates in a zone where the marginal cost of purchasing benefits is not rising steeply.

Designing tiered Mechanisms where different producer groups are paid different rates increases efficiency for Round One by 56 per cent and Round Two 49 per cent compared with the single fixed input price alternative.

If the bids are adjusted to eliminate the rent component, the percent gains from the auction fall to 284 per cent for the environmental-benefit based scheme and 86 per cent for the input-based scheme in Round One and 71 per cent and 86 per cent respectively in Round Two.

References

Asker, J. and Cantillon, E. (2004). *Properties of Scoring Auctions*. Mimeo.

Bushnell, J. and Shmuel, O. (1994). Bidder Cost Revelation in Electric Power Auctions, *Journal of Regulatory Economics*, 6, 5-26.

Faith, D. P., Walker, P. A., (1996b). Integrating conservation and development: incorporating vulnerability into biodiversity-assessment of areas. Biodiversity and Conservation 5, 431-446.

Falconer, K. and Whitby, M. (1999). The invisible costs of scheme implementation and administration. In: *Countryside Stewardship: Farmers, Policies and Markets.* Van Huylenbroeck, G. and Whitby, M. eds pp67-88. Pergammon: Amsterdam.

Gole, C., Burton, M. B., Williams, K.J., Claytonm H. Faith, D. P., White, B., Huggett, A. and Margules, C. R. (2005). Auction for Landscape Recovery (2004e). *Auction for Landscape Recovery Final Report (Southwest Australia) Project 21*. World Wide Fund for Nature Australia.

Hajkowicz, S., Higgins,A., Williams,K., Faith,D., and Burton,M. Optimisation and the Selection of Conservation Mechanisms. Unpublished manuscript, September 2005, CSIRO Sustainable Ecosystems, Brisbane.

Margules, C.R and Pressey, R.L (2000) Systematic conservation planning. *Nature* 405:243-253

Martello, S. and Toth, P.(1990) *Knaopsack Problems Algorithms and Computer implementations. New York: Wiley.*

National Heritage Trust (2004) Managing our Natural Resources: can markets help?

Stoneham,G., Chaudri,V., Ha,A. and Strappazzon,L. (2003) Auctions for conservation Mechanisms: an empirical examination of Victoria’s BushTender trial. *Australian Journal of Agricultural and Resource Economics* 47(4) pp477-501.

Wilson, R. (2002). The Architecture of Power Markets, *Econometrica*, 70, 1299-1341.

Winsten,C.B. (1957) Discussion on Mr. Farrell’s Paper, *Journal of the Royal Statistical Society* series A, General, 120, Part 3, pp282-84.