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Optimal Design of a Voluntary Green Payment Program under Asymmetric Information

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Green payment programs, where the government pays farmers directly for environmental benefits, are an alternative to the current method of achieving environmental benefits which restricts farming practices in exchange for deficiency payments. This article presents a voluntary green payment program using the principles of mechanism design under asymmetric information. Information asymmetry arises because the government knows only the distribution of farmers' production situations, rather than farm-specific information. The program is demonstrated with irrigated corn production in the Oklahoma high plains. A green payment program can reduce budget costs and pollution, while increasing the net social value of corn production.

Key words: asymmetric information, environmental benefits, green payment, mechanism design, stewardship programs

Introduction

Environmental benefits offered by U.S. farmers have been purchased primarily by making eligibility for subsidies conditional on compliance with conservation practices. To remain eligible for subsidies, farmers cannot drain wetlands or till previously untilled land, and they must adopt and follow conservation measures that reduce soil erosion. The private cost of providing these environmental benefits is less than the subsidies, consequently, there are continued high participation rates in U.S. farm commodity programs. However, if recent trends of reduced agricultural subsidies continue, the cost of meeting environmental restrictions will eventually be greater than the subsidies, and government will need to find a new mechanism to purchase environmental benefits from farmers. Tighter federal budgets are not likely to support both current commodity programs and programs to offset their detrimental environmental effects (Kuch).

An alternative to current programs is to pay farmers directly for the environmental benefits they provide. Such an alternative has been called a "green payment" or "environmental stewardship" program. A workable green payment program must overcome at least three potential problems. (*a*) A viable program must recognize that farmers often have more information about their own site-specific resource setting than does the government. That is, possible information asymmetries must be accounted for. (*b*) The program should continue the tradition of being voluntary. And (*c*) the links connecting production decisions, site-specific resource settings, the resulting pollution, and pollution damage must all be known.

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This article assumes that the last problem has been successfully overcome and develops a green payment program that overcomes the first two difficulties by applying the principles of mechanism design under asymmetric information. These principles were developed by Mirrlees; Dasgupta, Hammond, and Maskin; Myerson; Harris and Townsend; Baron and Myerson; Guesnerie and Laffont; and Chambers (1989). Previous applications to agricultural policy analysis include Lewis, Feenstra, and Ware, who analyzed the reorganization of subsidized industries under asymmetric information, and Chambers (1992), who examined the motivations underlying the choice of agricultural policy mechanisms. This study extends previous analyses by explicitly considering the environmental consequences of agricultural production. The motivation for this work is to show how it is possible to increase the efficiency with which environmental benefits are obtained from agriculture with targeted payments.

The Model

This study uses a principal-agent model to design the green payment program. Principal-agent models have been used to model situations where information asymmetries are important. Perhaps the most straightforward example is the relationship between stockholders of a firm (the principal) and the firm's management (the agent). Management has more firm-level production and marketing information than individual stockholders so there is a risk that management could take actions that work in its favor rather than in the interest of stockholders. Stockholders, therefore, can increase their expected returns by designing contracts with built-in incentives that induce management to take actions that maximize the value of the firm. Such a contract induces the agent (farmers) to adopt production practices that maximize net social welfare, which is the objective of the principal (the public).

The green payment program presents farmers with a policy menu that consists of combinations of the type of production practices allowed (e.g., input use and tillage practices) and a corresponding government payment. The menu can specify as many combinations as there are distinct resource settings. Participation is voluntary; thus, farmers may choose any combination or none of them. In developing the green payment program, the asymmetry of information between the government and producers plays an integral role in program design. We assume that although the government knows all possible resource settings, it cannot identify each individual farmer's resource setting. As Chambers (1992) points out, even if the government can identify individual farmers' resource settings, political pressures may preclude using this knowledge as the overt basis for policy formulation. For example, the 1992 National Resources Inventory (NRI) identifies production practices and resource settings for more than 800,000 nonfederal locations. Soil profile properties at each location can be identified by linking the 1992 NRI to the SOILS5 database. This linked database would be ideal for policy formulation; however, privacy considerations preclude the government from revealing the longitude and latitude of the NRI points. Given this information asymmetry, farmers may have an incentive to misrepresent their resource settings to obtain favorable combinations of production practices and payments. The program is designed to induce farmers to report their true resource settings. Thus, the program is second best because of this constraint.

Producers of an agricultural commodity are differentiated by their resource endowment. For simplicity assume that there are two groups of producers. The analysis can be extended in a straightforward manner to N groups of producers. Producers in group 1 have lower quality lands than producers in group 2. That is, for a given level of input use, producers in group 1 always have a lower crop yield and a smaller marginal product of input than producers in group 2. The two groups may also differ in terms of the impacts of their production activities on environmental quality. Assume that the government knows that there are two groups of producers, but it cannot identify to which group an individual producer belongs. Furthermore, assume that each producer knows his or her own group. Thus, information is asymmetric between the government and farmers.

Let x represent per acre input levels, with x_{i0} indicating the production practices on farm type i without government involvement. The corresponding per acre net return and pollution level, $\pi_i(x_{i0})$ and $z_i(x_{i0})$, are

(1) $$\pi_i(x_{i0}) = pf_i(x_{i0}) - wx_{i0}, \text{ and}$$

(2) $$z_i(x_{i0}) = g_i(x_{i0}),$$

where $f_i(\cdot)$ and $g_i(\cdot)$ are the production and pollution functions for producers in group i, and p and w are the output and input prices. Let x_{ie} denote the production practices that maximize the social value of production in type i farms. That is, x_{ie} is defined by:

(3) $$pf_i'(x_{ie}) - w - tg_i'(x_{ie}) = 0,$$

where t is the social cost per unit of pollution. If these production practices are adopted, income for producers in group i will be $\pi_i(x_{ie})$. The resulting pollution level is $z_i(x_{ie})$.

Under full information a regulation that directs type i farms to use production practice x_{ie} would be socially optimal. But often the government does not have enough farm-level information of funds to achieve this degree of regulation. Relying on farmers to report their true resource base may cause incentive compatibility problems as farmers attempt to maximize the sum of government and market returns, which is inconsistent with the government's intention of maximizing the sum of private and public gains. In addition, direct regulation runs counter to the tradition of voluntary farm programs.

Under the green payment program the government presents farmers with a policy menu: (x_i, s_i), $i = 1, 2$, where x_i is the production practices intended for farm type i, and s_i is the per acre payment from the government if x_i is chosen. The program should be designed so that producers have no incentive to choose the option intended for the other group. Specifically, (x_i, s_i) must be the optimal choice for producers in group i. This constraint is often referred to as the *self-selection* or *incentive compatibility* constraint in the mechanism design literature. A policy menu (x_i, s_i) $(i = 1, 2)$ is self-selecting if:

(4) $$\pi_1(x_1) + s_1 \geq \pi_1(x_2) + s_2, \text{ and}$$

(5) $$\pi_2(x_2) + s_2 \geq \pi_2(x_1) + s_1.$$

The self-selection constraints require that producers of each group prefer the policy option intended for them to the option intended for the other group.

The self-selection constraints imply that

(6) $$\pi_1(x_2) - \pi_1(x_1) \leq \pi_2(x_2) - \pi_2(x_1), \text{ or}$$

(7) $$f_1(x_2) - f_1(x_1) \leq f_2(x_2) - f_2(x_1).$$

Because $\partial f_1 / \partial x < \partial f_2 / \partial x$ for any x, (7) implies that $x_2 \geq x_1$. That is, producers with more productive land must be allowed to use at least the same level of inputs as producers with less productive land. Similar results have been derived in Guesnerie and Seade, Weymark, and Chambers (1992). Both self-selection constraints bind, if and only if, $f_1(x_2) - f_1(x_1) = f_2(x_2) - f_2(x_1)$. Thus, unless $x_1 = x_2$, only one self-selection constraint can bind and at least one group strictly prefers its policy option to the one intended for the other group. In this case, the inequalities in (6) and (7) hold strictly, and the policy is truly self-selecting. When $x_1 = x_2$, (4) implies $s_1 \geq s_2$, and (5) implies $s_2 \geq s_1$. Hence $s_1 = s_2$. Thus, both groups receive the same policy and are "bunched." Chambers (1992) and Guesnerie and Seade have shown that with only two groups bunching is not optimal if the government's objective depends on the payment level s_i.

To induce producers to participate the green payment program must satisfy individual rationality constraints. Farmers cannot be worse off participating than if they choose not to participate:

(8) $$\pi_1(x_1) + s_1 \geq \pi_1(x_{10}), \text{ and}$$

(9) $$\pi_2(x_2) + s_2 \geq \pi_2(x_{20}).$$

A green payment program is feasible if it satisfies equations (4), (5), (8), and (9). When the government uses a feasible program, farmers voluntarily choose the policy option intended for them.

The government's problem is to find a feasible program that maximizes its objective function. Assume that the government wishes to maximize social surplus from agricultural production. Given the policy menu (x_i, s_i) $(i = 1, 2)$, social value of production for farm type i, $\omega_i(x_i)$, is

(10) $$\omega_i(x_i) = pf_i(x_i) - wx_i - tg_i(x_i) = \pi_i(x_i) - tg(x_i),$$

and social surplus from production is

(11) $$\varphi_i(x_i, s_i) = \omega(x_i) - \lambda s_i,$$

where λ is the marginal deadweight cost of raising tax revenue to support the government payment. The government's problem can be formally stated as:

(12) $$\max_{x_i, s_i} \sum_{i=1}^{2} A_i[\pi_i(x_i) - tg_i(x_i) - \lambda s_i],$$

s.t. (4), (5), (8), and (9),

where A_i is the total acreage on the ith type farms.

The Kuhn-Tucker necessary conditions for the maximization problem (Wu and Coppins) are

(13) $$x_1\{A_1[\pi_1'(x_1)-tg_1'(x_1)]+\mu_1\pi_1'(x_1)-\mu_2\pi_2'(x_1)+\mu_3\pi_1'(x_1)\}=0,$$

(14) $$x_2\{A_2[\pi_2'(x_2)-tg_2'(x_2)]-\mu_1\pi_1'(x_2)+\mu_2\pi_2'(x_2)+\mu_4\pi_2'(x_2)\}=0,$$

(15) $$s_1[-\lambda A_1+\mu_1-\mu_2+\mu_3]=0,$$

(16) $$s_2[-\lambda A_2-\mu_1+\mu_2+\mu_4]=0,$$

(17) $$\mu_1[\pi_1(x_2)-\pi_1(x_1)-s_1+s_2]=0,$$

(18) $$\mu_2[\pi_2(x_1)-\pi_2(x_2)+s_1-s_2]=0,$$

(19) $$\mu_3[\pi_1(x_{10})-\pi_1(x_1)-s_1]=0, \text{ and}$$

(20) $$\mu_4[\pi_2(x_{20})-\pi_2(x_2)-s_2]=0,$$

where $\mu_j \geq 0$ $(j=1,2,3,4)$ are the Lagrange multipliers for the four constraints in (12). The solution to the government's problem, (x_i^*, s_i^*) $(i=1,2)$, satisfies equations (13) to (20).

Let us first analyze the properties of the optimal policy menu (x_i^*, s_i^*) $(i=1,2)$, when $\lambda \neq 0$. If $x_i^* < x_{i0}$ for $i=1,2$, then both s_1 and s_2 must be positive to satisfy the individual rationality constraints. Since "bunching" is not optimal in this case (see discussion above), only one self-selection constraint can bind. So, either $\mu_1=0$ or $\mu_2=0$. Equations (15) and (16) then indicate that if both s_1 and s_2 are positive only the following situations are possible:

(1) $\mu_1=\mu_2=0$, $\mu_3=\lambda A_1$, $\mu_4=\lambda A_2$; (2) $\mu_1=\mu_4=0$, $\mu_2=\lambda A_2$, $\mu_3=\lambda(A_1+A_2)$; (3) $\mu_2=\mu_3=0$, $\mu_1=\lambda A_1$, $\mu_4=\lambda(A_1+A_2)$; (4) only $\mu_1=0$; and (5) only $\mu_2=0$.

In all these situations, at least one individual rationality constraint is binding.

In situation 1, both individual rationality constraints are binding because $\mu_3>0$ and $\mu_4>0$. As a result, both groups of producers are indifferent between the green payment program and no program. Substituting μ_i $(i=1,2,3,4)$ into (13) and (14) gives

(21) $$\pi_1'(x_1)-\frac{t}{1+\lambda}g_1'(x_1)=0, \text{ and}$$

(22) $$\pi_2'(x_2)-\frac{t}{1+\lambda}g_2'(x_2)=0.$$

A comparison of equations (21) and (22) with equation (3) indicates that when opportunity costs of government spending are considered, the level of input use is determined as if the social cost per unit of pollution is $[t/(1+\lambda)]$. The opportunity cost of government spending decreases the importance of externality costs in determining optimal input use. This result reflects the tradeoff between the externality costs of pollution and the costs of raising government payments. The more input use is allowed, the larger the externality costs will be, but the social costs to raise government payments are smaller because lower payments are needed. Thus, if $\lambda > 0$, $x_{ie} \le x_i^*$, $i = 1, 2$. Equations (21) and (22) also show that as long as $t > 0$, $x_i^* \le x_{i0}$, $i = 1, 2$.

In situation 2, only the individual rationality constraint for group 1 is binding. This implies that producers in group 2 are better off than without any farm programs, while producers in group 1 are indifferent to participating in the program and having no program at all. In this situation, equations (13) and (14) can be simplified to:

$$A_1[\pi_1'(x_1) - tg_1'(x_1)] - \lambda A_2\pi_2'(x_1) + \lambda(A_1 + A_2)\pi_1'(x_1) = 0, \text{ and} \tag{23}$$

$$\pi_2'(x_2) - \frac{t}{1+\lambda} g_2'(x_2) = 0. \tag{24}$$

Equation (24) indicates that optimal production practices for group 2 are the same as in situation 1. So $x_{2e} \le x_2^* \le x_{20}$. Let $h(x_1)$ denote the left-hand side of (23). When the second-order sufficient conditions are satisfied, $h'(x_1) \le 0$ (see Wu and Coppins, pp. 449–50). Since $h(x_1^*) = 0$ and $h(x_{10}) = -tA_1 g_1'(x_{10}) - \lambda A_2 \pi_2'(x_{10}) \le 0$, x_1^* must be less than x_{10}. However, since $h(x_{1e}) = -\lambda A_2\pi_2'(x_{1e}) + \lambda(A_1 + A_2)\pi_1'(x_{1e})$ may be greater or less than zero, we cannot determine whether x_1^* is greater or less than x_{1e}. When $h(x_{1e}) \ge 0$ or $(A_1 + A_2)\pi_1'(x_{1e}) \ge A_2\pi_2'(x_{1e})$, then $x_{1e} \le x_1^*$, otherwise, $x_{1e} > x_1^*$. This result reflects the trade off between two factors. First, because the individual rationality constraint for group 1 is binding, allowing this group to use more input than x_{1e} would reduce the government payment and the social cost of raising tax revenue. Second, because the self-selection constraint for group 2 is binding, allowing group 1 to use more input would force the government to pay more to group 2, otherwise, group 2 would choose the menu intended for group 1. When the first factor outweighs the second factor, $x_{1e} \le x_1^*$, otherwise, the government would prescribe production practices that are more restrictive than the first-best ones.

Situation 3 is symmetric to situation 2 except that $x_{ie} \le x_i^*$ holds for both groups, in which case, equations (13) and (14) can be simplified to:

$$\pi_1'(x_1) - \frac{t}{1+\lambda} g_1'(x_1) = 0, \text{ and} \tag{25}$$

$$A_2[\pi_2'(x_2) - tg_2'(x_2)] - \lambda A_1\pi_1'(x_2) + \lambda(A_1 + A_2)\pi_2'(x_2) = 0. \tag{26}$$

Equation (25) indicates that optimal production practices for group 1 are the same as in situation 1. So, $x_{1e} \le x_1^* \le x_{10}$. Let $k(x_2)$ denote the left-hand side of (26). When the second-order sufficient conditions are satisfied, $k'(x_2) \le 0$ (see Wu and Coppins, pp. 449–50). Since $k(x_2^*) = 0$, and $k(x_{2e}) = -\lambda A\pi_1'(x_{2e}) + \lambda(A_1 + A_2)\pi_2'(x_{2e}) = \lambda A_1[f_2'(x_{2e}) - f_1'(x_{2e})]$ $+\lambda A_2\pi_2'(x_{2e}) \ge 0$, x_2^* must be greater than x_{2e}.

In situation 4, both individual rationality constraints bind. Thus, all producers are indifferent to participating in the program and having no program at all. Situation 4 is the same as situation 2 except that the individual rationality for group 2 is also binding. As in situation 2, it can be shown that $x_{2e} \le x_2^* \le x_{20}$ and $x_1^* \le x_{10}$, however, x_1^* may be greater or less than x_{1e} depending on the trade off between social costs of pollution and the efficiency losses of raising government payments. Similarly, it can be shown that situation 5 is the same as situation 3 except that the individual rationality for group 1 is also binding. As in situation 3, $x_{ie} \leq x_i^*$ is always true for both groups.

Now let us examine the properties of the optimal policy menu when $\lambda = 0$. In this situation, the government's problem can be simplified to:

(27) $$\max_{x_i} \sum_{i=1}^{2} A_i[\pi_i(x_i) - tg_i(x_i)],$$

(28) $$\text{s.t.} \quad \pi_1(x_2) - \pi_1(x_1) \leq \pi_2(x_2) - \pi_2(x_1).$$

Given the input level x_i^* from this maximization problem, s_1 and s_2 are selected to satisfy

(29) $$\pi_1(x_2^*) - \pi_1(x_1^*) \leq s_1 - s_2 \leq \pi_2(x_2^*) - \pi_2(x_1^*), \text{ and}$$

(30) $$\pi_i(x_i^*) + s_i \geq \pi_i(x_{i0}) \text{ for } i = 1, 2.$$

The first-order conditions for the maximization problem in (27) are

(31) $$A_1[\pi_1'(x_1) - tg_1'(x_1)] - \eta[\pi_2'(x_1) - \pi_1'(x_1)] = 0,$$

(32) $$A_2[\pi_2'(x_2) - tg_2'(x_2)] - \eta[\pi_1'(x_2) - \pi_2'(x_2)] = 0, \text{ and}$$

(33) $$\eta[\pi_1(x_2) - \pi_1(x_1) - \pi_2(x_2) + \pi_2(x_1)] = 0,$$

where $\eta \geq 0$ is the Lagrange multiplier for the constraint in (28). If $\eta = 0$, then equations (31) and (32) indicate that $x_i^* = x_{ie}$ for $i = 1, 2$. Since producers with high quality land must be allowed to use more input, it must be true that $x_{1e} = x_1^* \leq x_2^* = x_{2e}$. Furthermore, it can be shown that $x_{1e} \leq x_{2e}$ is also the sufficient condition for $x_i^* = x_{ie}$, $i = 1, 2$. In fact, when $x_{1e} \leq x_{2e}$, one can always choose s_1 and s_2 close and large enough so that they satisfy both (29) and (30). Since (29) implies incentive compatibility and (30) implies individual rationality, the socially optimal level of input use can be implemented. Thus, $\eta = 0$ if and only if $x_{1e} \leq x_{2e}$.

If $\eta > 0$ or $x_{1e} > x_{2e}$, then (33) indicates that both self-selection constraints are binding. Thus, $x_1^* = x_2^* \equiv x^*$. From (29) we can see that $s_1^* = s_2^* = s^*$. This implies that when $\lambda = 0$, bunching may be optimal. Substituting $x_1^* = x_2^* \equiv x^*$ into (31) and (32) and adding them together, we get $A_1[\pi_1'(x^*) - tg_1'(x^*)] + A_2[\pi_2'(x^*) - tg_2'(x^*)] = 0$.

To summarize, if $\lambda \neq 0$, then $x_{ie} \leq x_i^* \leq x_{i0}$ for $i = 1, 2$. This implies that when there are deadweight losses associated with green payments, the government should prescribe production practices that are less restrictive than first-best practices. The exception occurs when the self-selection constraint for the producers with high quality land is binding. In this case, the government may have to prescribe production practices that are more restrictive than the first-best ones for producers with low quality land in order to satisfy incentive compatibility.

If $\lambda = 0$, then the following policy menu is optimal in the sense that it satisfies the incentive compatibility and individual rationality constraints and maximizes social surplus from agricultural production. (*a*) If $x_{2e} \geq x_{1e}$, farmers are given three options: (x_{1e}, s_1), (x_{2e}, s_2), or no participation, where s_1 and s_2 are selected to satisfy

$$\pi_1(x_{2e}) - \pi_1(x_{1e}) \leq s_1 - s_2 \leq \pi_2(x_{2e}) - \pi_2(x_{1e})$$
$$\pi_i(x_{ie}) + s_i \geq \pi_i(x_{i0}) \text{ for } i = 1, 2.$$

In this case, producers in group i will voluntarily choose (x_{ie}, s_i), and the green payment program becomes a first-best policy. (*b*) If $x_{2e} < x_{1e}$, farmers are given two options: (x^*, s^*) or no participation, where x^* is defined by $A_1[\pi_1'(x^*) - tg_i'(x^*)] + A_2[\pi_2'(x^*) - tg_2'(x^*)] = 0$, and s^* satisfies $\pi_i(x^*) + s^* \geq \pi_i(x_{i0})$ for $i = 1, 2$.

When $x_{2e} > x_{1e} = 0$, the optimal policy is to idle land on type 1 farms. Such a land retirement program that enrolls the least expensive land first would satisfy incentive compatibility and therefore would result in the correct land being enrolled. However, if $x_{1e} > x_{2e} = 0$, that is, high quality land is also much more vulnerable to pollution than low quality land, then the socially optimal policy would be to idle land on type 2 farms. A land retirement program that first enrolls least expensive land will not be incentive compatible: farmers would have the incentive to misrepresent their environmental attributes. In fact, without appropriate procedures to establish the eligibility for participation, such programs would end up enrolling lands on type 1 farms.

A Green Payment Program for Irrigated Corn Production

Implementing the green payment program requires extensive information about resource-specific production functions for crops and pollution, the marginal cost of pollution, and the marginal social cost of taxes. Here we use technical information on irrigated corn production (and nitrogen pollution) in the Oklahoma high plains reported by Wu, Mapp, and Bernardo. We construct green payment contracts to promote the adoption of efficient production practices.

The study region is mostly upland plains with a semiarid climate. Annual precipitation is about 19 inches. Richfield clay loam, Ulysses clay loam, Dalhart fine sandy loam, and Dalhart loamy fine sands are the four principal cropland soil types in the region (Bernardo et al.). Because of data limitations, we only consider nitrate water pollution in designing the green payment program. A comprehensive analysis should consider other environmental indicators (e.g., soil erosion) and pollutants (e.g., pesticides) as well. To make the stewardship program enforceable, we choose production practices that are observable. Specifically, we let x represent alternative irrigation systems (including no crop production).

Corn accounts for less than 2% of cropland in this region but more than 10% of nitrogen loss in runoff and leaching (Wu et al.). According to the 1987 National Resources Inventory (U.S. Department of Agriculture), about 71% of corn is grown on clay loam soil and 29% on fine sandy loam soil. Because all corn acres are irrigated, no corn is grown on loamy fine sand. Clay loam soil is more suitable to corn production and less vulnerable to nitrogen runoff and leaching than fine sandy loam soil (Bernardo et al.; Petr and Bremer). Thus, corn producers are divided into two groups: group 1 with clay loam soils and group 2 with fine sandy loam soils.

Richfield clay loam and Dalhart fine sandy loam are selected to represent clay loam and fine sandy loam soils. Production and pollution functions for corn on these two soil types are taken from Wu, Mapp, and Bernardo as are estimates of water application costs, nitrogen

Table 1. A Comparison of Outcomes under the Current, First-Best, and Stewardship Corn Programs for the Oklahoma Panhandle

	Current Program			First-Best Program		Stewardship Program	
Variables	Clay[a]	Sandy[a]	Clay	Sandy	Clay	Sandy	Clay
Production practices:							
Nitrogen (lbs./ac.)	224.00	213.00	204.00	0	197.00	0	204.00
Water (in./ac.)	19.00	20.00	18.00	0	16.50	0	18.00
Irrigation system[b]	Fur	Spr	Spr	0	Spr	—	Spr
Yield (bu./ac.)	207.00	200.00	209.00	0	207.00	0	209.00
Nitrogen loss (lbs./ac.):							
Runoff	14.78	4.39	2.53	0	2.49	0	2.53
Leaching	0.95	3.17	0.30	0	0.23	0	0.30
Net return ($/ac.)	73.70	51.60	82.50	0	82.00	0	82.50
Gov. payments ($/ac.)[c]	48.90	45.50	49.80	0	0	52.0[d]	1.00[d]
Farm income ($/ac.)	122.60	97.10	130.30	0	82.00	52.0	82.50
Opp. costs of gov. pay.:							
$\lambda = 0$	48.90	45.50	49.80	0	0	52.0	1.00
$\lambda = 0.35$	66.00	61.40	67.20	0	0	70.2	1.35
Social costs of pollution							
$t =$ \$10	157.30	75.60	28.30	0	27.20	0	28.30
Net social surplus:							
$\lambda = 0, t =$ \$10	–83.60	–24.00	54.20	0	54.80	0	54.20
$\lambda = 0.35, t =$ \$10	–100.70	–39.90	34.80	0	54.80	–18.2	53.85

[a]Sandy = fine sand loam soils; Clay = clay loam soils.
[b]Spr = sprinkler systems; Fur = furrow systems.
[c]A program yield of 105.2 bushels per acre and a deficiency payment of \$0.48 per bushel are used in calculating the government payments (FAPRI).
[d]Any payment scheme that satisfies $s_1 \geq 51.6$, $s_2 \geq 0$, and $s_1 - s_2 \leq 82.5$ will be optimal. The payments specified here minimize government outlays.

price, irrigation fixed costs, and costs for all other fixed and variable costs for the study region. The target price, deficiency payment, and program yield for corn in 1994 are from FAPRI. Using this information, we estimate input use, yields, farm income, nitrogen runoff and leaching, government payments, and net social surplus for each type of farm under current commodity programs. The results are reported in the three columns headed "Current Program" of table 1. All corn on fine sandy loam soil is irrigated using sprinkler systems and about 35% of corn on clay loam soil is irrigated using furrow systems. Therefore, results are reported for both sprinkle and furrow irrigation on clay loam soil.

Results under a first-best policy are reported in the columns headed "First-Best Program" of table 1. These results are derived assuming that government price supports are eliminated and pollution externalities are internalized. We assume that the social cost per unit of pollution, t, is \$10. For any other value of t, the program can be similarly designed. Under a first-best policy farmers use less water and nitrogen fertilizer on clay loam soils and would not grow corn on fine sandy loam soils.

Results for the green payment program are reported in table 1 for two values of λ: λ=0.35 and λ=0. Alston and Hurd suggest that the marginal deadweight loss of a dollar of U.S. federal spending is likely between \$0.20 and \$0.50 so λ = 0.35 is assumed. Results for λ = 0 are derived for comparison purposes.

Net social surplus under current commodity programs is lower than under a first-best policy for both soil types. The difference is the result of (*a*) the deadweight loss from raising tax revenue to pay for the program, and (*b*) the lack of incentive for producers to consider environmental performance in their production decisions. The public good nature of environmental performance has created a market failure that results in excessive input use, production, and pollution. For example, producers using furrow irrigation systems on clay loam soils would use 15% more water and 14% more nitrogen than efficient levels where only sprinkler irrigation is used. As a result, total nitrogen losses per acre from runoff and leaching are 13 pounds more than the efficient level. Net social loss under current programs increase as the social costs of pollution and efficiency losses of government spending increase. For example, as λ increases from zero to \$0.35, net social loss per acre on fine sandy loam soil increases from \$24 to \$39.90.

The policy menu presented in table 2 would induce producers with fine sandy loam soils to idle their land in exchange for a payment of \$52 per acre from the government. This payment is greater than their expected net return from farming of \$51.60 per acre if they do not participate and if they choose sprinkler irrigation for corn production. Therefore, it is in their interest to choose the no.1 bundle in table 2, that is, to idle their land in exchange for a payment of \$52 per acre from the government. In practice, the policy menu may require farmers to grow an alternative crop rather than to idle the land. In this situation, the payment will be reduced by the net return from growing the alternative crop. Similarly, producers with clay loam soils would voluntarily choose sprinkler irrigation in exchange for a government payment of \$1 per acre. The payment levels reported in table 1 are specified to minimize government outlays. In fact, some producers in this region have already adopted sprinkler irrigation on clay loam soils even without any government payment. To ensure that all producers participate the government can simultaneously increase payments to both groups. A simultaneous increase in payments to both groups will not violate the incentive compatibility constraint.

Even when λ=0, net social surplus under the green payment program is lower than the efficient level on clay loam soils. This reflects that producers would use more nitrogen and water than the efficient level because the green payment contract does not restrict nitrogen and water use. Net social surplus with green payments from corn production on fine sandy loam soil is negative (–\$18.2) when λ = 0.35. However, it is still worthwhile to induce these farmers to idle their land because the current program results in a net social surplus of –\$39.90.

The green payment program would reduce nitrogen runoff and leaching and increase net social surplus of agricultural production. It would also reduce government spending on farm programs. Of the 25,063 acres of corn grown in the Oklahoma high plains, 17,795 acres are grown on clay loam soils (35% is furrow irrigated), and 7,268 acres are grown on fine sandy loam soils. If all farms participate, the total government payment for this region would be \$1,211,280 under the current programs and \$295,731 under the green payment program. Although farm income under the green payment program is lower than under current commodity programs, it is at least as high as without any government program, otherwise farmers would not participate. Adding a farm income constraint to the design of the stewardship program would increase government payments and reduce program efficiency,

Table 2. A Policy Menu for Corn Producers in the Oklahoma High Plains

Choice	Production Practice	Government Payment ($/acre)
1	Idle land	52
2	Sprinkler irrigation	1
3	No participation	0

but it would not eliminate all the advantages of the green payment program. For example, when $\lambda = \$0.35$, a green payment program that guarantees that both types of farmers are at least as well off as under the current commodity program would increase net social surplus per acre by $5.91 on fine sandy loam soil and $2.67 on clay loam soils relative to the levels achieved under the current program. In this situation, an additional $46.80 per acre must be paid to farmers with clay loam soils, and an additional $45.10 per acre would have to be paid to farmers with fine sandy loam soils. The increased payments increase deadweight losses from taxation by $16.38 per acre on clay loam soils and by $15.79 per acre on fine sandy loam soils. As a result of these deadweight losses, net social surplus under green payments would be reduced to $37.47 per acre on clay loam and to –$33.99 per acre on fine sandy loam soils, levels which are still $2.67 and $5.91 higher than that under the current programs on these two types of land. A green payment program that guarantees revenue per acre is at least 85% of current levels would increase social surplus per acre by $11.01 on fine sandy loam soils and $9.51 on clay loam soils. In this situation, total government payments would be $1,102,662, which is 9% lower than under current programs. Thus, a green payment program can be designed to improve economic efficiency and environmental performance while simultaneously providing large subsidies to producers.

Conclusions

Current farm programs use both taxes and subsidies to acquire environmental benefits from producers. Conservation Compliance provisions are the best example of indirect taxes in that the provisions restrict the choice of farming practices for those producers who farm highly erodible soils. The best example of the use of subsidies is the Conservation Reserve Program (especially the last signups) where eligibility for payments is limited to those producers who farm land that would offer significant environmental benefits if it were not farmed. In this article we present a green payment program under asymmetric information that is similar to the Conservation Reserve Program in that subsidies are paid in exchange for adopting production practices that would reduce environmental pollution. The program is voluntary and self-selecting, making it a second-best policy.

We design a green payment program for irrigated corn production in the Oklahoma high plains. In this program, payments are made in exchange for efficient irrigation systems, which includes the option of no crop production. Replacing current farm programs with the green payment program could reduce farm program costs, improve environmental performance, and increase net social surplus from corn production—the larger the social cost of pollution and efficiency loss of government spending, the larger the improvements in economic efficiency and environmental and fiscal performance.

Achieving such improvements may come at the expense of other objectives of farm programs. For example, the stability of farm commodity prices, farm income, and retail food prices may decrease without including other policy instruments. A green payment program could also significantly redistribute farm program payments because payments would be targeted at purchasing environmental amenities rather than tied directly to production levels. In addition, there is an enforcement issue. Compliance with the green payment program designed in this article is not difficult because irrigation systems and crop production are observable. However, enforcement costs likely would be prohibitive for green payment programs that attempt to alter directly farmers' applications of fertilizer and pesticides. Implementable programs must be designed so that observable actions taken by contracting farmers are adequate to determine compliance.

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