Cost-effectiveness of alternative payment and auction designs for biodiversity conservation in agriculture

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Abstract: Empirical evidence shows that biodiversity conservation policies implemented in agriculture sector in many OECD countries have not been environmentally effective nor cost-effective. There are several new policy mechanisms available to improve both environmental effectiveness and the cost-effectiveness, including spatially differentiated payments and conservation auctions. In this paper a theoretical framework is developed for describing farmers' participation in government payment programme for enhancing semi-natural wildlife habitats on farmland. Payment types analysed include uniform payment, three types of conservation auctions with environmental targeting, uniform payment with environmental targeting and two types of differentiated payments with environmental targeting. Quantitative results show that uniform payment performs less efficiently than other payment types, and that auctions with environmental targeting are the most cost-effective option from analysed payment types. If farmers have knowledge of the environmental value of their offer, the cost-effectiveness of auction is reduced because farmers tend to increase their bids to benefit from this information rent (overcompensating income forgone). Adding environmental targeting to the uniform payment policy greatly improves the cost-effectiveness of uniform payment.

Key words: conservation auction, uniform payment, differentiated payment, policy-related transaction costs, targeting

JEL codes: Q57, Q58

1. Introduction

Many OECD countries offer payments to farmers to promote farmland biodiversity conservation beyond conservation efforts required by environmental regulations or environmental cross-compliance. Many of these voluntary payment programmes offer a single, fixed payment for compliance with a predetermined set of biodiversity enhancing practices. The obvious problem with such an approach is that the heterogeneity in farmers' opportunity costs and/or the supplied biodiversity benefits is not taken into account in policy design and implementation, which reduces the cost-effectiveness of these payments. Indeed, empirical evidence shows that many of them have failed to achieve stated biodiversity objectives cost-effectively (Kleijn *et al*, 2001; 2004).

Hence, there is a need to identify more cost-effective ways to implement these policies. To this end, for example spatially differentiated payments and conservation auctions have been proposed to improve the benefit-cost ratio of environmental efforts and the budgetary cost-effectiveness of government spending on biodiversity conservation.

Given the spatial differences in costs and benefits, the problem with the uniform payment is that spatial heterogeneity neither in costs nor benefits is reflected in policy design and implementation. As a result, the cost-effectiveness (amount of conservation benefit for a certain amount of conservation budget) of uniform payments is reduced. Hence, due to spatial variation in costs and benefits the cost-effectiveness of biodiversity conservation requires spatially differentiated practices and payments. Wätzold and Drechsler (2005) develop a conceptual framework for assessing the cost-effectiveness losses of uniform payments relative to differentiated payments under different types of ecological benefit functions and cost functions. Their results show that the cost-effectiveness of uniform payments relative to differentiated payments varies significantly depending on the spatial variation of the costs and benefits (from 0% to almost 100% of the cost-effectiveness of differentiated payments). Overall their results indicate that the cost-effectiveness of uniform payments may be low.

Auctions and competitive bidding have been recently applied to environmental protection and biodiversity conservation in agriculture (Latacz-Lohmann and Hamsvoort 1997, Stoneham *et al.*, 2003, Vukina *et al.*, 2006). The basic idea in conservation auctions is that farmers bid competitively for a limited number of environmental conservation contracts. When making a bid a farmer faces a trade-off between net payoffs and acceptance probability so that a higher bid increases the net payoff but reduces the probability of getting a bid accepted. Thus, competitive bidding can push farmers to reveal – at least to some extent – their compliance costs. As a result competitive bidding could improve the budgetary cost-effectiveness of biodiversity conservation as farmers' information rents (i.e. the difference between payment level and farmer's compliance cost) are reduced. The primary reasons for implementing conservation auctions are to improve both allocative efficiency (bids with the highest benefit-cost ratio are selected for the programme) and budgetary cost-effectiveness (maximising environmental benefits with a given fixed budget).

Cost-effectiveness gains from auctions relative to fixed uniform payment schemes have been reported in many studies. However, these cost-effectiveness gains vary significantly between different studies. In Victoria, Australia, the BushTender programme addressed biodiversity conservation through improved bush management. Stoneham *et al.* (2003) report the first-round cost-effectiveness gains from the auction to be 700% – that is, the biodiversity conservation auction provided seven times more biodiversity benefits than a fixed price scheme with the same budget. The transaction costs of the conservation auction were estimated to be 50-60% of the expenditure in the first round.

White and Burton (2005) report the cost-effectiveness gains from The World Wildlife Fund auction (Auction for Landscape Recovery) in Australia relative to a fixed price scheme to be between 207% and 315% in the first round and between 165% and 186% in the second round, depending on whether the fixed price scheme is input-based or output-based.

Connor *et al.* (2008) use data from the Catchment Care auction (in the Onkaparinga catchment in South Australia), and their results show that with the same budget a uniform fixed payment achieves 56% of the estimated environmental benefit obtained with auctions. They also show that the cost-effectiveness gains from auctions come through the Environmental Benefit Index (EBI) bid prioritisation rather than through the reduction of information rents.

The remaining of the paper is structured as follows. A theoretical framework is developed in Section 2 and then applied with Finnish data to illustrate environmental effectiveness and cost-effectiveness of the alternative payment and auction designs in Section 3. Section 4 concludes with policy recommendations.

2. Theoretical framework, data and empirical illustration of environmental effectiveness and cost-effectiveness of different payment approaches

In this section a simple theoretical framework is developed to simulate a farmer's decision to participate in a government agri-environmental payment programme, as well as, analyse government's selection of participants for a programme.

Uniform payment for biodiversity strip

The starting point of the theoretical framework is a heterogeneous land quality model with different soil types and land productivities. Following Lichtenberg (1989) and Lankoski and Ollikainen (2003), land quality differs over field parcels and it is ranked by a scalar measure, q, with the scale chosen so that minimal quality is zero and maximal quality is one, i.e. $0 \leq q \leq 1$. Crop yield per hectare, y, is a function of land quality q and fertilizer application rate

l, that is, $y = f(l;q)$. In the absence of government agri-environmental payment programme farmers' profits are defined as $\pi_0 = pf(l;q) - cl - K$, where p and c represent the respective prices of crop and fertilizer and K other cultivation costs per hectare. Agriculture can contribute to species diversity and abundance by providing semi-natural habitats. The focus here is on a special type of field margin, a biodiversity strip, which can locate between crop fields or between a crop field and the forest. Biodiversity strips are uncultivated, managed and covered by perennial grasses. Let *m(q)* denote the share of field parcel of quality q allocated to crop production that is retained as a biodiversity strip. Heterogeneous productivity of land implies that the establishment of biodiversity strip m results in differential opportunity costs in different field parcels. For the ease of implementation of this policy, the government can set a fixed width of biodiversity strip, $\widehat{m}$, (e.g. 5 or 10 meters) and uniform payment for biodiversity strip $\widehat{b}$. In this case farmers' profits are defined as, $\pi_1 = (1-\hat{m})\left[pf(l;q) - cl - K\right] + (\hat{b} - h)\hat{m} - \Omega$, where h denotes the annualised establishment and management costs of biodiversity strip and Ω denotes farmer's private transaction costs of participating in agri-environmental programme. A farmer will participate in this programme if his profits under the programme, π_1, are higher than his reservation profits, π_0.

Conservation auctions

In the case of conservation auction farmers competitively bid for a limited amount of agri-environmental contracts. Iho *et al*. (2014) and Glebe (2013) modified Latacz-Lohmann and van der Hamsvoort (1997) model and included environmental benefit index (EBI) in the bidding. Following Iho *et al*. (2014) farmers make expectations on bid/EBI ratios when they participate in bidding. EBI values are denoted by e and the upper limit of the bidder's expectation about the maximum expected bid/EBI is denoted by $\overline{\beta} = b''/e''$. By assumption bidders' expectations about this implicit bid cap are uniformly distributed in the range $\left[\underline{\beta},\ \overline{\beta}\right]$, where the lower bar represents the minimum (defined by $\underline{\beta} = b'/e'$) and upper bar the maximum expected bid cap. The probability that the bid is accepted is given by

$$P(\theta \le \overline{\beta}) = \int_{\theta}^{\overline{\beta}} f(\theta)d\theta = 1 - F(\theta) \qquad (1)$$

Where $\theta = \frac{b}{e}$, $f(\theta)$is density function and $F(\theta)$ distribution function. The expected net payoff of the risk-neutral farmer from bidding is a product of the revenue from winning the bid and the acceptance probability:

$$(\pi_1 + b - \pi_0)(1 - F(\theta)), \qquad (2)$$

where π_0 denotes the profit under no participation and π_1 is profit under the secured conservation contract. The farmer chooses the bid, *b*, and thereby the ratio *b*/EBI, according to:

$$b^* = \pi_0 - \pi_1 + \frac{(1 - F(\theta))e}{f(\theta)}, \qquad (3)$$

where *f(θ)* is the probability density function associated with $F(\theta)$ and *e* is the field parcel's EBI-value.

The difference $\pi_0 - \pi_1$ in equation (3) represents the income forgone and the establishment and management costs of biodiversity strip and farmer's private transaction costs of participation. The additional term, $(1 - F(\theta))e / f(\theta)$, is the information rent.

The optimal bid in the presence of EBI is determined by

$$b^* = \frac{\pi_0 - \pi_1 + e\overline{\beta}}{2}. \qquad (4)$$

Hence, when EBI matters for participation in an auction, the optimal bid depends on the conservation costs and the expected cap multiplied by the bidder's own EBI value ($e\overline{\beta} = e(b''/e'')$).The higher is the EBI of the submitted field parcel, the higher is the bid ($\frac{db}{de} = \frac{\overline{\beta}}{2} > 0$). Glebe (2013) also shows that farmer's optimal bid changes when he receives information about the environmental score of the field parcel and farmer's bid increases (decreases) when informed that his environmental score is greater (smaller) than average score.

When farmers expect similar environmental performances across farmers, the optimal bid is the same as under the auction without EBI, that is, $b^* = \frac{\pi_0 - \pi_1 + b''}{2}$, (see Iho *et al*., 2014). Hence, in this case farmers' expectations are formed only on the basis of income forgone for adopting environmental practice and not on bid/EBI ratios.

Government selection of participants under various payment types

Following Connor *et al*. (2008) the bid selection problem for the government in the case of *auction* employing EBI can be written as: $\max \sum_i L_i EBI_i$ subject to $\sum_i L_i\, b_i \leq AEB$, where L_i is a set of binary choice variables taking a value of 1 for each bid that is selected and 0 for those that are not selected, *AEB* denotes the agri-environmental budget.

In the case of *uniform payment policy* $\hat{b}$ without environmental targeting through EBI, all farmers for whom the sum of the income forgone, the establishment and management costs of biodiversity strips, and private transaction costs is less than the uniform payment level are assumed to participate in the programme. From this subpopulation of farmers the programme participants are selected as a random draw up to the same budget limit as in the auction, *AEB*.

In the case of *uniform payment* $\hat{b}$ *policy with EBI targeting*, all farmers for whom the sum of the income forgone, the establishment and management costs of biodiversity strips, and private transaction costs is less than the uniform payment level are assumed to participate in the programme. From this subpopulation of farmers the programme participants are selected from highest to lowest ratio of EBI/payment until budget limit *AEB* is reached.

In the case of *environmentally differentiated payment policy with EBI targeting*, payment level is differentiated between soil types to reflect differential biodiversity significance of soil types[1]. All farmers for whom the sum of the income forgone, the establishment and management costs of biodiversity strips, and private transaction costs is less than differentiated payment level for a given soil type are assumed to participate in the programme. From this subpopulation of farmers the programme participants are selected from highest to lowest ratio of EBI/payment until budget limit *AEB* is reached.

[1] See Biodiversity benefit index in Table 1.

In the case of *differentiated payment policy on the basis of compliance costs with EBI targeting*, payment level is differentiated between soil types to reflect differential income forgone of establishing biodiversity strip. All farmers for whom the sum of the income forgone, the establishment and management costs of biodiversity strips, and private transaction costs is less than differentiated payment level for a given soil type are assumed to participate in the programme. From this subpopulation of farmers the programme participants are selected from highest to lowest ratio of EBI/payment until budget limit *AEB* is reached.

Three types of auction design alternatives are analysed in the empirical section:

- *One-dimensional bid-scoring index auction*: farmers' expectations regarding bid cap are formed on the basis of compliance costs and it is assumed that farmers have identical beliefs regarding variation in compliance costs (variation by 20% around the mean).

- *Two-dimensional bid-scoring index auction*: farmers' expectations regarding bid cap are formed on the basis of the ratio of bid to EBI (with assumed variation by 20% around the mean).

- *Group specific one-dimensional bid-scoring index auction*: farmers' expectations regarding bid cap are formed on the basis of compliance costs and it is assumed that farmers in a certain group have identical beliefs regarding variation in compliance costs (variation by 20% around the mean). In group specific auction, assumed low compliance costs farmers (those from lowest productivity soil type, that is, sandy soils) form expectations on the basis of heterogeneity within their group and without observable heterogeneity of higher cost bidders in other soil types. This type of auction should increase competition within low cost bidders and reduce their information rents.

In addition to various payment types a theoretical cost-effectiveness benchmark is calculated in the empirical section. The cost-effectiveness (C-E) benchmark describes a theoretical situation where the Government (buyer of the environmental good or service) knows each participant's compliance cost and offers a payment that exactly compensates compliance costs. In this case farmers' information rents (difference between payment level and compliance costs) are zero. Farmers are selected to the programme on the basis of the ratio

EBI/payment from highest to lowest until the budget limit is reached. This C-E benchmark maximises budgetary cost-effectiveness.

3. Empirical application of the theoretical framework

Data

For a quantitative illustration of the theoretical framework Finnish data is employed. A 5-meter wide biodiversity strip on a field-forest border was selected as a biodiversity enhancing measure.

Following Miettinen et al. (2014), the biodiversity strip is sown with grass seed mixture (*Trifolium pratense, Phleum pratense, and Festuca pratensis*). Grass seed mixture costs EUR 77 per ha. In addition to seed costs also tilling and sowing costs, as well as, potential harvest value of dry hay are taken into account. Total establishment costs are EUR 288/ha and annual management and labour costs are EUR 39/ha and EUR 182/ha, respectively. Profit margin (total revenue including decoupled agricultural support payments and revenue from dry hay minus variable costs and labour costs) for establishment and management of biodiversity strip is EUR 234/ha.

Spring barley (*Hordeum vulgare*) is selected as a representative crop for this application as it is the most common crop covering about half of the field parcels under crop cultivation in Finland. The soil type under cultivation is assumed to be one of the three most common soil types; clay, sandy and organic soil. Clay and silt soils cover over half of the cropland area in Finland, organic about 14% and sandy soils 35% (Puustinen et al., 2010).

Per hectare crop yield is modelled as a function of nitrogen fertilizer application. Mitscherlich yield function is applied for spring barley to define the optimal fertiliser application and yield level.

$$f(l;q) = \varphi(1 - \sigma \exp(-\rho l)) \qquad (5)$$

Where l is nitrogen application rate and φ, σ and ρ are parameters. The yields depend on soil type; clay > organic > sandy as well as soil productivity. Soil productivity differences are incorporated through maximum yield parameter, φ. Production cost data for barley cultivation is based on Tuottopehtori (2010).

Biodiversity benefits from a field-forest border biodiversity strip are based on biodiversity benefit index developed in Iho *et al*. (2011) for the purposes of Finnish agri-environmental auctions.

Table 1. Biodiversity benefit index

Soil type	North-West and North-East			East and West			South-West and South-East		
	Field slope			Field slope			Field slope		
	<1.5%	*1.5-6.0%*	*>6%*	*<1.5%*	*1.5-6.0%*	*>6%*	*<1.5%*	*1.5-6.0%*	*>6%*
Organic	13	19	27	19	28	40	24	34	49
Clay	19	27	39	28	40	57	34	49	70
Sandy	27	39	55	40	57	82	49	70	100

Source: (Iho et al., 2011).

In this index three characteristics describe biodiversity benefit of a biodiversity strip on a field-forest border: soil type, field slope and opening direction of the forest border. Forest borders opening to the South have usually higher plant and insect species richness and abundance than forest borders opening to other compass directions (Bäckman et al., 2004). Species richness of rare meadow plant species is usually highest in steep slope meadows opening to the South (Luoto, 2000 and Pykälä et al., 2005). Also butterfly species richness correlates with the slope of the field edge (Kuussaari et al., 2007). Soil type (soil textural class) and its chemical composition have large effect on plant species richness (and through that on diversity of fauna). On sandy soils plant and butterfly species richness is usually higher than in other soil types (Kivinen et al., 2006). Generally, plant species richness increases when soil nutrient level decreases, especially in the case of phosphorus.

Results

One hundred differential soil type/land productivity combinations were analysed. Table 2 provides a summary of basic results (minimum, mean and maximum) regarding nitrogen application, barley yield, profits and profit forgone.

Table 2. Nitrogen application, barley yield, profits, and profit forgone for establishing a 5-meter wide biodiversity strip (minimum, mean, and maximum)

	Nitrogen application kg/ha	Barley yield kg/ha	Profits EUR/ha	Profit forgone EUR/ha
minimum	95	3 452	482	45
mean	109	4 586	604	51
maximum	121	5 666	722	57

Farmers' profit forgone from establishing a 5-meter wide biodiversity strip varied between EUR 45 and EUR 57 per hectare.

The agri-environmental budget (*AEB*) was set at EUR 2000 and government selection of participants for various payment types followed the procedure described in Section 2. Uniform payment level is fixed at EUR 52/ha. Environmentally differentiated payment level varies from EUR 48/ha to EUR 54/ha depending on soil type. It is highest for sandy soils and lowest for organic soils on the basis of biodiversity benefit index in Table 1. Differentiated payment on the basis of compliance costs varies from EUR 48/ha to EUR 54/ha. It is highest for organic soils and lowest for sandy soils.

Policy-related transaction costs (PRTCs) for administration and farmers' private transaction costs were calculated for different payment types on the basis of Finnish studies (Ollikainen at al., 2008; Lankoski et al., 2010, Iho et al., 2011). The share of PRTCs of total payment transfers are reported in Table 3.

Table 3 provides main results regarding PRTCS, the number of selected participants under different payment types, total budget costs, total EBI points, the cost-effectiveness and targeting gains ratio.

As shown by earlier studies identified in the literature, the uniform payment policy (which does not employ systematic selection of participants on the basis of the cost-effectiveness) performs less efficiently than other payment types. This is indicated by its high cost per EBI point and the low performance relative to C-E benchmark. The one-dimensional bid scoring auction performs much better than the uniform payment as farmers are selected on the basis of benefit/cost ratio. The two-dimensional bid scoring auction performs only slightly better than uniform payment and clearly worse than one-dimensional bid scoring auction. The reason for this was shown in the theoretical framework, where farmers have access to EBI information, higher EBI increases bids and thus information rent for those farmers who are selected. This is confirmed in the first and second column of the Table 5 below which shows that relative to one-dimensional bid scoring auction farmers' information rents are twice as large under two-dimensional bid scoring auction. Increase in information rents clearly decreases the performance of two-dimensional bid scoring auction. Employing group specific one-dimensional bid scoring auction for low cost bidders reduces bidders' information rents relative to one-dimensional bid scoring auction without group specific competition. Overall performance of these two different one-dimensional bid scoring auctions is quite similar. Using EBI targeting as a part of uniform payment policy greatly improves the cost-effectiveness of uniform payment. In fact, it is ranked third in cost-effectiveness. Differentiated payments, either on the basis of compliance costs or environmental benefits, perform slightly better than uniform payment without EBI targeting but clearly less efficiently than one-dimensional bid scoring auctions (with and without group specific competition) and uniform payment with EBI targeting.

Table 3. Share of policy related transaction costs of total payment, number of selected participants for different payment schemes, total budget cost, total EBI points, cost-effectiveness and targeting gains ratio

Payment	Share of PRTCs of total payment transfer, %	Number of participants selected	Budget cost, EUR	EBI points	Cost-effectiveness, EUR/EBI point	C-E relative to C-E bench-mark %	Targe-ting gains ratio[1]
C-E benchmark	6.1	37	1 992	2 885	0.73	100%	25
Uniform payment	5.0	38	1 976	2 192	0.95	77%	-
One-dimensional bid scoring auction with EBI targeting	7.0	35	1 952	2 599	0.80	91%	8
Two-dimensional bid scoring auction with EBI targeting	7.0	31	1 964	2 337	0.90	81%	3
Group specific one-dimensional bid scoring auction with EBI targeting	7.7	36	1 986	2 660	0.80	91%	7
Uniform payment with EBI targeting	5.4	38	1 976	2 476	0.84	87%	28
Environmentally differentiated payment with EBI targeting	6.1	37	1 982	2 254	0.93	78%	2
Differentiated payment on the basis of compliance costs with EBI targeting	6.1	36	1 986	2 660	0.90	81%	5

1. C-E gains from EBI increase relative to the increase in PRTCs with uniform payment as a benchmark.

The results also highlight that the potential cost-effectiveness gains achieved using auction systems can be uncertain. They depend on detailed auction design and farmers' information and assumptions regarding selection criteria (e.g. criteria used for ranking and selecting bids and information provided regarding maximum acceptable bids and environmental scores). Auctioning can be the most cost-effective payment system if farmers bid based on compliance costs assumptions without any knowledge of EBI. But auction systems can also perform below uniform payment with EBI targeting if farmers have knowledge about EBI levels and their use in bid selections. This means that (i) there is uncertainty on these cost-effectiveness gains, and (ii) these gains can diminish over time when farmers' knowledge of selection criteria increases.

The last column of Table 3 shows the targeting gains ratio of different payment types. The targeting gains ratio identifies the cost-effectiveness gains from EBI targeting relative to the increase in PRTCs. Uniform payment without EBI targeting is a benchmark for calculating this ratio (i.e. the ratio of the difference in the value of EBI points and PRTCs for a given payment type and uniform payment). Targeting gains ratio varies greatly between different payment types. It is highest for uniform payment with EBI targeting in which case one EUR spent on PRTCs pays back EUR 28 through cost-effectiveness gains from improved environmental targeting. Hence, uniform payment with environmental targeting may be a good option in a situation where a government aims to improve environmental effectiveness and cost-effectiveness of the payment programme with relatively small additional expenditure on PRTCs. One-dimensional auctions also perform well with regard to targeting gains ratio while this ratio is lowest for environmentally differentiated payment with EBI targeting.

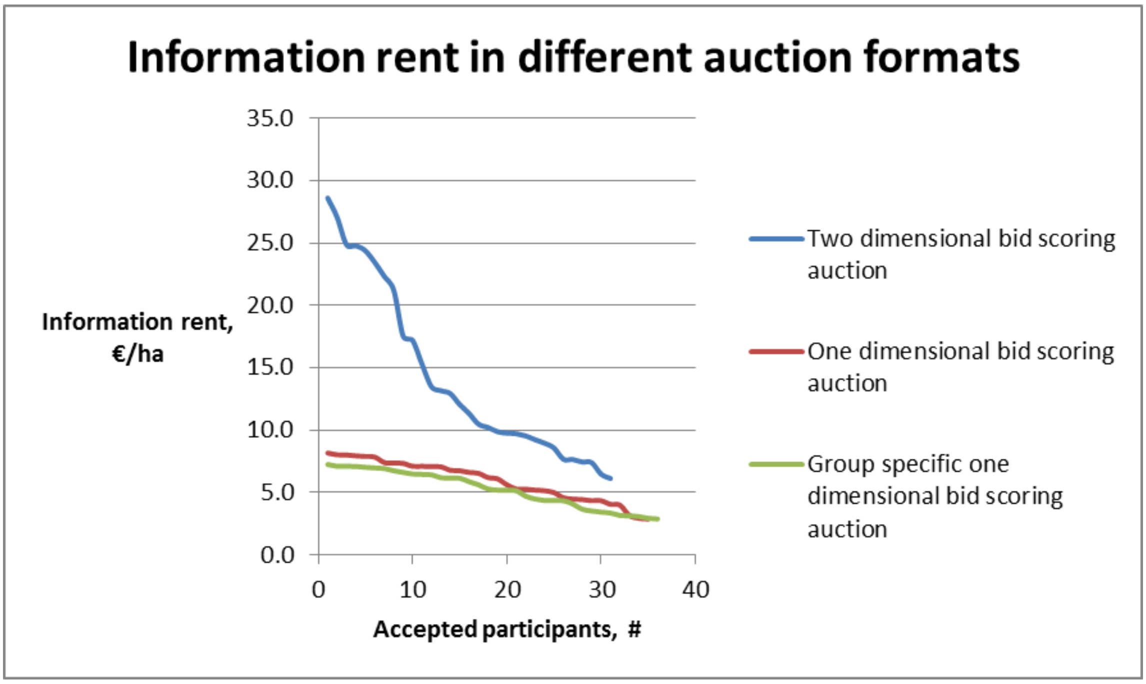
Table 4 provides results regarding information rent.

Table 4. Information rents under various payment types

Payment	Information rent		
	€/ha	**%**	**Total**
C-E benchmark	-	-	-
Uniform payment	4.5	8.6	169
One-dimensional bid scoring auction with EBI targeting	5.9	10.7	208
Two-dimensional bid scoring auction with EBI targeting	14.2	21.6	439
Group specific one-dimensional bid scoring auction with EBI targeting	5.2	9.5	189
Uniform payment with EBI targeting	3.8	7.3	145
Environmentally differentiated payment with EBI targeting	4.2	7.8	154
Differentiated payment on the basis of compliance costs with EBI targeting	2.8	5.5	109

Figure 1 shows the development of farmers' information rents in different auction formats. As indicated by theory and empirical results two-dimensional bid scoring auction results in highest information rents. As regards one-dimensional bid scoring auctions the group specific auction slightly reduces farmers' information rents relative to open one as it increases competition within the lowest cost sellers. Reduction of farmer's information rent (that is, the difference between the payment received for participating and true cost of participation for farmers) is important if the government's objective is to maximise budgetary cost-effectiveness of the program and to avoid overpayment of certain farmers.

Figure 1. Information rent in different auction formats



The data used in the results above portray a relatively limited variability in profits forgone for the establishment and management of biodiversity strip, which favours payment types that do not address so well heterogeneity in compliance costs. This is particularly the case for uniform payment with EBI targeting. Its relatively good performance could well be linked to this limited variability. In order to test the influence of the variability of income forgone a sensitivity analysis is conducted. In this sensitivity analysis the variation in income forgone is increased by 35%.

Table 5 provides the results from sensitivity analysis (variation of income forgone increased by 35%).

With a higher variability of income forgone, the relative cost-effectiveness of uniform payment without EBI targeting is reduced. The relative performance of one-dimensional bid scoring auction is further increased (it remains the most cost-effective option). Group specific one-dimensional bid scoring auction performs relatively less well with higher variability of income forgone. Relative cost-effectiveness of uniform payment with EBI targeting is reduced and both differentiated payments perform slightly better than it does. Overall, cost-effectiveness gains from targeting modalities are increased. However, with larger variations of income forgone, the variability of and the uncertainty on auction performance also increases.

If the focus is put on less uncertain instruments (in terms of efficiency gains) then uniform payments with EBI targeting appear to be the best “secure” option in the base case analysis, while larger variation on income forgone seem to favour environmentally differentiated payment with EBI targeting.

Table 5. Sensitivity analysis (variation of income forgone increased by 35%)

Payment	Budget cost	EBI points	Information rent	Cost-effectiveness EUR/EBI point	C-E relative to C-E benchmark	Targeting gains ratio[1]
	€	#	€/ha	€	%	
C-E benchmark	1964	2719	-	0.72	100%	24
Uniform payment	1976	2069	8.5	1.00	72%	-
One-dimensional bid scoring auction with EBI targeting	1954	2586	5.8	0.76	95%	10
Two-dimensional bid scoring auction with EBI targeting	1975	2350	14.0	0.90	80%	6
Group specific one-dimensional bid scoring auction with EBI targeting	1942	2586	5.4	0.81	89%	8
Uniform payment with EBI targeting	1976	2340	7.2	0.89	81%	27
Environmentally differentiated payment with EBI targeting	1951	2424	6.5	0.85	85%	7
Differentiated payment on the basis of compliance costs with EBI targeting	1988	2423	5.7	0.87	83%	12

Additional sensitivity analysis was conducted regarding PRTCs. Robustness of results regarding gains from targeting versus PRTCs were analysed by increasing PRTCs by 100%. Results are reported in Annex 1: Table 1. These results show that even with 100% increase in PRTCs gains from targeting clearly outweigh increase in PRTCs for most of the payment types.

4. Conclusions

While the empirical application conducted in the study is illustrative and focuses only on one type of biodiversity enhancing measure, some general conclusions and policy implications can be drawn.

Both the base case analysis and the sensitivity analysis show that – on the basis of Finnish data – the gains from environmental targeting are potentially very large and clearly outweigh the increase in PRTCs when targeted payment types are implemented.

The empirical application also shows that the cost-effective policy design to address heterogeneous agricultural and environmental conditions requires the combination of differentiated payment level and environmental targeting, for example by employing one-dimensional bid scoring auction with EBI targeting or differentiated payment with EBI targeting. It was shown, in the case of uniform payment, that large efficiency gains can be rapidly achieved at low PRTC by using environmental targeting alone, but the most cost-effective policy design and implementation requires addressing also differences in compliance costs.

Targeted payments can be used as effective and cost-effective mechanisms to complement environmental regulations and environmental cross-compliance schemes that provide base level biodiversity protection in agriculture.

When government objective is to maximise budgetary cost-effectiveness of these targeted payments (biodiversity protection and enhancement with given budget) then environmental targeting and tailoring of payment level in accordance with farmer's compliance cost are key factors for success of policy.

ANNEX 1

Table 1. 100% increase in PRTCs

	With PRTCs EUR/EBI point	**Targeting gains ratio**
	€	
C-E benchmark	0.77	13
Uniform payment	0.99	-
One-dimensional bid scoring auction with EBI targeting	0.86	4
Two-dimensional bid scoring auction with EBI targeting	0.96	2
Group specific one-dimensional bid scoring auction with EBI targeting	0.86	3
Uniform payment with EBI targeting	0.88	15
Environmentally differentiated payment with EBI targeting	0.99	1
Differentiated payment on the basis of compliance costs with EBI targeting	0.95	3

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