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Research Paper presented at AARES 2011 Conference

An empirical examination of the gains in cost-effectiveness from the use of multiple environmental outcome conservation tenders.

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February 2011

Abstract

The production and consumption of environmental goods and services are subject to many of the problems associated with public goods. Due to their non-rival and non-excludable nature, incentives for individuals to invest in their production are often absent. To address this market failure, government agencies have used a number of policy mechanisms to procure the supply of environmental outcomes on behalf of society. Recently, conservation tenders focussing on private land have been a favoured policy instrument used by many government agencies to purchase environmental outcomes in the public interest. The majority of these environmental tenders have focussed on a single environmental outcome.

It is contended in this paper that multiple environmental outcomes tenders can be more cost-effective than single outcome tenders as decisions are based on information regarding a wider set of environmental outcomes – a more complete picture. Tenders that focus on more than one outcome capitalise on economies of scope in the production of environmental outcomes, as well as incorporating synergies and trade-offs into decision making.

In this paper the results from a synthetic analysis of the benefits derived from running multiple-outcome tenders are compared to single outcome tenders, to empirically estimate potential cost-effectiveness gains. The baseline policy of running a multiple-outcome tender is compared to three alternative policy options: running a single outcome tender, running three single outcome tenders simultaneously, and running three single outcome tenders consecutively.

Results indicate that significant cost effectiveness gains can be made by running a multiple-outcome tender compared to the three policy alternatives. These results are analysed, and advantages and limitations of applying multiple-outcome tenders in the field are discussed.

Background

Uniform payment policies (or fixed price grants schemes) and conservation tenders are two policy mechanisms that have been used by government agencies to procure environmental goods and services on private land in the public interest. Historically, uniform payment policies have been the primary mechanism used for purchasing public environmental benefits on private land (Latacz-Lohmann and Hodge, 2003). However, these policies have been criticised on the premise that asymmetric information between the landholder and implementing agency on the true costs of management interventions may result in landholders being overpaid for the tasks they perform – an increased cost to government (Stoneham et al, 2003).

More recently in Australia, conservation tenders have been used increasingly in an attempt to cost-effectively purchase environmental benefits on private land (Windle and Rolfe, 2008). In these tenders, landholders submit a bid outlining the payment they require to undertake a given set of actions, and some form of scientific metric is used to predict the public environmental benefit resulting from those actions. Bids are then ranked from lowest to highest cost per unit environmental benefit – an environmental benefit supply curve. Bids are selected along this supply curve until the budget is exhausted (or the reserve price is exceeded).

In this paper the notion of cost effectiveness is used often. Cost effectiveness differs from economic efficiency. Cost effectiveness relates to the unit cost to the agency of procuring environmental outcomes. Government – acting on behalf of the general public – is concerned with cost effectiveness because they aim to procure environmental outcomes in a manner that represents value for money. For economic efficiency, the sum of the surplus to the landholder and the agency is maximised.

Tenders increase the cost-effectiveness to agencies of purchasing public environmental benefits from landholders, compared to traditional grants schemes, in the following ways:

1. Introducing competition to provide incentives for land-holders to reveal information on their opportunity cost, and
2. Using scientific metrics alongside information on bids to separate high and low cost suppliers of environmental benefit (Connor et al, 2008).

The majority of conservation tenders implemented in Australia have focussed on a single environmental outcome. In Victoria, BushTender, River Tender and Wetland Tender focus on native vegetation, rivers and wetlands respectively¹. In addition, carbon outcomes have been purchased to offset Victorian Government vehicle emissions². Conservation tenders have been shown to yield significant efficiency gains over uniform payment policies (Stoneham et al, 2003). However, many environmental outcomes are jointly produced, and in single outcome tenders efficiency gains from selecting the best sites based on a more complete picture of the environmental outcomes produced may be forgone. It is contended in this paper that the cost-effectiveness gains from running a conservation tender over a traditional grants approach can be improved upon by considering different environmental outcomes together.

The potential for considering more than one environmental outcome relating from a change in land management has been highlighted in the literature (Woodward, 2010; Strappazon et al, 2003).

¹ Recent River Tenders have commenced implementation in Wimmera, Glenelg Hopkins and North East Catchment Management Authorities in 2009. Recent Wetland Tenders commenced implementation in Wimmera, Glenelg Hopkins and Corangamite Catchment Management Authorities in 2009. Recent BushTenders have been run Mallee, Wimmera, Goulburn Broken and North Central Catchment Management Authorities from 2008 to 2011.

² The most recent VicFleet Tender was held in 2010. Freedom of trade between states prevented DSE from restricting eligibility to Victoria, even though some weight was given to environmental benefits.

(Woodward, 2010) shows that when caps are set correctly³ for multiple cap and trade schemes, allowing land holders to sell permits in multiple markets, or 'double dip', will maximise aggregate net benefits. In (Strapazzon et al, 2003) it is found that allocating property rights for a second good produced as a by-product of production of biodiversity in an auction setting, to landholders improves efficiency in comparison to allocating the property right to the environmental agency. This difference in efficiency is attributed to asymmetric information about the landholders' ability to maximise profit in supplying a portfolio of outcomes (Strapazzon et al, 2003). In (Stoneham, 2007) empirical results from an EcoTender pilot are used to support the notion that paying landholders for carbon sequestered (simulating a carbon market) in addition to their bid, results in a lower procurement cost to the agency.

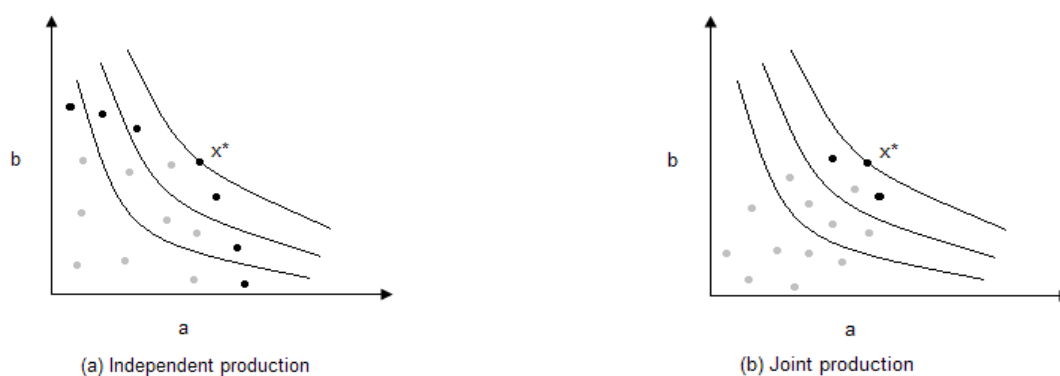
The Victorian Government's EcoTender is a conservation auction that focuses on multiple environmental outcomes (Eigenraam et al, 2006). In EcoTender, outcomes relating to native vegetation, rivers, wetlands, and catchment health (erosion, recharge and run-off) are targeted. The environmental benefit unit used in ranking (EBU) is a weighted sum of the component scores. Targeting multiple environmental outcomes in a single tender would provide incentives for landholders to choose a bundle of environmental goods to that maximises their expected tender pay-off. This saving could be shared between multiple investors focussing on single environmental outcomes reducing the cost to all parties. The EcoTender conservation auction has been shown to result in lower unit cost of environmental benefit than if the same bids are selected on the basis of only one environmental benefit (Edwards and Eigenraam, 2010).

Theory

Landholder bids consist of a bid price and a suite of management actions that the landholder commits to undertake should they be successful. For the same set of landholder bids, tenders focussing on different environmental outcomes will yield different supply curves. It is likely (although not necessary) that the rankings of landholders will differ between supply curves for different environmental outcomes.

When information on preferences for each environmental benefit is known, it is possible to purchase the collection of bids that maximise total net benefit to society within a given budget constraint. This is achieved by selecting the combination of bids from the production possibilities frontier that results in the bundle of environmental outcomes sitting on the outermost indifference curve. This is illustrated for two environmental goods 'a' and 'b' in figure 2 below.

Figure 1 – Optimal bundle of environmental outcomes from tender with two environmental outcomes



³ It is stated in (Woodard, 2010) that the authors believe that in reality caps are rarely set optimally for multiple pollutants. Co-ordination between programs is required to set the caps optimally.

In (a) and (b) of Figure 1, the three parallel lines represent society's indifference curves over bundles of goods 'a' and 'b'. Each point on the graph represents the bundle of goods obtained from selecting a combination of bids from the pool of all available bids such that the total cost does not exceed the tender budget. The dark points represent the combinations of bids that have the property there is no alternative combination of bids that yields strictly higher quantities of both goods within the budget constraint. In other words, a dominating combination of bids cannot be obtained without exceeding the tender budget.

The point x^* in each diagram denotes the optimal combination of bids within the budget constraint. In 1(a) the goods are produced independently and in 1(b) the goods are produced jointly. When the goods are produced independently, costs are generally expected to increase as the quantities of each good increase. When goods are jointly produced, it may be more expensive (or even impossible) to produce one good without producing the other. This can be seen in 1(b) where there are no combinations of bids within the budget constraint with high values of one good and low values of the other.

In reality, some actions may produce outcomes jointly, while others produce outcomes independently. Each landholder has a suite of management actions available to them. Some of these actions may yield multiple benefits and others may result in a single benefit. Landholders face incentives to select the management actions that maximise their expected private benefit⁴. Consequently in an environmental tender a mixture of bids for single and multiple-outcomes may be received. These bids will be influenced by the nature of the tender. In a single outcome tender the landholder will select management actions with regard to the outcome being targeted and will disregard other outcomes. In a multiple-outcome tender the landholder will choose management actions with regard to all environmental goods targeted in the tender. The weightings applied to each outcome in the metric will influence the landholders choice of actions to undertake.

There is much missing information on community preferences between environmental outcomes. In multiple-outcome tenders different outcomes are often weighted linearly, leading to linear indifference curves. The linearity of these indifference curves may be a reasonable assumption as it is often the case that a tender represents such a small quantity of overall environmental targets that a linear approximation is adequate. Moreover, if the targets are very far from being reached, diminishing marginal returns may not be relevant.

The weightings an agency gives to each environmental outcome in a tender defines the derivative of the linear indifference surface. Consider a vector $\underline{a} = (a_1, \dots, a_n)$ of environmental outcomes. Let $\underline{w} = (w_1, \dots, w_n)$ be a vector of weights such that the score a landholder receives for his/her bid is given by:

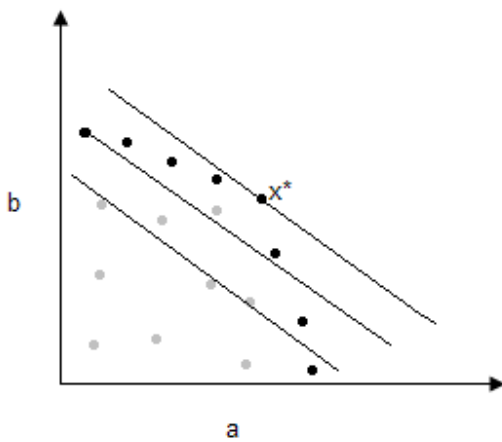
$$s = \underline{w} \cdot \underline{a} = \sum_{i=1}^n w_i a_i \text{ and } \sum_{i=1}^n w_i = 1.$$

The agencies marginal rate of substitution between two goods i and j is the ratio of their weightings $\frac{w_i}{w_j}$.

⁴ Private benefit obtained by the landholder is equal to their expected tender pay-off plus any additional private benefit gained from undertaking the given management actions.

Single outcome tenders are the special case where all but one of the weights w_i are equal to zero. In this case the indifference sets will be of the form: $\{a \in R^n \mid a_i = c\}$ where $c \in R_+$. In the case where there are two environmental goods produced and all weight in the metric is assigned to one good, the indifference curves will be lines perpendicular to the good targeted in the tender. Figure two below shows the intersection of the production possibilities frontier with linear indifference curves resulting from a metric that is a weighted combination of goods 'a' and 'b'.

Figure 2 – Optimal bundle of environmental outcomes from tender with two environmental outcomes and linear metric.



In Figure 2, the slope of the agencies indifference curve is given by the quotient of the weightings of good 'b' and good 'a' in the agencies scientific metric.

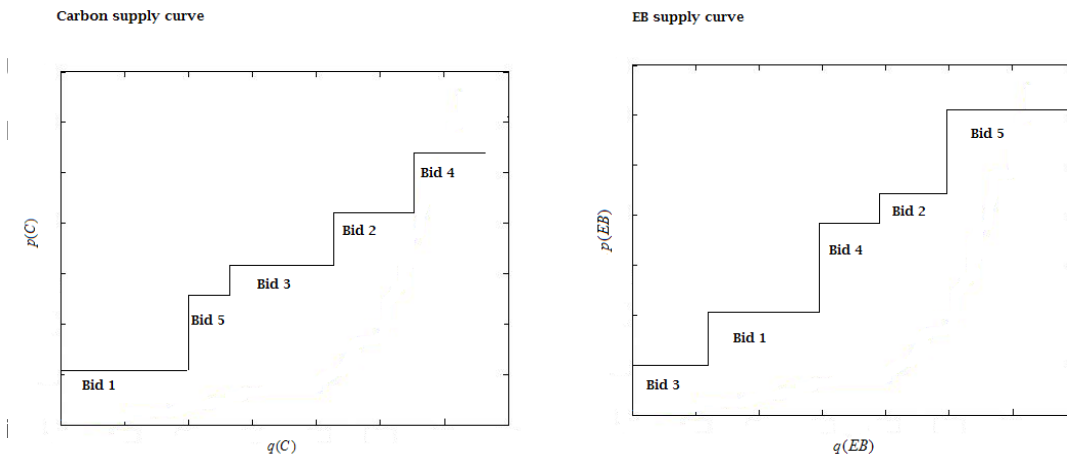
Tenders with different weightings for environmental outcomes will have different supply curves, even if they are constructed from the same bids. To see this we first consider a simple example with two tenders that each focus on a single outcome. Suppose that one tender focuses on carbon (C) and a second tender focuses on terrestrial environmental benefit (EB). In this example there are five landholders offering bundles of terrestrial and carbon benefit. The bid prices and quantities of the two benefits are given in table 1 below:

Table 1 – landholder bid price, carbon and terrestrial benefits

Bid	Price	Carbon (C)	Terrestrial (EB)
1	1000	100	75
2	600	20	20
3	1000	60	100
4	500	20	30
5	250	20	5

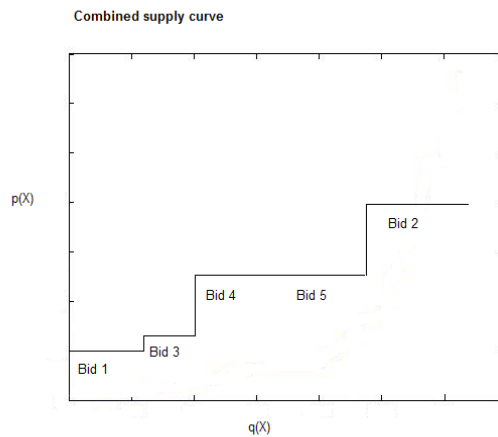
Supply curves for both carbon and terrestrial environmental benefit can be constructed from this information by selecting bids in order of highest to lowest cost per unit carbon and cost per unit terrestrial benefit respectively. The carbon and terrestrial EB supply curves are given in Figure 3 below.

Figure 3 – Supply curves for carbon and terrestrial environmental benefit.



It is clear from Figure 3 that the order of the bids in the carbon and terrestrial tender is different. In figure 4, a supply curve for a multiple-outcome tender focussing on carbon and terrestrial biodiversity where each good is weighted at equally is given. It can be seen that this tender yields a supply curve that differs from both the carbon and terrestrial supply curves.

Figure 4 – supply curve for weighted carbon and terrestrial tender



Changing the weightings of environmental outcomes in a tender may result in a change in the tender supply curve and therefore the choice of successful bids. If the weightings in the tender do not reflect society’s preferences for environmental outcomes, government funds may not be spent optimally.

Approach

As discussed in the background section, economic theory suggests that multiple-outcome tenders allow the agency to capitalise on economies of scope resulting from joint production of environmental outcomes. In this paper synthetic data with characteristics derived from real tender data is used to investigate potential cost savings to agencies from running multiple-outcome tenders. Empirical information from the West Gippsland EcoTender demonstration is used to create the synthetic dataset used in the comparison.

Monte Carlo simulations are used to run multiple iterations of cost effectiveness comparisons involving single and multiple-outcome tenders using synthetic data. The aim of this investigation is to use synthetically generated data to test the theory that multiple-outcome tenders can provide cost effectiveness gains over single outcome tenders. The rationale behind using synthetic data over real data in this analysis is that Monte Carlo results provide a distribution of results over the simulation data and are less sensitive to the specific combination of data obtained in the real tender.

Assumptions

Results presented in this paper rely on the following assumptions:

1. scoring systems (metrics) exist that can accurately predict and score environmental outcomes resulting from on-site management actions;
2. the population of scores for all components are distributed normally with the same co-efficient of variation as the West Gippsland EcoTender sample dataset⁵;
3. the utility function of the procuring agency is such that 'native vegetation', 'river' and 'carbon' units are valued equally.
4. the agency obtains constant utility for each additional unit of 'native vegetation', 'river' and 'carbon' – agency preferences are linear and there are no diminishing marginal returns.

Methodology

In Monte Carlo analysis data is generated randomly from pre-defined distributions for each iteration of the simulation. Multiple iterations are run and summary statistics are calculated for the simulation results. In each iteration, a randomly generated synthetic dataset is used to simulate landholder bids, area and environmental benefit scores per unit area. In this analysis, distributions of unit environmental benefit scores for 'native vegetation', 'river' and 'carbon' benefits are each generated randomly from datasets that are normally distributed with a mean of 50. The standard deviation of each distribution is defined so that the coefficient of variation⁶ in the distribution matches the coefficient of variation in the West Gippsland EcoTender empirical dataset⁷.

To reflect the fact that only some sites are adjacent to a river and have a river benefit (40 percent in West Gippsland EcoTender) each site is given a river flag – a random number drawn from a uniform distribution between 0 and 100. Sites with a river flag less than or equal to 40 are assigned a unit river score from the distribution. Sites with a river flag greater than 40 are deemed to be not adjacent to a river and are assigned a river score of zero. Similarly, to represent the fact that only 60 percent of sites in the West Gippsland EcoTender demonstration sequestered carbon, a carbon flag is assigned in the same manner. Sites with a carbon flag of less than or equal to 60 are deemed to sequester carbon and are assigned a unit carbon score. Sites with a carbon flag of greater than 60 are deemed not to sequester any carbon.

Each site is assigned an area score from a normal distribution where the mean and standard deviation are taken from the empirical data.⁸

⁵ The actual distributions may vary slightly from normal as a result of clipping the random variables at a very low positive value.

⁶ The coefficient of variation is the standard deviation divided by the mean. It is a normalised measure of dispersion.

⁷ The distributions for unit environmental benefit scores are clipped at .01 to avoid the generation of negative scores.

⁸ Where a negative number is generated for the area, it is replaced with .2Ha – the minimum area for eligibility in the West Gippsland EcoTender.

In this analysis, a budget of \$3,000,000 was used and data was generated for 300 landholders. This budget and number of participants was constructed to create a similar ratio of landholders to budget as the West Gippsland Ecotender. A normal distribution modelled on the WG EcoTender data was used generate bid data per unit area for each landholder.

In each iteration of the Monte Carlo simulation, a dataset is generated and that dataset is used to simulate a baseline multiple-outcome tender. The same dataset is used to simulate each of the following policy alternatives:

1. single outcome tenders for each outcome, each using the total budget;
2. three consecutive tenders assigning one third of the budget to each; and
3. three separate tenders assigning 1/3 of the budget to each.

Baseline Mechanism: multiple-outcome tender

In a multiple-outcome tender the environmental benefit score is defined to be the sum of the 'native vegetation', 'river' and 'carbon' scores. To simulate a multiple-outcome tender, the site data is ranked in ascending order by bid price per unit EBS and bids are selected along this multiple-outcome supply curve until there are insufficient funds to select the next bid. The total 'native vegetation', 'river', 'carbon' and 'EBS' is calculated for the simulated multiple-outcome tender.

1. Single outcome tender

To simulate a single outcome terrestrial tender, the site data is ranked by cost/terrestrial score and bids are selected down the list until there are insufficient funds to select the next bid. The total EBS is calculated for the simulated Terrestrial Tender. Analogous simulations are conducted ranking by 'cost/river' and 'cost/carbon' scores to simulate single outcome tenders for 'river' and 'carbon' respectively. The percentage additional EBS that is obtained in the baseline compared to the single

outcome tender is calculated as follows: $\frac{EBS_{multiple}}{EBS_{single}} \times 100$

2. Consecutive single outcome tenders

To simulate three single outcome tenders ran consecutively (terrestrial then river then carbon) one third of the budget is allocated for each tender. To simulate a terrestrial biodiversity tender, the site data is ranked by cost/terrestrial benefit unit and bids are selected down the list until there are insufficient funds to select the next bid. The sites that were not selected in the simulated terrestrial tender are ranked in ascending order by cost/river benefit unit. Sites are selected down the list until the selection of an additional site would exceed the 'river' budget. Sites that were not selected in the river tender are then ranked on their unit carbon cost. Sites are selected down this list until the carbon budget is exhausted. The total EBS for the three consecutive tenders is the sum of the EBS obtained in each

individual tender: $EBS_{NVRivCar} = EBS_{native\ veg} + EBS_{river} + EBS_{carbon}$

The percentage additional EBS that is obtained in the baseline compared to three consecutive tenders for 'native vegetation', 'river' and 'carbon' respectively is calculated as follows:

$$\frac{EBS_{Multiple}}{EBS_{NVRivCar}} \times 100 .$$

This calculation is repeated in reverse order ('carbon', 'river', 'native vegetation').

3. *Separate single outcome tenders*

To simulate three tenders being run separately, one third of the landholders are assigned⁹ to participate in each of 'native vegetation', 'river' and 'carbon' tenders. One third of the budget is allocated to each tender. To simulate a 'native vegetation' tender, the first group is ranked by cost/terrestrial benefit unit and bids are selected down the list until there are insufficient funds to select the next bid. Similarly to simulate 'river' and 'carbon' tenders, the second and third groups are ranked by cost/'river' benefit and cost/'carbon' benefit respectively and bids are selected down these lists until there are insufficient funds to select the next bids. The total EBS for the separate tenders is calculated as follows:

$$EBS_{seperate} = EBS_{native\ vegetation} + EBS_{river} + EBS_{carbon}$$

The percentage additional EBS that is obtained in the baseline compared to running the three tenders

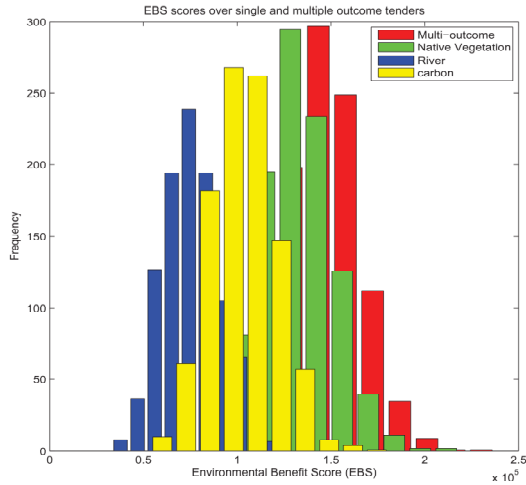
separately is calculated as follows: $\frac{EBS_{multiple}}{EBS_{seperate}} \times 100$

Results

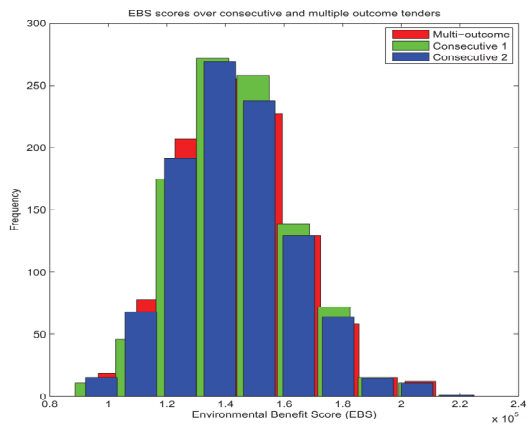
The distributions of total environmental benefit score (EBS) for simulations of the baseline multiple-outcome tender against each of the policy alternatives; a single outcome tender, 3 consecutive tenders, and 3 concurrent tenders, are presented in figure 5 below.

Figure 5 – Simulation distributions for environmental benefit scores

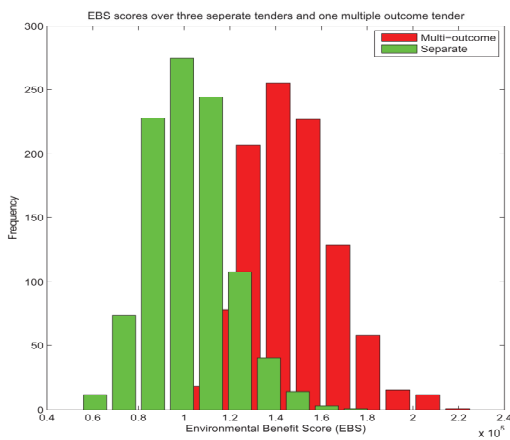
⁹ The site data is randomly divided into three datasets consisting of 1/3 of landholders each.



Higher scores are expected in multiple-outcome tenders than the 3 single outcome alternatives. Distributions for 'river' and carbon' are lower than 'terrestrial'.



Slightly higher scores are obtained in the multiple-outcome tender than the consecutive tender alternatives.



Significantly higher scores are obtained in the multiple-outcome tender compared to running 'native vegetation', 'river' and 'carbon' tenders separately.

The increase in environmental benefit scores observed in the simulation results are presented in tables 1-3 below. Information on the breakdown of terrestrial biodiversity, river and carbon scores is given in Appendix 1.

Table 1 – EBS gains from running a multiple-outcome tender over a single outcome tender (option 1).

	Native vegetation tender	River tender	Carbon tender
Mean percentage increase EBS¹⁰	12%	88%	42%
Range percentage increase EBS¹¹	3%-32%	39%-206%	17%-97%

Table 2 – EBS gains from running a multiple-outcome tender over three consecutive single outcome tenders (option 2).

Tender	consecutive tender (native vegetation, river, carbon)	consecutive tender (carbon, river, native vegetation)
Mean percentage increase EBS¹⁰	2%	2%
Range percentage increase EBS¹¹	0-6%	0-7%

Table 3 – EBS gains from running a multiple-outcome tender over three concurrent single outcome tenders (option 3).

Tender	consecutive tender (native vegetation, river, carbon)
Mean percentage increase EBS¹⁰	42%
Range percentage increase EBS¹¹	12%-100%

¹⁰ Average percentage increase in EBS obtained from running a multiple outcome tender over an alternative policy option using the simulation data.

¹¹ Lowest to highest percentage increase in EBS obtained from running a multiple outcome tender over an alternative policy option using the simulation data.

Discussion

These results indicate that there is potential for government agencies to purchase environmental benefit units at a lower unit cost using multiple-outcome tenders than using any of: one single outcome tender, multiple consecutive tenders, and multiple single outcome tenders. In addition, the results show that the savings obtained can vary widely depending on the specific bids received in an iteration.

Conditional probability

When interpreting the results from this simulation it is important to recognise that restricting eligibility to riparian sites, or sites that sequester carbon has an impact on the distribution of environmental benefit scores that satisfy eligibility requirements. The lowest (best) rankings for 'river' must have non-zero scores for at least two outcomes (terrestrial and 'river'). Similarly the lowest rankings for 'carbon' must have at least two outcomes (terrestrial and carbon). Intuitively, it would be expected that EBS scores should be higher for sites that have two or more outcomes on average.

To formalise this idea, we first consider the expected value of an environmental benefit score for a site given no information about the number of outcomes obtained. The expected value of the EBS can be defined in terms of means of the probability density functions from which the data is generated. In symbols:

$$E(X_{EBS}) = .24E(X_{Ter}) + .36[E(X_{Ter}) + E(X_{Car})] + .16[E(X_{Ter}) + E(X_{Riv})] + .24[E(X_{Ter}) + E(X_{Riv}) + E(X_{Car})]$$

Where X_{EBS} , X_{Ter} , X_{Riv} , and X_{Car} are random variables for 'EBS', 'terrestrial', 'river' and 'carbon' scores respectively. Recall that the distributions from which the simulation data is generated have a mean of 50 for each outcome. Hence we have $E(X_{Ter}) = E(X_{Riv}) = E(X_{Car}) = 50$. Therefore $E(X_{EBS}) = 100$. Given no information about the number of outputs on a site, the site has an expected environmental benefit score of 100.

Now consider a site that is known to sequester carbon. The expected EBS for a site, conditional on that site sequestering carbon is given by:

$$E(X_{EBS}^C) = \frac{.36[E(X_{Ter}) + E(X_{Car})] + .24[E(X_{Ter}) + E(X_{Riv}) + E(X_{Car})]}{.6} = 120$$

Similarly, the expected EBS for a site given that site is known to be riparian is calculated by:

$$E(X_{EBS}^R) = \frac{.16[E(X_{Ter}) + E(X_{Car})] + .24[E(X_{Ter}) + E(X_{Riv}) + E(X_{Car})]}{.4} = 130$$

This idea can easily be extended to show that EBS is positively correlated with the number of outcomes observed on the site. However, setting an eligibility requirement for 'carbon' or 'river' has an opposing effect of reducing the pool of sites eligible for selection. That may lead to forgoing low bid per unit EBS options. This notion is discussed in the next section.

(1) One single outcome tender

The percentage gains in environmental benefit score obtained from running a multiple-outcome tender compared to each of 'native vegetation', 'river' and 'carbon' tenders were significant in all cases but much higher for 'carbon and river' than 'native vegetation'. There are two important and competing factors influencing the cost-effectiveness gains from running multiple-outcome tenders over single outcome tenders.

The first is that there is substantial variation in the cost data as well as the EBS data (excluding the score for the outcome that is being focussed on). Restricting eligibility to sites that are adjacent to a river (40 percent) or sites that sequester carbon (60 percent) results in the exclusion of many low cost sites. As all sites have a 'terrestrial' score, all sites are eligible for selection in a terrestrial tender increasing the chance of low cost sites being selected over river and carbon tenders where only some sites are eligible for selection. To formalise this idea first consider a terrestrial tender. Unit bids for 'terrestrial' and 'environmental benefit' are both dependent on the following generated data:

1. bid per unit area
2. terrestrial score per unit area

Consequently there is a positive correlation between unit bids for 'terrestrial benefit' and 'environmental benefit'. In other words, if two sites are selected from the bids such that

$Rank_{EBS}(site\ 1) < Rank_{EBS}(site\ 2)$ then it follows that:

$$\Pr(Rank_{Terrestrial}(site\ 1) < Rank_{Terrestrial}(site\ 2)) > .5.$$

Now consider a river tender. Again suppose that two sites are selected such that

$Rank_{EBS}(site\ 1) < Rank_{EBS}(site\ 2)$. However, only 40 percent of sites have a non-zero river score. That is:

$$\Pr(Rank_{River}(site\ 1) < Rank_{River}(site\ 2)) < 1 - 0.6 = 0.4$$

Our lower bound on the probability of site 1 having a larger river score than site 2 (resulting from the positive correlation between unit bids for 'river' and 'environmental benefit') is as follows:

$$\Pr(Rank_{River}(site\ 1) < Rank_{River}(site\ 2)) > (1 - 0.6) \times .5 = 0.2$$

Consequently if site 1 is known to have a lower unit cost for EBS than site 2, the probability of site 1 also having a lower unit bid for terrestrial is in the range from 0.5 to 1, where the probability of site 1 having a lower unit bid for 'river' is in the lower range from 0.2 to 0.4. This idea can be extended naturally to tender selection; given that a site is selected in a multiple-outcome tender, the probability of that site being selected in a terrestrial tender is higher than the probability of that site being selected in a river tender. The same line of reasoning yields the following upper and lower bounds for carbon; given that $Rank_{EBS}(site\ 1) < Rank_{EBS}(site\ 2)$, then

$$\Pr(Rank_{Carbon}(site\ 1) < Rank_{Carbon}(site\ 2)) < 1 - 0.4 = 0.6$$

and

$$\Pr(Rank_{Carbon}(site\ 1) < Rank_{Carbon}(site\ 2)) > (1 - 0.4) \times .5 = 0.3$$

Hence the probability of site 1 having a greater river score, given a greater EBS is in the range from 0.3 to 0.6. Consequently the expected gains from running a multiple-outcome tender are likely to be largest when compared to a river tender and smallest when compared to a terrestrial tender^{12,13}. This corresponds to the simulation results.

¹² These bounds could be narrowed given information on correlations between scores.

¹³ Because the intersection of the ranges for $\Pr(River(site\ 2) > River(Site\ 2) | EBS(site\ 1) > EBS(site\ 2))$ and $\Pr(Terrestrial(site\ 2) > River(Site\ 2) | EBS(site\ 1) > EBS(site\ 2))$ is 0 we can conclude that the expected gain (in a randomly generated

(2) Three consecutive single outcome tenders

The three consecutive tenders demonstrated the smallest cost-effectiveness gain over the multiple-outcome tender out of all policy options. The average gain in EBS was 2 percent for both orderings of consecutive single outcome tenders. In this option all possible sites are eligible for consideration in at least two of the individual tenders (terrestrial and one other). We formalise this notion below.

Let S_{EBS} be the event of a site being selected in a multiple environmental outcome tender. Denote the event of a site being selected in three consecutive tenders (terrestrial, river, carbon) with one third of the budget allocated to each by $S_{consecutive}$. Similarly let $S_{Terrestrial}$, S_{River} and S_{Carbon} be the event of being selected in terrestrial, river and carbon tenders respectively, with one third of the tender budget. Then we have that:

$$\Pr(S_{consecutive} | S_{EBS}) = \Pr(S_{Terrestrial} | S_{EBS}) + \Pr(S_{River} | S_{EBS} \cap S_{Terrestrial}') + \Pr(S_{Carbon} | S_{EBS} \cap S_{Terrestrial}' \cap S_{River}')$$

If a site has a high score for any one of the single outcomes in relation to their bid price they are likely to be selected using a consecutive tender mechanism. The sites that will be selected in a multiple-outcome tender and rejected in the consecutive tender policy will be sites that rank fairly well in multiple categories, but not well enough to be selected in any of the consecutive tenders. It should be noticed that this policy favours the outcome that is tendered last, as outcomes that would have been selected in more than one ranking are purchased from the earlier tender budget.

While this policy option appears to be only slightly less cost effective than a multiple-outcome tender on the basis of on-site costs, there may be significant transaction costs associated with running three consecutive tenders. Once off administrative costs such as advertising and probity may be duplicated. Moreover, site visits and communications with landholders may be repeated for sites that are not selected in the first tender.

(3) Three simultaneous single outcome tenders

The simulation results showed that running three separate tenders was significantly less cost-effective than running one multiple-outcome tender. It was shown that running a multiple-outcome tender yielded an average 42 percent gain in EBS with a range of 12-100 percent in comparison to dividing the budget in three and running the three tenders separately.

In the simultaneous tender policy, each site is assigned to a tender with a probability of one third for each of 'terrestrial', 'river' and 'carbon'. Consequently the probability of a site being successful when randomly assigned to one of three separate tenders, given that it would be successful in a multiple-outcome tender is given by:

$$\Pr(S_{simultaneous} | S_{EBS}) = \frac{1}{3} \Pr(S_{Terrestrial} | S_{EBS}) + \frac{1}{3} \Pr(S_{River} | S_{EBS}) + \frac{1}{3} \Pr(S_{Carbon} | S_{EBS})$$

Suppose a site has a low bid per unit EBS which breaks down to a very low bid per unit river outcome and moderate to high bids per unit for the remaining outcomes. Unless the site is assigned to the tender for 'river' outcomes, it is unlikely to be selected in the simultaneous tender policy. As there is

dataset) in EBS from running a multiple tender over a river tender will be strictly larger than is gained from running a multiple tender over a terrestrial tender.

only a chance of one third, that the site is assigned to the river tender, the site is more likely to be rejected.

In this policy, a site with a low bid per unit EBS may not be selected for several reasons. Firstly the site may be allocated to a tender for an outcome where the site scores lowly. In particular, if a high EBS site is allocated to a tender for 'carbon' or 'river' and does not have a carbon or river score respectively, it is ineligible for selection. Secondly, the site may perform moderately high across all outcomes, however not high enough to be selected on the basis of any single outcome.

In reality, while landholders may not fully understand the relative benefits resulting from their actions across environmental outcomes, they may have some information that allows them to self-select into a tender that would maximise their expected pay-off. Factoring some level of self selection into the allocation result would be likely to increase the cost-effectiveness of the simultaneous tender policy.

Policy Application

Currently most conservation tenders run in Australia focus on a single environmental outcome. The results of this simulation indicate that there is a potential for cost-effectiveness gains to be made from collaborating to implement multiple-outcome tenders.

More generally, this work indicates that cost-effectiveness gains can be made from factoring joint production into decisions, not just in tenders. For example rules surrounding the 'additionally' of carbon can have the consequence of eliminating suppliers who can jointly produce carbon alongside other environmental goods. This precludes government and offset buyers teaming up to purchase carbon and other environmental goods together and sharing the cost savings. The elimination of these low cost suppliers may result in a higher carbon price and a lower uptake of environmental plantings than is socially optimal.

While increased cost-effectiveness may be a driver for implementing multiple-outcome tenders, there are also barriers to this approach. It is often the case that different sections of government have responsibility for different outcomes. To adopt a multiple-outcome approach, co-ordination between these different sections is required. This can be particularly difficult if the different sections of government have already identified priority geographic areas for works that don't overlap.

In cases where different agencies are responsible for procuring different outcomes, there is a risk to agencies participating in a multiple-outcome tender that little or none of their funds is spent on their desired outcome. This can occur when an outcome is more expensive than expected, or when an outcome is underweighted in the tender metric. As the relative costs of each outcome are unknown *a priori*, it is not possible to set the metrics weightings to ensure that a percentage of the budget is spent on a particular outcome.

While this paper focuses on a metric driven multiple-outcome tender, it would also be possible to run a multiple-outcome tender where the budget breakdown defines the quantity of each outcome purchased. For example, consider a multiple-outcome tender focussing on carbon and terrestrial biodiversity with agencies responsible for each outcome contributing half the budget each. The bids could be ranked twice – by cost per unit carbon and cost per unit terrestrial. Bids that would be accepted in each list, given the respective budget allocations are accepted. Bids that are listed in both lists could be cost-shared (half from each agency). The money each agency saves from the cost-sharing can be added to the respective agency budgets and more bids can be selected. This process is repeated until the additional budget yields no bids chosen by both agencies. This method is guaranteed to result in a unit cost to each agency that is no worse than if they implemented a single

outcome tender¹⁴. However, requiring that the percentage of the budget focussed on each outcome adds an additional constraint to the system reducing the flexibility of the agency(s) to trade-off between outcomes.

Transaction costs should also be considered when assessing tender options. Further to joint production benefits, multiple-outcome tenders may result in reductions in fixed costs (for example, administration and advertising) from economies of scale could be made by running one multiple-outcome tender instead of running multiple tenders separately. On the other hand, if running a multiple-outcome tenders results in significantly higher transaction costs (for example more costly site assessments from assessing multiple-outcomes instead of one) cost-effectiveness gains can be eroded. A multiple-outcome tender should only be implemented if the additional benefits outweigh the increased transaction costs.

Conclusion, limitations and further work

This work has indicated that there may be cost effectiveness gains from considering multiple-outcomes together. However multiple-outcome tenders require agencies to have information on their relative preferences for different outcomes. This information is often absent, although it should be noted that these decisions are already being made implicitly when funds are allocated to divisions in charge of different outcomes. Further work in determining this demand side information is required to inform multiple-outcome tenders (as well as better funding decisions).

This work has also demonstrated that cost-effectiveness gains from running a multiple outcome tender over the three policy alternatives can vary significantly across draws from the same underlying distributions. This shows that the exact gains from running a multiple outcome tender can vary considerably depending on the specific combinations of bids and environmental benefits received in a tender. This suggests that empirical work on cost effectiveness based on a single instance of bid and environmental benefit data should be interpreted with caution.

A limitation of this model is that bidder behaviour is likely to change based on the type of tender the government agency is running. Using the language of game theory, bidder behaviour can be thought of as a two stage sequential game where the government agency moves first, choosing the type of tender from a range of possible options (eg, 'native vegetation', 'river', 'carbon', and 'multiple'). The landholder will move second choosing the suite of management actions they will undertake and their bid price. The landholders move is dependent on the move made by the agency.

Because this synthetic data was generated using information from an empirical multiple-outcome tender, bids are expected to have demonstrated more joint production than if the data came from single outcome tenders.

In addition to the incentives faced by landholders to focus on multiple-outcomes rather than individual outcomes, the eligibility requirements of the WG EcoTender disallowed some single outcome activities (for example non-native plantings to sequester carbon). Because the synthetic data in this model is modelled from the empirical data from the West Gippsland EcoTender demonstration, many opportunities for separately produced outcomes were excluded. The lack of separately produced outcomes in this dataset may lead to the benefits of multiple-outcome tenders being understated. This work could be extended by including data from single outcome tenders.

Another limitation in this work relates to the simultaneous tender policy. It was assumed in this model that landholder's selection into a tender was random. In reality it would be expected that landholders

¹⁴ The unit cost to both agencies will be the same as a single outcome tender if and only if there are no bids that are selected on both agencies rankings.

self-select into the tender that maximises their expected pay-off. While it is realistic to anticipate that landholders may not have enough information to always make this decision optimally, assuming random selection is likely to understate the cost-effectiveness of this mechanism. This model could be improved upon by including developing a more realistic method for assigning landholders to the separate tenders.

Finally, two areas for further work arise from the discussion in the policy section. Firstly there is an opportunity for an investigation on transaction costs and how they affect the cost-effectiveness of various tender options. Secondly the relative cost-effectiveness of a 'cost-sharing' multiple-outcome tender could be investigated.

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Appendix 1 - Simulation Results

Table 1 Simulation results for running a multiple-outcome tender over a single outcome tender

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Tender	Mean native vegetation	Mean river	Mean carbon	Mean EBS	Range native vegetation	Range river	Range carbon	Range EBS	Mean percentage increase EBS (multiple over alternative)	Range percentage increase EBS (multiple over alternative)
Multiple-outcome tender	86534	40522	46704	173760	57326-123633	19814-75853	27766-69353	116109-252330	N/A	N/A
Native vegetation tender	91114	28066	36277	155455	61304 -128971	8621-53688	17797-56327	103805-227474	12%	3%-32%
River tender	29802	47868	16344	94014	10959-53603	27204-81980	4530-30557	49574-152677	88%	39%-206%
Carbon tender	49888	21326	51625	123505	22409-84752	6016-46563	30182-74909	73472-197648	42%	17%-97%

Table 2 Simulation results for running a multiple-outcome tender over three consecutive tenders

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Tender	Mean native vegetation	Mean river	Mean carbon	Mean EBS	Range native vegetation	Range river	Range carbon	Range EBS	Mean percentage increase EBS	Range percentage increase EBS
									(multiple over alternative)	(multiple over alternative)
Multiple-outcome tender	86534	40522	46704	173760	57326-123633	19814-75853	27766-69353	116109-252330	N/A	N/A
consecutive tender (native vegetation, river, carbon)	82532	39925	46887	170066	55154-119309	19892-69226	29081-71866	113857-248178	2%	0%-7%
consecutive tender (carbon, river, native vegetation)	85221	39938	45083	170905	57939-124475	19844-70216	27291-67784	113271-248108	2%	0%-6%

Table 3 Simulation results for running a multiple-outcome tender over three concurrent single outcome tenders

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Tender	Mean native vegetation	Mean river	Mean carbon	Mean EBS	Range native vegetation	Range river	Range carbon	Range EBS	Mean percentage increase EBS	Range percentage increase EBS
									(multiple over alternative)	(multiple over alternative)
Multiple-outcome Tender	86534	40522	46704	173760	57326-123633	19814-75853	27766-69353	116109-252330	N/A	N/A
Separate Tenders	56365	32126	34257	123359	27191-93218	13641-59945	16375-58422	65261-209917	42%	12%-100%

- 1) The mean native vegetation score obtained over the simulation data.
- 2) The mean native river score obtained over the simulation data.
- 3) The mean native carbon score obtained over the simulation data.
- 4) The mean native Environmental Benefit Score (EBS) obtained over the simulation data where the EBS is the sum of the scores for native vegetation, river and carbon.
- 5) The lowest simulation value for native vegetation to the highest simulation value for native vegetation.
- 6) The lowest simulation value for river to the highest simulation value for river.
- 7) The lowest simulation value for carbon to the highest simulation value for carbon.
- 8) The lowest simulation value for EBS to the highest simulation value for EBS.
- 9) Percentage increase in mean EBS (4) using from a multiple-outcome tender over the alternative.
- 10) The lowest to highest values obtained in the simulation for the percentage increase in EBS (4) from using a multiple-outcome tender over the alternative.