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## ABSTRACT

Green payment programs, where the government pays farmers directly for environmental benefits, have been proposed as an alternative to the current method of achieving environmental benefits by restricting farming practices in exchange for deficiency payments. This paper presents a voluntary green payment program using the principles of mechanism design under asymmetric information. The information asymmetry arises because government knows only the distribution of individual farmers' production situations, rather than farm-specific information. The program is applied to irrigated corn production in the Oklahoma Panhandle, where nitrogen fertilizer is a nonpoint source of pollution. We demonstrate empirically that a green payment program can increase farm income, decrease pollution, and increase the net social value of corn production relative to current deficiency payment programs.

# OPTIMAL DESIGN OF A VOLUNTARY GREEN PAYMENT PROGRAM UNDER ASYMMETRIC INFORMATION

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 currently is less than the subsidies, so there are continued high participation rates in U.S. farm commodity programs. However, if recent trends of reduced agricultural subsidies continue, the costs 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.

One proposal is to pay farmers directly for the environmental benefits they provide. Such proposals have been called "green payment" or "environmental stewardship" programs. The objective of this study is to develop a green payment program that is voluntary and incentive compatible. This work applies the principles of mechanism design developed by Mirrlees (1971); Dasgupta, Hammond, and Maskin (1979); Myerson (1979); Harris and Townsend (1981); Baron and Myerson (1982); Guesnerie and Laffont (1984); and Chambers (1989). Previous applications to agricultural policy analysis include Lewis, Feenstra, and Ware (1989), 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 mechanism design approach recognizes that the consequences of policy can be fully characterized through outcomes. By focusing on outcomes, rather than on an inevitably arbitrary set of program parameters such as target prices and loan rates, this approach does not, a priori, limit the range of policy instruments (Chambers 1992). Thus, mechanism design is an ideal approach for analysis of farm policy reform.

The motivation for developing a green payment program is to increase the efficiency with which farmer-supplied environmental benefits are purchased and to have an alternative to current policy ready to implement if farm subsidies continue to decline. Efficiency increases should result from direct, targeted payments for high-value environmental amenities. And, as Kuch (1994) points out, tighter federal budgets are not likely to support both current commodity programs and programs to offset their detrimental environmental effects.

## The Model

This green payment program directs payments to farmers according to their choices of production practices. Payments are made in exchange for adopting environmentally friendly farming practices. Under the program, the public signals its demand for crops through the commodity markets, and the government signals the public's demand for farm-produced environmental goods and services through green payments.

The program is modeled as a mechanism design problem. The government presents a policy menu that consists of two doubles: one is the type of production practices allowed (e.g., input use and tillage practices), and the other is the level of government payments. The menu may specify as many combinations as there are distinct resource settings. Farmers can choose any combination or none of them. So, participation is kept voluntary. 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 these differences as the overt basis for policy formulation. 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, given a level, producers in group 1 always have lower yields than producers in group 2. 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 input levels with measuring $x_{i0}$ indicating the current production practices on farm type i. The corresponding net return and pollution level, $\pi_i(x_{i0})$ and $z_i(x_{i0})$, are

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

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

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

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

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 to achieve this degree of regulation. Relying on farmers to report their true resource base may cause incentive compatability problems as farmers attempt to maximize the sum of government and market returns counter to governments' intention to maximize the sum of private and public gains. In addition, direct regulation runs counter to the tradition (of voluntary) farm programs.

Under a voluntary green payment program with asymmetric information, the government presents farmers with a policy menu that consists of two doubles $(x_i, s_i)$ (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 green payment 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 *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

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

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

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

Inequalities (4) and (5) imply that

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

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

Thus, if $\partial f_1 / \partial x \leq \partial f_2 / \partial x$ for all $x_1 \leq x \leq x_2$, then $x_2 \geq x_1$, and if $\partial f_1 / \partial x \geq \partial f_2 / \partial x$ for all $x_1 \leq x \leq x_2$, then $x_2 \leq x_1$. That is, producers with a larger marginal product must be allowed to use more inputs. When both (6) and (7) bind, then $f_1(x_2) - f_1(x_1) = f_2(x_2) - f_2(x_1)$. Thus, unless $x_1 = x_2$, only one self-selection constraint can bind and at least one of the groups prefers its policy option to the one intended for the other group. In this case, the inequalities in (6) and (7) hold strictly.

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:

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

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

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

$$\omega_i(x_i) = pf_i(x_i) - wx_i - tg_i(x_i) = \pi_i(x_i) - tg_i(x_i), \tag{10}$$

and social surplus from production is

$$\varphi_i(x_i, s_i) = \omega_i(x_i) - \lambda s_i, \tag{11}$$

where $\lambda$ is the marginal social cost of raising (tax revenue to support) the government payment. The government's problem can be formally stated as

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

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

where $A_i$ is the total acreage in the i[th] type farms.

The Kuhn-Tucker necessary conditions for the maximization problem are as follows:

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

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

$$s_1[-\lambda A_1 + \mu_1 - \mu_2 + \mu_3] = 0, \tag{15}$$

$$s_2[-\lambda A_2 - \mu_1 + \mu_2 + \mu_4] = 0, \tag{16}$$

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

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

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

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

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). 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. Equations (15) and (16) indicate that if both $s_1$ and $s_2$ are positive then only the following cases 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 $\mu_2 = 0$. These cases imply that at least two of the four constraints are binding. Also, when $x_1^* \neq x_2^*$, at least one individual rationality constraint must be binding because only one self-section constraint can bind.

In case 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 $\mu_i$ (i = 1, 2, 3, 4) into (15) and (16) gives

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

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

Equations (21) and (22) indicate that opportunity costs of government spending decrease the importance of externality costs in determining optimal input use. This result reflects the trade-off 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 fewer payments are needed. Thus, if $\lambda > 0$, $x_{ie} < x_i^*$. Equations (21) and (22) also indicate as long as $t > 0$, $x_i^* < x_{i0}$.

In case 2, equations (15) and (16) can be simplified to

$$\pi_1'(x_1) - \frac{t}{1+\lambda(1+A_2/A_1)} g_1'(x_1) - \frac{\lambda(A_2/A_1)}{1+\lambda(1+A_2/A_1)} \pi_2'(x_1) = 0, \tag{23}$$

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

Equation (24) indicates that optimal production practices for group 2 are the same as in case 1. However, because $\mu_2 > 0$, the self-selection constraint for producers in group 2 must be binding. As a result, production practices for producers in group 1 are further restricted. Otherwise, producers in group 2 would prefer the policy option intended for producers in group 1. Because only the individual rationality constraint for group 1 is binding, producers in group 2 are better off than without any farm programs, while producers in group 1 are indifferent between participating in the program and having no program at all. Case 3 is symmetric to case 2.

In cases (4) and (5), both individual rationality constraints bind. Thus, all producers are indifferent between participating in the program and having no program at all. As in previous cases, it can be shown that if $\lambda \neq 0$, $x_i^* > x_{ie}$ (i = 1, 2). When $\lambda = 0$, cases 4 and 5 are impossible because equations (15) to (20) imply that when only $\mu_1 = 0$, $(x_2^*, s_2^*) = (x_{20}, 0)$, and when only $\mu_2 = 0$, $(x_1^*, s_1^*) = (x_{10}, 0)$. However, $x_{20}$ does not satisfy (16) when only $\mu_1 = 0$, and $x_{10}$ does not satisfy (15) when only $\mu_2 = 0$. Intuitively, when government spending does not cause efficiency loss, the net social surplus cannot be maximized at $(x_{10}, 0)$ or $(x_{20}, 0)$ because net social surplus will be increased when payments are made in exchange for environmentally friendly practices.

Equations (21) to (24) indicate that if $\lambda = 0$, then $x_i^* = x_{ie}$ for i =1, 2. If $\lambda = 0$ and $x_i^* \neq x_{ie}$ (i =1, 2), then both self-selection constraints must be binding because when any one of the self-selection constraints is not binding, it falls into one of the first three cases discussed above. Thus, if $\lambda = 0$ and $x_i^* \neq x_{ie}$ (i =1, 2), $x_1^* = x_2^* = x^*$ and $s_1^* = s_2^* = s^*$, where $x^*$ is defined by $A_1[\pi_1'(x^*) - tg_1'(x^*)] = A_2[\pi_2'(x^*) - tg_2'(x^*)]$, and $s^*$ satisfies $\pi_i(x^*) + s^* \geq \pi_i(x_{i0})$ for i=1, 2.

These results are summarized in the following proposition.

**Proposition 1.** If $\lambda \neq 0$, then $x_{ie} \leq x_i^* \leq x_{i0}$ for i = 1, 2. The inequalities strictly hold when $t \neq 0$. If $\lambda = 0$, then the following policy is optimal in the sense that it satisfies the incentive compatibility and individual rationality constraints and maximizes social surplus from agricultural production:

a. If $f_1(x_{2e}) - f_1(x_{1e}) < f_2(x_{2e}) - f_2(x_{1e})$, farmers are given three options: $(x_{1e}, s_1)$, $(x_{2e}, s_2)$, or no participation at all, where $s_1$ and $s_2$ are selected to satisfy

$$\begin{aligned} \pi_1(x_{2e}) - \pi_1(x_{1e}) \leq s_1 - s_2 \leq \pi_2(x_{2e}) - \pi_2(x_{1e}) \\ \pi_i(x_{ie}) + s_i \geq \pi_2(x_{i0}) \quad \text{for } i = 1,2. \end{aligned} \tag{25}$$

b. Otherwise, farmers are given two options: $(x^*, s^*)$ or no participation, where $x^*$ is defined by $A_1[\pi_1'(x^*) - tg_1'(x^*)] = A_2[\pi_2'(x^*) - tg_2'(x^*)]$, and $s^*$ satisfies $\pi_i(x^*) + s^* \geq \pi_i(x_{i0})$ for i = 1, 2.

When $f_1(x_{2e}) - f_1(x_{1e}) < f_2(x_{2e}) - f_2(x_{1e})$, we can always choose $s_1$ and $s_2$ close and large enough so that they satisfy (25). Since the first set of inequalities in (25) implies incentive compatibility, and the second implies individual rationality, the socially optimal level of input use can be implemented. In this case, producers in group i will choose $(x_{ie}, s_i)$ for their own interest, and the stewardship program becomes a first-best policy. When $f_1(x_{2e}) - f_1(x_{1e}) >$, $f_2(x_{2e}) - f_2(x_{1e})$, there does not exist $s_1$ and $s_2$ such that $(x_{1e}, s_1)$ and $(x_{2e}, s_2)$ satisfy the self-selection constraints.

If $x_{2e} > x_{1e} = 0$, the optimal policy would be to idle the land on type 1 farms. Because $f_1(x_{2e}) - f_1(x_{1e}) = f_1(x_{2e}) < f_2(x_{2e}) = f_2(x_{2e}) - f_2(x_{1e})$, a land retirement program like CRP that enrolls the least expensive land first would satisfy incentive compatibility and would therefore result in correct land being enrolled. However, if $x_{1e} > x_{2e} = 0$, the socially optimal policy would be to idle the land on type 2 farms. Because $f_1(x_{2e}) - f_1(x_{1e}) = -f_1(x_{1e}) > -f_2(x_{1e}) = f_2(x_{2e}) - f_2(x_{1e})$, a land retirement program like CRP that enrolls the least expensive land first will not be incentive compatible and, therefore, will give farmers some 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.

## An Empirical Example

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. In this empirical example, we use technical information on corn production (and nitrogen pollution) in the Oklahoma Panhandle reported by Wu, Mapp, and Bernardo (1994). We construct green payment contracts for four combinations of $\lambda$ and $t$. The study region is generally characterized by upland plains and 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. 1993). Because of data limitations, we only consider nitrogen water pollution in designing the stewardship programs. A comprehensive analysis should consider other environmental indicators (e.g. soil erosion) and pollutants (e.g. pesticides) as well. In addition, this analysis ignores enforcement issues and assumes that farmers will actually honor their green payment programs and change their input use accordingly.

Corn accounts for about 2 percent of cropland in this region but more than 10 percent of nitrogen loss in runoff and leaching. According to the 1987 National Resources Inventory (U.S. Department of Agriculture), about 71 percent of corn is grown on clay loam soil and 29 percent 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. 1993; Petr and Bremer 1976). Thus, corn producers are grouped into two categories: one with clay loam soil and the other with fine sandy loam soil.

Richfield clay loam and Dalhart fine sandy loam are selected to represent clay loam and fine sandy loam soil. Production and pollution functions for corn on these two soil types are taken from Wu, Mapp, and Bernardo (1994) as are estimates of water application costs, nitrogen 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 1994. 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 columns 2 to 4 of Table 1. Although all corn on fine sandy loam soil is irrigated using sprinkler systems, about 35 percent 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 columns 5 to 8. These results are derived under the assumptions that government price supports are eliminated and the pollution externalities are internalized. These results are estimated for two different values of the social costs of pollution (i.e., t = \$5 and t = \$10). Because we have no information about the possible range of t, the results only show how sensitive the net social surplus is to changes in social costs of pollution.

The stewardship program results developed here are reported in columns 9 through 16 and are estimated for four combinations of $\lambda$ and t. In the first two combinations, $\lambda = 0$ is assumed. Alston and Hurd (1990), in a paper on public economics and optimal taxation, suggest that the marginal efficiency loss of a dollar of U.S. federal spending is likely between \$0.20 and \$0.50 so $\lambda = 0.35$ is assumed.

Net social surplus under current commodity programs is lower than the optimal level on both soil types. The difference is the net social loss from two factors. First, government spending on farm programs directly causes efficiency loss because the opportunity cost of one dollar of government spending is likely to be greater than \$1. Second, current farm programs do not provide an incentive for producers to consider environmental performance in their production decisions. The public good nature of environmental performance has created a marked failure that results in excessive input use and overproduction and pollution. For example, when t = \$5, producers use 31 percent more of water and 13 percent more of nitrogen than the efficient levels on fine sandy loam soil. As a result, corn yield is 5.8 percent higher than the efficient level, and nitrogen losses per acre are 1.5 pounds more than the efficient level. Net social loss increases as social costs of pollution and efficiency losses of government spending increase. For example, when t = \$5 and $\lambda = 0$, net social losses are \$2.6 per acre on fine sandy loam soil. As t increases to \$10, net social loss increases to \$24 per acre. Net social loss reaches \$101 per acre when t = \$10 and $\lambda$ = \$0.35. Outcomes under the stewardship program are closer to efficient outcomes on clay loam soil than on fine sandy loam soil because clay loam soil is much less vulnerable to nitrogen loss.

When $\lambda = 0$, the stewardship program becomes a first-best policy because $f_1(x_{2e}) - f_1(x_{1e}) < f_2(x_{2e}) - f_2(x_{1e})$ is satisfied for both t = \$5 and t = \$10. For example, when t = \$10, a policy menu, (irrigation system, nitrogen use, irrigation level, payments) = (no irrigation, 0, 0, 51.7) or (sprinkler, 197, 16.5, 0.5), will induce both producer groups to choose the efficient input levels. Producers with fine sandy loam soil will be willing to idle their land in exchange for a payment of \$51.70 per acre from the government. If they choose (sprinkler, 197, 16.7, 0.5), the bundle intended for producers with clay loam soil, their expected net return would be \$49 per acre. If they do not participate in government programs, their expected net return would be \$51.60 per acre. Producers with fine sandy loam soil benefit from idling their land and accepting the government payment. Similarly, it can be shown that producers with clay loam soil will voluntarily reduce their nitrogen use to 197 pounds and water use to 16.5 inches and accept a payment of \$0.50 per acre.

As predicted by the theoretical model, when $\lambda = 0.35$, producers under the stewardship program will use fewer inputs than under current commodity programs but more inputs than the efficient levels. For example, when t = \$5, producers will apply 17.7 inches of water and 201 pounds of nitrogen per acre on Dalhart fine sandy soil, which are 11.5 and 5.6 percent less than under current commodity programs and 13.6 and 6.0 percent more than the efficient levels.

Although net social surplus is negative (–\$13.9) on fine sandy loam soil when $t = \$10$ and $\lambda = 0.35$, it is still beneficial to let farmers with fine sandy loam soil produce. Alternatively, the government would have to pay at least \$51.60 per acre in order for these farmers to idle their land, which would cause an efficiency loss of \$18.10 per acre.

Comparing the status quo with outcomes under the green payment program shows that replacing current farm programs with the green payment program will reduce government spending on farm programs, reduce nitrogen runoff and leaching, and increase net social surplus of agricultural production. 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. Adding a farm income constraint to the design of the stewardship program would increase government payments and reduce program efficiency, but not eliminate all the advantages of the green payment program over current commodity programs. The design of the green payment program takes into account externality costs of agricultural production. For example, when $t = \$5$ and $\lambda = \$0.35$, a stewardship program guaranteeing that both types of farmers are as well off as under the current commodity program will increase net social surplus per acre by \$0.80 on fine sandy loam soil and \$2.40 on clay soil. A green payment program that guarantees income for both types of farmers is at least 90 percent of current income will increase net social surplus per acre by \$5.70 on fine sandy loam soil and \$6.30 on clay loam soil. In the second example, government payments will also be reduced by 18.5 percent on fine sandy loam soil and 12.6 percent on clay loam soil. Thus, a green payment program can be designed to improve economic efficiency and environmental and fiscal performance while simultaneously assisting producers.

## Concluding Remarks

Under the green payment program, payments are made in exchange for reduced input use that may cause environmental damage. The program is voluntary and self-selecting. The stewardship program is second-best because of these constraints.

We illustrate the application of our approach by designing a stewardship corn program for the Oklahoma Panhandle. Results indicate that replacing current farm programs with the stewardship program will reduce government spending on farm programs, 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 better environmental and fiscal performance and economic efficiency under the stewardship program 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 increase without including other policy instruments. Such a program could also significantly redistribute farm program payments because they would no longer be directly tied to production. In addition, this analysis assumes that farmers will actually honor their green payment programs and use specified production practices accordingly. In practice, there is an enforcement issue. Production practices such as irrigation and tillage that are observable can be enforced in the same way the Conservation Compliance Program is enforced. However, without introducing appropriate mechanisms, chemical use may not be monitored.

**Table 1. A Comparison of Outcomes Under the Current, First-Best, and Green Corn Programs for the Oklahoma Panhandle**

| Variables | The Status Quo | | | The Efficient Outcomes | | | | A Stewardship Program ($\lambda$ =0) | | | | A Stewardship Program ($\lambda$ =0.35) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Furrow | Sprinkler | | t=$5 | | t=$10 | | t=$5 | | t=$10 | | t=$5 | | t=$10 | |
| | Clay[a] | Sandy[a] | Clay | Sandy | Clay | Sandy | Clay | Sandy | Clay | Sandy | Clay | Sandy | Clay | Sandy | Clay |
| Production Practices | | | | | | | | | | | | | | | |
| Nitrogen (lb/a) | 224 | 213 | 204 | 189 | 200 | 0 | 197 | 189 | 200 | 0 | 197 | 201 | 201 | 159 | 198 |
| Water (in/a) | 19.0 | 20.0 | 18.0 | 15.3 | 17.0 | 0 | 16.5 | 15.3 | 17.0 | 0 | 16.5 | 17.7 | 17.1 | 9.4 | 16.7 |
| Irrigation System[b] | Fur | Spr | Spr | Spr | Spr | 0 | Spr | Spr | Spr | 0 | Spr | Spr | Spr | Spr | Spr |
| Yield (bu/a) | 207 | 200 | 209 | 189 | 208 | 0 | 207 | 189 | 208 | 0 | 207 | 195 | 208 | 169 | 207 |
| Nitrogen Loss (lb/a) | | | | | | | | | | | | | | | |
| Runoff | 14.78 | 4.39 | 2.53 | 4.53 | 2.50 | 0 | 2.49 | 4.53 | 2.50 | 0 | 2.49 | 4.59 | 2.51 | 3.22 | 2.49 |
| Leaching | 0.95 | 3.17 | 0.30 | 1.52 | 0.26 | 0 | 0.23 | 1.52 | 0.26 | 0 | 0.23 | 2.34 | 0.27 | 0.00 | 0.24 |
| Net Return ($/a) | 73.7 | 51.6 | 82.5 | 46.7 | 82.3 | 0 | 82.0 | 46.7 | 82.3 | 0 | 82.0 | 50.3 | 82.1 | 26.9 | 81.81 |
| Gov. Payments ($/a)[c] | 48.9 | 45.5 | 49.8 | 0 | 0 | 0 | 0 | 5.0[d] | 2.0[d] | 51.7[d] | 0.5[d] | 1.3 | 1.4 | 24.7 | 0.7 |
| Farm Income ($/a) | 122.6 | 97.1 | 130.3 | 46.7 | 82.3 | 0 | 82.0 | 51.7 | 84.3 | 51.7 | 82.5 | 51.6 | 83.5 | 51.6 | 82.5 |
| Opp. Costs of Gov. Pay. | | | | | | | | | | | | | | | |
| $\lambda$ =0 | 48.9 | 45.5 | 49.8 | 0 | 0 | 0 | 0 | 5.0 | 2.0 | 51.7 | 0.5 | | | | |
| $\lambda$ =0.35 | 66.0 | 61.4 | 67.2 | 0 | 0 | 0 | 0 | | | | | 1.76 | 1.89 | 33.3 | 0.9 |
| Social Costs of Pollu. | | | | | | | | | | | | | | | |
| t=$5 | 78.7 | 37.8 | 14.2 | 30.3 | 13.8 | 0 | 13.6 | 30.3 | 13.8 | | | 34.7 | 13.9 | | |
| t=$10 | 157.3 | 75.6 | 28.3 | 60.5 | 27.6 | 0 | 27.2 | | | 0.0 | 27.2 | | | 32.2 | 27.1 |
| Net Social Surplus | | | | | | | | | | | | | | | |
| $\lambda$ =0, t=$5 | -5.0 | 13.8 | 68.3 | 16.4 | 68.5 | | | 16.4 | 68.5 | | | | | | |
| $\lambda$ =0, t=$10 | -83.6 | -24.0 | 54.2 | | | 0 | 54.8 | | | 0.0 | 54.7 | | | | |
| $\lambda$ =0.35, t=$5 | -22.1 | -2.1 | 48.9 | 16.4 | 68.5 | | | | | | | 15.1 | 67.7 | | |
| $\lambda$ =0.35, t=$10 | -100.7 | -39.9 | 34.8 | | | 0 | 54.8 | | | | | | | -13.9 | 54.5 |

[a] Sandy=fine sandy 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 bushels are used in calculating the government payments (FAPRI 1994).
[d] When t = $5, any payment scheme that satisfies $s_1 \geq 4.9$, $s_2 \geq 0.2$ and $s_1 - s_2 = 2.9$ will be incentive compatible and will satisfy the individual rationality constraints. Therefore, such a scheme will induce producers to use the socially optimal input levels. Similarly, when t = $10, any payment scheme that satisfies $s_1 \geq 51.6$, $s_2 \geq 0.5$ and $49.6 \leq s_1 - s_2 \leq 82.0$ will be optimal. The payment levels specified here minimize government outlays.

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