An Analysis of Agri-Environmental Policies and their Trade and Welfare Effects

by G. SCHAMEL[1]

1 Introduction

In theory, agricultural production should be compatible with a clean and diverse environment. In practice, it is known as a source of positive and negative environmental effects. Examples of negative environmental impacts are nitrate residues from fertilizers found in groundwater reservoirs, saline aquifers and waterways due to irrigation systems, public health concerns due to pesticide residues in food, as well as soil erosion, wetland degradation or biodiversity loss due to intensive agricultural production. On the other hand, rural landscapes in a sustainable natural environment are recognized as a provider of non-market benefits (OECD). Tourists and urban residents value the existence of agricultural landscapes and rural life. Contingent valuation (CV) studies have verified substantial non-market benefits for rural areas with environmentally benign agricultural production (ROMMEL; HACKL, PRUCKNER; AAKKULA).

Recent agri-environmental discussions and programs reflect a growing interest in preserving rural landscapes in a sustainable natural environment (USDA). Policies such as land use controls or subsidies have been suggested to internalize non-market benefits of agricultural land use (LOPEZ, ET AL.). In 1997, more than 5.5m hectares or 1/3 of Germany's arable land was enrolled in agri-environmental programs (BMELF). Moreover, agricultural policy and environmental goals conflict when price support enhances the use of polluting inputs and technologies (REICHELDERFER). In order to undo negative environmental effects, farm policy is often supplemented by conservation programs (USDA). Although the joint existence and interdependence of positive and negative agricultural externalities is known, separate policies aim at each problem and are typically analyzed independently (POE).

Policies that restrict agricultural land use are frequently justified by amenity benefits from land farmed less intensively (e.g. countryside stewardship policy) while input regulations are implemented due to negative environmental impacts (e.g. pesticide regulations). Independent analysis of such policies ignores interaction effects: a polluting input tax will reduce the returns and lower the subsidy needed to move land into environmentally benign production. Moreover, the social cost of polluting production depends on the area farmed such that a change in land use policy implies a change in the optimal pollution policy. In general, a change in social value of either externality requires adjustments of both policies.

Linkages between trade and the environment have been on the policy agenda for a number of years. Various authors have analyzed negative externalities and policy implications on trade and environmental issues (e.g. KRUTILLA; ANDERSON; COPELAND; SCHAMEL, DE GORTER). However, few studies examine a more relevant case of multiple, related externalities (e.g. PETERSON; OLLIKAINEN). In this paper, we study agri-environmental policies to correct for joint positive and negative external effects. The analytical model builds on an indirect utility approach (SCHAMEL; MÆSTAD; PETERSON), but distinguishes "alternative" and "conventional" agricultural production methods that generate non-market benefits (environmental amenities) and external costs (pollution) respectively. Compared with conventional production methods, alternative production is characterized by less intensive and non-polluting input use. We focus mainly on a closed economy setting and derive social welfare-maximizing agri-environmental policies, but also examine welfare-maximizing factor allocations and policies for small and large economies assuming free trade. In conclusion, we summarize the results and provide some policy implications.

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2 Agricultural Economy Model

Consider an agricultural sector in a closed economy with a large number of identical consumers. Agriculture produces "alternative" and "conventional" commodities, denoted by a and m, respectively, which are produced according to the production functions $a = F_a(L_a, X_a)$ and $m = F_m(L_m, X_m)$, where L_i and X_i are the amount of arable land and agricultural inputs allocated to the production of commodity i, respectively. The economy is endowed with L hectares of arable land and X units of agricultural inputs, and the entire endowment of each factor is of homogeneous quality. Each $F_i(\cdot)$ is strictly increasing, strictly concave, and exhibits constant returns to scale. By homogeneity, $F_i(L_i, X_i) = L_iF_i(1, X_i/L_i) = L_if_i(x_i)$, where x_i represents the per-hectare input ratio X_i/L_i and $f_i(\cdot)$ is the per-hectare production function. Alternative production requires more inputs per hectare such that $f_m(x_i) > f_a(x_i)$.

Agricultural production leads to two externalities. First, consumers receive amenity benefits from land allocated to alternative agriculture L_a. Second, conventional input use generates pollution. Emissions $E = G(L_m, X_m)$ depend on conventional inputs L_m and X_m. If $G(\cdot)$ is homogeneous of degree one, $E = L_mg(x_m)$, where $g(\cdot)$ is emissions per hectare. When L_m and X_m both double such that x_m remains constant, emissions will also double. Assume that g is strictly increasing, strictly convex, and that $g(0) = 0$.

Preferences for agricultural goods are given by an aggregate utility function $U(a, m, L_a, E)$, which is strictly quasi-concave, strictly increasing in (a, m, L_a), and strictly decreasing in E. Income I is equal to the total payments on the factors of agricultural production. Consumers use their income to purchase a and m, but cannot influence the levels of L_a and E. Let m be the numeraire good and p the price of a. Then, indirect utility function V is defined by:

$$V(p, I, L_a, E) = \max U(a, m, L_a, E) \quad s.t. \quad pa + m \leq I, \quad (a, m) \in \Re_+^2$$

$V(\cdot)$ is the social welfare with an optimal combination of price, income, agricultural land allocation, and emissions. $a(p, I, \cdot)$ and $m(p, I, \cdot)$ are the demands for alternative and conventional commodities, respectively and solve the utility maximization problem stated above. If the utility function is properly restricted such that $a(p, I, \cdot)$ and $m(p, I, \cdot)$ are monotonic in p, there is a unique price that will clear agricultural markets for any amount of production. Since the production functions exhibit constant returns to scale, factor payments from both commodities are equal to revenues. Thus, p and I are functions of L_a and x_a, and these relationships are implicitly defined by the equations:

[1] $a(p(L_a, x_a), I(L_a, x_a), \cdot) = L_af_a(x_a)$
[2] $I(L_a, x_a) = p(L_a, x_a)L_af_a(x_a) + (L-L_a)f_m(x_m(L_a, x_a))$

where $x_m(L_a, x_a) = (xL - x_aL_a)/(L-L_a)$, and $x = X/L$. The problem of maximizing social welfare in a closed economy is:

$$\begin{aligned} &\max V[p(L_a, x_a), I(L_a, x_a), L_a, (L-L_a)g(x_m(L_a, x_a))] \\ &s.t. \quad L_a \ \hat{I} \ [0, L], x_a \ \hat{I} \ [0, xL/L_a] \end{aligned}$$

If $p(\cdot)$, $I(\cdot)$, and $g(\cdot)$ are continuous and the constraint set $[0, L]\times[0, xL/L_a]$ is compact, an optimal solution (L_a^o, x_a^o) exists. Appropriate assumptions on $U(\cdot)$ and $F_i(\cdot)$ exclude boundary solutions. An interior solution satisfies the first-order conditions:[2]

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[2] Both factors are allocated to both commodities if marginal utilities and marginal products approach infinity as their respective arguments approach zero.

[3] $$\partial V / \partial L_a = V_p p_L + V_L I_L + V_L + V_E [-g(\cdot) + L_m g'(\partial x_m / \partial L_a)] = 0$$

[4] $$\partial V / \partial x_a = V_p p_x + V_L I_x + V_E L_m g'(\partial x_m / \partial x_a) = 0$$

where subscripts denote partial derivatives with respect to L_a and x_a unless defined otherwise. Roy's Identity implies that $V_p = -a(p, I, \cdot)V_I$. Utility maximization requires that $p(\cdot) = U_a/U_m$ and we know that $V_I = U_m$, $V_L = U_L$, and $V_E = U_E$. After substituting all these conditions, the partial derivatives of $I(L_a, x_a)$ from [2], and the market clearing condition [1] into [3] and [4], we obtain two expressions in terms of the utility and production functions:

[5] $$U_a f_a(\cdot) + U_L = U_m [f_m(\cdot) - f'_m(\cdot)(x_m - x_a)] + U_E [g(\cdot) - g'(\cdot)(x_m - x_a)]$$

[6] $$U_a f'_a(\cdot) = U_m f'_m(\cdot) + U_E g'(\cdot)$$

Equation [5] defines the optimal allocation of L_a: the LHS is the marginal benefit of using arable land for alternative production plus the marginal amenity value of alternative land use; the RHS is the marginal opportunity value of using arable land to produce *m* minus the marginal opportunity cost of the resulting emissions (note that $U_E < 0$).

Equation [6] defines the optimal choice of alternative inputs per hectare x_a. It is determined by equating marginal per hectare benefits of producing *a* and the marginal opportunity value minus marginal external cost in terms of conventional production *m* foregone. Note that both equations form a simultaneous system to define the optimal choice of L_a and x_a (L_a appears in both equations through the expression for x_m). Any shift in preferences that changes either U_L or U_E implies a change in both L_a^o and x_a^o.

3 Optimal Agri-Environmental Policy

Without policy intervention, producers will not choose a socially optimal factor allocation because L_a and *E* are externalities and thus the market will not internalize the social cost of emissions and the amenity benefits of alternative land use. Consider four policy instruments that may be imposed jointly: a subsidy for alternative land use (*s*), conventional input taxes (t_L, t_X), and a direct emissions tax (t). The problem is to determine the socially optimal policy vector (s, t_L, t_X, t). Following DIXIT and NORMAN, factor allocations, the policy vector, and prices *p* describe producer behavior via a revenue function $R(L_a, x_a, s, t_L, t_X, t, p)$ given by:

$$R(\cdot) = max[pL_a f_a(\cdot) + sL_a - t_L(L-L_a) - t_X(L-L_a)x_m - t(L-L_a)g(\cdot) + (L-L_a)f_m(\cdot)]$$
$$s.t.\quad L_a \in [0, L],\ x_a \in [0, XL/L_a]$$

Strict concavity assumptions imply that a unique interior solution must satisfy the following first-order conditions:

[7] $$pf_a(\cdot) + s + t_L + t_X x_a + t[g(\cdot) - g'(\cdot)(x_m - x_a)] = [f_m(\cdot) - f'_m(\cdot)(x_m - x_a)]$$

[8] $$pf'_a(\cdot) + t_X + t\, g'(\cdot) = f'_m(\cdot)$$

Using the fact that $U_a/U_m = p(\cdot)$ and comparing [5] to [7] and [6] to [8], the welfare-maximizing policy vector (s, t_L, t_X, t) must satisfy conditions:

[9] $$s + t_L + t_X x_a + t[g(\cdot) - g'(\cdot)(x_m - x_a)] = \frac{U_L}{U_m} - \frac{U_E}{U_m}[g(\cdot) - g'(\cdot)(x_m - x_a)]$$

[10] $$t_X + t\, g'(\cdot) = -\frac{U_E}{U_m} g'(\cdot)$$

which are evaluated at (L_a^o, x_a^o). Equation [5] implies that for an optimal allocation of arable land conventional farmers should be penalized for the per-hectare social cost of pollution which is $-U_E/U_m[g(\cdot)-g'(\cdot)(x_m - x_a)]$. However, equation [7] implies that the actual penalty for conventional farmers is $t_L + t_X x_a + t[g(\cdot)-g'(\cdot)(x_m - x_a)]$. When emissions are observable and directly taxable, an emissions tax $t^o = -U_E/U_m$ imposes the correct penalty for an optimal allocation of alternative land provided that $s^o = U_L/U_m$ and $t_L^o = t_X^o = 0$. The optimal policy vector is Pigouvian and equals $(s^o, t_L^o, t_X^o, t^o) = (U_L/U_m, 0, 0, -U_E/U_m)$. Input taxes are not needed and each externality is taxed/subsidized at its marginal social value. Optimal levels of s^o and t^o are based on welfare maximizing allocations (L_a^o, x_a^o), which are simultaneously determined via equations [5] and [6]. Consequently, change of externality values (U_L/U_m or U_E/U_m) would induce an adjustment in both the optimal allocation (L_a^o, x_a^o) and policy choice s^o and t^o. For example, if the amenity value U_L/U_m increases it would lead to a (nonzero) adjustment in the optimal emissions tax even if U_E/U_m remains fixed.

In practice, the main problem is that pollution is not observable and agri-environmental policy has to target polluting inputs. Because emissions depend on conventional land and input use (L_m and X_m), policy combinations targeting their allocation will also yield a socially optimal outcome. If $t = 0$, equations [9] and [10] imply that optimal conventional input and land taxes (t_X and t_L) and the alternative land use subsidy s must satisfy:

$$[11] \quad t_X = -\frac{U_E}{U_m} g'(\cdot)$$

$$[12] \quad s = \frac{U_L}{U_m} - \frac{U_E}{U_m}[\,g(\cdot) - g'(\cdot)x_m\,] - t_L = \frac{U_L}{U_m} - \frac{U_E}{U_m} g(\cdot) - t_X x_m - t_L$$

Equation [11] implies that optimal polluting input taxes t_X are strictly positive and equal the rate of marginal social costs. The optimal alternative land use subsidy in equation [12] has interesting attributes if polluting inputs are taxed at $t_X = -U_E/U_m\, g'(\cdot)$. Farmers using land for alternative production should be rewarded for the marginal amenity benefit U_L/U_m. However, since polluting inputs are taxed, providing incentives to engage in alternative production, the subsidy necessary for optimal alternative land use is less than the marginal amenity benefit provided. Moreover, any conventional land tax t_L would be an another incentive to engage in alternative production and further erode the subsidy needed for an optimal land allocation. It is easy to show that the subsidy correction term $-U_E/U_m[g(\cdot)-g'(\cdot)x_m] - t_L$ in equation [12] is always negative when $t_L \geq 0$.[3]

When emissions are not observable ($t = 0$), a per-hectare polluting input tax equal to $t_X x_m = -(U_E/U_m)g'(\cdot)x_m$ differs from the marginal social pollution cost per hectare. Equation [12] implies that the optimal conventional land tax t_L equals $-(U_E/U_m)g(\cdot) - t_X x_m$, provided that alternative land use is rewarded for the marginal amenity benefit U_L/U_m and conventional inputs are taxed according to $t_X x_m = -(U_E/U_m)g'(\cdot)x_m$. Under these policy conditions, it follows that $t_L > 0$ only when $-(U_E/U_m)g(\cdot) > t_X x_m$. However, from equations [11] and [12] it also follows that when alternative land use is subsidized at U_L/U_m and conventional inputs are taxed at $t_X = -(U_E/U_m)g'(\cdot)$, it is optimal to <u>subsidize</u> conventional land use because then $t_L = -U_E/U_m[g(\cdot)-g'(\cdot)x_m] < 0$. This means that an alternative land subsidy at the rate of marginal amenity benefits combined with a conventional input tax implied by equation [11] would shift too much land into alternative production and thus provide too much amenity benefits and too little conventional production such that a conventional land subsidy is necessary.

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[3] Equation [12] implies that $s < U_L/U_m$ if $-U_E/U_m[g(\cdot)-g'(\cdot)x_m] - t_L < 0$. Since $g(\cdot)$ is convex and $g(0) = 0$, the expression in brackets is negative. Combined with the fact that $U_E < 0$, it follows that $s < U_L/U_m$ when $t_L \geq 0$.

When $t_L = 0$ and $t_X = -(U_E/U_m)g'(\cdot)$, the optimal alternative land subsidy is $s = U_L/U_m - U_E/U_m[g(\cdot)-g'(\cdot)x_m]$ which is positive only if the marginal amenity benefit of additional alternative land exceeds the savings in social pollution costs $U_E/U_m[g(\cdot)-g'(\cdot)x_m]$ from the land shifting to alternative production. In other words, it only makes sense to subsidize alternative land use if the amenity benefit gained is larger than the reduced social costs of pollution per hectare from conventional production facing an input but no land tax. When both $t_L = 0$ and $t_X = 0$, the optimal alternative land use subsidy implied by conditions [9] and [10] would be equal to $U_L/U_m - U_E/U_m\, g(\cdot)$ and strictly positive.

Other important conclusions follow from equations [11] and [12]. First, when alternative land use is only non-polluting but provides no amenity benefits ($U_L = 0$), it is still optimal to tax conventional inputs at $t_X = -(U_E/U_m)g'(\cdot)$. However, such an input tax would shift too much land into alternative production such that a conventional land subsidy (or an alternative land <u>tax</u>) equal to $-U_E/U_m[g(\cdot)-g'(\cdot)x_m] < 0$ is needed. Second, when conventional production is non-polluting ($U_E = 0$) while alternative land use provides amenity benefits ($U_L > 0$), it is optimal to either tax conventional land or subsidize alternative land at U_L/U_m and no input tax is needed. Third, when alternative production is non-polluting while conventional land use pollutes but amenity benefits are exogenous (i.e. both production systems provide them), the optimal conventional input tax is $t_X = -(U_E/U_m)g'(\cdot)$ which would also shift too much land into alternative production such that a conventional land subsidy (or an alternative land <u>tax</u>) equal to $-U_E/U_m[g(\cdot)-g'(\cdot)x_m] < 0$ is needed.

4 Open Economy Model

Suppose that agricultural commerce is now open to international trade. Domestic agriculture generates positive and negative externalities as described above without cross-border effects. If the home country is <u>small</u> and does not price discriminate between domestic and foreign production, domestic prices p are equal to world prices P and domestic income is $I(L_a, x_a) = pL_af_a(x_a) + (L-L_a)f_m(x_m)$. The social welfare maximization problem is given by:

$$\max_{L_a \in [0, L],\ x_a \in [0, xL/L_a]} \quad V[p, I(L_a, x_a), L_a, (L-L_a)g(x_m(L_a, x_a))]$$

with first-order conditions

$$\partial V/\partial L_a = V_L I_L + V_L + V_E[-g(\cdot) + L_m g'(\partial x_m/\partial L_a)] = 0 \qquad \text{and}$$
$$\partial V/\partial x_a = V_L I_x + V_E L_m g'(\partial x_m/\partial x_a) = 0\,.$$

Substituting the derivatives of I for a small country, $V_I = U_m$, $V_L = U_L$, and $V_E = U_E$ from the envelope theorem, and $p = U_a/U_m$ from utility maximization, these conditions become:

$$U_a f_a(\cdot) + U_L - U_m[f_m(\cdot) - f_m'(\cdot)(x_m - x_a)] - U_E[g(\cdot) - g'(\cdot)(x_m - x_a)] = 0$$
$$U_a f_a'(\cdot) - U_m f_m'(\cdot) - U_E g'(\cdot) = 0$$

Mathematically, these conditions are exactly identical to conditions [5] and [6] for the closed economy case. Therefore, the main policy conclusion derived for a closed economy remain valid for a small open economy. However, since prices are exogenous, the relative value of alternative production $U_a/U_m = p$ remains fixed and any change in the value of an externality (U_L/U_m or U_E/U_m) will induce different adjustments in the optimal policy choice and factor allocation for a small open economy.

If the domestic country is large relative to the world market, prices $p(\cdot)$ are endogenous and the policy problem to maximize social welfare becomes:

$$\max_{L_a \in [0, L],\; x_a \in [0, xL/L_a]} \quad V[p(L_a, x_a), I(L_a, x_a), L_a, (L-L_a)g(x_m(L_a, x_a))]$$

The price and income relations $p(\cdot)$ and $I(\cdot)$ satisfy:

[13] $a(p(L_a, x_a), I(L_a, x_a), \cdot) = L_a f_a(x_a) + a^*(p(L_a, x_a))$

[14] $I(L_a, x_a) = p(L_a, x_a)L_a f_a(x_a) + (L-L_a)f_m(x_m(L_a, x_a))$

where $a^*(\cdot)$ is foreign excess supply. The first-order conditions for a large country are:

$$\partial V/\partial L_a = V_p p_L + V_L I_L + V_L + V_E[-g(\cdot) + L_m g'(\partial x_m/\partial L_a)] = 0 \qquad \text{and}$$
$$\partial V/\partial x_a = V_p p_x + V_L I_x + V_E L_m g'(\partial x_m/\partial x_a) = 0.$$

After substituting Roy's Identity $V_p = -aV_I$ and $V_I = U_m$, $V_L = U_L$, $V_E = U_E$, the derivatives I_L and I_x, the condition $p = U_a/U_m$, and the market clearing condition [13], it follows:

[15] $$pf_a(\cdot) - a^*(p)p_L + \frac{U_L}{U_m} = \frac{U_E}{U_m}[g(\cdot) - g'(\cdot)(x_m - x_a)] + [f_m(\cdot) - f'_m(\cdot)(x_m - x_a)]$$

[16] $$pf'_a(\cdot) - a^*(p)p_x = f'_m(\cdot) + \frac{U_E}{U_m}g'(\cdot)$$

Both conditions contain an extra term $-a^*(\cdot)p_j$ (where $j = L_a, x_a$), compared to the previously obtained optimality conditions [5] and [6]. Because $a_p < 0$ and $a^*_p > 0$, the partial derivatives of condition [13] with respect to L_a and x_a imply that $p_L < 0$ and $p_x < 0$. Thus, the world price will decrease when either factor allocation to alternative agriculture increases. If the domestic economy is a net importer of alternative commodities, $a^*(\cdot) > 0$ such that $-a^*(\cdot)p_j$ is positive. Thus, the marginal benefits from alternative production are higher for a large country which increases the optimal factor shares allocated to alternative production. If the country is a net exporter of alternative commodities, $a^*(\cdot) < 0$ such that $-a^*(\cdot)p_j$ is negative, the optimal factor shares of alternative production are lower relative to a small country.

The result is intuitively consistent because importers gain from policies that decrease world prices while exporters gain from policies that increase world prices. If policy intervention is justified by external benefits and costs, the model predicts that importers have an incentive to overrate the benefits of alternative production while exporters have an incentive to overrate the environmental costs of conventional production.

5 Summary and Policy Implications

We derive optimal agri-environmental policies when agricultural production creates two externalities: amenity benefits from land allocated to alternative agriculture and pollution from conventional production. When pollution is observable and directly taxable, polluting input taxes are not needed and the optimal tax/subsidy combination is Pigouvian and equal to the marginal social value of each externality. When pollution is not observable and a direct pollution tax is not feasible, the optimal conventional input tax t_X is strictly positive and equal to marginal social costs created. A concurrent optimal alternative land use subsidy s has two interesting features. First, it is less than marginal amenity benefits because conventional input taxes already provide incentives to shift to alternative production and any conventional land tax t_L would be an added incentive to shift and further reduce the subsidy needed to optimally allocate land. Thus, a subsidy for alternative land use equal to marginal amenity benefits and a concurrent optimal polluting input tax t_X shifts too much land into alternative production and requires a subsidy for conventional land use optimally allocate land. For policy purposes this implies that non-market benefits of alternative land use estimated in empirical CV studies may not be interpreted as an appropriate land use subsidy when agriculture is also polluting. Only when agriculture is non-polluting ($U_E = 0$) and alternative land use provides amenity benefits ($U_L > 0$), the estimated non-market benefits of alternative land use may be an appropriate land use subsidy (or conventional land tax).

Second, when conventional land use is not regulated ($t_L = 0$) but polluting inputs are, it only makes sense to support alternative land use if amenity benefits gained are larger than social pollution cost savings from land shifting to alternative production. Thus, the higher society values the social costs of pollution (U_E) the more it justifies an agri-environmental policy that fosters environmentally benign production and restricts polluting inputs (e.g. countryside stewardship policy plus polluting input taxes).

Furthermore, agri-environmental regulation often varies because positive and negative external effects of agricultural production are location-specific. Moreover, the relationship between polluting inputs and non-point pollution from agricultural sources is unknown. Thus, local land use regulations will not guarantee an optimal allocation of agricultural land in the absence of a suitable policy environment. When amenity benefits and pollution damages are large (e.g. around metropolitan areas or in densely populated countries), targeted policies would encourage alternative and discourage conventional agriculture (e.g. restricting land use in nature reserves or extensive farming as an alternative to chemical-intensive crops).

Agri-environmental policy may be complementary to other policy goals such as farm income support. However, using a carrot to support alternative (environmentally benign) production and to raise farm income without concurrently restricting conventional input use may be socially inefficient if the stick is less costly to curtail conventional production. With respect to international trade, large importers gain from agri-environmental policies that decrease world prices while large exporters gain from policies that increase world prices. Thus, importers have an incentive to overrate the benefits of alternative production while exporters have an incentive to overrate the social costs of conventional production. However, non-internalizing agri-environmental policies may also exploit terms of trade effects and distort international trade. It will be difficult to determine how significant such trade distortions are, should such issues arise during international trade negotiations.

The model supports three general policy implications to achieve environmental as well as agricultural policy objectives in an open economy. First, reform agricultural policies to allow for further trade liberalization and growing environmental concerns (e.g. remove incentives to over-apply chemicals, to over-plant supported crops, and to farm environmentally sensitive land). Second, devise programs that promote the (voluntary) adoption of cost effective technologies and management practices to improve environmental conditions and maintain farm income. Third, promote research, development, and transfer of new technologies that meet current and anticipate future demands on environmental quality. Although we focus on deriving welfare-maximizing agri-environmental factor allocations and policies, the model can be extended to analyze effects on agricultural markets, incomes, and pollution.

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