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ABSTRACT

Conservation programs administered by USDA have traditionally been voluntary, with USDA providing technical and financial assistance to farmers. This tradition is continued in the Federal Agriculture Improvement and Reform Act of 1996. Under these programs, farmers commit themselves to adopting a land management practice and, in turn, the government provides technical and financial assistance. Our analysis suggests that these voluntary programs are more efficient than a program that mandates adoption if and only if the per acre social cost of government expenditures under these program is less than the largest per acre farmer loss under the mandatory approach plus the additional implementation and enforcement cost. This necessary and sufficient condition is likely to be satisfied when (a) the deadweight loss from raising the government revenue is zero or small, (b) a large proportion of government services is public goods, (c) the area the program targets is large, (d) the price of government services is lower than what farmers would have to pay for equivalent private services, (e) the maximum per acre loss under the mandatory program is large, and (f) the monitoring and enforcement cost is much larger for the mandatory program than for the voluntary program.

THE RELATIVE EFFICIENCY OF VOLUNTARY VERSUS MANDATORY ENVIRONMENTAL REGULATIONS

The trend of increasing government involvement in designing and implementing environmental programs in the agricultural sector continues with the Federal Agriculture Improvement Act of 1996 (FAIR). The Act reauthorizes Conservation Compliance, the Conservation Reserve Program, and the Wetlands Reserve Program, which were all established in previous farm bills. In addition, FAIR establishes the Environmental Quality Incentives Program. FAIR requires the Secretary of Agriculture to implement these programs by providing technical and financial assistance to farmers and by entering into contracts with owners and operators. It authorizes the Secretary to "provide technical assistance, cost-share payments, and incentive payments to producers . . . based on (A) the significance of the soil, water, wildlife habitat, and related natural resource problems in a watershed, multistate area, or region; and (B) the structural practices or land management practices that best address the problems, and that maximize environmental benefits for each dollar expended, as determined by the Secretary" (Subtitle D of Title III, FAIR). A common characteristic of these Department of Agriculture (USDA) programs is that they are voluntary.

In addition to USDA involvement, the U.S. Environmental Protection Agency (EPA) programs also affect agriculture. A common characteristic of numerous EPA approaches is that they are mandatory. Examples include the Clean Water Act, the Clean Air Act, and the Federal Insecticides, Fungicides and Rodenticide Act. These acts give EPA authority to ban products that pose a threat to human health and to set effluent or emission standards. Mandatory approaches are also widely used to control nutrient and chemical applications in Europe. Austria, Germany, Finland, the Netherlands, and Denmark all have regulations governing fertilizer and manure applications (Anderson, DeBossu, and Kuch). Local governments also rely on mandatory programs. Olmsted County in Minnesota has developed a mandatory program for farmers to adopt erosion-reducing management practices (Helfand and House). And the Central

Platte Natural Resource District of Nebraska has adopted a set of fertilizer use restrictions to protect groundwater quality (Anderson, DeBossu, and Kuch).

When an industry causes an environmental problem, policymakers must make a choice. They can either require the industry to correct the problem, or they can create incentives for the industry to correct the problem voluntarily. For example, animal production units often create odor problems for rural residents. Politicians feel they have to do something. Should they mandate that all livestock farmers adopt a potentially costly management practice that reduces odor, or should they enact a voluntary program that educates farmers about the practice, and entices farmers to adopt the practice with cost-share payments?

Most studies on the choice of instruments for environmental protection focus on the comparative advantage of taxes and standards.[1] One exception is Stranlund, who developed a model to compare a mandatory regime with a voluntary regime in the context of compliance to an environmental norm. Stranlund assumes that a mandatory program is in place but the government is considering the adoption of a voluntary program. A voluntary program dominates the mandatory program if it generates the same level of compliance and government revenue but higher aggregate utility. Stranlund derives the conditions for a dominant voluntary program to exist. However, as Stranlund notes, his welfare analysis cannot be applied to cases in which individuals' net benefits are zero or negative. In addition, Stranlund assumes that farmers will comply with the environmental norm when the government provides enough services, so direct government payments are not necessary.

Here, we extend and generalize Stranlund's model and compare the efficiency of voluntary and mandatory programs to control nonpoint pollution from agriculture. Instead of analyzing whether a voluntary program dominates a given mandatory program, we evaluate the relative efficiency of the two approaches and allow farm benefits to be zero or negative, which implies that direct government payments may be needed to induce adoption under the voluntary program.

The problem we address is that the government wants farmers to adopt a certain management practice on environmentally sensitive land. The government can mandate its adoption, with noncompliance punished by a fine or a tax. Or the government can use a stewardship program, under which it provides technical assistance and, possibly, cost-share or incentive payments to farmers who adopt the practice. We derive the condition that determines which approach involves lower social costs. Satisfaction of this condition depends upon the proportion of government services that are public goods, the relative prices of private and public efforts to reduce adoption costs, the maximum decrease in profit from adopting the practice under the tax, and the deadweight loss of raising government payments. We implicitly assume that environmental benefits that accrue from adoption of the practice are greater than the social costs of adoption.

The Model

Consider a region that has A acres of environmentally sensitive land. These acres are located on N farms, with farm i having a_i acres. Let these farms be indexed so that $a_i \leq a_{i+1}$ for $i = 1, \ldots, N\text{-}1$. Production on these acres is profitable but causes environmental damage. Suppose a management practice is available that reduces environmental damage, and adoption improves social welfare. However, farmers do not voluntarily adopt the practice because it would decrease profits. The decrease results from additional equipment costs or from lack of experience in implementing the practice.

Suppose farmers can reduce the decline in profit through their own efforts. For example, they might learn how to avoid or minimize yield loss by gathering information about the management practice and by learning how it works. Denote the per acre effort in farm i as e_i. The effort is assumed to be purely private in the sense that it has no effect on other farmers' adoption costs. The effort is assumed purchased in a competitive market, with a unit price of one.

The government can promote adoption of the management practice by undertaking efforts to reduce adoption costs and by cost sharing. For example, the government can reduce adoption cost by gathering and disseminating information about the practice and by providing education and training. We group government services into three categories according to the cost of providing the services to an additional farm. If the marginal cost of providing a service to an additional farm is zero, the service is a pure public good. A typical example of this type of program is gathering and disseminating information. On the other hand, if the marginal cost is constant, the service is a pure private good. A typical example of this type of program is cost sharing. Finally, if the marginal cost is greater than zero but decreasing, the service is a semipublic good. An example of this type of program would be technical assistance. Although it is costly to provide technical assistance to an additional farm, the cost may be decreasing because the necessary techniques have been developed. We refer to all government payments and pure private services as *cost sharing* and the remainder as *services*.

Assume that the government does not distinguish between individual farmers, but instead provides the same level of services per acre to farmers who adopt the management practice. Denote the level of government services per acre as g and the total provision of government services as G. Then $G = \upsilon g$, where υ is a parameter indicating the "publicness" of government services. If all government services are pure public goods, then $\upsilon = 1$; if all government services are pure private goods, then $\upsilon = A^*$, where A^* is the total acreage of land that adopts the practice. In general, $1 < \upsilon < A^*$. Let p be the price of the government services. Then the total cost of government services is $p\upsilon g$.

Let c_i be the per acre loss (the decrease in profit) on farm i after adopting the management practice. This loss depends upon both farm i's own efforts and the level of government services. Assume that individual efforts and government services are perfect substitutes and the loss function takes a quadratic form:

$$c_i = c(x_i, a_i) = \alpha_0 + \beta a_i - \alpha_1 x_i + \frac{1}{2}\alpha_2 x_i^2, \tag{1}$$

where $x_i \equiv e_i + g$, and α_0, α_1, α_2, and β are parameters. The loss function is assumed to be decreasing, convey and twice differentiable in x_i. That is, $\partial c_i / \partial x_i \leq 0$ and $\partial^2 c_i / \partial x_i^2 \geq 0$. These assumptions imply that $\alpha_1 \geq 0$, and $\alpha_2 \geq 0$. Given x, the cost function can be increasing or decreasing in a_i. So, β can be positive or negative. For example, the same equipment may be needed to practice no-till whether a farmer is farming 500 acres or 1000 acres. This type of economy of scale tends to make β negative. On the other hand, no-till farming requires timely weed management. Small farms can often do better in this regard than large farms. This type of diseconomy of scale tends to make β positive. Overall, if there are economies of scale in adopting the practice, β will be negative; otherwise, β will be positive.

Suppose the government wants to see adoption of the management practice on all environmentally sensitive land in the region and is considering two alternative measures to achieve this environmental objective. Under the first measure, adoption is mandatory. The government provides no service to reduce c_i, but instead imposes a fine or a tax on nonadopters. Assume that detection of nonadopters is certain, but there will be some monitoring and implementation costs. Under the second measure, adoption is voluntary and is promoted through a stewardship program, under which the government not only undertakes efforts to reduce c_i but also makes payments to farmers who adopt the practice. The pertinent question is, which measure is more efficient at achieving the government's objective? Before we try to answer this question, it is necessary to determine how farmers might respond to these two measures.

Farmers' Decisions under the Mandatory Program

Under a mandatory program, the government takes no action to reduce the adoption costs, but instead imposes a fine or a tax of τ dollars per acre on nonadopters. For simplicity, assume that if a farmer chooses to adopt the practice, it will be adopted on all vulnerable land. Let σ_i be a dichotomous variable indicating farmer i's adoption decision: $\sigma_i = 1$ if farmer i adopts the practice and $\sigma_i = 0$ otherwise. Let π_i be the per acre net return in farm i before adopting the practice on vulnerable land. Then farmer i's decision problem under the regulatory measure is

$$\max_{\sigma, e_i} \ \pi_i - \sigma_i c(e_i, a_i) - e_i - (1 - \sigma_i)\tau . \tag{2}$$

Note first that farmers who do not adopt the management practice have no incentive to reduce adoption cost. Thus, if $\sigma_i = 0$, $e_i = 0$. In this case, farmer i's per acre, after-tax net return is $(\pi_i - \tau)$. Farmers who decide to adopt the management practice would like to minimize the adoption cost. Thus, given that $\sigma_i = 1$, the farmer's problem becomes $\min_{e_i} c(e_i, a_i) + e_i$. The first-order condition for this minimization problem is

$$-c_1(e_i^t, a_i) = 1, \tag{3}$$

where e_i^t is the optimal per acre effort on farm i under the tax. The left-hand side of (3) is the marginal benefit of the effort in farm i (i.e., the reduction in loss), and the right-hand side is the price of the effort. Thus, at the optimal level of effort marginal cost equals marginal benefit. Using (1), (3) becomes

(4) $$e_i^t \equiv e^t \equiv \frac{\alpha_1 - 1}{\alpha_2}.$$

Thus, on a per acre basis, each farmer devotes the same amount of effort to reduce adoption cost. Substituting (4) back into (1), we get the per acre adoption cost for farm i:

(5) $$c_i^t \equiv c\left(e_i^t, a_i\right) = \alpha_0 + \beta a_i - \frac{\left(\alpha_1^2 - 1\right)}{2\alpha_2}.$$

Thus, if farm i adopts the practice, its per acre decrease in profit under the tax will be

(6) $$L_i^t \equiv c\left(e_i^t, a_i\right) + e_i^t = \alpha_0 + \beta a_i - \frac{(\alpha_1 - 1)^2}{2\alpha_2}.$$

Farm i will adopt the practice if and only if this loss is less than the tax rate, i.e.,

(7) $$L_i^t \leq \tau.$$

If there are overall economies of scale in adopting the management practice, then $\beta < 0$, and loss under the tax L_i^t decreases as farm size increases. Given a tax rate, large farms will be more likely to adopt the practice. If there are diseconomies of scale in adopting the practice, then the loss under the tax will increase with farm size and small farms will be more likely to adopt the desired management practice.

Expression (7) indicates that all farmers adopt the practice when the tax rate is set high enough. Thus, under the mandatory program, the minimum social cost of achieving the government's environmental objective equals

(8) $$SC_t^* \equiv \sum_{i=1}^{N} a_i L_i^t + R = A\alpha_0 + \beta \sum_{i=1}^{N} a_i^2 - \frac{A(\alpha_1 - 1)^2}{2\alpha_2} + R_t,$$

where R_t is the monitoring and implementation cost of the mandatory program.

Farmers' Decisions under the Voluntary Program

Under the voluntary program, adoption of the practice is promoted through a stewardship program, under which the government not only provides services to farmers but also shares adoption costs by providing direct payments. Let s be the per acre government payment to farmers who adopt the management practice. Then farmer i's decision problem under this program is

(9) $$\max_{\sigma_i, e_i} \ \pi_i - \sigma_i c(e_i + g,\ a_i) - e_i + \sigma_i s.$$

Again, farmers who do not adopt the management practice have no incentive to try to reduce the adoption cost. Thus, if $\sigma_i = 0$, $e_i = 0$. In this case, farmer i's per acre net return is π_i. On the other hand, farmers who adopt the management practice will seek to minimize the cost of doing so. Thus, given $\sigma_i = 1$, farmer i's objective is to

(10) $$\min_{e} \ c(e_i + g,\ a_i) + e_i,$$

$$\text{s.t.} \quad e_i \geq 0.$$

The first-order condition for this minimization problem is

(11) $$e_i^v \ c_1(e_i^v + g,\ a_i) + 1 = 0,$$

where e_i^v is the effort in farm i under the voluntary program. Note that the optimal effort under the tax, e^t, satisfies $c_1(e_i^t,\ a_i) + 1 = 0$. Thus, if $g < e^t$, $e_i^v = e^t - g$; and if $g \geq e^t$, $e_i^v = 0$. Let $c_i^t \equiv c(e_i^t + g,\ a_i)$. Then, $c_i^v = c_i^t$ if $g < e^t$, and $c_i^v = c(g, a_i) \leq c(e^t, a_i) = c_i^t$ if $g \geq e^t$. That is, if the government provides fewer services than what farmer i would like to purchase under the tax, farmer i will make up the difference. However, if the government provides more services than what farmer i would like to purchase under the tax, farmer i will make no effort. In this case, the adoption cost is lower under the voluntary program than under the tax.

Now consider farmers' adoption decisions under the voluntary program. If the government provides fewer services than what farmer i would purchase under the tax, its per acre net return would be $\pi_i - c_i^t - (e^t - g) + s$ if it adopts. Thus, farmer i will adopt the management practice if and only if

(12) $$\pi_i - c_i^t - (e^t - g) + s \geq \pi_i$$

or

(13) $$s \geq L_i^t - g,$$

where $L_i^t - g$ is the per acre loss under the voluntary program. Thus, farmer i will adopt the practice if and only if the payment rate is greater than the loss.

If there are economies of scale in adopting the management practice, the L_i^t decreases as farm size increases. Given the level of government effort and the payment rate, large farms will be more likely to adopt the management practice. Thus, if $s \geq L_1^t - g$, then $s \geq L_i^t - g$ for $i = 1, \ldots, N$. That is, if the smallest farm in the region adopts the management practice, all farms will do so. On the other hand, if there are diseconomies of scale in adopting the management practice, then L_i^t increases with farm size, and smaller farms will be more likely to adopt the practice. Thus, if $s \geq L_N^t - g$, then $s \geq L_i^t - g$ for $i = 1, \ldots, N$.

Now, consider the case in which the government provides more services than what farmer i would purchase under the tax (i.e., $g \geq e^t$). In this case, farmer i makes no effort to reduce the adoption cost. The per acre payment farmer i receive for adopting the management practice is s, whereas the per acre loss is $c(g, a_i)$. Thus, farmer i will adopt the practice if and only if

$$(14) \qquad s \geq c(g, a_i).$$

The Optimal Levels of Government Services and Payment Rates

Given farmers' response to the voluntary program, the government's objective is to choose the appropriate level of services and payment rate to minimize the social cost of achieving its environmental objective. The loss in per acre net return in farm i after adopting the management practice is $(c_i^v + e_i^v - s)$. Total government expenditure under the voluntary program is $(As + p\upsilon g)$. Let λ be the marginal deadweight loss from distortionary taxes needed to raise government revenue. Then the social cost of the government expenditure is $(1 + \lambda)(As + p\upsilon g)$. Thus, under the voluntary program, the government's objective can be formally stated as

$$(15) \qquad \min_{g,s} \sum_{i=1}^{N} a_i\left(c_i^v + e_i^v - s\right) + (1 + \lambda)(sA + p\upsilon g),$$

$$(16) \qquad \text{s.t.} \quad s \geq c_\delta^v + e_\delta^v,$$

where $\delta = 1$ if there are economies of scale in adopting the management practice, and $\delta = N$ if there are diseconomies of scale in adopting the practice. Thus, when constraint (16) is satisfied, all farmers in the region adopt the practice.

To solve this minimization problem, recall that if $g \le e^t$, $c_i^v = c_i^t$ and $e_i^v = e^t - g$, and if $g > e^t$, $c_i^v = c(g, a_i)$ and $e_i^v = 0$. Assume for the moment that $g \le e^t$. In this case, (15) and (16) become

(17) $$\min_{g,s} \sum_{i=1}^{N} a_i L_i^t + \lambda A s + \left[(1+\lambda)p\upsilon - A\right] g$$

(18) $$\text{s.t.} \qquad s + g \ge L_\delta^t .$$

Note that as long as $s + g \ge L_\delta^t$, all farms in the region will adopt the practice. Thus, increasing s or g is equally effective in promoting adoption. The government would like to increase the parameter that causes the smaller deadweight loss. The marginal deadweight loss of increasing s is $\partial(\lambda As)/\partial s = \lambda A$, whereas the marginal deadweight loss of increasing g is $\partial[(1+\lambda)p\upsilon g - Ag]/\partial g = (1+\lambda)p\upsilon - A$, where $(1+\lambda)p\upsilon g$ is the social cost of government services, and Ag is the saving in private efforts. $\partial[(1+\lambda)p\upsilon g - Ag]/\partial g > \partial(\lambda As)/\partial s$ if and only if $(1+\lambda)p\upsilon - A > \lambda A$ or $p\upsilon > A$.

This result suggest that given $g \le e^t$, if $p\upsilon > A$, the government will choose $g_1 \equiv 0$ and $s_1 \equiv L_\delta^t$ to achieve its environmental objective. Substituting these results into (17) gives the social cost of the voluntary program

(19) $$SC_v^1 \equiv \sum_{i=1}^{N} a_i L_i^t + \lambda A L_\delta^t + R_v ,$$

where R_v is the implementation cost of the voluntary program. Because the regulatory program is likely to incur a lower enforcement cost than the voluntary program, we assume $R_v < R_r$, where R_r is the monitoring and implementation cost of the regulatory program. Because in this case the government does not provide any service, but instead provides a direct payment of L_δ^t per acre, total government expenditure is

(20) $$E_1 \equiv A L_\delta^t .$$

Given $g \le e^t$, if $p\upsilon < A$, the marginal deadweight loss of increasing g will be smaller than the marginal deadweight loss of increasing s. Thus, given $g \le e^t$, the optimal levels of government services and payment rate will be $g_2 \equiv e^t$ and $s_2 \equiv L^t_\delta - g$. Substitute the results into (17), we get the social cost of the voluntary program

$$(21) \qquad SC^2_v \equiv \sum_{i=1}^{N} a_i L^t_i + \lambda A(L^t_\delta - e^t) + [(1+\lambda)p\upsilon - A]e^t + R_v$$

$$= A\alpha_0(1+\lambda) + \left(\sum_{i=1}^{N} a_i^2 + \lambda A a_\delta\right)\beta - \frac{A(1+\lambda)}{2\alpha_2}(\alpha_1 - 1)\left[(\alpha_1 + 1) - \frac{2p\upsilon}{A}\right] + R_v .$$

And total government expenditure is

$$(22) \qquad E_2 = A(L^t_\delta - e^t) + p\upsilon e^t .$$

Finally, if $p\upsilon = A$, it does not matter whether the government or farmers make the effort. In this case, the total cost of the voluntary program is $SC^1_v = SC^2_v$.

Now, consider the case of $g > e^t$. Note first that it will never be socially optimal for government to provide services if government has to pay a higher price than farmers. Thus, only when $p\upsilon < A$, $g > e^t$. Recall that given $g > e^t$, $c^v_i = c(g, a_i)$ and $e^v_i = 0$. Substitute this result into (15), we get

$$(23) \qquad \min_{g,\, s} \sum_{i=1}^{N} a_i\, c(g, a_i) - s + (1+\lambda)(sA + p\upsilon g),$$

$$(24) \qquad \text{s.t.} \qquad s - c(g, a_\delta) \geq 0.$$

Since it is costly to raise government expenditures, the $s - c(g, a_\delta) \geq 0$ constraint must be binding at the optimum solution. When we substitute $s = c(g, a_\delta)$ into (23) and differentiate the result with respect to g, we get the first-order condition for the minimization problem:

$$(25) \qquad \sum_{i=1}^{N} a_i c_1(g, a_i) + \lambda A c_1(g, a_\delta) + (1+\lambda)p\upsilon = 0.$$

Substituting (1) into (25) and solving for g, we obtain

$$(26) \qquad g_3 \equiv \frac{\alpha_1}{\alpha_2} - \frac{p\upsilon}{A\alpha_2}.$$

Comparing (26) with (4) indicates that when $p\upsilon < A$, we indeed have $g_3 > e^t$. Thus, government provides more services than what a farmer would purchase if and only if the per acre cost of government services is less than the price farmers would have to pay. In this case, the government payment is

(27) $$s_3 \equiv c(g_3, a_\delta) = \alpha_0 + \beta a_\delta - \frac{1}{2\alpha_2}\left[\alpha_1^2 - \left(\frac{p\upsilon}{A}\right)^2\right].$$

The change in per acre net return in farm i is

(28) $$L_i^v \equiv c(g_3, a_i) - s_3 = \beta(a_i - a_\delta).$$

The total government expenditure under the voluntary program equals

(29) $$E_3 \equiv As_3 - p\upsilon g_3 = A(\alpha_0 + \beta a_\delta) - \frac{A}{2\alpha_2}\left(\alpha_1 - \frac{p\upsilon}{A}\right)^2.$$

Substituting these results into (14), we obtain the social cost of the voluntary program

(30) $$SC_v^3 \equiv \sum_{i=1}^{N} a_i L_i^v + (1+\lambda)E^* + R_v$$

$$= A\alpha_0(1+\lambda) + \left(\sum_{i=1}^{N} a_i^2 + \lambda A a_\delta\right)\beta - \frac{A(1+\lambda)}{2\alpha_2}\left(\alpha_1 - \frac{p\upsilon}{A}\right)^2 + R_v.$$

In summary, if $p\upsilon > A$, the government should not provide any service, but instead provide a direct payment of $s_1 = L_\delta^t$ per acre. In this case, the minimum social cost of the voluntary program is $SC_v^* \equiv SC_v^1$, and the optimal government expenditure is $E^* \equiv AL_\delta^t$. On the other hand, if $p\upsilon < A$, the level of services government provides could be g_2 or g_3. If the level of services the government provides is g_2, the total social cost of the voluntary program will be given by equation (21); if the level of services the government provides is g_3, the total social cost of the voluntary program will be given by equation (28). To determine which level of services the government should provide when $p\upsilon < A$, we compare equation (21) with equation (28):

(31) $$SC_v^3 - SC_v^2 = -\frac{A(1+\lambda)}{2\alpha_2}\left(\frac{p\upsilon}{A} - 1\right)^2 < 0.$$

Since the social cost of the voluntary program is always smaller when the level of services is g_3, the optimal level of government services is g_3. Thus, when $p\upsilon < A$, the minimum social cost of the voluntary program is $SC_v^* = SC_v^3$, and the optimal level of government expenditure is $E^* = E_3$. Finally, if $p\upsilon = A$, $SC_v^1 = SC_v^2 = SC_v^3$. In this case, it does not matter whether the government or farmers make the effort to reduce adoption cost.

Relative Efficiency

In this section, we evaluate the relative efficiency of the two programs we have described. A program is said to be more efficient if it can be used to achieve the government's environmental objective at a lower social cost. Proposition 1 provides the condition that determines the relative efficiency of the two programs.

Proposition 1. *The voluntary program is more efficient than the mandatory program if and only if*

$$(1+\lambda)\frac{E^*}{A} \leq L_\delta^t + \frac{\Delta R}{A}, \tag{32}$$

where $\delta = 1$ *if there are economies of scale in adopting the management practice,* $\delta = N$ *if there are diseconomies of scale in adopting the practice, and* $\Delta R \equiv R_t - R_v$ *is the difference in enforcement costs under the two programs.*

Before proving this proposition, it is useful to interpret (32). If there are economies of scale in adopting the management practice, farm 1, the smallest farm in the region, will suffer from the largest loss per acre under the tax. On the other hand, if there are diseconomies of scale in adopting the management practice, farm N, the largest farm in the region, will suffer from the largest loss per acre under the tax. Thus, L_δ^t is the largest loss among all farms in the region under the tax. Proposition 1 reveals that the voluntary program will be more efficient if and only if the per acre social cost of government expenditure under the voluntary program is less than the largest loss under the regulatory program plus the additional implementation cost of the regulatory program.

Proof: First, consider the case of $p\upsilon < A$. In this case, the social cost of the voluntary program is $SC_v^* \equiv SC_v^3$. The social cost of the regulatory program is always given by equation (8). Thus, the difference between the social costs of the two programs equals

$$(33)\quad SC_t^* - SC_v^* = \sum_{i=1}^{N} a_i(L_i^t - L_i^v) + \Delta R - (1+\lambda)E^* .$$

Substituting (6) and (28) into (33)

$$(34)\qquad SC_t^* - SC_v^* = \sum_{i=1}^{N} a_i\left[\alpha_0 + \beta a_\delta - \frac{(\alpha_1 - 1)^2}{2\alpha_2}\right] + \Delta R - (1+\lambda)E^*$$

$$= AL_\delta^t + \Delta R - (1+\lambda)E^* .$$

Thus, $SC_t^* - SC_v^* > 0$ if and only if condition (32) holds.

Now, consider the case of $p\upsilon \geq A$. In this case, the social cost of the voluntary program is $SC_v^* \equiv SC_v^1$, and the optimal government expenditure is $E^* \equiv AL_\delta^t$. By using equations (8) and (19), we obtain the difference between the social costs of the two programs:

$$(35)\qquad SC_t^* - SC_v^* = \Delta R - \lambda AL_\delta^t$$

$$= AL_\delta^t + \Delta R - (1+\lambda)E^* .$$

Again, $SC_t^* - SC_v^* > 0$ if and only if condition (32) holds.

Condition (32) is useful because in order to check whether it is satisfied, we only need to calculate the decrease in profits on the farm that has the most difficulty in adopting the management practice, instead of calculating loss in every farm of the region. The condition emphasizes the loss for the least profitable farm because it is the loss for this farm that determines the per acre government payment under the voluntary program.

To see when condition (32) is likely to be satisfied, we analyze some special cases. Corollary 1 evaluates the relative efficiency of the two programs when there is no deadweight cost of raising government expenditure. Corollary 2 examines the case in which all government services are purely public goods and the loss from adopting the management practice can be reduced to zero by private or public efforts. Finally, in corollary 3, we investigate the case in which all government services are purely private goods and the government cannot purchase these services at a lower price than farmers.

Corollary 1. *When $\lambda = 0$, the mandatory program cannot be more efficient than the voluntary program.*

Proof: First, consider the case of $p\upsilon < A$. In this case, the optimal government expenditure is given by equation (29). Substitute L_δ^t from (6) and E^* from (29) into (34) and notice that $\lambda = 0$,

(36)
$$SC_t^* - SC_v^* = AL_\delta^t + \Delta R - E^*$$
$$= \frac{1}{2\alpha_2}\left(\alpha_1 - \frac{p\upsilon}{A}\right)^2 - \frac{1}{2\alpha_2}(\alpha_1 - 1)^2 + \Delta R$$
$$= \frac{\alpha_2}{2}\left(g_3^2 - e^{t2}\right) + \Delta R > 0.$$

Note that when $p\upsilon < A$, $g_3 > e^t$. This result suggests that given $\lambda = 0$, when the government can provide the services at a lower price than farmers (i.e., $p < 1$) and some of the services are public foods (i.e., $\upsilon < A$), the voluntary program will be more efficient than the regulatory program.

Now, consider $p\upsilon \geq A$. In this case, the difference between the social costs of the two programs is given by equation (35). Substitute $\lambda = 0$ into (35),

(37)
$$SC_t^* - SC_v^* = \Delta R \geq 0.$$

In this case, the mandatory program cannot be more efficient than the voluntary program because it incurs at least the same enforcement cost as the voluntary program.

The intuition behind Corollary 1 is straightforward. When $p\upsilon < A$, government services either avoid duplicated private efforts or cost less ($p < 1$). As a result, the optimal level of government service will be higher than e^t under the voluntary program. For the first $p\upsilon e^t$ dollars the government spends on services, farmers save Ae_t^t. Under the mandatory program, farmers will devote Ae^t dollars to cost reduction. Because $p\upsilon e^t < Ae^t$, social welfare improves under the voluntary program. In addition, because the government can reduce the adoption cost at a lower cost than farmers, it will devote more effort to cost reduction than each individual farmer under the regulatory program. This will further improve social welfare.

When $p\upsilon \geq A$, the government will not provide any service. As a result, farmers will make the same effort under the two programs. The only difference between these two programs is that the mandatory program forces farmers to adopt the management practice by penalty, whereas the voluntary program induces farmers to adopt through direct payments. Because government payments do not cause any deadweight loss while the regulatory program incurs a larger enforcement cost, the voluntary program is more efficient.

Corollary 2. *If $p\upsilon/A \to 0$ as $A \to \infty$ and the loss in the least advantageous farm can be reduced to zero by private and public efforts, then the voluntary program will be more efficient than the mandatory program when the total acreage of environmentally sensitive land is large enough.*

***Proof*:** When $p\upsilon < A$, the optimal government expenditure E^* is given by equation (29). Substitute E^* into (34) and rearrange terms,

(38)
$$SC_t^* - SC_v^* = \frac{A}{2\alpha_2}\left[2\alpha_1 - \frac{p\upsilon}{A} - 1\right]\left[1 - \frac{p\upsilon}{A}\right] - \lambda A\left[\alpha_0 + \beta a_\delta - \frac{1}{2\alpha_2}\left(\alpha_1 - \frac{p\upsilon}{A}\right)^2\right] + \Delta R .$$

Note that the first term on the right-hand side of (38) approaches $+\infty$ as $A \to \infty$. Also, as $A \to \infty$,

(39)
$$\alpha_0 + \beta a_\delta - \frac{1}{2\alpha_2}\left(\alpha_1 - \frac{p\upsilon}{A}\right)^2 \to \alpha_0 + \beta a_\delta - \frac{1}{2\alpha_2}\alpha_1^2,$$

which is the minimum of $c(a_\delta, x)$. The assumption that the loss for the least profitable farm can be reduced to zero implies that the minimum is negative or zero. If it is negative, then the second term on the right-hand side of (38) approaches $+\infty$ as $A \to \infty$. If it is zero, then by L'Hospital's rule[2] (Chiang, p. 429), we obtain

(40)
$$\lim_{A \to \infty} A\left[\alpha_0 + \beta a_\delta - \frac{1}{2\alpha_2}\left(\alpha_1 - \frac{p\upsilon}{A}\right)^2\right]$$

$$= \lim_{A \to \infty} \frac{\alpha_0 + \beta a_\delta - \frac{1}{2\alpha_2}\left(\alpha_1 - \frac{p\upsilon}{A}\right)^2}{\frac{1}{A}}$$

$$= \lim_{A \to \infty} \frac{-\frac{1}{\alpha_2}\left(\alpha_1 - \frac{p\upsilon}{A}\right)\left(-\frac{p\upsilon}{A^2}\right)}{-\frac{1}{A^2}} = -\frac{\alpha_1 p\upsilon}{\alpha_2}.$$

In this case, the second term on the right-hand side of (38) approaches a finite number. Because the first term on the right-hand side of (38) approaches $+\infty$ and the second term approaches either $+\infty$ or a finite number, $SC_t^* - SC_v^*$ becomes positive as A becomes large enough. This shows that the voluntary program will be more efficient when the total acreage of environmentally sensitive land is large enough.

Under what circumstances will the assumptions in Corollary 2 be satisfied? First, $p\upsilon/A \to 0$ when all government services are pure public goods. In this case, $\upsilon = 1$. In fact, as long as υ is a limited number or increases at a slower rate than A, $p\upsilon/A \to 0$. This case may occur when there are different types of farms and the government has to provide technical information for each type of farm. Second, loss from adopting the management practice can be reduced to zero if the loss results from a lack of information or experience. The intuition behind Corollary 2 is that, as total acreage of environmentally sensitive land becomes larger, government services will avoid more and more duplicated private efforts. The benefits of government services will eventually outweigh their costs because the marginal cost of providing services is declining.

Corollary 3. *When $p\upsilon = A$, the mandatory program is more efficient than the voluntary program if and only if*

(41) $$\lambda E^* > \Delta R.$$

Proof: When $p\upsilon = A$, $E^* \equiv AL_\delta^t$. Substituting the result into (32) gives (41).

Corollary 3 reveals that when all government services are purely private and the government cannot provide them at a lower cost than farmers, then the mandatory program is more efficient if and only if the additional enforcement cost of the mandatory program is less than the deadweight loss of government expenditure under the voluntary program. When $p\upsilon = A$, $E^* \equiv E_1 = E_2 = E_3 = AL_\delta^t$. This suggests that when $p\upsilon = A$, the total government expenditure will be the same whether the government provides the services or farmers themselves make the effort to reduce the adoption cost. When the government provides more services to reduce the adoption cost, it will save farmers' efforts. As a result, direct payments can be reduced.

Concluding Remarks

Conservation programs administered by USDA have traditionally been voluntary, with USDA providing technical and financial assistance to farmers. This tradition is continued in the Federal Agriculture Improvement and Reform Act of 1996. Under these programs, farmers commit themselves to adopting a land management practice and, in turn, the government provides technical and financial assistance. Our analysis suggests that these voluntary programs are more efficient than a program that mandates adoption if and only if the per acre social cost of government expenditures under these program is less than the largest per acre farmer loss under the mandatory approach plus additional implementation and enforcement cost. This necessary and sufficient condition is likely to be satisfied when (a) the deadweight loss from raising the government revenue is zero or small, (b) a large proportion of government services are public goods, (c) the price of government services is lower than what farmers would have to pay for equivalent private services, (d) the maximum per acre loss under the mandatory program is large, and (e) the monitoring and enforcement cost is much larger for the mandatory program than for the voluntary program.

These findings suggest that voluntary programs are most efficient when the technical assistance the government provides are public goods and the area the program targets is large. These are the characteristics of many soil conservation programs where farmers commit themselves to a land management practice, such as leaving crop residue on the soil to reduce soil erosion, and in return the government provides technical and financial assistance. The technical assistance is largely information about how the management practice works and how it can be used to provide economic and environmental benefits. There may be some costs associated with providing the technical assistance to additional farmers, but the costs are very low. In the case of soil management practices, many farmers find that profits are largely unchanged after adoption. These farmers would have suffered a larger loss under a mandatory program..

ENDNOTES

1. The literature on instrument choice has covered the comparative advantage of taxes and standards under uncertainty (e.g., Weitzman: Adar and Griffin), enforcement issues (e.g., Harford: Harrington; Russell), as well as other dimensions for judging policy instruments (e.g., Bohm and Russell: Dewees). These issues are typically discussed in the context of point source of pollution. In the context of nonpoint source pollution, Griffin and Bromley and Shortle and Dunn analyzed cost effectiveness of incentives and standards that are applied to agricultural runoff or management practice. Other studies (e.g., Helfand and House; and Johnson, Adams, and Perry.) examined the effects of input use tax and standards on farm income and groundwater quality.

2. L' Hospital's rule states that when $\lim_{x\to\infty} f(x) = \lim_{x\to\infty} g(x) = 0$, $\lim_{x\to\infty} f(x) \;\; g(x)$

   $= \lim_{x\to\infty} f'(x) \;\; g'(x)$.

REFERENCES

Adar, Z., and J. M. Griffin. "Uncertainty and the Choice of Pollution Control Instruments." *J. Environ. Econ. Manage.* 3(1976):178-88.

Anderson, G.D., A.E. DeBossu, and P.J. Kuch. "Control of Agricultural Pollution by Regulation." In *Agriculture and Water Quality: International Perspectives*, eds. J.B. Braden and S.B. Lovejoy. Boulder, Colorado: Lynne Rienner, 1990.

Bohm, P. and C.S. Russell. "Comparative Analysis of Alternative Policy Instruments." In *Handbook of Natural Resource and Energy Economics, vol. I*, eds. A.V. Kneese and J.L. Sweeney. Elsevier Science Publishers B.V., 1985.

Chiang, A.C. *Fundamental Methods of Mathematical Economics*, 3rd edition. New York: McGraw-Hill Book Company, 1984.

Dewees, D.N. "Instrument Choice in Environmental Policy." *Econ. Inquiry* 21(1983):53-71.

Griffin, R.C., and D.W. Bromley. "Agricultural Runoff as a Nonpoint Externality: A Theoretical Development." *Amer. J. Agr. Econ.* 64(August 1982):547-52.

Harford, J. "Firm Behavior under Imperfectly Enforceable Pollution Standards and Taxes." *J. Environ. Econ. Manage.* 5(1978):26-43.

Harrington, W. "Enforcement Leverage When Penalties are Restricted." *J. Public Econ.* 37(1988):29-53.

Helfand, G.E., and B.W. House. "Regulating Nonpoint Source Pollution under Heterogeneous Conditions." *Amer. J. Agr. Econ.* 77(November 1995):1024-32.

Johnson, S.L., R.M. Adams and G. M. Perry. "The On-Farm Costs of Reducing Groundwater Pollution." *Amer. J. Agr. Econ.* 73(November 1991):1063-73.

Russell, C.S. "Monitoring and Enforcement." In *Public Policies for Environmental Protection*, ed. P.R. Portney, Resources for the Future, Washington, D.C., 1990.

Shortle, J.S., and J.W. Dunn. "The Relative Efficiency of Agricultural Source Water Pollution Control Policies." *Amer. J. Agr. Econ.* 68(August 1986):668-77.

Stranlund, J.K. "Public Mechanisms to Support Compliance to an Environmental Norm." *J. Environ. Econ. Manage.* 28(1995):205-22.

Weitzman, M.L. "Prices vs. Quantities." *Rev. Econ. Studies* 41(1974):477-91.