Auctioning Conservation Payments using Environmental Indices

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Introduction

Agri-environmental programs provide benefits in multiple environmental dimensions. Acknowledging this fact, conservation programs increasingly rank producer applications by using environmental indices to award contracts based on competitive bidding. As it is often the case that for environmental goods there are no well-established markets, an auction is a mechanism increasingly used by governments for procuring such goods in a cost-effective manner. However, auctions are typically structured so that participants place a monetary bid on well-defined, one-dimensional goods. For agricultural conservation programs, the multiple dimensions of environmental goods combined with the extent of potential participants, require the government adopt a simple standardized approach for evaluating applications; hence the environmental index approach. The underlying assumption of the ranking system is that the environmental index, by weighting and aggregating an array of environmental indicators into a single output, represents a preference ordering on environmental states.

This paper provides a framework for analyzing how producers' incentives to participate in a conservation program are affected by the specifics of the environmental index used to rank applications. Two environmental objectives are assumed: the farmer exercises control over the level of one of the environmental goods to be provided but not the other. The optimal bids are obtained analytically for two cases – a land retirement and a working lands program – and then auctions are simulated for these two cases to provide insight on issues pertaining to current U.S. conservation programs.

Until now, the literature has focused on cost-effectiveness of specific environmental measures (Feng et al., 2004; Wu and Babcock, 1996), on different forms of environmental targeting (Wu and Babcock, 2001), on the moral hazard involved in conservation contracts (Ozanne et al., 2001; White, 2002), and the use of auctions in conservation programs as a way of decreasing farmers' information rents (Latacz-Lohmann and Van der Hamsvoort, 1998). The paper presented here builds on the literature and moves forward the debate by analysing theoretical aspects for a conservation program using an environmental index to rank applications in a sealed bid auction. Given that environmental ranking in a systematic way is a relatively recent development, very little

is known on how the environmental index approach affects the environmental improvements being proposed by applicants. This gap, which this paper attempts to fill, is important considering that during the period 2002-2007 years upwards of $10 billion will be spent in the U.S. on agri-environmental conservation measures decided upon by environmental ranking.

Ranking agri-environmental application using an index: A framework for farmers' response

Suppose the government announces an agri-environmental payment program in which farmers are asked to present a combination of environmental improvements and related bids. To guide the bids, the government indicates the weights assigned to different environmental aspects and to cost-saving, establishing their relative priority. Drawing on the farmers' bids, a score value (I) is computed for each application. An application will be accepted according to the score value insofar as the score exceeds a cutoff value (I_c), which is announced after bids have been submitted.

Farmers form their bids so as to maximize their expected profits from participation. To be accepted into the program a farmer's application index score must be above the endogenously determined cutoff value. Obviously, the farmer's bidding strategy will be guided by expectations about this cutoff value.

We assume that farmers have private information about profits from farming, both under business-as-usual (p_0) and the conservation technology (p_1) where profits are defined as the net present value of per acre returns to land (excluding conservation payments and costs incurred to install conservation technologies). We further assume a risk-neutral farmer, implying that he will submit a bid if the expected profit in case of participation exceeds profits under the private optimum. The expected profits depend on the probability of being accepted in the program. Let *F(I)* be the cumulative probability distribution of being accepted as a function of the index score, and $\underline{I}$ denote the score value below which the bidder's expectation of being accepted is zero, i.e. the minimum index value to have a chance at entering the program. Then the probability of being accepted into the program is defined by

$$P(I > I_c) = \int_{\underline{I}}^{I} f(I)dI = F\left(I\right)$$

When deciding whether to participate, and what type of application to propose, a producer faces a problem with three <u>decision variables</u>: the endogenous environmental performance for the bid (e_{env}), the cost-share rate to request (s), and the rental rate for the environmental benefit provided (r). A producer deciding to install a level e_{env} of environmental improvement faces a cost $h(e_{env})$. We assume a positive and increasing marginal cost of conservation ($h'(e_{env}) > 0$ and $h''(e_{env}) > 0$). Assigning p_0 *and* p_1 as the profits from agricultural production before and after bid acceptance, the objective to be maximized by the producer can be expressed as:

$$\left[(p_1 - p_0) + r - (1-s) \cdot h(e_{env}) \right] \cdot F(I) \qquad \text{(eq.1)}$$

The index that aggregates multiple-dimensional information into a single summary output requires the choice of indicator variables, the assignment of unit scale for each indicator, choosing a functional form used to aggregate the indicator variables into a single summary output for evaluation purposes, and assigning weights signaling tradeoffs. For generality, assume there are two environmental objectives, the first being an exogenous environmental component (e_0) over which the farmer has no control, while the second is the endogenous environmental improvement chosen by the farmer to improve the bid (e_{env}).[1]

In addition to the environmental components, indices used in agri-environmental programs often include one or more cost-saving components. Here we include two cost-saving components in the index. The first creates an incentive for the producer to request a lower cost-share (s) relative to the maximum allowable cost-share (s_{max}) for the conservation practices being installed, and the second is similar, but concerning the rental rate for the environmental improvement provided (r) relative to the maximum allowable rental rate ($r_{max}(e_{env})$).[2] Each component in the index has an associated weight expressing its relative priority, specifically, w_0, w_{env}, w_s, w_r are the weights assigned respectively to exogenous environmental performance, endogenous environmental performance, cost-share request, and rental request. The index is then expressed as:

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[1] For example, in the Conservation Reserve program (CRP) farmers have no control over how many soil erosion points their bid receives because it is purely dependent on location. Conversely, the wildlife habitat score depends on the land cover a farmer proposes in the bid.

[2] The maximum allowable rental rate ($r_{max}(e_{env})$) is a function of environmental performance so as to reflect more faithfully a payment for environmental services.

$$I = \left[w_0 \cdot e_0 + w_{env} \cdot e_{env} + w_s \cdot \left(1 - \frac{s}{s_{max}} \right) + w_r \cdot \left(1 - \frac{r}{r_{max}(e_{env})} \right) \right] \cdot I_{max} \qquad \text{(eq.2)}$$

A common procedure to address incommensurability between the environmental subcomponents being aggregated is to convert the variables from their natural units to "normalized" units and then aggregate the results. Typically, the normalization of variables scales the data into the interval 0 to 1. Normalization has to be applied also to the cost-saving components if they are included alongside the environmental objectives in the index. Here the cost-saving subcomponents provide a score of zero if the maximum allowable cost-share or rental rate is requested, and a score of 1 if no financial compensation is requested (before multiplying by the weight). The normalizations adopted imply that $e_{env} \leq 1$, $s \leq s_{max}$, and $r \leq r_{max}(e_{env})$. Finally, the weights must sum to one: $w_0 + w_{env} + w_r + w_s = 1$. With all the above assumptions, the sum of the components inside the brackets varies in the [0,1] range; therefore, the maximum attainable score is given by I_{max}.

In words, the way the index operates is that the higher the exogenous and the endogenous environmental performance, the greater the score, and the better the chances of a bid being accepted, and the lower the cost-share and rental rate requested, the better chances a bid has. The producer's decision problem is to maximize the expected outcome of a bid, which is expressed as the product of the change in returns if the bid is accepted and the probability of acceptance. The inequality constraints simply represent the allowable range for the decision variables.

Setting up the Lagrangean one obtains the following necessary conditions for an interior solution (see Appendix A0):

Condition 1: $\qquad (1-s) \cdot h'(e_{env}) = \dfrac{w_{env}}{w_r} r_{max}(e_{env}) + \dfrac{r}{r_{max}(e_{env})} \cdot r'_{max}(e_{env}) \qquad$ (eq.3)

Condition 2: $\qquad w_{env} e_{env} = w_s \dfrac{(1-s)}{s_{max}} \cdot h_c(e_{env}) - w_r \dfrac{r}{r_{max}(e_{env})} \cdot h_{r_{max}}(e_{env}) \qquad$ (eq.4)

Where $h_c(e_{env})$ and $h_{r_{max}}(e_{env})$ are the elasticity of conservation practice cost and maximum allowed rental rate, respectively, relative to the environmental performance. The cost elasticity expresses a farmer's change in cost as greater environmental performance is written into an application. The rental rate elasticity, instead, is a program design parameter by which policymakers

express how the rental rate provided by the program varies with environmental performance delivered by farmers. Based on the necessary conditions, the first proposition is as follows:

Proposition 1. *If the maximum allowable rental rate of a conservation program does not depend on the level of environmental improvement ($r_{max}(e_{env}) = \overline{r}_{max}$), then, if the optimal bid is an interior solution, the endogenous environmental improvement will be independent of both the bid's exogenous environmental improvement and rental rate requested and satisfy*

$$\frac{s_{max} h(e_{env})}{w_s} = \frac{\overline{r}_{max}}{w_r} \tag{eq. 5}$$

Proof: From the first necessary condition for an interior solution (eq. 3) if r_{max} does not depend on the level of endogenous environmental improvement then the first necessary condition (eq. 1) simplifies to: $(1-s) \cdot h'(e_{env}) = \dfrac{w_{env}}{w_r} \overline{r}_{max}$, which when substituted in the second necessary condition obtains $\dfrac{s_{max} h(e_{env})}{w_s} = \dfrac{\overline{r}_{max}}{w_r}$. Q.E.D.

The ratios in equation 5 can be interpreted as "cost-benefit" ratios where at the numerator is the cost to the government (of cost-sharing and environmental payments respectively) and at the denominator the weight assigned to the specific cost component. The implication is that if an interior solution exists then the endogenous environmental improvement must be such that the "cost-benefit" ratios for the maximum allowable cost-share and rental rate must be equal.

What the proposition implies is that the exogenous environmental performance and the rental rate requested will determine the probability of acceptance and profitability of participating but not affect the proposed endogenous environmental improvement.

An analytical solution to the farmer participation decision can be obtained for special cases of the general problem. The next section investigates the properties of the analytical solution for examples representative of different types of conservation programs.

Land retirement vs. working lands programs: insights from applying the framework

The best known instance of using an environmental index in an auction setting is the U.S. Environmental Benefits Index (EBI) used to rank CRP applications. A lesser known case, but growing in importance due to increased funding, is the ranking adopted by the U.S. Environmental Quality Incentives Program (EQIP).

In what follows, two special cases are considered: the first is representative of a land retirement program, bearing considerable resemblance with the CRP, and the second example outlines the approach for a working lands program. In the discussion of the two cases several additional assumptions are made concerning the functional forms for the probability of acceptance ($F(I)$) and the cost of installing environmental improvements ($h(e_{env})$). For the acceptance of a bid with score I we assume a uniformly distributed probability density, which translates into a piecewise linear cumulative distribution function:

$$F(I) = \begin{cases} 0 & for\ I < \underline{I} \\ \dfrac{I - \underline{I}}{\overline{I} - \underline{I}} & for\ I \in [\underline{I}, \overline{I}] \\ 1 & for\ I > \overline{I} \end{cases} \qquad (eq.\ 6)$$

Where ($\underline{I}$) is the value of I below which a bid is surely rejected, and ($\overline{I}$) is the value of above which a bid is surely accepted (as perceived by the farmer). A linear interpolation between these two extremes seems a plausible assumption in terms of how a farmer would assess the chance of a bid being accepted. For the cost of installing environmental improvements we assume costs increase quadratically with environmental performance.

Land Retirement Programs

It is typically the case for land retirement programs to provide a rental payment based on the profitability of the land to be retired, and not the environmental benefits provided. The first simplification we can introduce is then to assume that r_{max}, which represents the maximum rental rate a farmer can request, does not depend on the environmental performance of the bid. The second assumption is that the cost-share is fixed as a percentage-rate of the cost of installing the new vegetative practices listed in the bid, and therefore, the farmer does not have the option of proposing a lower cost-share rate to enhance the chances of being accepted in the program. The two assumptions imply:

Proposition 2. *For a land retirement program such that* $r_{max}(e_{env}) = \overline{r}_{max}$ *and* $s = s_{max}$. *, the necessary and sufficient condition for an optimal bid is:*

$$(1 - s_{max}) \cdot h'(e_{env}) = \frac{w_{env}}{w_r} r_{max}, \qquad (eq.7)$$

which implies the optimal endogenous environmental performance will be greater the greater the

ratio $\dfrac{w_{env}}{w_r}$ *, and the maximum allowable cost-share and rental rates.*

Proof: See Appendix A1.

Proposition 3. *For a land retirement program such that* $r_{max}\left(e_{env}\right)=\bar{r}_{max}$ *and* $s=s_{max}$ *the following apply: (i) farmers in high rental rate counties (higher r_{max}) will tend to offer a higher level of endogenous environmental performance; (ii) the higher the program's maximum allowable cost-share the higher will be the level of endogenous environmental performance offered by the farmer (iii) a change in the endogenous environmental weight will always have a greater impact on the endogenous environmental performance if the change is made vis-à-vis the cost-saving objective as opposed to the exogenous environmental objective.*

Proof: The comparative statics are very straightforward, and can be obtained by differentiating implicitly Equation 6. See Appendix for details.

In the next section we simulate an auction similar to those held by the U.S. Department of Agriculture to offer land for enrollment in the Conservation Reserve Program (CRP). The results are useful in verifying whether the results obtained above on a bid-by-bid basis apply to the program outcome as a whole, but also to derive the impact on cost-effectiveness of different combinations of environmental weights (endogenous vs. exogenous).

Model Application to a Hypothetical Land-retirement Program

An auction is simulated for the competitive bidding of land retirement contracts. The program is offered to 1000 model farms of equal size (100 acres) but different returns to land, site-specific environmental benefits, and costs of providing environmental services above and beyond just retiring land from production (e.g. by providing land cover). These differences are reflected in different values of e_0, π_0, π_1, $h(e_{env})$, sampled from uniform distributions.

The program budget is set to 1 million USD. The Program parameter values are assigned so as to replicate a CRP-like program. The weight assigned to the rental rate requested is $w_r=0.268$, equivalent to the importance assigned to the cost-factor based on the share of points assigned to it in the Environmental Benefits Index (EBI). We assumed the maximum attainable score to be 560 (as

for the EBI) and that the bidders expectation about I_c (the cutoff index value) is uniformly distributed in the range [240,280] since historically the EBI cutoff has been in the range 245 (18th Signup) to 259 (15th Signup). The soil adjusted rental rate (r_{max}) is uniformly distributed in the range $35/acre to $165/acre (where the upper end of the range coincides with the maximum allowed rental rate paid by CRP). Finally, quadratic costs of improving environmental performance through more elaborate conservation practices are assumed.

Results for Land Retirement Simulation: The quantitative results for the simulated auction of land retirement contracts are listed in Table 2.The columns indicate how many farmers enroll, environmental performance, cost, and a measure of income transfer, while the rows indicate different combinations of weights assigned to the exogenous and endogenous environmental objectives.

TABLE 2. Simulated performance of the land retirement program under different weighting schemes for endogenous and exogenous environmental performance.

$[w_0, w_{env}]$	Enrolled farms	Average endogenous environmental impact	Average exogenous environmental impact	Profit loss without program (as share of program budget)	income transfer with program (as share of program budget)
[0, 0.732]	51	0.98	0.34	0.20	0.28
[0.1, 0.632]	50	1.00	0.34	0.19	0.25
[0.2, 0.532]	49	1.00	0.35	0.18	0.22
[0.3, 0.432]	48	0.95	0.37	0.18	0.21
[0.4, 0.332]	49	0.87	0.41	0.18	0.22
[0.5, 0.232]	67	0.75	0.59	0.24	0.28
[0.6, 0.132]	105	0.43	0.92	0.38	0.42
[0.7, 0.032]	113	0.01	1.00	0.45	0.54

The first thing to emerge is that for higher values of the exogenous weight more farmers are enrolled in the program (Table 2). This is due to the fact that endogenous environmental improvements require installing new land cover, which comes at a cost, whereas the exogenous environmental performance comes at no extra cost. As one would expect, the greater the weight assigned to an objective, the higher the average impact for the objective. For land retirement this relationship between weights and outcomes is valid both for average environmental performance and

for the aggregate sum of environmental performance over all accepted bids. In Figure 1 the tradeoff frontier is presented in terms of the two objectives. It is computed as the aggregate impact in each environmental dimension.
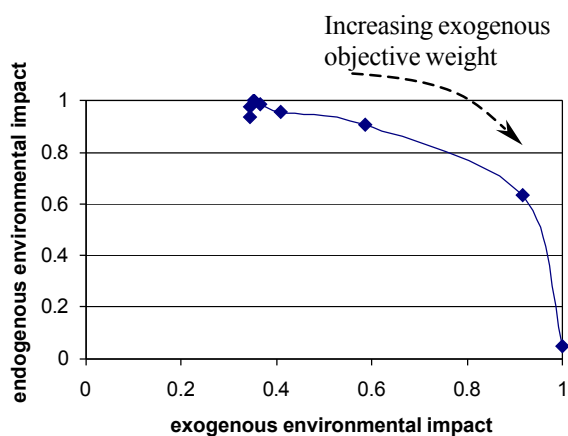
Figure 1. Simulated Environmental Tradeoff Frontier: Land retirement

The tradeoffs involved are quite small for small values of the exogenous weight; in fact, the two lowest levels are dominated in both environmental dimensions by outcome of w_0=0.2. Up to w_0=0.4 the outcomes are quite similar. Where the real tradeoffs start being felt is for w_0>0.4 where at the extreme end (w_0=0.7) nearly no endogenous environmental performance is provided.

An important aspect in terms of the program's efficiency is the extent to which farmers manage, due to informational rents, to be paid more than they would otherwise require to participate in the program. In this respect, we notice that the ratio of funds that functions as an income transfer (overcompensation of forgone profits) varies quite substantially with the relative change in weights for environmental objectives (Table 2). The cost-effectiveness is best in the mid-range of w_0 (0.2 to 0.4), where the most endogenous environmental performance is provided, On the other hand, in the upper range of w_0 the income transfer is higher because it is the exogenous environmental performance that matters, and a good exogenous performance enables the farmer to extract a good payment without incurring any additional costs.

Working Land Payment Programs

Working lands payment programs (WLPPs), by allowing continued production, do not need to provide rental rate payments to make up for lost production. Instead WLPPs typically provide a cost-share payment to defray administrative and installation costs of conservation practices. However,

under a WLPP, the rental payment in the general model can be used to represent a base payment for previous stewardship activities. Assuming previously undertaken conservation activities on a farm were decided independently of the program, then this approach implies the exogenous environmental component can be interpreted as conservation practices that have already been installed by the farmer. Here we assume that the change in profit associated with undertaking the actions required by the program (π_0 - π_1) can be augmented by an amount $w_0 \cdot e_0 \cdot r_{max}$ indicating a payment that is proportional to the exogenous environmental component (stewardship) and the importance assigned to the stewardship objective. Equation 4 is the relevant necessary condition, which is the starting point for the following proposition:

Proposition 4. *For a working lands payment program with a stewardship payment ($r = w_0 \cdot e_0 \cdot \bar{r}_{max}$) and bidding down on cost-share payments, a necessary condition for an interior optimal bid is:*

$$\frac{h(e_{env})}{h'(e_{env})} = \frac{w_s}{w_{env}} \frac{(1-s)}{s_{max}} \qquad \text{(eq. 8)}$$

And to respect the following constraints:

(a) interior cost-share $\quad \dfrac{w_s}{s_{max}} - w_s < w_{env} \dfrac{h(e_{env})}{h'(e_{env})} < \dfrac{w_s}{s_{max}}$

(b) second-order condition $\dfrac{h(e_{env})}{h'(e_{env})} > 2 \dfrac{h'(e_{env})}{h''(e_{env})}$

Proof: The second necessary condition (Eq. 4) simplifies into eq. ?? since by definition

$h_c = \dfrac{h'(e_{env}) \cdot e_{env}}{h(e_{env})}$ and if $r_{max}(e_{env}) = \bar{r}_{max}$ then $h_{r_{max}} = 0$. The constraints to be respected for an interior solution are obtained by substituting in Eq. 11 the upper (s_{max}) and lower (0) bounds for the cost share rate. Finally, the condition for which the solution is in fact a maximum is presented in Appendix A4. Q.E.D.

Intuitively, it does not appear that an interior optimal solution will be the obvious outcome for the working lands program as specified here. The second order condition for a maximum is particularly difficult to satisfy. For linearly increasing costs of conservation it clearly cannot apply because the second derivative at the denominator is zero. In fact, the conditions where the conditions are not satisfied are more general than just the linear case.

Proposition 5. *For a working lands payment program with a stewardship payment ($r = w_0 \cdot e_0 \cdot \bar{r}_{max}$)*
and bidding down on cost-share payments, the optimal solution will be a corner solution if any of
the following applies:

  (i)   if conservation costs are linear, quadratic, or exponential in the level of
         environmental improvement

  (ii)   if the interior solution is such that $h''(e_{env}) < 4 \cdot \dfrac{h'(e_{env}) - h'(0)}{e_{env}}$

Proof: See Appendix A4.

Based on proposition 5, and the range of cost-share weights and allowable cost-share rates, it
is very likely that the optimal bid will be a corner solution., Table 3 reports the possible corner
solutions.

TABLE 3. Possible optimal bids for a working lands program (N/A=not applicable)

		Endogenous environmental performance		
		e_{env}=0	0<e_{env}<1	e_{env}=1
Cost-share rate requested	**s=0**	All payments go towards financing past stewardship	Stewardship-driven endogenous performance	Stewardship-driven maximum endogenous performance
	0<s<s_{max}	N/A	(Interior solution)	Maximum endogenous performance with limited cost-recovery
	s= s_{max}	N/A	Endogenous performance with maximum cost-recovery	Maximum cost-recovery & Maximum endogenous performance

Case 1: e_{env}=0

The option where all funds go to financing past stewardship is not a desirable outcome since the
payments provide no additionality. However if a farmer has provided very good stewardship in the
past and program design parameters are not chosen carefully this can occur.

Proposition 6. *To avoid payments going all to fund past stewardship we must have that*

$w_{env} \cdot e_{env}^* > w_s \dfrac{s^*}{s_{max}}$ *where* e_{env}^* *and* s^* *are the environmental improvement and cost-share rate*

for a bid that provides more than just past stewardship.

Case 2: 0<e_{env}<1

The most policy-relevant cases will be the ones with an intermediate endogenous environmental performance because they will be more common than the extreme cases in which endogenous environmental performance of a bid is either zero or at its maximum. Furthermore it will be informative to know when a maximum cost recovery solution is preferred (by producers) to a stewardship-driven endogenous performance option, which will come at a lower cost but provide lower endogenous environmental performance. To do this we must find where the maximum cost-recovery solution provides greater expected profits than the stewardship-driven solution.

Proposition 7. *Assume a farmer faces conservation costs such that the optimal bid is not an interior solution (as per Proposition 5). Let $[e^*_{env}, s_0]$ represent the stewardship-driven solution and $[e^{**}_{env}, s_{max}]$ the maximum cost-recovery solution. Then $e^*_{env} < e^{**}_{env}$ and a sufficient condition for the higher environmental performance bid to be optimal is that:*

$$w_s + (1-x) \cdot \left\{ w_0 \cdot e_0 - \frac{\bar{\bar{I}}}{\bar{I}} \right\} < w_{env} \left[x \, e^{**}_{env} - e^*_{env} \right] \quad \textit{where we defined} \quad x = \sqrt{(1 - s_{max})}$$

Proof: See Appendix A6.

The condition provides only an order of magnitude indication: it informs what the minimum difference in endogenous environmental performance between the two solutions must be for the higher endogenous environmental performance to be guaranteed. The larger the left-hand side of the inequality, the greater the difference has to be between the two environmental solutions for the higher environmental improvement to be offered.

Case 3: $e_{env}=1$

Clearly this is the most desirable outcome in environmental terms, but it is also the most unlikely since the last incremental improvement will typically be very expensive. This solution can be the optimal bid only if the marginal expected profit for $e_{env}<1$ (case 2) is positive as e_{env} approaches 1. In other words, at the margin, the cost of conservation of an additional "unit" of environmental improvement must be proportionately less than the increase in the probability of acceptance associated with such an improvement.

If the solution with the greatest expected profit is the one in which the maximum environmental improvement is provided without any cost-share request, it is a clear indication that payments provided for good stewardship are too high because they more than cover new

conservation costs. A bid that requests a cost-share for conservation costs to be incurred so as to maximize expected profits while providing maximum environmental performance does not guarantee greater efficiency, but at least it employs two instruments (payment for stewardship and payment for new conservation) to pursue two objectives. In this case the cost-share requested would be::

$$s = \frac{s_{max}}{2 \cdot w_s} \left[\left\{ \left[w_0 \cdot e_0 + w_{env} \right] - \frac{I_{srej}}{\overline{I}} \right\} - \frac{w_s \left[\left(p_1 - p_0 \right) - \left(1 - s_{max} \right) \cdot h \left(e_{env} \right) \right]}{s_{max} h \left(e_{env} \right)} \right] \qquad \text{(Eq. 9)}$$

Model Application to a Hypothetical Working Lands Payment Program

The application to a working land program is meant to capture the tradeoffs between rewarding past stewardship and creating incentives to install new environmental measures. In this respect, the simulation incorporates aspects of both EQIP and CSP. As for the land retirement simulation, the program is offered to 1000 model farms of equal size (500 acres) but different levels of previous environmental stewardship, site-specific environmental benefits, and costs of providing environmental services. These differences are reflected in different values of e_0, π_0, π_1, $h(e_{env})$, sampled from uniform distributions.

We assume, as in the case of the land retirement example, a piecewise linear cumulative distribution function and quadratic costs of installing conservation practices. Based on Proposition 5 the interior stationary point is always a saddle point, meaning that the maximum is not an interior solution and that farmers will tend to submit applications in one of the categories listed in Table 3. The cost-share requested is either zero (participation is driven by stewardship payments and not cost-share) or one (self-driven endogenous performance) (See Appendix A3). For some parameter values it can occur that all payments go towards financing past stewardship.

The program budget is set to 1 million USD. The starting weight assigned to the base payment for stewardship is $w_0 = 0.1$, whereas the one assigned to the cost-share component is $w_s = 0.2$. We assumed the maximum attainable score to be 100 and that the bidders expectation about I_c (the cutoff index value) is uniformly distributed in the range [60,80] The maximum allowable cost-share rate is 75% of the cost of installing a conservation practice.

Results for Working Lands Payment ProgramSimulation

Comparing the results reported in Table 4 with those concerning the land retirement simulation (Table 2), the behavior of the two auction environments appears to be quite different in terms of sensitivity to values adopted for the objective weights. First of all, since farmers are paid for previous stewardship, increasing the weight of the exogenous environmental component now entails less farms can be enrolled as w_0 increases. However, for $w_0=0.5$ a radical shift occurs: the number of farms enrolled increases, the average endogenous environmental impact drops by 75%, the cost-share requested goes to zero, and nearly all the funds become income transfers. The reason for this shift is that the fact that there is no interior solution implies that changing a parameter even by a small amount may alter what a farmer proposes as a bid in a substantial way. In this case increasing w_0 has the effect of making the sufficient condition for a superior environmental outcome (Proposition 7) difficult to satisfy. In fact, for $w_0<0.4$ all the accepted bids request full cost-share providing high quality environmental benefits, while for $w_0=0.5$ the accepted bids all have zero cost share.

TABLE 4. Simulated performance of a working lands program under different weighting schemes for endogenous and exogenous environmental performance.

$[w_0, w_{env}]$	Enrolled farms	Average endogenous environmental impact (new practices)	Average exog. environmental impact (previous stewardship)	Profit loss without program	Cost of practices	cost share	Income transfer
					(as share of program budget)		
[0, 0.7]	32	0.91	0.19	0.66	1.33	1.00	0.34
[0.1, 0.6]	29	0.94	0.24	0.68	1.28	0.96	0.32
[0.2, 0.5]	25	0.97	0.29	0.69	1.22	0.91	0.31
[0.3, 0.4]	22	0.98	0.33	0.71	1.16	0.87	0.29
[0.4, 0.3]	19	0.99	0.36	0.74	1.11	0.83	0.26
[0.5, 0.2]	98	0.26	0.33	-0.80	0.53	0.00	0.96

What is surprising, and could not be predicted by looking at the first order conditions alone (for a single bid), is that despite at higher weights assigned for stewardship (exogenous environmental component) which entails bids of low endogenous environmental quality, in aggregate the endogenous environmental outcome for $w_0=0.5$ is better than for some lower values of w_0 (Figure

2). The implication is that stewardship payments, although not necessarily targeted towards installing new practices, can perform quite well in terms of new conservation.
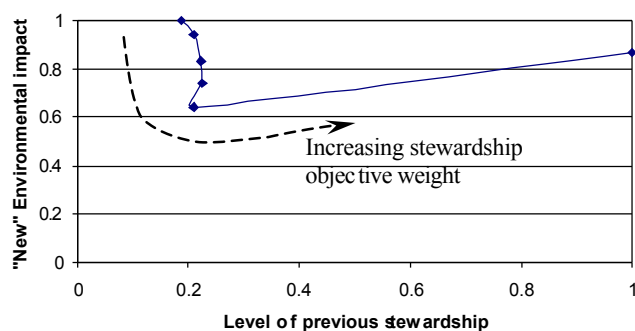
Figure 2. Simulated Environmental Tradeoff Frontier: Working Lands Payment Program

Conclusions

The results presented focus on finding the optimal solution to the program participation problem based on how the environmental index interacts with producers' characteristics. The formulation is general enough to address issues pertaining to CRP and for working lands to combine conceptual design elements of both EQIP and of the U.S. Conservation Security Program (CSP).

We derive the optimal bid from the farmer's perspective for both land retirement and working lands agri-environmental payment programs and we analyze how these solutions depend on program design parameters. For land retirement programs we conclude that, for the cases considered, the exogenous environmental performance does not affect the endogenous environmental performance offered in a bid, but it does impact the rental rate requested. Farmers in higher rental rate counties will tend to offer a higher level of endogenous environmental performance. A numerical example illustrates how a land retirement program has stable characteristics in terms of the tradeoff frontier between environmental objectives.

For working lands payments programs we find there is no interior solution to the decision problem for the cases considered, which generates a dichotomy between sets of program design parameters that either favor bidding based on past stewardship and low payments, or favor providing bids with higher endogenous environmental performance but requesting the maximum allowable payment. A necessary condition is derived for the latter case to apply. A numerical example highlights that changing the objective weights can have more than proportionate impacts on the endogenous environmental performance offered by farmers.

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Appendix: Due to space limitations the appendices are not included in this version of the paper; however, they are available from the author upon request.