CONSERVATION AUCTIONS:
WHAT IS THE OPTIMAL BID RANKING SYSTEM?

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Abstract

This paper analyses how the performance of conservation auctions can be influenced by the calculation of the scoring index and the type of information that is transferred to bidders. Economic efficiency can be enhanced if farmers are informed on the environmental score of their land. On the other hand, the cost-effectiveness can be increased by withholding information on farmers' environmental score. Both economic efficiency and cost-effectiveness can be enhanced if the environmental score is known to farmers, but they are not fully informed about the calculation of the overall scoring index.

Key words: Auction theory; conservation programme

1. Introduction

Auctions have been increasingly used for allocating conservation contracts to farmers. The attention paid to conservation auctions is based on the widely held belief that competitive bidding enhances the cost-effectiveness of conservation programmes. The most prominent example of auctioning agri-environmental contracts is the Conservation Reserve Program in the United States (REICHELDERFER and BOGGESS, 1988). Other examples are the Australian BushTender Trial and EcoTender Trial, as well as various European pilot projects (STONEHAM *et al*., 2003; LATACZ-LOHMANN and SCHILIZZI, 2005; GROTH, 2006).

LATACZ-LOHMANN and VAN DER HAMSVOORT (1997; 1998) analysed the cost-effectiveness of a multi-unit auction for land conservation contracts. They demonstrated that the cost-revelation mechanism of a bidding process has the advantage of reducing information rents in agri-environmental schemes. They also showed that the rent-reducing potential of conservation auctions depends significantly on bidders' expectations of the range of maximum acceptable bid levels.

The current paper deals with the question of how bidders' expectations can be influenced by the set up of a conservation auction. The objective is to analyse how withholding of information about the environmental score may affect the cost-effectiveness and economic efficiency of conservation contracts. In this context we investigate how the selection of the scoring system may influence farmers' bidding behaviour.

The results of a laboratory experiment undertaken by CASON et al. (2003) suggest that government expenses can be saved if some information on the environmental scoring is withheld from bidders. In order to analyse the role of information within a bidding approach, we extend the auction model introduced by LATACZ-LOHMANN and VAN DER HAMSVOORT (1997; 1998). We consider a bid ranking system which also includes the environmental benefit of programme participation. The analysis is restricted to a one-shot auction and does thereby not capture the potential influence of information on the learning effect within repeated auctions (HAILU and SCHILIZZI, 2004).

The remainder of the article is structured as follows: after presenting the modelling framework, section three analyses the performance of an auction in which bids are ranked merely based on farmers' proposed compensation payments. Section four considers an auction in which environmental programme benefits are included in the bid ranking system and in which farmers are fully informed about their environmental score. Section five analyses the performance of a conservation auction if information on the environmental score

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are withheld. Section six considers full information on site-specific environmental scores, but assumes that farmers are not informed on how environmental scores will be weighed in comparison to proposed payments. To provide a numerical example of how withholding of information in combination with alternative scoring systems may affect auction performance, section seven applies the modelling framework to a hypothetical conservation programme. The article ends with a discussion of the predominant findings.

2. Model

Consider a government designing a voluntary conservation programme. Costs involved with participating in the conservation contract are heterogeneous since they depend on natural conditions and farmers' management skills. We assume that site-specific conservation costs can be estimated by farmers, but not by the government. The government only understands the range and distribution of those costs.

If the government allocates conservation contracts based on a fixed price scheme, farmers with low conservation costs can realise an information rent. Given the heterogeneity of conservation costs and farmers informational advantage over the government, auctioning of conservation contracts may lead to a reduction of the programme outlay. We consider that the government implements a discriminatory sealed bid auction in which each farmer can submit a bid (*b*), a proposed per acre compensation payment for land subscribed to the conservation programme. The environmental programme benefit depends on location-specific factors and does thereby vary across fields plots. Let the per acre environmental benefit (*z*) of programme participation be equally distributed in the range $[\underline{z}, \bar{z}]$.

The government pursues two different goals. On the one hand, it aims to maximise the net environmental benefit (NEB), defined as the difference between environmental benefits and opportunity costs involved with programme participation. On the other hand, it tries to achieve this goal with least public expenses. An important policy variable to be decided upon is to select a suitable scoring system by which bids are ranked. The benchmark scenario (auction type I) considers that the scoring index (*I*) is identical to the financial bid (*b*), while subsequent auction types deal with bid scoring indices which incorporate both the proposed compensation payment (*b*) and the environmental benefit (*z*). Since we consider that only the government has information on site specific environmental benefits, a further policy variable is to decide to what extent this information should be spread to farmers.

3. Benchmark auction

As a benchmark, we consider that the environmental benefit *z* has no influence on the way how bids are scored. The bid index (*I*) is merely determined by the financial bid (*I*=*b*). Farmers have expectations on the distribution of the index value $\tilde{I}$, above no bids will be accepted. We assume symmetry so that all bidders have the same expectations on the index cap. Consider that farmers are informed about the calculation of the scoring index, but not about $\tilde{I}$. The critical index $\tilde{I}$ will be selected by the government once the scoring rule has been determined and all bids have been received. We consider that the expected critical scoring index is uniformly distributed in the range $[\underline{I}, \bar{I}]$, where $\bar{I}$ and $\underline{I}$ represent the maximum and minimum expected index cap, respectively. The distribution function can then be written as:

(1) $$F(I)=\begin{cases} 0 & if \quad I < \underline{I} \\ \dfrac{I-\underline{I}}{\bar{I}-\underline{I}} & if \quad \underline{I} \leq I \leq \bar{I} \\ 1 & if \quad I > \bar{I} \end{cases}$$

If the bid is accepted ($I \leq \tilde{I}$), farmers' net pay-off (π) per acre is equal to

(2) $$\pi = b - c$$

Since we neglect the reservation utility, farmers will only participate in the auction if the net pay-off exceeds zero. The probability that a farmer's bid will be accepted is

(3) $$P\left(I \leq \tilde{I}\right) = \int_{I}^{\bar{I}} f\left(\tilde{I}\right) d\tilde{I} = 1 - F(I)$$

where $f(\tilde{I})$ denotes the density functions of the expected index cap. Based on the bid acceptance probability of equation (3), the *expected* net pay-off becomes:

(4) $$E[\pi] = (1 - F(I))(b - c)$$

In the benchmark scenario (*I=b*), the distribution of the bid cap β, above no bids will be accepted, is identical to that of $\tilde{I}$, hence $h(\beta) = f(\tilde{I})$ and $H(b) = F(I)$. Let the expected bid cap be in the range $[\underline{\beta}, \bar{\beta}]$. The government may determine the maximum bid cap $\bar{\beta}$ by announcing a reservation price, above no bids will be accepted. The minimum expected bid cap $\underline{\beta}$ is unlikely to be smaller than the minimal costs ($\underline{\beta} \geq \underline{c}$), since farmers will have some idea about the range of conservation costs. In order to analyse the potential efficiency and cost-effectiveness of an auction approach, we assume $\underline{\beta} = \underline{c}$. By maximising equation (4) with respect to *b*, we can derive the optimal bid of a risk-neutral farmer. Applying the first-order conditions of a local maximum ($\partial E(\pi)/\partial b = 0$), we obtain

(5) $$b = \max\left\{\frac{(1 - H(b))}{h(b)} + c, \underline{\beta}\right\}$$

Note that the minimum bid cap will have no influence on farmers' bids, given that $\underline{\beta} = \underline{c}$. Making use of equation (1) and (5), the optimal bid therefore becomes:

(6) $$b = \frac{(\bar{\beta} + c)}{2}$$

In order to minimise public expenses, the government should choose a reservation price equal to the ex-post chosen critical bid cap ($\bar{\beta} = \bar{I} = \tilde{I}$). The NEB maximising reservation price for the benchmark auction (auction I*)* should be equal to the expected environmental benefit ($\bar{\beta} = E[z]$).[2] The optimal bid of a risk neutral farmer thereby becomes:

(7) $$b_I = \frac{E[z] + c}{2}$$

We conclude that auction I has the potential to reduce farmers' information rent by 50 %, when compared to a fixed payment ($\bar{\beta} = E[z]$). The bid curve of the benchmark scenario is depicted in Figure 1 and 2.

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[2] Note that this would be also the welfare maximising reservation price, if transaction costs and deadweight losses of raising taxes were neglected. However, if transaction and administration costs associated with tax raising are accounted for, the welfare maximising reservation price should be lower than the expected environmental value ($\bar{\beta} < E[z]$).

4. Including the environmental score in the bid ranking system

Let us now analyse the performance of an auction if the bid scoring index will be determined by both the financial bid and the environmental contribution (z) of programme participation. Farmers get to know the range of environmental scores $[\underline{z}, \bar{z}]$. We also consider that the government informs them on the environmental performance of their land.

Let specific values of z be unrelated to the level of conservation costs. The reason for this assumption is that, if z could be expressed as a function of costs involved with participating in the conservation programme, a price-discriminatory payment scheme would be more efficient and cost-effective than a bidding process.

To ensure that higher environmental values increase the chances of bid acceptance, we consider the following scoring index (auction II):

(8) $$I = b - z$$

Including the environmental score in the bid ranking system will have an effect on farmers' bidding behaviour, since their expectations on the critical bid cap are now dependent on the environmental score of their land. Maintaining the assumption that the index cap follows a uniform density function, we can derive the distribution of the expected bid cap by making use of equations (1) and (8):

(9) $$H(b) = \begin{cases} 0 & if \quad b < \underline{I} + z \\ \dfrac{b - z - \underline{I}}{\bar{I} - \underline{I}} & if \quad \underline{I} + z \le b \le \bar{I} + z \\ 1 & if \quad b > \bar{I} + z \end{cases}$$

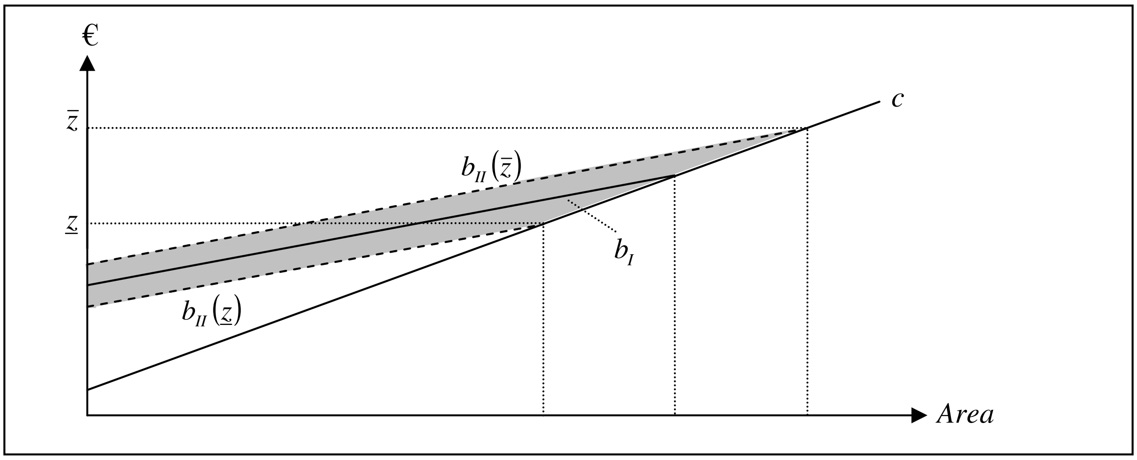
We consider that expectations on the minimum bid cap are the same as those of the benchmark auction, hence $\underline{\beta} = \underline{c}$. However, the government may announce a different reservation price to influence farmers' expectations on $\overline{\beta}$. The reservation price maximising the NEB should be equal to the maximal environmental benefit ($\overline{\beta} = \bar{z}$). This would ensure a maximum scoring index of zero ($\bar{I} = \tilde{I} = 0$), implying that all (and only) farmers' bids are *accepted*, whose per acre conservation costs do not exceed environmental programme benefits. Note that $\bar{I} = 0$ also ensures that all (and only) farmers will *participate* in the auction whose costs do not exceed their environmental score ($c \le z$). This is in contrast to auction I, where all (and only) farmers with $c \le E[z]$ would submit a bid. In auction I some bids (with $c < E[z]$) will be accepted although conservation costs may exceed environmental benefits, while others (with $c > E[z]$) will not participate in the auction, even if $z > c$. We conclude that auction II leads to a higher NEB than that of auction I.

Let us now compare the government expenses linked to auctions I and II. Making use of $\overline{\beta} = \bar{z}$, $\underline{\beta} = \underline{c}$ and equation (5) and (9), we derive the optimal bid of a risk neutral farmer for auction II:

(10) $$b_{II} = \frac{z + c}{2}$$

The range of bids for different values of z is depicted as the grey area in Figure 1. The upper limit of submitted bids is determined by the maximal environmental score ($b_{II}(\bar{z})$), whereas $\underline{z}$ determines the lower limit of risk neutral farmers' bids ($b_{II}(\bar{z})$). For farmers with low conservation costs ($c \le \underline{z}$), the expected bid ($E[b(c)]$) is equal to that resulting from the benchmark auction (equation 7). Figure 1 illustrates that, if we consider a uniform density function for conservation costs (linear *c*-curve), the total government expenses of auction type II will be larger than the expected expenses of auction I. However, since total expenses depend crucially on the distribution of conservation costs, government expenses do not necessarily increase when moving from auction I to II.

Figure 1: Bids of auction type I and II



5. Withholding information on the environmental score

We will now analyse the economic performance of a conservation auction if the government withholds information on site-specific environmental benefits (auction III). We consider that bidders are informed about the calculation of the scoring index, which is given by equation (8). Farmers are also informed about the range and distribution of environmental benefits. The distribution function of z is given by:

$$(11)\qquad G(z)=\begin{cases} 0 & if \quad z<\underline{z} \\ \dfrac{z-\underline{z}}{\bar{z}-\underline{z}} & if \quad \underline{z}\le z\le \bar{z} \\ 1 & if \quad z>\bar{z} \end{cases}$$

From the perspective of farmers, both the critical index value $\tilde{I}$, above no bids will be accepted and the environmental score z are uncertain. The bid cap can therefore be interpreted as the sum of two random variables ($\beta=\tilde{I}+z$). The maximum bid cap ($\bar{\beta}=\bar{I}+\bar{z}$) will be announced as reservation price, while the minimum bid cap is assumed to be at the lowest cost level ($\underline{\beta}=\underline{I}+\underline{z}=\underline{c}$). If we consider $\bar{I}-\underline{I}\ge\bar{z}-\underline{z}$, the distribution function of the bid cap is:[3]

$$(12)\qquad H(b)=\begin{cases} 0 & if \quad b<\underline{I}+\underline{z} \\ \dfrac{(b-\underline{I}-\underline{z})^2}{2(\bar{I}-\underline{I})(\bar{z}-\underline{z})} & if \quad \underline{I}+\underline{z}\le b\le \underline{I}+\bar{z} \\ \dfrac{2(b-\underline{I})-(\bar{z}+\underline{z})}{2(\bar{I}-\underline{I})} & if \quad \underline{I}+\bar{z}\le b\le \bar{I}+\gamma\underline{z} \\ 1-\dfrac{(\bar{I}+\bar{z}-b)^2}{2(\bar{I}-\underline{I})(\bar{z}-\underline{z})} & if \quad \bar{I}+\underline{z}\le b\le \bar{I}+\bar{z} \\ 1 & if \quad b>\bar{I}+\bar{z} \end{cases}$$

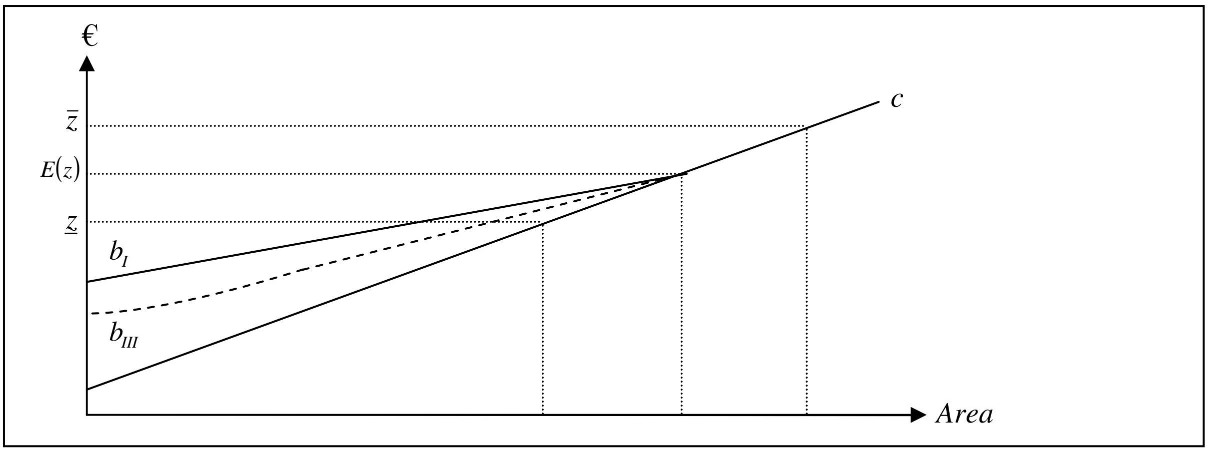
[3] The analysis would lead to the same result if we had chosen the other case that $\bar{I}-\underline{I}\le\bar{z}-\underline{z}$. We consider only one case to avoid an extensive use of algebra.

By inserting equation (12) into (5), we obtain the optimal bid of a risk neutral farmer:

$$
(13) \qquad b_{III} = \begin{cases} \dfrac{2\left(\underline{I}+\underline{z}\right)+c+\sqrt{\left(\underline{z}-c\right)^2+\underline{I}\left(\underline{I}+2\underline{z}-2c\right)+6\left(\bar{I}-\underline{I}\right)\left(\bar{z}-\underline{z}\right)}}{3} & \text{if} \quad \underline{I}+\underline{z} \le b \le \underline{I}+\bar{z} \\ \dfrac{2\bar{I}+\left(\bar{z}+\underline{z}\right)+2c}{4} & \text{if} \quad \underline{I}+\bar{z} \le b \le \bar{I}+\underline{z} \\ \dfrac{\bar{I}+\bar{z}+2c}{3} & \text{if} \quad \bar{I}+\underline{z} \le b \le \bar{I}+\bar{z} \end{cases}
$$

Analogously to auction I, the maximal NEB would be reached if $\bar{\beta} = E[z]$. For this case, equation (13) takes a smaller value than equation (7). We conclude that auction III will unambiguously reduce the programme outlay when compared with that of auction I (Figure 2). The underlying reason why withholding information on the environmental score (z) will reduce the programme outlay is that the sum of random variables will lead to a more favourable bid cap distribution function. In the context of sequential auctions, withholding of information on the environmental score may also reduce farmers' ability to estimate the bid cap of previous auctions and thereby hinder "learning" among bidders.

Figure 2: Bid curve of auction type I and III



A disadvantage of withholding information (auction III) is that it reduces the NEB level when compared with auction II. The question of whether auction III is preferable to II therefore depends on the governments' objective function, of how public expenses are weighed against NEB losses. Intuitively, we can derive from Figure I that NEB gains of auction II will be higher the higher the variation of environmental benefits (the larger the difference between $\bar{z}$ and $\underline{z}$). This implies that withholding of information on the environmental score should be only considered if $\bar{z} - \underline{z}$ is relatively small.

6. Uncertain weighing of the environmental score

The previous section has demonstrated that concealing information on the environmental score of farmland will lower programme outlays, but also reduce the NEB. This section will deal with an auction set-up (auction IV), which may reduce government expenses without necessarily reducing the NEB.

Consider that the government introduces the following scoring index:

$$(14) \qquad I = b - \gamma z$$

where γ denotes a weighing factor for the environmental benefit. Assume that farmers are informed about z and the range of the weighing factor $\lfloor \underline{\gamma}, \bar{\gamma} \rfloor$, but not about the value of the weighing factor. The weighing factor will be chosen ex-post by the government and becomes thereby a stochastic variable from farmers' perspective. Let the expected distribution of γ be given as follows:

$$(15) \quad V(\gamma) = \begin{cases} 0 & if \quad \gamma < \underline{\gamma} \\ \dfrac{\gamma - \underline{\gamma}}{\bar{\gamma} - \underline{\gamma}} & if \quad \underline{\gamma} \le \gamma \le \bar{\gamma} \\ 1 & if \quad \gamma > \bar{\gamma} \end{cases}$$

The index caps are subsequently given by $\bar{I} = \bar{\beta} - \bar{\gamma}z$ and $\underline{I} = \underline{\beta} - \underline{\gamma}z$. For the case that $\bar{I} - \underline{I} \ge z(\bar{\gamma} - \underline{\gamma})$, the distribution of the expected bid cap can be written as:[4]

$$(16) \quad H(b) = \begin{cases} 0 & if \quad b < \underline{I} + \underline{\gamma}z \\ \dfrac{(b - \underline{I} - \underline{\gamma}z)^2}{2(\bar{I} - \underline{I})(\bar{\gamma} - \underline{\gamma})z} & if \quad \underline{I} + \underline{\gamma}z \le b \le \underline{I} + \bar{\gamma}z \\ \dfrac{2b - (\bar{\gamma} - \underline{\gamma})z - 2(\underline{I} + \underline{\gamma}z)}{2(\bar{I} - \underline{I})} & if \quad \underline{I} + \bar{\gamma}z \le b \le \bar{I} + \underline{\gamma}z \\ 1 - \dfrac{(\bar{I} + \bar{\gamma}z - b)^2}{2(\bar{I} - \underline{I})(\bar{\gamma} - \underline{\gamma})z} & if \quad \bar{I} + \underline{\gamma}z \le b \le \bar{I} + \bar{\gamma}z \\ 1 & if \quad b > \bar{I} + \bar{\gamma}z \end{cases}$$

Making use of (1), (5) and (16), the optimal bid of a risk neutral bidder becomes:

$$(17) \quad b = \begin{cases} \dfrac{2\underline{\gamma}z + c + 2\underline{I} + \sqrt{(\underline{\gamma}z - c)^2 + \underline{I}(2\underline{\gamma}z - 2c + \underline{I}) + 6z(\bar{I} - \underline{I})(\bar{\gamma} - \underline{\gamma})}}{3} & if \quad \underline{I} + \underline{\gamma}z \le b \le \underline{I} + \bar{\gamma}z \\ \dfrac{2\bar{I} + z(\bar{\gamma} + \underline{\gamma}) + 2c}{4} & if \quad \underline{I} + \bar{\gamma}z \le b \le \bar{I} + \underline{\gamma}z \\ \dfrac{\bar{I} + \bar{\gamma}z + 2c}{3} & if \quad \bar{I} + \underline{\gamma}z \le b \le \bar{I} + \bar{\gamma}z \end{cases}$$

Maximum welfare for auction IV is reached if $\bar{\beta} = \bar{z}$, hence $\bar{I} = \bar{z}(1 - \bar{\gamma})$. The optimal bid thereby becomes

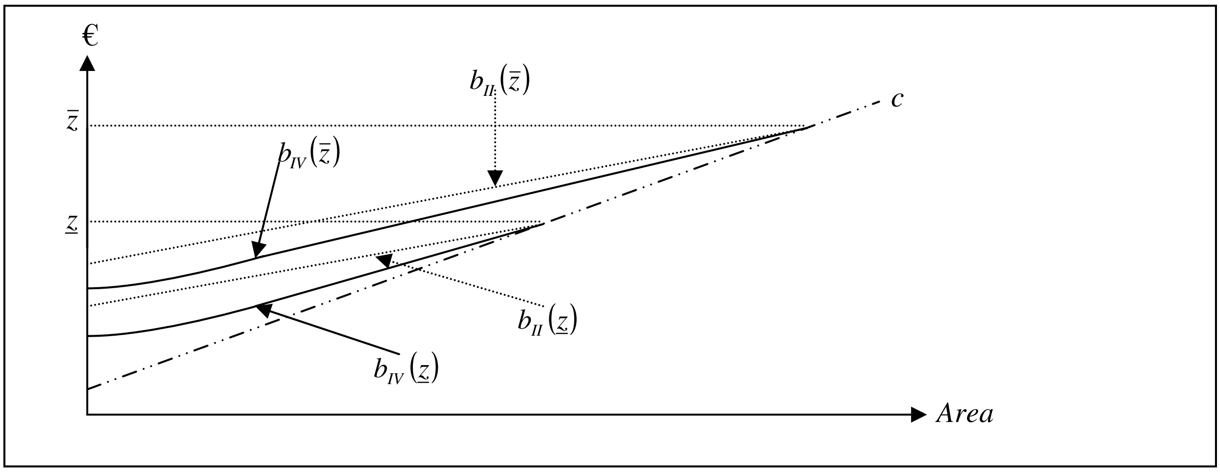
$$(18) \quad b_{IV} = \begin{cases} \dfrac{c + 2\underline{\beta} + \sqrt{c^2 + \underline{\beta}(-2c + \underline{\beta}) - 6z\underline{\beta}}}{3} & if \quad \underline{I} \le b \le \underline{I} + z \\ \dfrac{z + 2c}{4} & if \quad \underline{I} + z \le b \le \bar{I} \\ \dfrac{z + 2c}{3} & if \quad \bar{I} \le b \le \bar{I} + z \end{cases}$$

Note that auction IV leads to the same NEB as auction II, since farmers will only bid if $z \ge c$. Moreover, a comparison with equation (10) demonstrates that auction IV is more cost-effective than auction II ($b_{IV} < b_{II}$). Figure 3 illustrates that the optimal bid of auction IV ranges between $b_{IV}(\bar{z})$ and $b_{IV}(\underline{z})$. The expected bid of auction IV is therefore unambiguously lower than that of auction II. We summarise that farmers should be given information on the

[4] The analysis would lead to the same result if we had chosen the other case that $\bar{I} - \underline{I} \le z(\bar{\gamma} - \underline{\gamma})$. We consider only one case to avoid an extensive use of algebra.

environmental score to ensure that all (and only) efficient bid will be submitted. On the other hand, information on the calculation of the scoring index should be withheld to influence farmers' expectations on the bid cap and thereby to reduce the programme outlay.

Figure 3: Bids of auction type II and IV



7. Simulation

This section presents a numerical simulation of how the bid scoring system affects the outlay and NEB of a conservation auction. We consider 100 equally distributed acres of land with conservation costs ranging between \$50 and \$300 per acre. We assume further that the environmental benefit of programme participation is uniformly distributed between \$150 and \$300 per acre and not correlated to the conservation costs. Programme outlays based on the calculation of optimal bids for risk neutral farmers have been calculated for auctions I-IV. Results are summarized in table 1.

If welfare maximisation is the primary goal, with a fixed payment system the government would need to pay \$15,750 in order to reach the NEB of \$6,152. With auction I, public expenses could be reduced by almost 20%. Auction type II may enhance the programme outlay by 4%, but at the same time increase the NEB by 6%. A modified version of auction III ($I = b - 0.54z$) would reach the same NEB level as in the benchmark scenario, but reduce the programme outlay by 7.2%. The auction set-up IV ($I = b - \gamma z$ where $\bar{\gamma} = 1.35$, $\underline{\gamma} = 1.05$) would reduce public expenses by 1.4% and increase the NEB by 6%.

Table 1: **Auction performance for different scoring systems**

	Total expenses	Total expenses	E(NEB)	E(NEB)
Fixed Payment	15750	124,3%	6152	100%
Auction I	12674	100,0%	6152	100%
Auction II	13186	104,0%	6523	106%
Auction III	11765	92,8%	6152	100%
Auction IV	12503	98,6%	6523	106%

8. Discussion

The article has analysed the influence of the scoring system on the cost-effectiveness and efficiency of a conservation auction. In this context we have analysed how withholding of information on the environmental score affects auction performance. If the government has information on site-specific environmental benefits of programme participation, an environmental score should be incorporated in the bid scoring system, because it may reduce programme outlays and/or increase the NEB. The NEB will be enhanced if the government informs farmers on the bid scoring system and their environmental score, since it can be ensured that only land will participate in the programme on which environmental benefits exceed conservation costs. On the other hand, concealing information on farmers' environmental score may affect farmers' expected distribution function and may thereby reduce programme outlays. Both cost-effectiveness of public expenses and the NEB can be enhanced if farmers know their environmental score, but are not fully being informed about the calculation of the scoring index.

The simulation has further demonstrated that the information rent can be reduced even more, if the bid cap is determined by the product of random variables. The analysis considered a single environmental score. If the environmental benefit is divided into several score components, optimal bids can be reduced further, provided that environmental scores are not known by farmers. A question left for future empirical research is to assess the extent to which farmers' bids can be influenced by the selection of the scoring system.

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