Are Green Payments Good for the Environment?

Erik Lichtenberg

There is growing interest in green payments subsidizing conservation measures on working farmland based on the premise that they have positive effects on the environment and agriculture simultaneously without causing international trade distortions. This paper uses a Ricardian land market equilibrium model to examine the impacts of green payments. The analysis shows green payments can worsen ambient pollution damage by subsidizing the expansion of more intensive crop cultivation. Some forms of green can increase cultivation intensity (and thus environmental damage) as well. These adverse effects can be avoided by careful targeting, but such targeting is likely to be quite difficult.

Key Words: conservation, cost sharing, Environmental Quality Incentives Program (EQIP), green payments, nonpoint source pollution

One of the notable features of the 2002 farm bill is a new emphasis on promoting conservation on working farmland. In contrast to previous legislation, whose conservation provisions emphasized land retirement, the current farm bill authorizes a sixfold increase in cost sharing for conservation practices under the Environmental Quality Incentives Program (EQIP) and other programs. It also includes authorization of a new program, the Conservation Security Program (CSP), under which farmers are offered both annual rental payments and cost sharing for implementing various kinds of conservation projects on working farmland.

This new emphasis on green payments that subsidize conservation on working farmland seems to be driven by political currents likely to endure. One impetus toward green payments comes from political pressure exerted by environmental advocacy groups. Environmentalists have argued that farm income supports linked to current output create incentives for farmers to overuse pesticides and fertilizers, with resulting adverse effects on environmental quality. Environmentalists have therefore pushed for the expansion of conservation subsidies as a politically attractive means of addressing nonpoint source pollution emanating from agriculture.

Further impetus for this shift in farm programs comes from World Trade Organization (WTO) restrictions on output-distorting income supports. Green payments are widely held not to alter incentives governing farmers' yield objectives (and thus input use) as understood under WTO rules, rendering them exempt from WTO limits on farm subsidy payments.

The attraction of green payments stems from a belief that they have positive effects on the environment and agriculture simultaneously—and that they accomplish these effects in ways which don't distort international trade. But is this premise correct? In this paper, a Ricardian land market equilibrium model is used to examine this question theoretically. The analysis raises some questions about the procedures used to allocate green payments and the wisdom of using green payment programs to achieve environmental objectives.

The Model

A Ricardian model is used that characterizes land market equilibrium under risk neutrality where diversification among crops and farming practices is due to heterogeneous land quality. This model was introduced by Caswell and Zilberman (1986) to

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model irrigation technology adoption. Lichtenberg (1989) developed a more general formulation of the model and applied it empirically. Malik and Shoemaker (1993) used it to examine optimal targeting of cost sharing in cases where cost sharing is necessary to make adoption of conservation practices economically attractive. Lichtenberg (2002) used the model to discuss the implications of heterogeneity for environmental policies aimed at agriculture. These papers all apply a formulation in which pollution arises from the use of a specific input. Here, a more general formulation is adopted based on the output-oriented model of agriculture and the environment presented by Lichtenberg (2002).

Consider a farming region of size N that is small relative to the total agricultural economy. Assume the landscape can be divided into plots of equal size, each of which is of quality $\theta \in [0, 1]$. Let $G(\theta)$ be the amount of land of quality no greater than θ (i.e., the cumulative distribution of land quality θ), and $g(\theta)$ be the amount of land of quality exactly θ (i.e., the density of land quality θ). Assume the land has two uses, intensive crop production and a residual use like pasture or hay production. To simplify the analysis (but with no loss of generality), assume residual use has a negligible impact on environmental quality and the rent generated by this residual use, π, is invariant with respect to land quality.

Intensive crop production produces two outputs, an agricultural commodity y and environmental damage q. These outputs can be produced using either of two technologies, each of which can be characterized by a standard quasi-convex cost function $C^j(y_j, q_j, \theta), j = 1, 2$. The marginal cost of the agricultural commodity is positive and increasing in output y (letting subscripts denote derivatives, $C^j_y, C^j_{yy} > 0$). Environmental damage is valuable to the farmer because it lowers the cost of producing the agricultural commodity. Assume that it lowers both the total cost of production and the marginal cost of the agricultural commodity ($C^j_q, C^j_{yq} \leq 0$). Convexity implies $C^j_{qq} \geq 0$ as well. Without loss of generality, assume land quality is measured in such a way that the cost of production under either technology is lower when land quality is higher, i.e., $C^j_\theta < 0$. Diminishing marginal productivity of land quality implies $C^j_{\theta\theta} > 0$. The rent generated by intensive crop production using technology j on a parcel of land of quality θ is thus $py_j - C^j(y_j, q_j, \theta)$.

Assume each farmer's contribution to ambient pollution, M, is proportional to the level of on-farm environmental damage chosen, q:

$$(1) \quad M = \int \Big\{ \sum_j \delta_j(\theta) m^j(\theta) q_j(\theta) \Big\} g(\theta)\, d\theta,$$

where $m^j(\theta)$ is the share of on-farm environmental damage from using technology j on land of quality θ that is added to ambient pollution, and $\delta_j(\theta)$ is the share of land of quality θ allocated to technology j. (Note that this formulation allows for differential effects of farming on ambient pollution due to differences in technology and land quality.) Finally, let social damage from ambient pollution be a convex function of ambient pollution, $D(M)$.

Following the exposition in Lichtenberg (2002), this analysis focuses on the case where the resource-conserving farming system (a) causes less environmental damage, and (b) has a comparative advantage on lower quality land, i.e., its productivity is less sensitive to land quality. This characterization makes intuitive sense when topography is the critical element of land quality. Land with steep slopes is more costly to cultivate than flatter land. It is also more prone to erosion and runoff problems. Implementing erosion-control measures like plowing on the contour, stripcropping, or lining natural channels in the field with rocks or grass protects against erosion which would lower productivity (or increase cost) and reduces sediment and nutrient runoff at the same time. These measures also provide more protection on more steeply sloped land than on flatter land.

This characterization also fits many situations in which improved application efficiency promises to enhance both environmental and productive performance. For example, improving nutrient management through split fertilizer application or chemigation via low-volume irrigation systems essentially involves substituting conservation technologies as a means of obtaining the nutrient- and water-delivery services that the soil would otherwise provide. These technologies tend to have a comparative advantage on lower quality land, and because they feature increased application efficiency, they reduce environmental damage at the same time.

These characteristics can be formalized as follows. Assume that environmental damage under technology 1 (the less polluting technology) reduces both total cost and the marginal cost of the agricultural commodity less than environmental damage under technology 2 on any given quality of land:

$$0 > C^1_q(\theta) > C^2_q(\theta),\ C^1_{yq}(\theta) > C^2_{yq}(\theta).$$

(Recall that these derivatives are all negative, so this assumption means the absolute value of C_q and

C_{yq} is less under technology 1 than under technology 2.) Also, assume $m^1(\theta) < m^2(\theta)$, i.e., a given level of on-farm environmental damage causes less ambient pollution under technology 1 than under technology 2. Further assume $m^j_\theta < 0$, and $m^2_\theta < m^1_\theta$.

Profit-maximizing input use and the land market equilibrium allocation of land between the two production technologies is found by choosing the level of output of the agricultural commodity under each technology on each quality of land $[y_1(\theta), y_2(\theta)]$, environmental degradation under each technology on each quality of land $[q_1(\theta), q_2(\theta)]$, and the share of land allocated to each technology on each quality of land $[\delta_1(\theta), \delta_2(\theta)]$ in order to maximize agricultural rent:

$$\begin{aligned}\int_0^1 \Big\{ &\delta_1(\theta)\big[py_1 - C^1(y_1, q_1, \theta)\big] \\ &+ \delta_2(\theta)\big[py_2 - C^2(y_2, q_2, \theta)\big] \\ &+ \big[1 - \delta_1(\theta) - \delta_2(\theta)\big]\pi \Big\} g(\theta)\, d\theta.\end{aligned}$$

This is a non-autonomous control problem over land quality θ. Both output of the agricultural commodity and environmental degradation will vary with land quality.

Land market equilibrium is analyzed under the following regularity assumptions, which correspond to the standard single-crossing condition generally used in models of this kind: (*a*) There exists a farm type $\theta^o_j > 0$, such that $py^o_j - C^j(y^o_j, q^o_j, \theta^o_j) = 0$, $j = 1, 2$, where the superscript "*o*" denotes profit-maximizing choices in the absence of environmental regulation; (*b*) $\theta^o_1 < \theta^o_2$, so that in an unregulated regime the lowest quality of land on which the intensive crop is grown will utilize technology 1; (*c*) $C^2_\theta < C^1_\theta$ for all θ, where technology 1 is less sensitive to land quality than technology 2; and (*d*) $py^o_1 - C^1(y^o_1, q^o_1, 1) < py^o_2 - C^2(y^o_2, q^o_2, 1)$, where technology 2 is more profitable than technology 1 on the highest quality of land. In contrast to Malik and Shoemaker (1993) (but in accord with empirical evidence about adoption of conservation practices), it is assumed some farmers find it profitable to adopt technology 1 even in the absence of cost sharing. The results obtained here can be easily extended to the case considered by Malik and Shoemaker (1993) where cost sharing is necessary to make adoption of technology 1 profitable for any farmer.

In the absence of environmental regulation, output of the agricultural commodity and environmental degradation under each technology will be determined by the conditions:

$$(2)\qquad p - C^j_y\big(y^o_j(\theta),\, q^o_j(\theta),\, \theta\big) = 0$$

and

$$(3)\qquad -C^j_q\big(y^o_j(\theta),\, q^o_j(\theta),\, \theta\big) = 0, \quad j = 1, 2\ \forall\theta.$$

The control problem is linear in the shares of land allocated to each technology on each quality of land; as a result, each share is either at its lower (zero) or upper bound (one) on each quality of land.

Under the regularity conditions assumed above, each activity (the residual use, technology 1, technology 2) will be used on a compact subset of the possible values of land quality. The lowest quality of land on which the intensive crop is grown will be θ^o_1, determined by

$$(4)\qquad py^o_1(\theta^o_1) - C^1\big(y^o_1(\theta^o_1),\, q^o_1(\theta^o_1),\, \theta^o_1\big) = \pi.$$

There will also be a unique critical switching quality of land θ^o_c, defined by

$$\begin{aligned}(5)\qquad \sigma(\theta) \equiv\ & py^o_1(\theta^o_c) - C^1\big(y^o_1(\theta^o_c),\, q^o_1(\theta^o_c),\, \theta^o_c\big) \\ & - py^o_2(\theta^o_c) - C^2\big(y^o_2(\theta^o_c),\, q^o_2(\theta^o_c),\, \theta^o_c\big) = 0.\end{aligned}$$

The equilibrium allocation of land will be such that all land of quality lower than θ^o_1 will be allocated to the residual use; all land of quality $\theta^o_1 \le \theta < \theta^o_c$ will produce the intensive crop using technology 1 ($\delta_1 = 1$, $\delta_2 = 0$); and all land of quality $\theta^o_c \le \theta \le 1$ will produce the intensive crop using technology 2 ($\delta_1 = 0$, $\delta_2 = 1$).

This land market equilibrium can be depicted graphically using the profit-maximizing rent curves $py^o_j - C^j(y^o_j, q^o_j, \theta^o_j)$ drawn in land quality space, as shown in figure 1. The rent curves for technologies 1 and 2 are concave in land quality because of diminishing reductions in marginal cost from (equivalently, diminishing marginal productivity of) land quality. The rent curve for the residual use, π, is horizontal because it is invariant with respect to land quality. The regularity conditions imposed here imply that the technology 1 rent curve cuts the horizontal axis to the left of the horizontal intercept of the technology 2 rent curve, and that the technology 2 rent curve is everywhere steeper than the technology 1 rent curve. These conditions also imply that the technology 2 rent curve is steep enough to intersect the technology 1 rent curve somewhere in the $[0, 1]$ interval. As figure 1 indicates, the residual use is the most profitable on the lowest qualities of land; technology 1 is more profitable than technology 2 on the lowest qualities

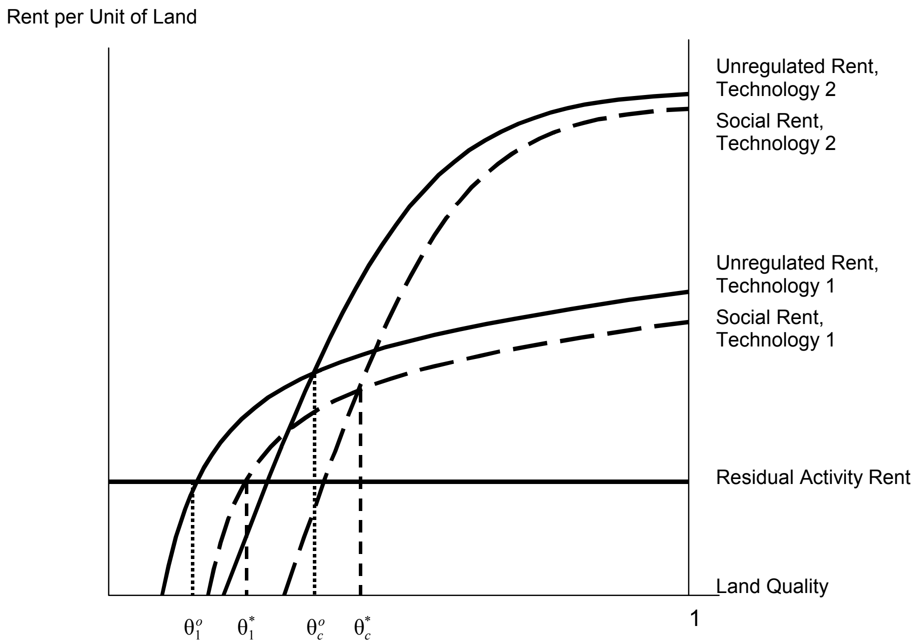

Figure 1. Equilibrium land allocations in the social optimum and in the absence of environmental regulation

of land used to produce the intensive crop (land of quality between θ_1^o and θ_c^o); and technology 2 is the most profitable on high-quality land (land of quality greater than θ_c^o).

Comparison to the Social Optimum

It is straightforward to show that the unregulated land market equilibrium features too high a level of intensive crop production on every quality of land, too much environmental degradation on every quality of land, too much land producing the intensive crop, and too much medium-quality land producing the agricultural commodity under the more polluting technology.

The social optimum is found by choosing the level of output of the agricultural commodity under each technology on each quality of land [$y_1(\theta)$, $y_2(\theta)$], environmental degradation under each technology on each quality of land [$q_1(\theta)$, $q_2(\theta)$], and the share of land allocated to each technology on each quality of land [$\delta_1(\theta)$, $\delta_2(\theta)$] in order to maximize agricultural rent less ambient pollution damage $D(M)$ subject to equation (2). The necessary conditions for social welfare-maximizing output of the intensive crop y and environmental degradation q on any given quality of land under technology j are:

(6) $$p - C_y^j = 0$$

and

(7) $$-C_q^j - \lambda m^j = 0,$$

where λ, the shadow price of ambient environmental damage, equals $D'(M)$, the marginal social cost of environmental damage. These are standard. Equation (6) states that intensive crop output should be chosen to equate marginal production cost with price. Equation (7) states that environmental damage should be chosen to equate the reduction in production cost with the marginal value of its contribution to ambient pollution.

Diminishing marginal productivity implies both y_j and q_j are decreasing in the shadow price of ambient pollution damage λ. Since the unregulated land market equilibrium is just the social optimum with $\lambda = 0$, it follows that y and q are larger when there is no regulation.

The condition defining the minimum quality of land on which the intensive crop is cultivated is

(8) $$py_1^*(\theta_1^*) - C^1\left(y_1^*(\theta_1^*),\ q_1^*(\theta_1^*),\ \theta_1^*\right) - \lambda m^1(\theta^*) = \pi,$$

which shows rent per unit of land area in intensive crop production using technology 1 (including the marginal value of its contribution to ambient pollution) should equal rent to the residual use. Differentiating using the envelope theorem yields

$$\frac{\partial \theta_1^*}{\partial \lambda} = \frac{1}{-C_\theta^1} > 0.$$

Greater marginal damage from ambient pollution λ implies that less low-quality land should be allocated to production of the intensive crop. Since the unregulated land market equilibrium equals the social welfare-maximizing land market equilibrium with $\lambda = 0$, it follows that $\theta_1^* > \theta_1^o$; i.e., too much low-quality land is allocated to the intensive crop.

The condition defining the critical switching quality of land θ_c^* is

$$(9) \quad \left[p y_1^* - C^1(y_1^*, q_1^*, \theta_c^*) - \lambda m^1(\theta_c^*)\right] - \left[p y_2^* - C^2(y_2^*, q_2^*, \theta_c^*) - \lambda m^2(\theta_c^*)\right] = 0,$$

which states that rent under both technologies producing the intensive crop (including the marginal value of the contribution of each to ambient pollution) should be equal. Differentiating using the envelope theorem yields

$$\frac{\partial \theta_c^*}{\partial \lambda} = \frac{m^1 - m^2}{\left[C_\theta^2 - C_\theta^1\right] + \lambda\left[m_\theta^2 - m_\theta^1\right]} > 0.$$

Greater marginal damage from ambient pollution λ implies more medium-quality land should be allocated to production of the intensive crop using the resource-conserving technology (technology 1). Because the unregulated land market equilibrium equals the social welfare-maximizing land market equilibrium with $\lambda = 0$, it follows that $\theta_c^* > \theta_c^o$; i.e., too much medium-quality land produces the intensive crop using technology 2.

Figure 1 compares land allocations in the social optimum and in the absence of environmental regulation. The socially optimal rent curves for the intensive crop under both technologies lie below and to the right of the corresponding rent curves in the absence of environmental regulation. The vertical distance between the socially optimal and unregulated rent curves equals the value of ambient pollution damage attributable to intensive crop production under each technology on each quality of land. It is greater for the more polluting technology (technology 2). The two socially optimal rent curves for the intensive crop thus intersect to the right of the intersection of the unregulated rent curves.

It follows that ambient pollution damage is higher in absence of environmental regulation than in the social optimum. To see this, consider a first-order approximation:

$$\begin{aligned} D'(M)\Delta M \approx\ & \int_{\theta_1}^{\theta_c} m^1(\theta)\Delta q_1(\theta) g(\theta)\, d\theta \\ & + \int_{\theta_c}^{1} m^2(\theta)\Delta q_2(\theta) g(\theta)\, d\theta \\ & - m^1(\theta_1) q_1(\theta_1) g(\theta_1)\Delta\theta_1 \\ & + \left[m^1(\theta_c) q_1(\theta_c) - m^2(\theta_c) q_2(\theta_c)\right] g(\theta_c)\Delta\theta_c, \end{aligned}$$

where the Δ terms represent deviations of the unregulated land market equilibrium levels from the socially optimal ones. Equations (6) and (7) imply that Δq_1 and $\Delta q_2 > 0$; environmental damage in the unregulated land market equilibrium exceeds the social optimum on all qualities of land. The fact that $\partial\theta_1^*/\partial\lambda > 0$ implies $\Delta\theta_1$ is negative (too much low-quality land is allocated to intensive crop production), while the fact that $\partial\theta_c^*/\partial\lambda > 0$ implies $\Delta\theta_c$ is negative (too much medium-quality land is allocated to the more environmentally damaging technology). It follows that $\Delta M > 0$; i.e., ambient pollution is greater in the unregulated equilibrium than in the social optimum.

Impacts of Green Payments

This section evaluates the premise underlying the attraction of green payments—that they mitigate ambient pollution damage by moving the land market equilibrium closer to the social welfare-maximizing equilibrium. There are two ways of implementing green payments. One is to give farmers a fixed payment per acre either as a rental payment or as a flat rate subsidy set according to the farming technology adopted (rather than according to actual expenses). The second is to set payments according to the actual expenses the farmer incurs.

Conservation cost sharing under EQIP and other programs is based on actual expenses incurred: Farmers are reimbursed for a percentage of their actual costs. The CSP pays a fixed rental rate in addition to cost sharing. Rental rates are fixed legislatively and are invariant with respect to land quality, although they do vary to some extent according to the level of conservation effort the farmer contracts to undertake. Because regulations for implementing the CSP have not yet been finalized, it is unclear how cost sharing will be implemented under CSP. However, the precedents set by other federal conservation cost-sharing programs suggest reimbursements will be based on actual expenses incurred.[1]

These payments can be incorporated into the model as follows. Let T denote a fixed payment like the CSP rental payment, and s denote the share of actual cost reimbursed.[2] Then rent per acre generated by technology 1 with a fixed green payment can be written as $py_1 - C^1(y_1, q_1, \theta) + T$. Similarly, the rent generated by technology 1 on land of quality θ when green payments are based on reimbursement of actual costs incurred is given by $py_1 - (1 - s)C^1(y_1, q_1, \theta)$.

Clearly, the fixed payment T does not affect the choice of agricultural commodity output y or environmental damage q on the intensive margin, i.e., on land using technology 1 without a subsidy. But it does affect the minimum quality of land in production θ_1 and the critical switching quality of land θ_c [Malik and Shoemaker (1993) and Lichtenberg (2002) derive the same result]. Differentiating equation (4) defining θ_1 using the envelope theorem (after modifying rent under technology 1 to incorporate the fixed payment T), we find:

$$\frac{\partial \theta_1^T}{\partial T} = \frac{1}{C_\theta^1} < 0,$$

which implies a fixed per acre green payment increases the amount of low-quality land allocated to cultivation of the intensive crop. Differentiating equation (5) defining θ_c using the envelope theorem (again after modifying rent under technology 1 to incorporate the fixed payment T), we find:

$$\frac{\partial \theta_c^T}{\partial T} = \frac{1}{C_\theta^1 - C_\theta^2} > 0,$$

which implies a fixed per acre payment increases the amount of medium-quality land allocated to the conservation technology.

Graphically, the fixed payment T causes a parallel upward shift in the technology 1 rent curve (see figure 2). As a result, the minimum-quality land using technology 1 decreases while the maximum-quality land using technology 1 increases.

The impact of the fixed payment on ambient pollution damage is

$$D'(M)\left[-q_1(\theta_1^T)g(\theta_1^T)\frac{\partial \theta_1^T}{\partial T} + \left[q_1(\theta_c^T) - q_2(\theta_c^T) \right] g(\theta_c^T)\frac{\partial \theta_c^T}{\partial T} \right].$$

The first term in square brackets is positive—switching land from the residual use to production of the intensive crop increases environmental damage, even under technology 1. The second term is negative because producing the intensive crop under technology 1 causes less environmental damage than producing it under technology 2. Consequently, the net effect of green payments on ambient pollution damage is ambiguous. However, it is clearly possible that offering the fixed per acre green payment T will actually worsen ambient pollution problems. Such perverse outcomes are more likely to occur in regions having a lot of marginal low-quality land [$g(\theta_1^T)$ is large, especially compared to $g(\theta_c^T)$] and/or where low-quality land use is quite sensitive to the green payment ($\partial\theta_1^T/\partial T$ is large), especially compared to the responsiveness of medium-quality land ($\partial\theta_c^T/\partial T$).

Cost sharing based on actual expenses incurred will affect the choice of agricultural commodity output y and environmental damage q, as well as the minimum quality of land producing the agricultural commodity θ_1 and the critical switching quality of land θ_c. Differentiating equations (2) and (3), after modifying them to incorporate reimbursement for costs incurred while using technology 1, with respect to the cost share s gives:

$$\frac{\partial y_1}{\partial s} = \frac{C_y^1 C_{qq}^1}{(1 - s)\left[C_{yy}^1 C_{qq}^1 - (C_{yq}^1)^2\right]} > 0$$

and

$$\frac{\partial q_1}{\partial s} = \frac{-C_y^1 C_{yq}^1}{(1 - s)\left[C_{yy}^1 C_{qq}^1 - (C_{yq}^1)^2\right]} > 0.$$

Specifically, both y and q increase on all qualities of land that would use technology 1 even in the absence of green payments. Intuitively, cost sharing has no direct effect on incentives for environmental damage, but it does have an indirect effect—it makes it profitable to produce more of the agricultural

[1] Another important difference between EQIP and CSP is that EQIP payments are made to farmers for installing new conservation measures, while CSP payments are made for ongoing conservation measures. The implications of the restriction on EQIP payments are discussed in greater detail below.

[2] A fixed payment T also corresponds to an income support subsidy which is completely decoupled from current output such as the direct payments and counter-cyclical payments provided in the current farm bill. The results obtained here thus also apply to these decoupled subsidies.

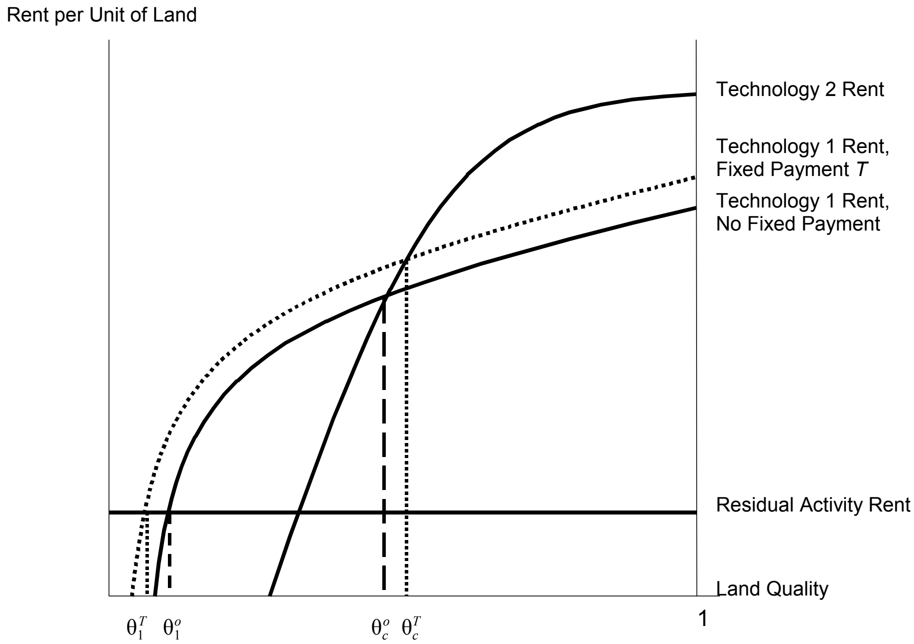

Figure 2. Impact of a fixed per acre green payment on equilibrium land allocations in the absence of environmental regulation

commodity, which creates an incentive for more environmental degradation as a means of lowering the marginal cost of the agricultural commodity. As a result, green payments based on reimbursement of actual expenses incurred worsens environmental damage on all land on which technology 1 is the most profitable in the absence of cost sharing.

As in the case of a fixed payment, cost sharing based on actual expenses incurred will shift the technology 1 rent curve upward, whereby the minimum quality of land using technology 1 will fall while the maximum quality of land using technology 1 will rise. Differentiating the equation defining θ_1 using the envelope theorem, we find:

$$\frac{\partial \theta_1^T}{\partial s} = \frac{C^1}{(1 - s)C_\theta^1} < 0,$$

where green payments based on reimbursement for actual expenses incurred increase the amount of low-quality land allocated to cultivation of the intensive crop.[3]

Differentiating the equation defining θ_c using the envelope theorem, we find:

$$\frac{\partial \theta_c^T}{\partial s} = \frac{C^1}{(1 - s)C_\theta^1 - C_\theta^2} > 0,$$

showing that green payments based on reimbursement for actual expenses incurred increase the amount of medium-quality land allocated to the conservation technology.

The impact of reimbursement for actual expenses incurred on ambient pollution damage is denoted by:

$$D'(M)\left[\int_{\theta_1}^{\theta_c} \frac{\partial q_1}{\partial s} g(\theta)\, d\theta - q_1(\theta_1^s)g(\theta_1^s)\frac{\partial \theta_1^s}{\partial s} + \left[q_1(\theta_c^s) - q_2(\theta_c^s)\right]g(\theta_c^s)\frac{\partial \theta_c^s}{\partial s}\right].$$

The first term in square brackets is the intensive margin effect of reimbursement for actual expenses incurred, i.e., the increase in environmental degradation on all land that would use technology 1 in the absence of green payments. It is positive. The second

[3] Note that such a shift in land allocation might not occur under EQIP, which cost-shares installation of new conservation measures on existing working farmland. If the residual activity and intensive agriculture do not produce similar outputs (e.g., pasture or grazing land versus cropland), then land of quality less than θ_2^o would not be eligible for EQIP payments at all, and land of quality less than θ_c^o would not be eligible for EQIP payments if the operator were already using technology 1. These limitations would not occur under CSP or under generic proposals for green payments often discussed in the literature.

term in square brackets is the lower extensive margin effect of shifting land from the residual use to cultivation of the intensive crop under technology 1. It, too, is positive.[4] The third term in square brackets is the upper extensive margin effect of switching technologies used to cultivate the intensive crop from technology 2 to technology 1. It is negative, and thus the net effect of this form of green payment on environmental damage is ambiguous. Again, however, it is possible that ambient pollution damage will actually get worse. Such a perverse outcome is more likely if the cost of producing the agricultural commodity is quite sensitive to environmental degradation (C_{yq} is large in absolute value); the region has a lot of marginal low-quality land and low-quality land use is quite sensitive to the green payment; and/or the region has relatively little medium-quality land and medium-quality land use is not very sensitive to cost sharing.

Implications for Targeting

The preceding discussion assumed implicitly that every farmer using technology 1 would automatically be awarded green payments. This is not necessarily the case, however, even with the expanded funding authorized by the farm bill. Budget constraints may lead to rationing of funds. As reported by the Farm Services Agency of the U.S. Department of Agriculture (USDA), requests exceed the funds currently available by a ratio of 5:1. Those constraints will be relaxed substantially in the future if Congress appropriates the full funding authorized by the 2002 farm bill, but constraints on the overall federal budget may prevent it from doing so.

Nevertheless, even in the absence of budget limitations, some farmers may be prevented from receiving green payments by oversight exerted by conservation technicians from the Natural Resources Conservation Service (NRCS). At present, for example, every cost-share proposal under EQIP must meet the approval of an NRCS technician before it can even be considered for funding. NRCS technicians will not approve proposals which are inconsistent with an operation's approved conservation plan or with other general conservation goals. Also, as noted earlier, EQIP payments are generally restricted to projects involving installation of new conservation measures on existing operations. Proposals involving shifts from pasture or grazing land to cropland or other major land use changes should be ineligible for cost sharing under EQIP.

Thus, even though green payments might have perverse effects on ambient environmental quality in some circumstances, those effects can be avoided by careful targeting. For example, as Malik and Shoemaker (1993) have pointed out previously, distortions on the lower extensive margin can be avoided by making conservation projects resulting in the expansion of more intensive crop cultivation ineligible for green payments. In cases such as those modeled here, this would mean enforcing conservation compliance provisions disqualifying cost sharing or CSP contracts for projects involving crop production on land currently in low-intensity, non-polluting uses like pasture or hay production.[5] Distortions on the intensive margin can be avoided by decoupling cost-share reimbursements from actual expenses, for example, by setting fixed repayment amounts based on formulas. Cost sharing and CSP contracts could be awarded preferentially to farmers cultivating medium-quality land on which resource-conserving and more intensive farming systems are close to equally profitable, since these are the circumstances in which green payments for practices like those considered here actually result in reductions in environmental damage.

Paradoxically, green payments are more likely to have perverse effects on ambient environmental quality when they are targeted toward land seemingly most in need of conservation. For example, land quality augmenting technologies such as those modeled here have the greatest profitability advantage on the lowest qualities of land used for intensive crop cultivation. Weighting vulnerability to erosion damage or other indicators of low land quality heavily in making green payment awards will favor provision of funding for projects most likely to result in expansion of intensive crop production. In contrast, green payments result in the greatest improvements in ambient environmental quality when they are targeted toward medium-quality land used for intensive crop production; yet

[4] The second term will be zero and the first term will be smaller under EQIP if payments are made only for installation of new conservation measures on existing operations, as noted above. Thus, perverse outcomes are less likely under EQIP than under CSP or generic green payment programs.

[5] The USDA's record in this regard is not encouraging. A recent study by the U.S. General Accounting Office (2003) found that 60% of all citations for conservation compliance violations issued by NRCS were subsequently granted waivers by the Farm Services Agency, largely with little or no justification. As I have argued elsewhere (Lichtenberg, 2004), the USDA's culture as an agency dedicated to representing and serving the farm community is a major impediment to its ability to enforce regulatory provisions that are directly contrary to farmers' interests.

this land seems much less in need of conservation from a purely physical or agronomic viewpoint than low-quality land.

These considerations provide a possible explanation for the results obtained by Bastos and Lichtenberg (2001) in their empirical study of federal conservation cost-sharing awards in Maryland. They found federal cost-share funds were *not* awarded preferentially to the most erodible land. Quite the reverse was found: Land with the greatest tolerance for soil loss (i.e., least vulnerability to erosion) was significantly more likely to have received cost sharing than land with the lowest soil loss tolerance (greatest erosion vulnerability). Moreover, federal cost-share funds were awarded preferentially to land with medium and high crop production potential. While puzzling at first glance, these results seem consistent with targeting cost sharing toward land around the critical switching quality θ_c (although Bastos and Lichtenberg do not rule out other interpretations—for example, that cost sharing targets enhancing crop productivity rather than environmental quality).

The analysis of the preceding section also points to another potential problem: Even when targeting avoids cases where green payments worsen environmental quality, it remains possible that they will accomplish absolutely nothing in terms of improvements in ambient environmental quality. Participation in these programs is voluntary. The farmers most likely to want to enroll are those for whom using resource-conserving technologies would be the most profitable even in the absence of green payments. Thus, voluntary green payment programs can be subject to adverse selection effects in the sense that payments may be made to farmers who would have implemented resource conservation measures even without receiving those payments. In such cases, green payments amount to pure income transfers resulting in no additional improvements in ambient environmental quality.

A recent paper by Lichtenberg and Smith-Ramirez (2003) examines this issue more closely. Their empirical study of cost sharing and conservation effort exerted by Maryland farmers found that farmers with operations having streams running through them or bordering the Chesapeake Bay were not more likely to have been awarded cost-share funding, even though nutrient pollution in the Bay and its tributaries is the predominant environmental concern associated with agriculture in the state. For farmers without bodies of water on their operations, proximity to the nearest body of water similarly made no difference in the probability of having been awarded cost sharing. The authors also found evidence that cost-share awards were not targeted toward farmers whose behavior would change as a result of the award. Farmers who were awarded cost sharing used a smaller number of conservation practices and achieved no greater coverage than those who did not receive cost-share awards.

Conclusion

This paper uses a Ricardian land market equilibrium model to examine the impacts of green payments on the intensity of cultivation, on environmental damage on-farm, and on ambient pollution. In contrast to earlier studies, a model is used where output of an intensive crop and on-farm environmental degradation are joint products (rather than assuming environmental damage is linked to a specific input). Like those studies, this analysis shows that green payments can lead to the extension of intensive crop production, and thus may worsen ambient pollution damage by subsidizing the expansion of more intensive crop cultivation. It is also shown that green payments based on actual costs incurred can increase cultivation intensity and the degree of on-farm environmental degradation (as a by-product of making increased cultivation intensity more profitable), as well as possibly extending intensive crop production. As a result, green payment of this kind may worsen ambient pollution damage on both the intensive and extensive margins. Extensive margin distortions can be avoided by careful targeting, although optimal targeting criteria may not seem intuitively sensible from a physical or agronomic perspective.

The analysis also indicates that in some cases green payments will not lead to improvements in ambient pollution because they are made to farmers who would have found it profitable to adopt resource-conserving technologies even without subsidies. Targeting to avoid such outcomes is likely to be quite difficult. Overall, the analysis suggests optimal targeting of green payments can be quite complex, given the potential for exacerbating environmental quality problems and given the potential for adverse selection.

The analysis presented here was conducted under very specific assumptions about the relationship between land quality, agricultural productivity, on-farm environmental damage, ambient pollution, and the effects of conservation measures. While the case considered here is intuitively appealing for many common environmental problems emanating from agriculture, other cases are certainly possible. Of particular interest is the case where on-farm environmental damage contributes more to ambient pollution on low-quality land. The socially optimal land market equilibrium in such cases is likely not to have the simple structure of the case analyzed here. Instead, the social rent curves for each technology may not be monotonic in land quality, making it likely that there are multiple marginal qualities of land at which it is socially optimal to switch from one technology to another. The possibility of such outcomes underscores the point made in the preceding paragraph—that optimal targeting of green payments is likely to be extremely difficult.

The extent to which these adverse effects actually occur is, of course, an empirical question. But since the current farm bill envisages a rapid expansion of spending on green payments, it seems important to study this question much more intensively to provide a basis for determining how best to proceed with implementing this expansion.

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