Prescriptive use of Environmental Indices:
A "how to" guide for conservation programs.

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Abstract
A framework for analyzing conservation programs that rank applications using environmental indices is presented. 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. The distinction is made between environmental objectives based on whether the farmer exercises control or not over the level proposed in a bid to participate in a program. The optimization model is solved analytically for two cases – a land retirement and a working lands program – highlighting the differences in the results.

Keywords: environmental payments, program design, participation incentives (JEL: C6, H57, Q21,Q28)

Introduction

Agri-environmental programs provide benefits in multiple environmental dimensions. Acknowledging this fact, programs increasingly rank producer applications by using environmental indices. 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.

The best known instance of this approach is the U.S. Environmental Benefits Index (EBI) used to rank Conservation Reserve Program (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). Design issues for these programs fall under the general rubric of government procurement of environmental goods. The extent of potential participants combined with the multiple dimensions of environmental goods requires the government adopt a simple standardized approach for evaluating applications; hence the environmental index approach.

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; Cattaneo, 2003) . 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. Given that environmental ranking in a systematic way is a relatively recent development, no literature addresses how it might be done. In particular, 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 over the next 6 years upwards of $10 billion will be spent in the U.S. on agri-environmental conservation measures decided upon by environmental ranking.

The paper provides a framework with which to analyze the impact of agri-environmental program design parameters on farmers incentives to participate in the program. It focuses, in particular, on how the weights used in an index influence the type of bids submitted into a program. The analysis represents a first step towards understanding the strategic issues to be considered when constructing an environmental index for prescriptive purposes.

The paper presents and discusses the necessary conditions for an interior solution in the general case by solving the Lagrangean. The remaining part of the paper analyzes in detail two sub-cases: (i) a CRP-like land retirement case where the decision variables are the environmental performance provided in the bid and the rental rate requested, and (ii) a working lands program with environmental performance and cost-share request as variables. These two-variable problems accurately reflect existing programs and have the added advantage of being analytically tractable.

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

The index approach to designing an agri-environmental program weighs the different objectives of interest such that a score can be computed for each producer's application to participate in the program and accept the best applications accordingly. Weighing the objectives and computing an application's score are simply the final steps of the process from a program design perspective. Developing an index that aggregates multiple-dimensional information into a single summary output requires the following steps: (i) choice of indicator variables, (ii) assignment of unit scale for each indicator , (iii) functional form used to aggregate the indicator variables into a single summary output for evaluation purposes, and (iv) weights signaling tradeoffs. Here we focus exclusively on the role of the weights as program design parameters.

The approach taken develops an optimization problem for a producer thinking about participating in an agri-environmental program that ranks applications using an index.

Maximize $$\left[(\pi_1 - \pi_0) + r - (1-s)\cdot h(e_{env})\right]\cdot F(I) \qquad \text{(eq.1)}$$

Subject to:

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

$$e_{env} \le 1$$

$$s \le s_{max}$$

$$r \le r_{max}(e_{env})$$

and we also assume that : $$w_0 + w_{env} + w_r = 1,$$

$$h'(e_{env}) > 0, \quad h''(e_{env}) < 0.$$

The problem definition is general enough to describe actual agri-environmental programs. In the general case, a producer faces a problem with three decision variables: 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). The parameters and functions included in the model are:

I	Index score
$F(I)$	Probability of a bid being accepted as a function of index score
$h(e_{env})$	Cost of installing environmental improvements
$\bar{I}$	Maximum attainable score
π_0 and π_1	Profits from agricultural activity before and after bid acceptance
e_0	exogenous environmental component over which producer has no control
w_0, w_{env}, w_s, w_r	Weights assigned respectively to exogenous environmental performance, endogenous environmental performance, cost-share request, rental request

s_{max} Maximum allowable cost-share

$r_{max}(e_{env})$ Maximum allowable rent is function of environmental performance

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.

The reason for introducing an exogenous environmental component (e_0) is that often producers wanting to submit a bid have control only over a subset of the environmental factors being weighted by the ranking process. For example, in CRP producers have no control over how many soil erosion points their bid receives because it is purely dependent on location. Conversely, they do control their wildlife habitat score because it is linked to what cover they would introduce upon entering CRP. For some programs past stewardship can be treated as an exogenous environmental component in the bid application.

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

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

The implication of the first condition is that, for an interior solution, the marginal cost to the farmer of participating in the program (LHS in eq. 3) is linked to two factors: the first is the relative weight assigned to the environmental and cost components of the bid and on the extent to which the maximum rental rate allowed reflects the environmental benefits provided, the second factor depends on the share requested of the maximum allowed rental rate and on whether the rental rate increases with environmental benefits provided so as to cover the increasing cost. Intuitively, the first component highlights that the greater (i) the environmental weight and (ii) the maximum allowable rental rate, the more conservation will be proposed by farmers because it increases their expected financial benefit from applying. The second component implies that the greater the share requested of the maximum allowable rental rate, and the more the allowable rental rate increases with the environmental benefits provided, the more conservation will be provided.

Condition 2: $$w_{env}e_{env} = w_s\frac{(1-s)}{s_{max}}\cdot\eta_c(e_{env}) - w_r\frac{r}{r_{max}(e_{env})}\cdot\eta_{r_{\max}}(e_{env}) \qquad \text{(eq.4)}$$

Where $\eta_c(e_{env})$ and $\eta_{r_{\max}}(e_{env})$ are the elasticity of cost and 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.

The second necessary condition expresses the optimal environmental performance (from the perspective of a farmer applying to participate) as depending on both the cost component faced by the farmer and the rental rate requested. The two terms on the right hand side of Equation 4 can be viewed as balancing the profitability of participating in the program and maximizing the probability of the application being accepted. 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

In what follows, two special cases are considered: the first is representative of a land retirement program, bearing considerable resemblance with the U.S. Conservation Reserve Program (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:

$$F(I)=\begin{Bmatrix} 0 & for\ I<I_{srej} \\ \dfrac{I-I_{srej}}{I_{sacc}-I_{srej}} & for\ I\in\left[I_{srej},I_{sacc}\right] \\ 1 & for\ I>I_{sacc} \end{Bmatrix} \qquad \text{(eq. 5)}$$

Where I_{srej} is the value of *I* below which a bid is surely rejected, and I_{sacc} is the value of *I* above which a bid is surely accepted. The assumption seems reasonable to the extent that *F(I)* represents the probability of acceptance *perceived* by the farmer, who will likely have an idea of what index score will get an application approved for sure, and what score will be rejected for sure. 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 either that costs increase linearly or quadratically with environmental performance. Only the quadratic cost increases are presented here since the linear ones are but a special case that can be obtained by the reader by setting the quadratic component to zero. These additional assumptions enable us to verify the second order conditions (Hessian), and examine corner solutions where appropriate.

<u>*Land Retirement Programs*</u>

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: $r_{max}\left(e_{env}\right)=\overline{r}_{max}$ and $s=s_{max}$. Equation 3 then simplifies to:

$$(1-s_{max})\cdot h'(e_{env})=\frac{w_{env}}{w_r}r_{max} \qquad \text{(eq.6)}$$

Assuming a cost structure for installing different practices provides some additional insight in terms of the optimal values for *r* and e_{env}. A quadratic cost of improving environmental performance through more elaborate conservation practices is a reasonable option assuming an increasing marginal cost of installing better practices. We therefore assume the following: $h\left(e_{env}\right)=\alpha\cdot(1+\beta\cdot e_{env})\cdot e_{env}$ with α representing the linear parameter, and β the quadratic parameter.

The interior solution, in terms of *r* and e_{env}, for a farmer wanting to participate in a land retirement program, assuming he faces quadratic costs of environmental improvements is:

$$e_{env} = \frac{r_{max}}{2\alpha\beta \cdot (1-s_{max})}\left[\frac{w_{env}}{w_r} - \frac{\alpha \cdot (1-s_{max})}{r_{max}}\right] \qquad \text{(eq. 7)}$$

$$r = \frac{r_{max}+r_{min}}{2} - \frac{r_{max}}{2w_r}\left[\frac{I_{min}}{\overline{I}} - e_0 w_0 - e_{env} w_{env}\right] + r_{max}\left[\frac{1}{4}\frac{w_{env}}{w_r} + \frac{1}{4}\frac{\alpha \cdot (1-s_{max})}{r_{max}}\right]\cdot e_{env} \qquad \text{(eq. 8)}$$

$$r = \frac{r_{min}+r_{peps}(e_{env})}{2} + \frac{r_{max}}{4}\left[\frac{w_{env}}{w_r} + \frac{\alpha \cdot (1-s_{max})}{r_{max}}\right]\cdot e_{env} \qquad \text{(eq. 8')}$$

where r_{min} is the minimum payment a farmer would accept for him to participate, taking into consideration per hectare profit foregone from retiring land, and r_{peps} is the rental rate at which the probability of being accepted is a value epsilon just greater than 0 (see appendix for derivation). The necessary condition for this interior solution to be valid is: (see appendix for derivation):

$$\frac{\alpha(1+2\beta)\cdot(1-s_{max})}{r_{max}} > \frac{w_{env}}{w_r} > \frac{\alpha(1-s_{max})}{r_{max}} \qquad \text{(eq. 9)}$$

First we analyze optimal environmental performance based on eq. 7:

1) As one would expect, the greater the ratio $\frac{w_{env}}{w_r}$ the higher the optimal endogenous environmental performance provided by the farmer because the environmental objective is increasingly important relative to the cost of a bid.
2) environmental performance provided in a bid will tend to increase when the maximum allowable rental rate for the parcel is high (obtained by Differentiating Eq. 7 relative to r_{max}: the derivative is always positive);
3) similarly, optimal environmental performance provided in a bid will tend to increase when the cost-share for installing practices is high.

The optimal environmental performance does not depend directly on the weight assigned to the exogenous environmental component (w_0). However, since the weights must always sum to 1, the ratio $\frac{w_{env}}{w_r}$ will depend on w_0. The impact of changing the weight of the exogenous environmental component, assuming it is traded off with the other environmental component ($\frac{\partial w_{env}}{\partial w_0} = -1$), can be obtained by differentiating implicitly Equation 6, and is described by:[1]

$$\frac{\partial e_{env}}{\partial w_0} = \frac{-r_{max}}{w_r}\frac{1}{(1-s_{max})h''(e_{env})} \qquad \text{(eq. 10)}$$

indicating, as one would expect, that the endogenous component of environmental provision decreases as greater weight is given to the exogenous environmental component. Several less obvious conclusions can be drawn: (i) farmers in high rental rate counties (higher r_{max}) will tend to be more sensitive -- in terms of the endogenous environmental performance they offer -- to the relative weights of the two environmental components; (ii) environmental improvements with a high rate of increase in marginal cost per unit of environmental performance will be less sensitive to shifts in w_0 and w_{env}.

The optimal rental rate for a farmer to request is less straightforward to analyze than environmental performance. The expression (Eq. 8) can be broken down in two components:

[1] The logic behind choosing this special case in terms of how weights interact is that policymakers will typically weigh the environmental component against the cost component. Whether the degree of provision of an environmental objective is in farmers' control or not has not, up to now, been a program design consideration. Note that if w_0 varies so that w_{env}/w_r is unaffected, then e_{env} does not change.

- the first component sets the rental rate at midway between the break even rental rate (r_{min}) and the rental rate at which the probability of being accepted is a value epsilon just greater than 0 (r_{peps}). ;
- the second term is positive and ranges between $\frac{1}{4}\frac{w_{env} \cdot e_{env}}{w_r}$ and $\frac{1}{2}\frac{w_{env} \cdot e_{env}}{w_r}$ (this follows from necessary conditions for an interior solution (Eq. 9)).

An intuitive interpretation is that the first term determines a "reasonable" rental rate for the farmer – above the breakeven point and with a good chance of acceptance (once e_{env} is known). The second term can be viewed as an environmental benefit payment: it adjusts the reasonable rental rate to account for the level of environmental performance actively provided by the farmer.

Special cases and corner solutions:

- As a special case, if costs of environmental improvements are linear ($\beta = 0$) the condition for an interior solution becomes extremely restrictive; if the producer provides environmental performance (e_{env}>0) it is optimal to request the maximum rental rate. The producer's decision to provide a non-zero environmental performance depends on the ratio w_{env}/w_r. The only case in which an interior solution can exist is for $\frac{w_{env}}{w_r} = \frac{\alpha \cdot (1 - s_{max})}{r_{max}}$; however, these are all parameters determined exogenously either through program design or farmers' cost constraints.
- The corner-solutions when costs increase quadratically are such that: (i) if w_{env}/w_r is below the range for which an interior solution exists then e_{env}=0, and

$$r = \frac{r_{max} + r_{min}}{2} - \frac{r_{max}}{2w_r}\left[\frac{I_{min}}{\overline{I}} - e_0 w_0\right] \quad \text{(eq. 11)}$$

- or (ii) if w_{env}/w_r is above the specified range then either $r=r_{max}$, or e_{env}=1and the other has to be determined numerically as the root of a quadratic equation.

These results are relevant in an applied context because the Conservation Reserve Program retired approximately 28 million acres on the basis of EBI ranking. The EBI ranks CRP offers by weighing program costs for enrolling land in CRP against six environmental objectives (Land Cover, Water Quality, Erosion Control, Enduring Benefits, Air Quality, and State or National Conservation Priority Areas). The results are consistent with an analysis by Cattaneo et al. (2002) reporting that the aggregate environmental index associated with land enrolled in CRP had a positive relationship with the weights assigned to wildlife benefits and enduring benefits, which are the ones under producers' control, but not with the weights for other environmental indicators (exogenous performance).

In Figure 1(a)-1(d) we present the decision surfaces for a hypothetical farmer wanting to submit a bid in the Conservation Reserve Program. The value for CRP of the parameters in our analysis are: $w_r = 0.268$, $w_{env} = 0.205$, $w_0 = 0.527$ based on the share of points assigned in the Environmental Benefits Index (EBI)

I_{srej} = 240 (value of EBI below which a bid is surely rejected), and

I_{sacc}=280 (value of EBI above which a bid is "surely" accepted

We assume the farmer's bid to be in a county where the net present value for soil adjusted rental rate is $165/acre ($r_{max}$), and we provide two alternative cost structures: high cost conservation cover practices and low cost ones. We also portray two different levels of exogenous environmental performance: high (e0=0.74) and low (e0=0.54).

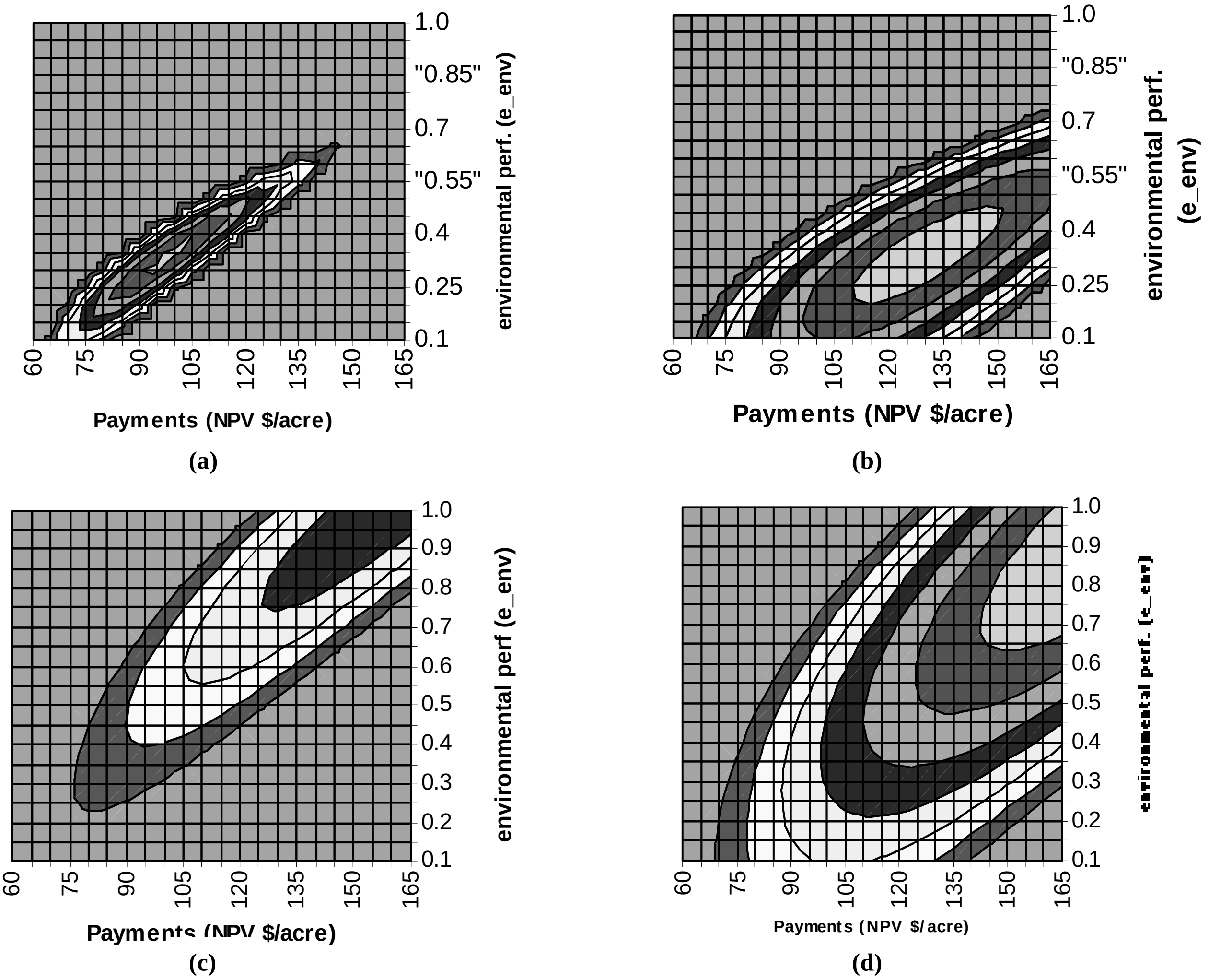


Figure 1. Expected profit isoclines for a farmers participation in a hypothetical land retirement program under different conservation cost assumptions and exogenous environmental performance.

Based on the numerical assumptions in the box above, we simulated the decision surface of our hypothetical case, so as to map the expected profit isoclines and observe how bids are affected by the cost of conservation practices and how much exogenous environmental perfomance happens to be associated with the land being offered (concentric ellipses with the center being the maximum). .

From this simple numerical example, we check that the conditions derived for an interior solution are , in fact, valid. We also observe that if a farmer has land with greater exogenous environmental performance upon retirement, effectively broadens the area with positive expected profits. This means producers can choose from a broader range of bids with a positive outcome (even though only one maximizes the expected profit). Furthermore, for an interior solution changing the exogenous environmental performance (or weight) affects the rental rate requested (payments) but does not affect the amount of endogenous environmental performance provided in a bid (as per eq. 7). Figures 1(c) and 1(d) portray how, with lower costs of installing cover practices, a change in the exogenous environmental performance of a bid can have an impact on both the rental rate requested and the endogenous environmental performance offered in a bid. The higher the exogenous component, the lower will be the endogenous environmental component, and the higher the rental rate requested.

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. Due to information asymmetries program managers may decide to introduce a bidding mechanism whereby farmers propose contracts with lower cost share rates than the maximum allowed. The bidding down of the cost-share is meant to elicit producers willingness-to-accept a payment. The lack of a rental payment in WLPPs implies that in our model $r_{max}\left(e_{env}\right)=0$ and $w_r=0$. In a WLP the exogenous environmental component can be interpreted as conservation practices that have already been installed by the farmer (good stewardship). Equation 4 is the relevant necessary condition, which simplifies to:

$$w_{env}e_{env}=w_s\frac{(1-s)}{s_{max}}\cdot\eta_c(e_{env}) \qquad \text{(eq. 12)}$$

and we assume, as in the case of the land retirement example, a piecewise linear cumulative distribution function and quadratic costs of installing conservation practices. Then we can write

$$\eta_c(e_{env})=\frac{h'(e_{env})}{h(e_{env})}\cdot e_{env}=\frac{1+2\beta e_{env}}{1+\beta e_{env}}$$

$$w_{env}e_{env}=\frac{w_s(1-s)}{s_{\max}}\frac{1+2\beta e_{env}}{1+\beta e_{env}} \qquad \text{(eq. 13)}$$

This solution, however, upon checking the Hessian, is for all intents and purposes a saddle point, meaning that the maximum is not an interior solution and that farmers will tend to submit applications in one of the following categories:

(i) Good stewards: s=0

In this case the farmer is not asking for any cost-share from the program, although part of the difference in profits may derive from a flat payment from participation.

Maximize $$L=\left[\left(\pi_1-\pi_0\right)-h\left(e_{env}\right)\right]\left\{\frac{\left[w_0\cdot e_0+w_{env}\cdot e_{env}+w_s\right]-\frac{I_{srej}}{\overline{I}}}{I_{sacc}-I_{srej}}\right\}\cdot\overline{I}$$

We obtain e_{env} as a solution to the first order condition:

$$\frac{dL}{de_{env}} = w_{env}\left[(\pi_1-\pi_0)-h(e_{env})\right]-h'(e_{env})\left\{\left[w_0\cdot e_0+w_{env}\cdot e_{env}+w_s\right]-\frac{I_{srej}}{\bar{I}}\right\}=0 \qquad \text{(eq. 14)}$$

<u>(ii) Maximum cost recovery: s=s_{max}</u>

Here we find that some farmers have an interest in providing greater environmental benefits, but only if the full allowable cost-share is obtained.

Maximize $$L=\left[(\pi_1-\pi_0)-(1-s_{max})\cdot h(e_{env})\right]\left\{\frac{\left[w_0\cdot e_0+w_{env}\cdot e_{env}\right]-\frac{I_{srej}}{\bar{I}}}{I_{sacc}-I_{srej}}\right\}\cdot\bar{I}$$

$$\frac{dL}{de_{env}} = w_{env}\left[(\pi_1-\pi_0)-(1-s_{max})\cdot h(e_{env})\right]-(1-s_{max})\cdot h'(e_{env})\left\{\left[w_0\cdot e_0+w_{env}\cdot e_{env}\right]-\frac{I_{srej}}{\bar{I}}\right\}=0$$

(eq. 15)

<u>(iii) Maximum environmental performance: e_{env}=1</u>

Maximize $$L=\left[(\pi_1-\pi_0)-(1-s)\cdot h(e_{env})\right]\left\{\frac{\left[w_0\cdot e_0+w_{env}+w_s\cdot\left(1-\frac{s}{s_{max}}\right)\right]-\frac{I_{srej}}{\bar{I}}}{I_{sacc}-I_{srej}}\right\}\cdot\bar{I}$$

$$\frac{dL}{ds}=-\frac{w_s}{s_{\max}}\left[(\pi_1-\pi_0)-(1-s)\cdot h(e_{env})\right]+h(e_{env})\left\{\left[w_0\cdot e_0+w_{env}+w_s\left(1-\frac{s}{s_{\max}}\right)\right]-\frac{I_{srej}}{\bar{I}}\right\}=0$$

(eq. 16)

where, eq. 16 has no solution since both terms are negative, and therefore the cost-share rate is either s=0 or $s=s_{max}$

<u>(iv) Rewarding past stewardship: e_{env} =0</u>

In this case the program is paying $(\pi_1-\pi_0)$ for good past stewardship in the form of the exogenous environmental component (e_0).

The most policy-relevant cases will be the intermediate ones (i) and (ii) 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 good stewardship 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 $[e^{**}_{env}, s_{max}]$ provides greater expected profits than the good stewardship solution $[e^{*}_{env}, s_0]$, which by (dis)equating the objectives for cases (i) and (ii) implies:

$$\left[(\pi_1-\pi_0)-h(e^*_{env})\right]\left\{\frac{\left[w_0\cdot e_0+w_{env}\cdot e^*_{env}+w_s\right]-\frac{I_{srej}}{\bar{I}}}{I_{sacc}-I_{srej}}\right\}\cdot\bar{I}<\left[(\pi_1-\pi_0)-(1-s_{max})\cdot h(e^{**}_{env})\right]\left\{\frac{\left[w_0\cdot e_0+w_{env}\cdot e^{**}_{env}\right]-\frac{I_{srej}}{\bar{I}}}{I_{sacc}-I_{srej}}\right\}\cdot\bar{I}$$

If we define $\xi = \sqrt{(1-s_{max})}$, we can rewrite the equation above as (see Appendix A3):

$$w_s + (1-\xi)\cdot\left\{w_0 \cdot e_0 - \frac{I_{srej}}{\bar{I}}\right\} < w_{env}\left[\xi e_{env}^{**} - e_{env}^{*}\right] \quad \text{(eq, 17)}$$

is a *sufficient* condition for the higher endogenous environmental, higher cost-share solution to be optimal from the farmers' perspective. 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. The difference between the two levels of environmental improvement essentially has to compensate for (i) the additional cost-share associated with higher endogenous environmental improvements, and (ii) the level of exogenous environmental improvements being provided.

In Figure 2(a)-2(d) we present the decision surfaces for a hypothetical farmer wanting to submit a bid in an EQIP-like working lands payment program. The value of the parameters in our analysis are:

For 2(a) , 2(c), and 2(d) $w_s = 0.04$, $w_{env} = 0.50$, $w_0 = 0.46$,

For 2(b)) $w_s = 0.10$, $w_{env} = 0.50$, $w_0 = 0.4$,

which put a slightly greater emphasis on new environmental improvements than on past stewardship, and provide some variation in cost-share weight. We assume a maximum total of 100 points and that:

I_{srej} = 35 (value of EBI below which a bid is surely rejected), and

I_{sacc}=80 (value of EBI above which a bid is "surely" rejected

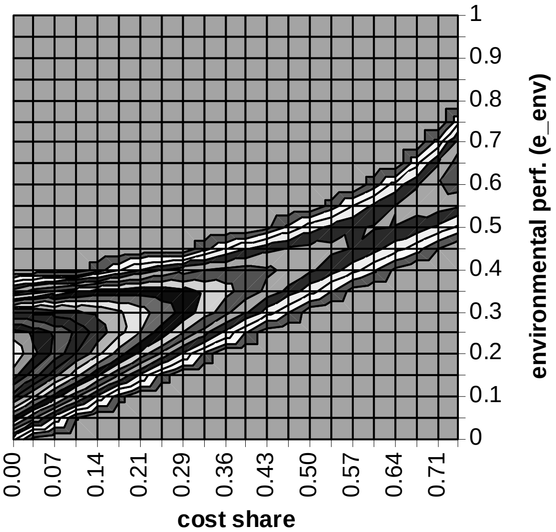
We assume s_{max}=0.75, and that the farmer increases profits by $50/acre. This increase in profits can be due to either improved returns from conservation and/or payments for good stewardship from the WLPP. We also portray three cost structures:

For 2(a) and 2(b): high conservation costs [α=20, β=15]

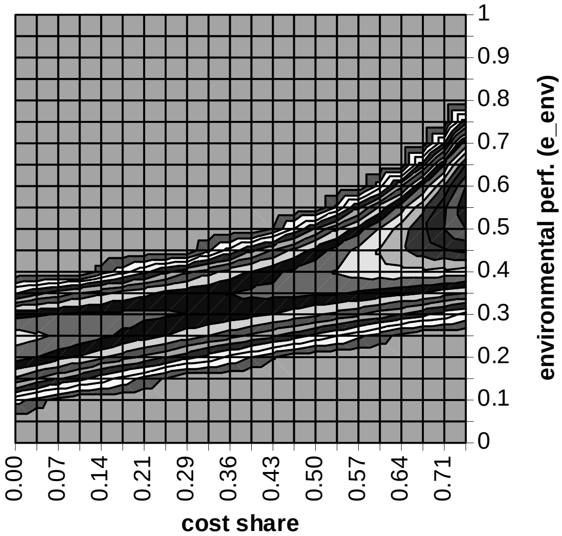
Figure 2(c) : medium conservation costs [α=3, β=15]

Figure 2(d) low conservation costs [α=2.89, β=8].

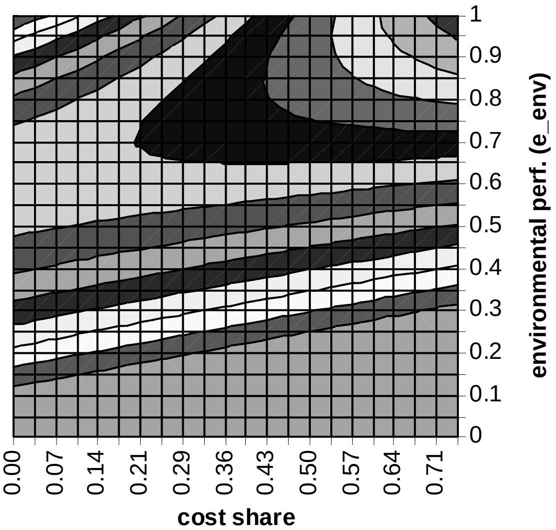
In Figures 2(a) and 2(b) the saddle-point nature of the solution is evident: shifting the weight associated with the cost-share component from 0.10 to 0.04 causes a switch in the preferred level of endogenous environmental performance from 0.2 (at zero cost-share) to 0.55 (at maximum cost-share). In Figure 2(b) we observe, instead, how at medium conservation costs the incentive is to provide the maximum environmental performance trying to recuperate as much as possible of the conservation practice costs. When costs are low (3(d)) the tendency is to provide high environmental performance at zero cost-share. (The large areas in pale blue represent the zero expected profit from participation, all other isoclines represent a positive expected profit).



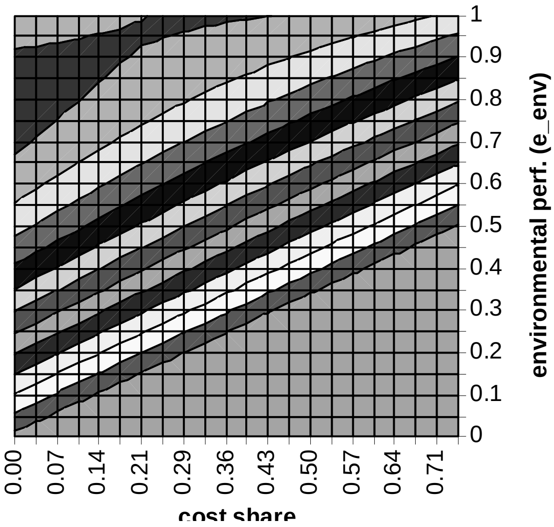
(a) High cons. Costs & w_s=0.10



(b) High cons. Costs & w_s=0.04



(c) Medium cons. costs & w_s =0.04



(d) low cons. costs & w_s =0.04

Figure 2. Expected profit isoclines for a farmers participation in a hypothetical land working lands payment program under different conservation cost assumptions and exogenous environmental performance.

Policy implications - The formulation for the working land case is combines conceptual design elements of both the U.S. Environmental Quality Incentives Program (EQIP) and of the U.S. Conservation Security Program (CSP). Bidding down the cost-share was an integral part of EQIP at its inception in 1996, while rewarding good stewardship is a new element in U.S. agri-environmental policy that was introduced by CSP.

The importance of the results presented here derive from the fact that these are voluntary programs. Therefore, a crucial component of the success of a program is to receive applications that match well the program objectives. It will typically be the case that new environmental improvements are sought by the program. This would entail lower weights on cost-share and exogenous environmental performance (stewardship), and higher allowable cost-share rates. If a program is geared more towards rewarding good stewardship then the reverse will be true. These results are not surprising; however, 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. So, for example, reducing the cost share rate to save money may have the undesirable effect of farmers proposing much lower endogenous environmental performance. This is the case for Figure 2(b), which depicts a 0.75 cost share and the farmer providing a bid with a 0.55 endogenous environmental performance (eep). Reducing the cost share rate to 0.5 makes it optimal for the farmer to submit a bid with a 0.25 eep. A 33% change in cost share reduces by 50% the eep of the bid (but it also reduces the government payments were the bid to be accepted).

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 main goal, however, is providing a framework to analyze how producers' incentives to participate in a conservation program are affected by the specifics of the application evaluation procedure.

The distinction is made between environmental objectives based on whether the farmer exercises control or not over the level proposed in a bid to participate in a program. The reason for introducing an exogenous environmental component is that often producers wanting to submit a bid have control only over a subset of the environmental factors being weighted by the ranking process. For example, in land retirement programs, soil erosion is likely to be one of the objectives, but farmers have no control over how many soil erosion points their bid receives because it is purely dependent on location. Conversely, they do control their wildlife habitat score because it is linked to what cover they would introduce upon entering CRP. For working lands programs, an increasing importance is being attributed to past stewardship. This too can be treated as an exogenous environmental component in the bid application since the farmer has no control today over past environmental management decisions.

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 <u>land retirement programs</u> 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. A higher *weight* assigned to objectives falling under the exogenous environmental performance category will tend to reduce endogenous environmental performance, and farmers in higher rental rate counties will tend to be more sensitive to this dualism.

For <u>working lands payments programs</u> we find there is no interior solution to the decision problem, which generates a dichotomy between sets of 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 examples highlights that reducing the cost share can have more than proportionate impacts on the endogenous environmental performance offered by farmers. So reducing the cost-share provided might, in fact, negatively affect the cost-effectiveness of a program.

Further applications of this framework might consider the impact of adopting a tiered payment structure based on environmental benefits, or of producers' perceived uncertainty in terms of what score is necessary to be accepted into a program.

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Appendices

A1. Deriving rental rate requested (Equation 8)

$$r = \frac{r_{max} + r_{min}}{2} - \frac{r_{max}}{2w_r}\left[\frac{I_{min}}{\overline{I}} - e_0 w_0\right] + r_{max}\left[\frac{3}{4}\frac{w_{env}}{w_r} + \frac{1}{4}\frac{\alpha \cdot (1 - s_{max})}{r_{max}}\right] \cdot e_{env}$$

$$r = \frac{r_{max} + r_{min}}{2} - \frac{r_{max}}{2w_r}\left[\frac{I_{min}}{\overline{I}} - e_0 w_0 - e_{env} w_{env}\right] + r_{max}\left[\frac{1}{4}\frac{w_{env}}{w_r} + \frac{1}{4}\frac{\alpha \cdot (1 - s_{max})}{r_{max}}\right] \cdot e_{env} \qquad \text{(eq. 8)}$$

based on Equation 2, adapted for the land retirement example:

$$I = \left[w_0 \cdot e_0 + w_{env} \cdot e_{env} + w_r \cdot \left(1 - \frac{r}{r_{max}}\right)\right] \cdot \overline{I}$$

$$w_r \cdot \left(1 - \frac{r}{r_{max}}\right) = \frac{I}{\overline{I}} - w_0 \cdot e_0 - w_{env} \cdot e_{env}$$

$$r = r_{max} - \frac{r_{max}}{w_r}\left(\frac{I}{\overline{I}} - w_0 \cdot e_0 - w_{env} \cdot e_{env}\right)$$

by substituting I_{min} for I we obtain the upper limit of r for which there is a non-zero probability of an application being accepted:

$$r_{peps} = r_{max} - \frac{r_{max}}{w_r}\left(\frac{I_{min}}{\overline{I}} - w_0 \cdot e_0 - w_{env} \cdot e_{env}\right)$$

so that we can rewrite equation 8 as:

$$r = \frac{r_{min} + r_{peps}}{2} + \frac{r_{max}}{4}\left[\frac{w_{env}}{w_r} + \frac{\alpha \cdot (1 - s_{max})}{r_{max}}\right] \cdot e_{env} \qquad \text{(eq. 8')}$$

A2. Land retirement: Necessary Conditions for an interior solution (quadratic cost of conservation)

Based on Equation 7, and having defined environmental performance (e_{env}) to be in the range [0,1], we can state that for e_{env} <1 the following must apply:

$$\frac{2\alpha\beta \cdot (1 - s_{max})}{r_{max}} > \left[\frac{w_{env}}{w_r} - \frac{\alpha \cdot (1 - s_{max})}{r_{max}}\right]$$

$$\frac{\alpha(1 + 2\beta) \cdot (1 - s_{max})}{r_{max}} > \frac{w_{env}}{w_r}$$

Similarly for e_{env} >0 the following must apply:

$$\left[\frac{w_{env}}{w_r} - \frac{\alpha \cdot (1 - s_{max})}{r_{max}}\right] > 0$$

$$\frac{w_{env}}{w_r} > \frac{\alpha \cdot (1 - s_{max})}{r_{max}}$$

Therefore the necessary conditions, relative to e_{env}, for an interior solution are:

$$\frac{\alpha(1 + 2\beta) \cdot (1 - s_{max})}{r_{max}} > \frac{w_{env}}{w_r} > \frac{\alpha(1 - s_{max})}{r_{max}}$$

A3. Working lands program: Obtaining the sufficient condition for the higher environmental improvement solution.

$$\left[(\pi_1-\pi_0)-h\left(e_{env}^{*}\right)\right]\left\{\frac{\left[w_0\cdot e_0+w_{env}\cdot e_{env}^{*}+w_s\right]-\frac{I_{srej}}{\bar{I}}}{I_{sacc}-I_{srej}}\right\}\cdot\bar{I}<\left[(\pi_1-\pi_0)-(1-s_{max})\cdot h\left(e_{env}^{**}\right)\right]\left\{\frac{\left[w_0\cdot e_0+w_{env}\cdot e_{env}^{**}\right]-\frac{I_{srej}}{\bar{I}}}{I_{sacc}-I_{srej}}\right\}\cdot\bar{I}$$

$$\left[(\pi_1-\pi_0)-h\left(e_{env}^{*}\right)\right]\left\{\left[w_0\cdot e_0+w_{env}\cdot e_{env}^{*}+w_s\right]-\frac{I_{srej}}{\bar{I}}\right\}<\left[(\pi_1-\pi_0)-(1-s_{max})\cdot h\left(e_{env}^{**}\right)\right]\left\{\left[w_0\cdot e_0+w_{env}\cdot e_{env}^{**}\right]-\frac{I_{srej}}{\bar{I}}\right\}$$

substituting the f.o.c for the two cases (equations 15 & 16) to obtain:

$$\frac{h'\left(e_{env}^{*}\right)}{w_{env}}\left\{\left[w_0\cdot e_0+w_{env}\cdot e_{env}^{*}+w_s\right]-\frac{I_{srej}}{\bar{I}}\right\}^2<(1-s_{max})\cdot\frac{h'\left(e_{env}^{**}\right)}{w_{env}}\left\{\left[w_0\cdot e_0+w_{env}\cdot e_{env}^{**}\right]-\frac{I_{srej}}{\bar{I}}\right\}^2$$

$e_{env}^{*}<e_{env}^{**}$ implying that $h'(e_{env}^{*})<h'(e_{env}^{**})$ then a *sufficient condition* for the better environmental outcome is:

$$\left\{\left[w_0\cdot e_0+w_{env}\cdot e_{env}^{*}+w_s\right]-\frac{I_{srej}}{\bar{I}}\right\}^2<(1-s_{max})\cdot\left\{\left[w_0\cdot e_0+w_{env}\cdot e_{env}^{**}\right]-\frac{I_{srej}}{\bar{I}}\right\}^2$$

$$\left\{\left[w_0\cdot e_0+w_{env}\cdot e_{env}^{*}+w_s\right]-\frac{I_{srej}}{\bar{I}}\right\}<\sqrt{(1-s_{max})}\cdot\left\{\left[w_0\cdot e_0+w_{env}\cdot e_{env}^{**}\right]-\frac{I_{srej}}{\bar{I}}\right\} \qquad \text{(eq. 17)}$$