Green Payments and Dual Policy Goals

Hongli Feng[1]

May 13, 2002

Abstract

This paper analyzes the efficient design of green payments. Green payments can generate environmental benefits and support farmers' income. We extend a standard adverse selection model by incorporating dual policy goals into the design of green payments: conservation and income support. We also introduce heterogeneity into conservation efficiency type. The results of our dual-goal model and the standard adverse selection model are significantly different. The differences arise from two aspects. First, since farmers may receive green payments for conservation, or income support, or both, the incentive structure in the standard adverse selection model can be significantly altered. Second, information rent is no longer just a cost to induce truthful revelation, it also acts as income support if it goes to farmers whose income support is valued by policymakers. These two differences have important implications for the design of green payments.

[1] Correspondence: Center for Agricultural and Rural Development, Iowa State University, Ames, Iowa, 50011. E-mail: hfeng@Iastate.edu. The author thanks John Beghin, David Hennessy, Brent Hueth, and Cathy Kling for insightful comments. Errors and omissions are the responsibility of the author.

Paper to be presented at the 2002 annual meeting of American Agricultural Economics Association.

Green Payments and Dual Policy Goals

Abstract

This paper analyzes the efficient design of green payments. Green payments can generate environmental benefits and support farmers' income. We extend a standard adverse selection model by incorporating dual policy goals into the design of green payments: conservation and income support. We also introduce heterogeneity into conservation efficiency type. The results of our dual-goal model and the standard adverse selection model are significantly different. The differences arise from two aspects. First, since farmers may receive green payments for conservation, or income support, or both, the incentive structure in the standard adverse selection model can be significantly altered. Second, information rent is no longer just a cost to induce truthful revelation, it also acts as income support if it goes to farmers whose income support is valued by policymakers. These two differences have important implications for the design of green payments.

Introduction

Green payments are payments a government provides to farmers for voluntarily maintaining or adopting conservation practices that enhance the environment, natural resources and/or wildlife habitat. As shown by the recent debate over the 2002 farm bill, originally referred to as Conservation Security Act in the U.S. senate, green payments have moved to the center stage of agri-environmental policies. There are two basic reasons for this interest.

First, green payments provide a foundation for farm support by society at large. Since fiscal year 1998, congress has passed a series of ad hoc emergency relief bills to boost farm income worth near $30 billion (Mercier). If agriculture is to continue to receive the direct payments it has been receiving in recent years, many analysts believe more substantial justification will be needed (Babcock, Claassen et al).

Second, green payments can address agri-environmental problems that have not been adequately addressed. The Conservation Reserve Program (CRP) and the Wetland Reserve Program (WRP) provide conservation services by taking land out of production. There is also strong demand for conservation on land in production, as evidenced by Veneman. Cost-share programs, such as Environmental Quality Incentive Program (EQIP) and the Wildlife Habitat Incentives Program, pay farmers for environment-friendly farming practices. However, when the cost share is less than 100 percent, farmers have no incentive to participate unless the targeted practices also provide private benefits. Green payments, such as the conservation security program initiated in the 2002 farm bill, cover comprehensive practices and are also more generous, and thus are better positioned to meet conservation needs for land both in and out of production.

Wu and Babcock (1995, 1996) adopt the mechanism design framework to analyze green payment contracts when conservation efficiency is not known. Smith also uses a similar framework to analyze the least-cost land retirement mechanism. The main common features of these models are that, (1) there is adverse selection because the principal does not know the value of one parameter of the agents' true characteristics; and (2) the principal can commit herself to decision rules which are admissible on informational grounds. Guesnerie and Laffont provide a complete solution to this class of principal-agent problems, which we will refer to as the standard adverse selection (AS) models. For other examples of application in agricultural and/or environmental contexts, see Bourgeon and Chambers, and Hueth.

A standard AS model for green payments can be described as follows. Policymakers (the principal), given available funds, intend to obtain maximal conservation services from farmers (the agents) at the least cost. However, policymakers do not know the conservation efficiency of an individual farmer, although they know its distribution among farmers. If we model conservation efficiency as having one of two outcomes, high or low, then the well known prediction is that the optimal condition for conservation by the high efficiency type is the same as in the complete information case. However, for the low efficiency type the optimal condition is different, which may require this type to provide conservation service at less than the first-best level.

The difference arises because, if the compensation to each type just equals its conservation cost, i.e., each type's net gain is zero, then the high efficiency type can earn a positive profit by pretending to be the other type. To induce truthful revelation, as implied by the revelation principle[2], a "bribe", information rent, has to be paid to the high efficiency type

[2] The revelation principle basically says that any mechanism is isomorphic to a revelation mechanism, by

which is equal to the amount it would obtain by pretending to be the other type. When setting the optimal conservation for the low efficiency type, we have to recognize that for each additional unit of conservation by this type, there is some informational cost. For later reference, we call this effect the "cost effect" of information rent.

In a standard AS model, it is assumed that policymakers do not care about farmers' income. In this paper, the simple mechanism design framework is broadened to represent the more realistic situation where policymakers care about income support as well as conservation. This is a critical feature for policy analysis that has not been addressed in previous work. We refer to this model as dual-goal model. Formally, benefits from both conservation and income support enter policymakers' objective function in the dual-goal model. Further, we assume that the government is only concerned with the net farm income of relatively small family farms. We also explicitly introduce heterogeneity into each conservation type. That is, there may be both small and large farmers within each conservation type. We analyze the situation where 1) conservation efficiency is not observable (just as in standard AS models) and, 2) policies cannot (or do not) target farm size, as in Bourgeon and Chambers.

It is interesting and policy relevant to study these two kinds of incomplete information. Past studies (Chambers, Bourgeon and Chambers, and Hueth) suggest that policymakers may not be able to explicitly discriminate between small and large farmers, even though farm size can be observed. Instead, they have to explicitly treat all farmers the same. Although some policies limit government payments to large farms, they are often modified or contain loopholes under the political influence of large farms. For example, in the 1996 farm bill, Confined Animal Feeding Operations with over 1000 animal units were not eligible for EQIP. However, this size limitation is removed in the 2002 farm bill. Payment caps are a way to target more payments to small farmers, given total funding. The payment limit on EQIP is dramatically increased in the 2002 farm bill relative to the previous farm bill.

While policymakers may know the proportion of farmers with high (or low) conservation efficiency, they in general do not know a specific farmer's conservation efficiency. For example, how the adoption of conservation tillage affects a farmer's profit depends on many

which the principal elicits truthful answers about the unknown parameter of the agents. This is a well known result in the literature. For more discussions on the revelation principle, see Myerson and Dasgupta, Hammond, and Maskin.

factors: natural resource endowments of the field, weather conditions, the farmer's years of experience and days of off-farm work, the equipment the farmer already has, etc. It is unlikely that policymakers will have information on all these specifics of a farm. Even though a farmer's conservation efficiency is known, it cannot always be used as a basis for payments. For example, the 2002 farm bill stipulates: "If the Secretary determines that the environmental values of 2 or more applications for cost-share payments or incentive payments are comparable, the Secretary shall not assign a higher priority to the application only because it would present the least cost to the program established under the program." (the U.S. Congress)

These two kinds of information incompleteness also make comparison meaningful and interesting. AS models apply to situations where incomplete information exists. However, if we only assume that conservation inefficiency is not contractible but farm size is, then standard AS models can be applied to each farm size and no complication would arise. As we will show later, the optimal design of green payments in the dual-goal model may differs significantly from that in a standard AS model. Given that income support is likely to be a goal, either implicit or explicit, of green payments programs, our extension of standard AS models is a significant contribution to the formal analysis of green payments and the application of AS models in general. For example, the dual-goal model provides one explanation why the 2002 farm bill removed language in the 1996 farm bill that required selection and evaluation be based on maximizing environmental benefit per dollar expended.

The rest of this paper is organized as follows. We lay out the basic elements of the model in the next section. In addition, we briefly present a standard adverse selection model in the setting of green payments. In the third section, we examine green payments with dual policy goals. Specifically, we solve a dual-goal model, investigate the cost effect and income effect of information rent, and compare the results of the dual-goal model with those of the standard adverse selection model. A discussion in the context of the U.S. agriculture is provided at the end of the section. Section 4 concludes.

Model Setup

Farmers produce two types of goods: a market good q and conservation e. The market good generates revenue pq, where p is the market price of q. There is no market for conservation. It is costly to provide a positive level of e, so e equals zero in the absence of any external incentives.

Farmers are characterized by two variables: farm size ϕ and conservation efficiency θ. For simplicity, we assume ϕ and θ have two levels: $\phi \in \Phi \equiv \{\phi_L, \phi_S\}$ and $\theta \in \Theta \equiv \{\theta_h, \theta_l\}$. We denote their joint and marginal distributions as P_{ij}, P_i, and P_j, respectively, where $\phi_i \times \theta_j \in \Phi \times \Theta$. The two variables may be correlated and the correlation is indicated by $P_L P_h - P_S P_l$. For example, positive correlation may occur if large farmers are able to adopt conservation practices more efficiently because they have more efficient management. Negative correlation may occur if small farmers can provide conservation services at a relatively low cost because their land is very environmentally sensitive.

Denote the cost function of providing e and q as $c(q, e; \phi, \theta)$, and assume a higher θ is associated with lower total and marginal costs for a given level of e and q, i.e., $c_\theta(\cdot) < 0$, $c_{e\theta}(\cdot) < 0$. Let $\pi(e; \phi, \theta) = \max\limits_q \{pq - c(q, e; \phi, \theta)\}$ be a farmer's profit given that she provides e. When no conservation services are provided, farmers of the same size are assumed to have the same cost, then we have $\pi(0; \phi, \theta_l) = \pi(0; \phi, \theta_h)$. For income support to be relevant, we assume there is a target income $\bar{y}$ deemed desirable for a farmer by policymakers, with $\pi(0; \phi_S, \theta) < \bar{y}$, and $\pi(0; \phi_L, \theta) \geq \bar{y}$, where $\theta \in \Theta$. Thus, small farmers do not achieve the target income even with zero conservation services, while large farmers do.

Policymakers intend to make payments to farmers as incentives for conservation and as a way of supporting farmers whose status quo income is below $\bar{y}$. We refer to such payments as green payments and denote them as $g(\phi, \theta)$. The benefit policymakers derive from supporting small farmers' income are represented as $\tilde{w}(y)$, with

$$\tilde{w}(y) = \begin{cases} w(y), & \text{if } y \leq \bar{y}, \\ 0, & \text{if } y > \bar{y}, \end{cases} \tag{1}$$

where y is a farmer's income which is the sum of profits and green payments, i.e., $y \equiv \pi(e; \phi, \theta) + g(\phi, \theta)$; w is concave with $w_y \geq 0$, $w_{yy} \leq 0$ and $w_y(\bar{y}) = 0$. Thus, policymakers only derive benefit from supporting small farmers. The closer a farmer's income is to the target income, the less marginal benefit policymakers derive from supporting her. Once a farmer's income exceeds the target income, policymakers will not want to support her any more.[3]

The social benefit of conservation is denoted as $v(e)$ with $v' \geq 0$, $v'' \leq 0$. Funds for green payments are usually financed with some sort of distortionary tax whose unit deadweight loss we denote as $\lambda > 0$[4]. In a green payments program, policymakers' problem is to choose the optimal conservation and green payments to maximize the sum of farmers' profit, environmental benefit, and the benefit from income support, minus the social cost of funding green payments.

The main objective of this paper is to investigate whether and how the results of standard adverse selection models will be modified and the policy implications of such modifications when we incorporate more information on agents into the model and dual goals are associated with green payments. Thus, we will model a green payments program as a truthful direct revelation mechanism, just as in standard adverse selection models. In such a mechanism, the government offers farmers a menu of conservation levels and green payments and farmers can pick any one choice from the menu. This way of modelling enables researchers to focus on the outcome of policies, instead of specifics about policy design. For comparison purposes, we beginning by briefly presenting the major results of a standard adverse selection model. For more details see Guesnerie and Laffont, and Bourgeon and Chambers.

A Standard Adverse Selection Model

Suppose, we characterize farmers by their conservation efficiency (θ), which is not contractible, and disregard for now farm size (ϕ) and income support $w(\cdot)$. Then, the policymakers' problem is to choose a menu of conservation and green payments, $[e(\theta),\ g(\theta)]$, to

[3] For examples of studies where policymakers attach different weight to the welfare of different farmers, see Chambers. A more general form of $\tilde{w}(y)$ may require $\tilde{w}(y) < 0$, for y greater than a threshold levle. That is, very large farms are considered undesirable to the society.

[4] An alternative explanation for λ is that it is the multiplier of policymakers' budget constraint.

maximize net social surplus subject to certain constraints, i.e.,

$$\max_{e,g} \sum_j \left[v(e(\theta_j)) + \pi\left(e(\theta_j);\theta_j\right) - \lambda g(\theta_j)\right] P_j \tag{2a}$$

$$s.t. \qquad \pi\left(e(\theta_j);\theta_j\right) + g(\theta_j) \geq \pi(0;\theta_j), \tag{2b}$$

$$\pi\left(e(\theta_j);\theta_j\right) + g(\theta_j) \geq \pi\left(e(\theta_{j'});\theta_j\right) + g(\theta_{j'}), \quad \text{where } \theta_j,\ \theta_{j'} \in \Theta \tag{2c}$$

The first set of constraints (2b), denoted as (IR_j), are the individual rationality constraints for type θ_j, which require voluntary participation. This is because it is in general politically infeasible to require farmers to provide conservation without compensation due to long-standing concern for farm income support. In fact, most agri-environmental programs are voluntary mechanisms, for example, CRP, WRP, EQIP, and the conservation security program in the 2002 farm bill. The second set of constraints (2c), denoted as (IC_j), are the incentive compatibility constraints: revealing her true type gives a farmer a higher income than pretending to be the other type. The set of equations in (2) describes a standard adverse selection model.

We briefly solve the above model in two stages, as in Bourgeon and Chambers. In the first stage, the optimal green payments are obtained for given conservation services, and in the second stage the optimal conservation services are determined. The two-stage version of (2) is as follows,

$$\max_{e} \sum_j \left[v(e(\theta_j)) + \pi\left(e(\theta_j);\theta_j\right)\right] P_j + \tilde{z}^*\left(e(\theta_l), e(\theta_h)\right) \tag{3}$$

$$\text{where } \tilde{z}^*(\cdot) = \max_{g} \left\{\tilde{z}(\cdot) : \text{ (2b) and (2c)}\right\},$$

$$\text{and } \tilde{z}(\cdot) = \sum_j \left[-\lambda g(\theta_j) P_j\right].$$

All constraints are depicted in Figure 1 except (IR_h) which will be satisfied if (IR_l) and (IC_h) are satisfied. The green payments that satisfy (IC_h) are along the line IC_h and the area above it and those satisfying (IC_l) are along the line IC_l and the area below it. IC_l and IC_h have a slope equal to 1 and intercepts as indicated. The relative position of IC_l and IC_h is determined by the condition: $e(\theta_h) \geq e(\theta_l)$, which is well known in the literature and can be easily derived from (2b) and (2c). So, the feasible green payments fall within the shaded area. In the figure, $\tilde{z}(\cdot)$ is a negatively sloped line with slope equal to $\left(-\frac{P_l}{P_h}\right)$, and intercept equal to $\left(-\frac{\tilde{z}}{\lambda P_h}\right)$. Then the lowest point in the shaded area is the unique feasible green payments maximizing $\tilde{z}(\cdot)$. This implies that constraints (IR_l) and

(IC_h) bind. From the binding constraints, we derive the optimal green payments, $\tilde{g}^*(\theta_j; e)$, for any given $e(\theta_h) \geq e(\theta_l)$,

$$\tilde{g}^*(\theta_h; \tilde{e}) = \pi(0; \theta_h) - \pi(\tilde{e}(\theta_h); \theta_h) + \tilde{I}(\tilde{e}(\theta_l)), \tag{4a}$$

$$\tilde{g}^*(\theta_l; \tilde{e}) = \pi(0; \theta_l) - \pi(\tilde{e}(\theta_l); \theta_l), \tag{4b}$$

$$\text{where} \quad \tilde{I}(e) \equiv \pi(e; \theta_h) - \pi(e; \theta_l). \tag{4c}$$

$\tilde{I}(e)$, known as the information rent, is the amount of extra payment the high efficiency type can get for providing conservation services e if it pretends to be the low efficiency type. Since $\pi_\theta = -c_\theta > 0$ and $\pi_{e\theta} = -c_{e\theta} > 0$; then $I(e) > 0$ and $I_e(e) > 0$. Thus, from (4), to prevent misrepresentation, the high efficiency type's green payments include not only their lost profit in providing conservation services but also an information rent, while the green payments for the low efficiency type just equals their lost profit.

Plugging $\tilde{g}^*(\theta_j; e)$ into (3), we then obtain the optimal conditions for e (subscripts indicate derivatives):

$$v_e(\tilde{e}^*(\theta_h)) = -(1+\lambda)\pi_e(\tilde{e}^*(\theta_h); \theta_h), \tag{5a}$$

$$v_e(\tilde{e}^*(\theta_l)) = -(1+\lambda)\pi_e(\tilde{e}^*(\theta_l); \theta_l) + \lambda \tilde{I}_e(\tilde{e}^*(\theta_l))\frac{P_h}{P_l}. \tag{5b}$$

As is well known, for the high efficiency type, the optimal condition is the same as that of the complete information case: the marginal benefit of conservation equals the marginal cost of conservation which includes the lost profit and the cost of raising funds for green payments. For the low efficiency type, the marginal information rent cost is added to the marginal cost side: for any amount of conservation services by the low efficiency type, a payment has to be paid to the high efficiency type for it to truthfully reveal itself.

The AS model serves as the base case for analyzing the more realistic situation where two goals, conservation and income support, are associated with green payments.

An Adverse Selection Model with Dual Goals

When policymakers intend to use green payments to obtain conservation services from farmers and to support only small farmers' income, $\tilde{w}(\cdot)$ is added to the objective function and ideally conservation, e, and green payments, g, are functions of both farm size, ϕ, and conservation efficiency, θ. Then, the policymakers' problem is modified from (2) to the following,

$$\max_{e,g} \quad \sum_i \sum_j \left[v(e(\phi_i,\theta_j)) + \pi(e(\phi_i,\theta_j)) + \tilde{w}\left(y(\phi_i,\theta_j)\right) - \lambda g(\phi_i,\theta_j)\right] P_{ij}, \tag{6a}$$

$$s.t. \qquad \pi\left(e(\phi_i,\theta_j);\phi_i,\theta_j\right) + g(\phi_i,\theta_j) \geq \pi(0;\phi_i,\theta_j), \tag{6b}$$

$$\pi\left(e(\phi_i,\theta_j);\phi_i,\theta_j\right) + g(\phi_i,\theta_j) \geq \pi\left(e(\phi_{i'},\theta_{j'});\phi_i,\theta_j\right) + g(\phi_{i'},\theta_{j'}), \tag{6c}$$

where $\phi_i, \phi_{i'} \in \Phi$, θ_j, $\theta_{j'} \in \Theta$. The first set of constraints, denoted as (IR_{ij}), are the individual rationality constraints for type (ϕ_i, θ_j). The second set of constraints, denoted as (IC_{ij}), are the incentive compatibility constraints. These constraints are very similar to (2b)-(2c). The only difference is that the former incorporate two parameters, and the latter, one. There are 4 individual rationality constraints (one for each type) and 12 incentive compatibility constraints—each type of farmers can choose to pretend to be one of the other three types.

It is well known that multi-dimensional, including two-dimensional, adverse selection models are very complicated to solve, there are only a few studies in the literature, see Laffont, Maskin and Rochet, and Armstrong and Rochet. The latter examine a class of two-dimensional screening problems, where each type parameter comes from a binary distribution, just as ϕ and θ in this paper. Similar to Armstrong and Rochet, but in a less stringent way, we make one assumption about farmers' cost function:

Assumption 1: $c_{e\phi}\left(e, q; \phi, \theta\right) = 0$.

The assumption is that farm size and the marginal cost of conservation are additively separable in the cost function, that is, $c\left(e, q; \phi, \theta\right) = f\left(e, q; \theta\right) + h\left(q; \phi, \theta\right)$. The assumption is innocuous for the following reasons. First, the notion that large farmers may be more conservation efficient or otherwise is captured by the correlation between ϕ and θ. Second, we can always define θ in such a way that it ranks farmers' marginal cost of conservation regardless of the value of ϕ. Finally, the paper's major contribution is not affected even if this assumption does not generalize: we show one way to extend the standard adverse selection model, which has important implication in the design of policies like green payments.

With this assumption, we derive the following lemma,

Lemma 1 *Under Assumption 1, the policy menu is in effect* $\left[e\left(\theta\right), g\left(\theta\right)\right]$*, instead of* $\left[e(\phi,\theta),\ g(\phi,\theta)\right]$.

A proof is given in the appendix. With Lemma 1, we can rewrite problem (6) as,

$$\max_{e,g} \sum_j \left[v(e(\theta_j)) + \tilde{\pi}\left(e(\theta_j);\theta_j\right) + w\left(y(\phi_S,\theta_j)\right) \frac{P_{Sj}}{P_j} - \lambda g(\theta_j) \right] P_j \tag{7a}$$

$$s.t. \qquad \pi\left(e(\theta_j);\phi_i,\theta_j\right) + g(\theta_j) \geq \pi(0;\phi_i,\theta_j), \tag{7b}$$

$$\pi\left(e(\theta_j);\phi_i,\theta_j\right) + g(\theta_j) \geq \pi\left(e(\theta_{j'});\phi_i,\theta_j\right) + g(\theta_{j'}), \tag{7c}$$

where $\phi_i \in \Phi$, θ_j, $\theta_{j'} \in \Theta$, and $\tilde{\pi}\left(e(\theta_j);\theta_j\right) = \sum_i \frac{P_{ij}}{P_j} \pi\left(e(\theta_j);\phi_i,\theta_j\right)$, which is the average income of farmers with conservation efficiency θ_j.

Because of the heterogeneity introduced within each conservation type, there are one individual rationality constraints and two incentive compatibility constraints for each conservation type. However, with Assumption 1, the constraints for farmers with the same conservation efficiency either both hold or both do not hold. That is, for ϕ_i, $\phi_{i'} \in \Phi$, and $\theta_j \in \Theta$, if (IR_{ij}) holds, then $(\mathrm{IR}_{i'j})$ must also hold. Likewise, if (IC_{ij}) holds, then $(\mathrm{IC}_{i'j})$ must also hold. This is because from $\pi_{\phi e} = -c_{\phi e} = 0$, we know $\left[\pi\left(e(\theta_j),\phi_L,\theta\right) - \pi\left(e(\theta_{j'}),\phi_L,\theta\right)\right] - \left[\pi\left(e(\theta_j),\phi_S,\theta\right) - \pi\left(e(\theta_{j'}),\phi_S,\theta\right)\right] = \int_{\phi_S}^{\phi_L} \left[\pi_\phi\left(e(\theta_j),\phi,\theta\right) - \pi_\phi\left(e(\theta_{j'}),\phi,\theta\right)\right] d\phi = 0$. Henceforth, we will refer to the individual rationality constraints simply as (IR_h) or (IR_l), and the incentive compatibility constraints simply as (IC_h) or (IC_l). Just as in the standard AS model, we can derive $e\left(\theta_h\right) \geq e\left(\theta_l\right)$ from (7b) and (7c). And, similar to Figure 1, we can depict the feasible set determined by (7b) and (7c) by the shaded area in Figure 2.

We again solve (7) as a two-stage problem,

$$\max_{e} \sum_j \left[v(e(\theta_j)) + \tilde{\pi}\left(e(\theta_j);\theta_j\right)\right] P_j + z^*\left(e(\theta_l), e(\theta_h)\right) \tag{8a}$$

$$\text{where } z^*\left(\cdot\right) = \max_{g} \left\{ z\left(\cdot\right) : \text{ (7b) and (7c)} \right\}, \tag{8b}$$

$$\text{and } z\left(\cdot\right) \equiv \sum_j \left[w\left(y(\phi_S,\theta_j)\right) P_{Sj} - \lambda g(\theta_j) P_j \right]. \tag{8c}$$

That is, the optimal green payments are first obtained for given conservation services and then the optimal conservation services are determined.

First stage maximization

From (8), the first stage problem is,

$$\max_{g} \qquad z\left(\cdot\right) = \sum_j \left\{ w\left[\pi(e(\theta_j);\phi_S,\theta_j) + g(\theta_j)\right] P_{Sj} - \lambda g(\theta_j) P_j \right\}, \tag{9}$$

$$s.t. \quad \text{(7b) and (7c)}.$$

With $w(\cdot)$ as a component of $z(\cdot)$, how the value of $z(\cdot)$ changes with green payments is more complicated than in the standard adverse selection model. As a reference point, we derive the green payments, $g^0(e) \equiv \left[g^0(\theta_h; e),\ g^0(\theta_l; e)\right]$, which maximize $z(\cdot)$ subject to no constraint. That is, $g^0(e)$ is derived from the following conditions[5]:

$$w_g\left[\pi(e(\theta_h); \phi_S, \theta_h) + g^0(\theta_h; e)\right]\frac{P_{Sh}}{P_h} = w_g\left[\pi(e(\theta_l); \phi_S, \theta_l) + g^0(\theta_l; e)\right]\frac{P_{Sl}}{P_l} = \lambda, \tag{10}$$

where , referred to as , is the optimal solution to the unconstrained first stage maximization. Condition (10) indicates that $g^0(e)$ should be such that the marginal benefit of income support is equal to the marginal cost of transfer and is equal for farmers of different conservation efficiency.

Depending on how $g(e)$ deviates from $g^0(e)$, we can infer how the value of $z(\cdot)$ changes with $g(e)$ and thus find the optimal green payments in the feasible set. As shown in Figure 2(a)-2(c), there are three possible cases: $g^0(e)$ is below, in, or above the feasible set. Since the rest of our analysis is going to hinge on the position of $g^0(e)$, we discuss it in more details here.

The position of $g^0(e)$

It turns out that the overlap of small farms and those with high (or low) conservation efficiency is an important factor that determines the position of $g^0(e)$. More specifically, where $g^0(e)$ locates depends on the relative magnitudes of the proportion of small farms among those with high conservation efficiency and the proportion of small farms among those with low conservation efficiency. We will discuss more about the magnitudes of these two proportions in the context of the U.S. agriculture at the end of this section.

If $\frac{P_{Sh}}{P_h} \leq \frac{P_{Sl}}{P_l}$, then from (10) and by the concavity of $w(\cdot)$, we have

$$\pi(e(\theta_h); \phi_S, \theta_h) + g^0(\theta_h; e) \leq \pi(e(\theta_l); \phi_S, \theta_l) + g^0(\theta_l; e). \tag{11}$$

Given that $\pi_\theta(\cdot) > 0$, we have,

$$\begin{aligned} \pi(e(\theta_h); \phi_S, \theta_h) + g^0(\theta_h; e) &\leq \pi(e(\theta_l); \phi_S, \theta_h) + g^0(\theta_l; e), & \text{(12a)} \\ \pi(e(\theta_l); \phi_S, \theta_l) + g^0(\theta_l; e) &\geq \pi(e(\theta_h); \phi_S, \theta_l) + g^0(\theta_h; e). & \text{(12b)} \end{aligned}$$

[5] Throughout this paper, all solutions are interior solutions and all subscripts to functions are derivatives.

If green payments are at $g^0(e)$, then (12) indicates that type θ_h is better off by misrepresenting itself, while type θ_l is better off by truthfully revealing itself. The intuition for this is as follows. When there are relatively more small farmers among those with low conservation efficiency, i.e., $\frac{P_{Sh}}{P_h} \leq \frac{P_{Sl}}{P_l}$, $g^0(\theta_l; e)$ is relatively high because income support for type θ_l is relatively more efficient. Such $g^0(\theta_l; e)$ creates incentives for type θ_h to misrepresent itself as type θ_l. Thus, (IC$_l$) is satisfied but (IC$_h$) is not, i.e., $g^0(e)$ is below the feasible set, as shown by dot g^0 in Figure 2(a).

If $\frac{P_{Sh}}{P_h} > \frac{P_{Sl}}{P_l}$, then

$$\pi(e(\theta_h); \phi_S, \theta_h) + g^0(\theta_h; e) > \pi(e(\theta_l); \phi_S, \theta_l) + g^0(\theta_l; e). \tag{13}$$

Intuitively, when $\frac{P_{Sh}}{P_h} > \frac{P_{Sl}}{P_l}$, the income support for type θ_h is relatively more efficient and so $g^0(\theta_h; e)$ is high relative to $g^0(\theta_l; e)$ to provide more income support for type θ_h. Depending on the magnitude of $g^0(\theta_h; e) - g^0(\theta_l; e)$, we have two cases. If the difference is very large, then the following is possible,

$$\begin{aligned} g^0(\theta_h; e) - g^0(\theta_l; e) &> \pi(e(\theta_l); \phi_S, \theta_l) - \pi(e(\theta_h); \phi_S, \theta_l) \\ &> \pi(e(\theta_l); \phi_S, \theta_l) - \pi(e(\theta_h); \phi_S, \theta_h). \end{aligned} \tag{14}$$

That is, type θ_l gains by taking $\left[g^0(\theta_h; e),\ e(\theta_h)\right]$, because its gain from green payments (the first difference) more than offsets its profit loss (the second difference). So (IC$_l$) will not be satisfied while (IC$_h$) will, which implies that $g^0(e)$ is above the feasible set, as shown by dot g^0 in Figure 2(c). Of course, when $g^0(\theta_h; e)$ is not so high relative to $g^0(\theta_l; e)$, it may happen that (13) holds but not (14). That is, neither type will have incentive to pretend to be the other type and $g^0(e)$ will lie in the feasible set, as shown by dot g^0 in Figure 2(b).

The optimal green payments for any given conservation level

Using $g^0(e)$ as a reference point, we can find the optimal green payments $g^*(e)$. Before presenting the solution to the first stage problem, we introduce some notation. We first define $t(\theta_j)$ as the *net payments* to farmers of type θ_j, i.e., payments over and above the decline in profit from conservation, or,

$$t(\theta_j) \equiv g(\theta_j) - [\pi(0; \phi, \theta_j) - \pi\left(e\left(\theta_j\right); \phi, \theta_j\right)], \qquad \text{where } \phi \in \Phi,\ \theta_j \in \Theta.$$

Similar to the use of $g^0(e)$, we define the optimal net payments and optimal green payments to both types for a given e as $t^*(e) \equiv [t^*(\theta_h;e), t^*(\theta_l;e)]$, and $g^*(e) \equiv [g^*(\theta_h;e), g^*(\theta_l;e)]$, respectively.

We next define information rent in our dual-goal setting as,

$$I(e) \equiv \pi\left(e;\phi,\theta_h\right) - \pi\left(e;\phi,\theta_l\right).$$

Thus, from (4c), $I(e)$ is very similar to $\tilde{I}(e)$, except that here information rent is for a given farm size. Just as in the standard AS model, $I(e) > 0$ and $I_e(e) > 0$.

The solutions to the first stage problem are presented in the following proposition,

Proposition 1 *For any given $e\left(\theta_h\right) \geq e\left(\theta_l\right)$, if $g^0(e)$ is in the feasible set, then $g^*(e) = g^0(e)$. If $g^0(e)$ is below the feasible set, then for $t^*(e) \geq 0$,*

$$g^*(\theta_h;e) = \pi(0;\phi,\theta_h) - \pi\left(e\left(\theta_h\right);\phi,\theta_h\right) + I(e\left(\theta_l\right)) + t^*(\theta_l;e), \tag{15a}$$

$$g^*(\theta_l;e) = \pi(0;\phi,\theta_l) - \pi\left(e\left(\theta_l\right);\phi,\theta_l\right) + t^*(\theta_l;e). \tag{15b}$$

If $g^0(e)$ is above the feasible set, then for $t^*(e) \geq 0$,

$$g^*(\theta_h;e) = \pi(0;\phi,\theta_h) - \pi\left(e;\phi,\theta_h\right) + t^*(\theta_h;e). \tag{16a}$$

$$g^*(\theta_l;e) = \pi(0;\phi,\theta_l) - \pi\left(e\left(\theta_l\right);\phi,\theta_l\right) - I(e\left(\theta_h\right)) + t^*(\theta_h;e), \tag{16b}$$

Moreover, the following holds both when $g^0(e)$ is below and above the feasible set,

$$\lambda = \left\{ w_g\left[\pi(e(\theta_h);\phi_S,\theta_h) + g^*(\theta_h;e)\right]\tfrac{P_{Sh}}{P_S} + w_g\left[\pi(e(\theta_l);\phi_S,\theta_l) + g^*(\theta_l;e)\right]\tfrac{P_{Sl}}{P_S}\right\} P_S. \tag{17}$$

A proof is given in the appendix. The intuition for Proposition 1 is as follows. When $g^0(e)$ is in the feasible set, the incentive constraints of both types are satisfied. Therefore, the constrained maximization is in effect the unconstrained maximization, and so $g^*(e) = g^0(e)$.

For the case where $g^0(e)$ is below the feasible set, equation (15b), which is basically a rewrite of the definition of net payments, says that the optimal green payments for the low efficiency type equal its lost profits plus net payments. From (15a), the optimal green payments for the high efficiency type have three parts: lost profits, $\pi(0;\phi,\theta_h) - \pi\left(e\left(\theta_h\right);\phi,\theta_h\right)$, net payments received by the low efficiency type, $t^*(\theta_l;e)$, and the information rent, $I(e\left(\theta_l\right))$. The information rent exists because the incentive constraint for the high efficiency type is not satisfied. In order to induce this type to reveal itself truthfully, it has to get paid an extra amount equal to the amount it would get if it pretends to be the other type—the information rent.

Similarly, we can derive (16), which differs from (15) because, when $g^0(e)$ is above the feasible set, it is for the low efficiency type that the incentive constraint is not satisfied. For this type to tell the truth, its green payments can not be less than those of the high efficiency type minus information rent, which is the amount of profits the low efficiency type would lose if it misrepresents itself.

Equation (17) requires that, at the optimal green payments, the marginal cost of income support (λ) equals the expected marginal benefit from income support. The term in braces is the expectation conditional on small farmers. Multiplying this by P_S gives us the unconditional expected marginal benefit from income support. Expectations are taken because green payments cannot be directed at a specific group of farmers due to incomplete information.

Combining (15) and (17), we can solve $g^*(e)$ and $t^*(e)$ for the case where $g^0(e)$ is below the feasible set. Combining (16) and (17), we can solve $g^*(e)$ and $t^*(e)$ for the case where $g^0(e)$ is above the feasible set.

Second Stage Maximization

After obtaining the optimal green payments for any given conservation level, we derive the optimal conservation levels. We present the solution to the second stage problem, (8a), in Proposition 2, with its proof given in the appendix. Just as the first stage, we also have three cases here:

Proposition 2 *If $g^0(e)$ is in the feasible set, then*

$$v_e(e^*(\theta_h)) = -(1+\lambda)\pi_e\left(e^*(\theta_h);\phi,\theta_h\right), \tag{18a}$$

$$v_e(e^*(\theta_l)) = -(1+\lambda)\pi_e\left(e^*(\theta_l);\phi,\theta_l\right). \tag{18b}$$

If $g^0(e)$ is below the feasible set, then,

$$v_e(e^*(\theta_h)) = -(1+\lambda)\pi_e\left(e^*(\theta_h);\phi,\theta_h\right), \tag{19a}$$

$$v_e(e^*(\theta_l)) = -(1+\lambda)\pi_e\left(e^*(\theta_l);\phi,\theta_l\right) + \left[\lambda - \tfrac{P_{Sh}}{P_h} w_g(y^*(\phi_S,\theta_h))\right] I_e(e^*(\theta_l))\tfrac{P_h}{P_l}. \tag{19b}$$

If $g^0(e)$ is above the feasible set, then,

$$v_e(e^*(\theta_h)) = -(1+\lambda)\pi_e\left(e^*(\theta_h);\phi,\theta_h\right) - \left[\lambda - \frac{P_{Sl}}{P_l} w_g(y^*(\phi_S,\theta_l))\right] I_e(e^*(\theta_h))\frac{P_l}{P_h}, \quad (20)$$

$$v_e(e^*(\theta_l)) = -(1+\lambda)\pi_e\left(e^*(\theta_l);\phi,\theta_l\right). \quad (21)$$

In the above equations $v_e(\cdot)$ is the marginal benefits of conservation and $-(1+\lambda)\pi_e(\cdot)$ is its marginal costs including farmers' marginal profit loss, $-\pi_e\left(e^*(\theta_h);\phi,\theta_h\right)$ and the costs of raising funds for green payments, $-\lambda\pi_e\left(e^*(\theta_h);\phi,\theta_h\right)$. Equations (18) indicate that, when $g^0(e)$ is in the feasible set, the optimal conditions for conservation by both types are such that the marginal cost and marginal benefit of conservation are equalized. This would be the optimal condition when there is complete information. Given that no constraint is binding in this case, it is not surprising that we obtain this result.[6]

When $g^0(e)$ is above or below the feasible set, only for one of the two conservation types does the optimal condition remain the same as its counterpart in (18). For the other type, an extra term is attached, which we will discuss in more detail below.

Cost effect and income effect of information rent

From proposition 1, when $g^0(e)$ is below the feasible set, we know the high efficiency type derives information rent, $I(e(\theta_l))$ for any given $e(\theta_l)$. As $e(\theta_l)$ increases, this information rent increases at rate $I_e(e(\theta_l) > 0$. Since the social cost for every dollar of transfer is λ dollars, the social cost increases at $\lambda I_e(e(\theta_l))$. We call $\lambda I_e(e(\theta_l))$ the *cost effect* of information rent because it is the bribe that has to be paid to the high efficiency type for its truthful revelation. This effect is also present in the standard adverse selection model, see (5b).

However, this is not the only effect of information rent in our dual-goal model. As the high efficiency type gets more information rent, its income increases. The desirability of this income increase depends on the proportion of small farmers within the high efficiency type, which is reflected by the term $\frac{P_{Sh}}{P_h}$. At one extreme, $P_{Sh} = 0$, that is, there are no small farmers within the high efficiency type, then increased income for the high efficiency type serves no purpose. But, given that one of the objectives of green payments is to boost small farmers' income, as long as $P_{Sh} > 0$, there is some expected benefit from an income increase

[6] In all cases, we also need to verify that $e(\theta_h) \geq e(\theta_l)$. If this condition is not satisfied, the solutions have to be modified.

for the high efficiency type. Specifically, as $e(\theta_l)$ increases, the social welfare from income support will increase at rate $\frac{P_{Sh}}{P_h} w_g(y^*(\phi_S, \theta_h)) I_e(e^*(\theta_l))$. We call this term the *income effect* of information rent because information rent acts as an income support to small farmers. Since the income effect and the cost effect tend to offset each other, they enter equation (19b) with opposite signs.

The last term, $\frac{P_h}{P_l}$, in (19b), which is also present in (5b), indicates the magnitude of the net effect of information rent. When there are relatively more high conservation efficiency farmers, i.e., $\frac{P_h}{P_l}$ is high, more farmers will obtain information rent. And thus, information rent will have a relatively larger effect.

A similar explanation applies to the case where $g^0(e)$ is above the feasible set. As $e(\theta_h)$ increases, $I(e(\theta_h))$ also increases. This makes it harder for the low efficiency type to misrepresent itself, so their payments can be reduced at the rate, $I_e(e(\theta_h))$. This in turn implies that society can save costs of at rate $\lambda I_e(e(\theta_h))$, which is the *cost effect* of information rent in this case. Similar to the previous case, the reduction of payments to some farmers will affect the social benefit from income support if these farmers include small farmers. This effect is captured by $\frac{P_{Sl}}{P_l} w_g(y^*(\phi_S, \theta_l)) I_e(e^*(\theta_h))$, which is the *income effect* of information rent in this case.

Comparing the results of the dual-goal model (7) with the results of the standard AS model (2), we observe a couple of major points, which differ the dual-goal model from the standard AS model. (*i*) *In the dual-goal model, the incentive compatibility constraint could be satisfied for both types, only for the high efficiency type, or only for the low efficiency type, while in the standard AS model it is the incentive constraint for the high efficiency type that is not satisfied.* The difference, which is due to the payments intended for income support, is shown by the difference between (4) and the equations in Proposition 1. Which one of the three cases in the dual-goal model holds depends on the relative size of income support for each type. (*ii*) *In the dual-goal model, information rent has both income effect and cost effect, while in the standard AS model, it only has the cost effect.* This difference is reflected by the additional terms in (19b) and (20), as compared to (5b). (*iii*) *In the dual-goal model, the individual rationality constraint may no longer hold for either type, while in the standard AS model it holds for the low efficiency type.* This difference is illustrated by Figure 1 and Figure 2. As long as there are some small farmers in each conservation type, policymakers will want to make some net transfer to both types, which implies non-binding individual rationality constraints.

Discussions in the context of the U.S. agriculture and environment

In the United States, there is evidence that payments for conservation services act as income support. In addition, policymakers not only want to support (small) farms with high conservation efficiency but also those with low efficiency. For example, in the 1996 farm bill, selection and evaluation of applications for EQIP were based on maximizing environmental benefit per dollar expended. According to the new farm bill, as mentioned in the introduction section, the Sectary of Agriculture must not discriminate against farmers which are not cost-effective. The new bill also stipulates that "the Sectary shall not use competitive bidding or any similar procedure" in entering into conservation security contracts with farmers.

With incomplete information, we are usually in a second-best environment. However, as shown by Proposition 2, in the dual-goal model the first-best conservation levels can be achieved if $g^0(e)$ is in the feasible set. That is, when $\frac{P_{Sh}}{P_h} > \frac{P_{Sl}}{P_l}$ but not by a large degree, coupling payments for conservation and payments for income support can restore the first best. If $\frac{P_{Sh}}{P_h} < \frac{P_{Sl}}{P_l}$ is generally true, then the gain of coupling the two payments will be limited. The exact sizes of $\frac{P_{Sh}}{P_h}$ and $\frac{P_{Sl}}{P_l}$ depend on the definition of small farms and the environmental indicator(s).

According to the definition of Economic Research Services at the U. S. Department of Agriculture, more than 90% of farms are small, i.e., with sales less than $250,000. However, among these 40% are residential/lifestyle farms, i.e., small farms whose operators report a major occupation other than farming. Suppose policymakers intend to support all other small farms, then $P_S = .50$. A farm's conservation efficiency may depend on which environmental indicator(s) are considered. Below, we take wind erosion as one example. According to Claassen et al, among those with high conservation efficiency[7], about 40% are small farms, i.e., $\frac{P_{Sh}}{P_h} = .4$, and among small farms, about 20% have high conservation efficiency,

[7]Here we assume that farms with high levels of erosion can more efficiently achieve environmental benefits, i.e., erosion reduction. Admittedly, this is not necessarily the case, but it gives us a general measure of conservation efficiency, which would otherwise be hard to botain.

i.e., $\frac{P_{Sh}}{P_S} = .2$. Given these two ratios and P_S, we obtain $\frac{P_{Sl}}{P_l} = .53$. Thus, $\frac{P_{Sh}}{P_h} < \frac{P_{Sl}}{P_l}$, in the context of soil erosion.

Conclusions

This paper contributes to the analysis of the design of green payments by capturing one critical feature of green payments—income support—with a dual-goal adverse model. When policymakers (the principal) intend to provide income support for some farmers (the agents), the principal will not necessarily minimize the payments to the agents for any given level of services provided by them. Instead, she prefers the net payments to some agents to be greater than zero. This positive net payments will directly alter agents' incentives to reveal their true costs of providing the services. In addition, given that the principal cares about some agents' income, any factor that affects these agents' income will affect the optimal scheme the principal would like to employ to obtain services from the agents.

Although we discussed the dual-goal model in the context of green payments, we believe it is applicable to any context where the principal cares about some agents' income. One example of such context is public finance. For projects such as the construction of an office building equipped with advanced technology, a local government may have two goals: to minimize the cost of a high-tech building and to create jobs for local people. Due to equal employment as required by law, the local government cannot explicitly discriminate against outsiders. Moreover, the local government may not have complete information as to whether an outsider will do a better job at a lower cost either. Suppose a bidding scheme is to be used, then the local government may have a problem similar to the dual-goal model in this paper.

Appendix

Proof of Lemma 1. Since $\pi_{e\phi} = c_{e\phi} = 0$, then we can write $\pi(e;\phi,\theta)$ as $u(e;\theta) + v(\phi,\theta)$. We prove Lemma 1 by showing that a farmer's choice of (e,g) is independent of ϕ. Each type chooses (e,g) to maximize its income, $u(e;\theta) + v(\phi,\theta) + g$, which is equivalent to maximizing $u(e;\theta) + g$. This is because $v(\phi,\theta)$ is not affected by either e or g. Since both type ϕ_L and type ϕ_S face the same maximand, $u(e;\theta) + g$, which does not have ϕ in it, farmers of type ϕ_L or ϕ_S can easily pretend to be the other type and no (e,g) can be designed to tell them apart. ■

Proof of Proposition 1. When $g^0(e)$ is in the feasible set, since no constraint is binding, then the unconstrained solutions are also the constrained solutions to the first stage problem. Thus, $g^*(e) = g^0(e)$. Next we prove the proposition for the case when $g^0(e)$ is not in the feasible set. By definition,

$$z = \sum_j \left\{ w\left[\pi(e(\theta_j);\phi_S,\theta_j) + g(\theta_j)\right] P_{Sj} - \lambda g(\theta_j) P_j \right\},$$

Totally differentiating both sides, and setting $dz = 0$, we get,

$$0 = \left[w_g(y(\phi_S,\theta_l))P_{Sl} - \lambda P_l\right] dg(\theta_l) + \left[w_g(y(\phi_S,\theta_h))P_{Sh} - \lambda P_h\right] dg(\theta_h),$$

where[8] $y(\phi_S,\theta_j;e) = \pi(e(\theta_j);\phi_S,\theta_j) + g(\theta_j;e)$. Rearrange, then,

$$\frac{dg(\theta_h;e)}{dg(\theta_l;e)} = -\frac{w_g(y(\phi_S,\theta_l))P_{Sl} - \lambda P_l}{w_g(y(\phi_S,\theta_h))P_{Sh} - \lambda P_h} \tag{22}$$

Differentiate $\frac{dg(\theta_h;e)}{dg(\theta_l;e)}$ with respect to $dg(\theta_l;e)$,

$$\frac{d^2 g(\theta_h;e)}{d[g(\theta_l;e)]^2} = -\frac{w_{gg}y((\phi_S,\theta_l;e))P_{Sl}[w_g(y(\phi_S,\theta_h;e))P_{Sh} - \lambda P_h] - [w_g(y(\phi_S,\theta_l;e))P_{Sl} - \lambda P_l] w_{gg}(y(\phi_S,\theta_h;e))P_{Sh}}{[w_g(y(\phi_S,\theta_h;e))P_{Sh} - \lambda P_h]^2} \tag{23}$$

Then, by the definition of $g^0(\theta_j;e)$, we know

$$w_g(y^0(\phi_S,\theta_l;e))P_{Sl} - \lambda P_l = w_g(y^0(\phi_S,\theta_h;e))P_{Sh} - \lambda P_h = 0,$$

where $y^0(\phi_S,\theta_j;e) \equiv \pi(e(\theta_j);\phi_S,\theta_j) + g^0(\theta_j;e)$.

[8] We write $g(\theta_j)$ and $y(\phi_S,\theta_j)$ as $g(\theta_j;e)$ and $y(\phi_S,\theta_j;e)$ to emphasize that at the first stage, we are discussing green payments for a given e.

If $g^0(e)$ is below the feasible set, then the optimal green payments $g^*(e)$ lie to the northwest of $g^0(e)$, since $g^*(e)$ must lie in the feasible set. That is[9],

$$g^*(\theta_h; e) > g^0(\theta_h; e) \quad \text{and} \qquad g^*(\theta_l; e) < g^0(\theta_l; e). \tag{24}$$

From (22), (23) and by the concavity of $w(\cdot)$, we know for any green payments to the northwest of $g^0(e)$,

$$\frac{dg(\theta_h; e)}{dg(\theta_l; e)} > 0, \quad \text{and} \quad \frac{d^2 g(\theta_h; e)}{d[g(\theta_l; e)]^2} < 0,$$

i.e., the isoquant of $z(\cdot)$ is concave to the northwest of $g^0(e)$, as shown in Figure 2(a). As green payments move further away from $g^0(e)$ in the northwest direction, the value of $z(\cdot)$ decreases due to the concavity of $w(\cdot)$. Moving in the north direction, type θ_h would get excessive payments, and the benefit gain from increased income support is less than the cost increase through transfer. Similarly, moving in the west direction, type θ_l would get too little transfer, the lost benefit outweighs the saved transfer.

We then conclude constraint ($\text{IC}_{\phi h}$) binds but not ($\text{IC}_{\phi l}$). As we mentioned in the paper, (15b) is just a rewrite of the definition of $t^*(\theta_l; e)$. Let ($\text{IC}_{\phi h}$) bind, substitute (15b) for $g^*(\theta_l; e)$, and rearrange using the definition of $I(\cdot)$, then we obtain (15a).

For the case where $g^0(e)$ is above the feasible set, the proof is similar. ■

Proof of Proposition 2. When $g^0(e)$ is in the feasible set, no constraint binds. Then, by differentiating the objective function in (7a) with respect to e and g and then rearranging, we get (18). Next we prove the proposition for the case when $g^0(e)$ is below the feasible set.

Rewriting (8a), we have,

$$\begin{aligned} &\max_{e} \quad \textstyle\sum_j \left[v(e(\theta_j)) + \tilde{\pi}\left(e(\theta_j), \theta_j\right)\right] P_j + z^*\left(e(\theta_l), e(\theta_h)\right) \\ &= \textstyle\sum_j \left[v(e(\theta_j)) + \tilde{\pi}\left(e(\theta_j), \theta_j\right)\right] P_j + \sum_j \left[w\left(y^*(\phi_S, \theta_j)\right) P_{Sj} - \lambda g^*(\theta_j) P_j\right] \\ &= \textstyle\sum_j \left[v(e(\theta_j)) + \tilde{\pi}\left(e(\theta_j), \theta_j\right)\right] P_j + \sum_j \left\{w\left[\pi(e(\theta_j); \phi_S, \theta_j) + g^*(\theta_j)\right] P_{Sj} - \lambda g^*(\theta_j) P_j\right\} \end{aligned}$$

[9] The following holds as strict inequality because of the concavity of $w(\cdot)$. For example, if $g^*(\theta_h; e) > g^0(\theta_h; e)$ but $g^*(\theta_l; e) = g^0(\theta_l; e)$, then we can increase the value of $z(\cdot)$ by decreasing both $g^*(\theta_h; e)$ and $g^*(\theta_l; e)$ a little. By the concavity of $w(\cdot)$, the reduction of $z(\cdot)$ through the decrease of $g^*(\theta_l; e)$ will be offset by the increase of $z(\cdot)$ through the decrease of $g^*(\theta_h; e)$. In addition, total green payments are reduced.

Plugging in $g^*(\theta_j)$ from (15),

$$\begin{aligned}
&\max_{e} \quad \textstyle\sum_j \left[v(e(\theta_j)) + \tilde{\pi}\left(e(\theta_j), \theta_j\right)\right] P_j + w\left[\pi(0;\phi_S,\theta_l) + t^*(\theta_l;e)\right] P_{Sl} \\
&- \lambda\left[\pi(0;\phi,\theta_l) - \pi\left(e\left(\theta_l\right);\phi,\theta_l\right) + t^*(\theta_l;e)\right] P_l \\
&+ w\left[\pi(0;\phi_S,\theta_h) + I(e\left(\theta_l\right)) + t^*(\theta_l;e)\right] P_{Sh} \\
&- \lambda\left[\pi(0;\phi,\theta_h) - \pi\left(e\left(\theta_h\right);\phi,\theta_h\right) + I(e\left(\theta_l\right)) + t^*(\theta_l;e)\right] P_h
\end{aligned} \tag{25}$$

Only $e\left(\theta_l\right)$, not $e\left(\theta_h\right)$, enters $t^*(\theta_l;e)$ because (17) can be rewritten as,

$$\lambda = \left\{w_g\left[\pi(0;\phi_S,\theta_h) + I(e\left(\theta_l\right)) + t^*(\theta_l;e)\right]\tfrac{P_{Sh}}{P_S} + w_g\left[\pi(0;\phi_S,\theta_l) + t^*(\theta_l;e)\right]\tfrac{P_{Sl}}{P_S}\right\} P_S. \tag{26}$$

Thus, setting the derivative of (25) with respect to $e\left(\theta_h\right)$ to zero, we obtain (19a).

The derivative with respect to $e\left(\theta_l\right)$ is more complicated,

$$\begin{aligned}
v_e(e^*(\theta_l)) \quad = \quad & -(1+\lambda)\pi_e\left(e^*(\theta_l);\phi,\theta_l\right) + \left[\lambda - \tfrac{P_{Sh}}{P_h} w_g(y^*(\phi_S,\theta_h))\right] I_e(e^*(\theta_l))\tfrac{P_h}{P_l} \\
& - t^*_{e_l}(\theta_l;e)\left[w_g(y^*(\phi_S,\theta_h))P_{Sh} + w_g(y^*(\phi_S,\theta_l))P_{Sl} - \lambda\right]
\end{aligned} \tag{27}$$

The last term on the right describes the effect of changes in net payment $t^*(\theta_l;e)$ when e_l changes. The term in the last square brackets is the expected marginal benefit minus marginal cost of income support, which is zero at the optimal by (17). So the last term on the right drops out, and we get (19b).

For the case where $g^0(e)$ is above the feasible set, the proof is similar. ■

Figure 1. The optimal green payments for given $e(\theta_h) \geq e(\theta_l)$ —the standard adverse selection model

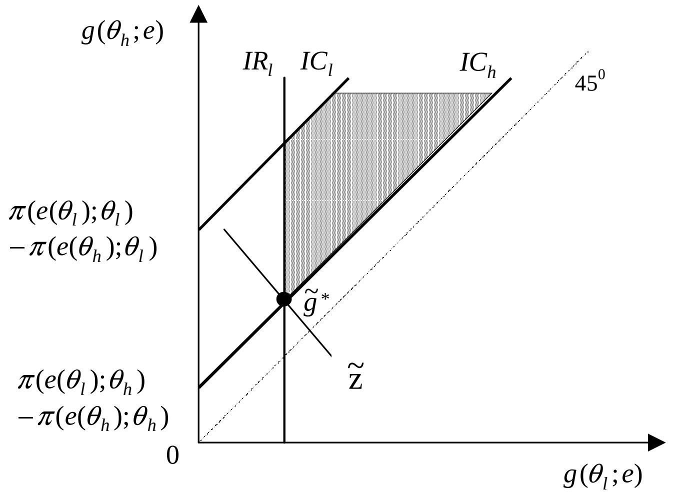
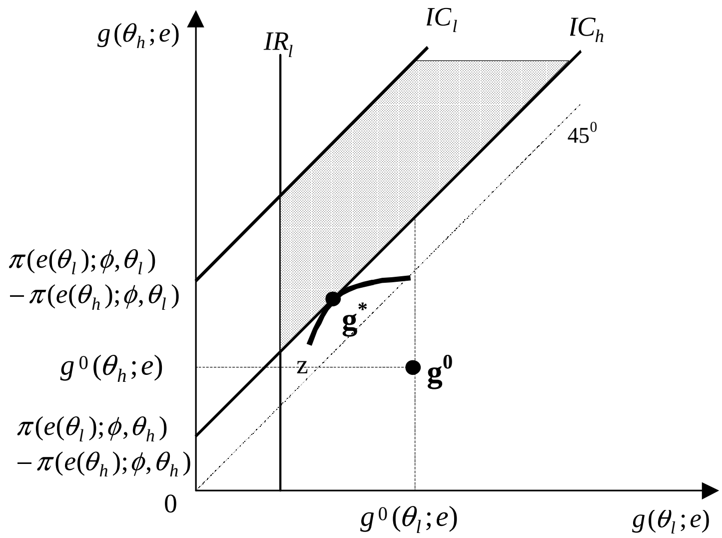
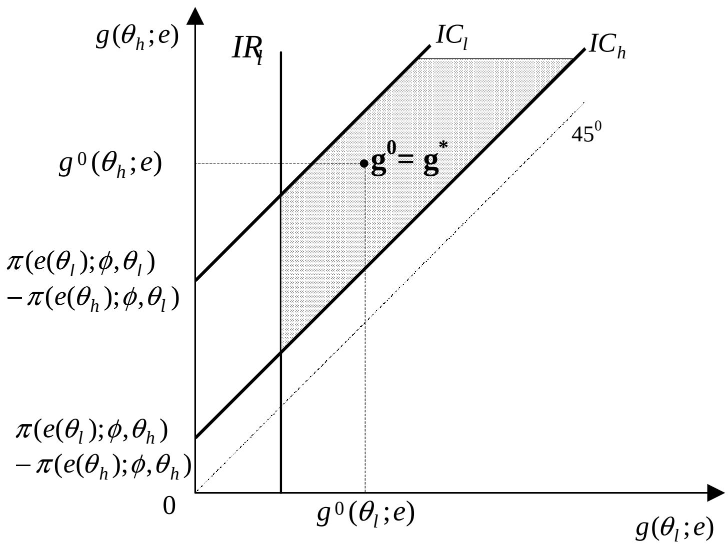


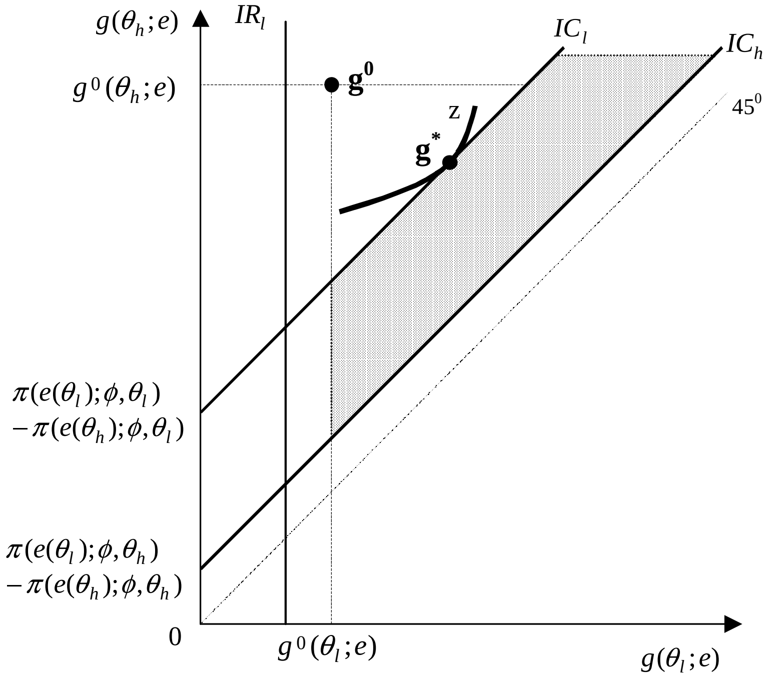
Figure 2. The optimal green payments for given $e(\theta_h) \geq e(\theta_l)$ —the adverse selection model with dual goals



(a) For $\mathbf{g^0}$ below the feasible set



(b) For $\mathbf{g^0}$ in the feasible set



(c) For $\mathbf{g^0}$ above the feasible set

References

[1] Armstrong, Mark and Jean-Charles Rochet. "Multi-dimensional Screening: a User's Guide". *European Economic Review* 43 (1999): 959-979.

[2] Babcock, Bruce A. "A Farm Policy Objective: the Search Goes On". *Iowa Ag Review*, 6(4) (Fall 2000): 1-3.

[3] Bourgeon, Jean-Mark and Robert G. Chambers. "Stop-and-Go Agricultural Policies". *Amer. J. Agr. Econ.* 82 (February 2000): 1-13.

[4] Chambers, Robert. "On the Design of Agricultural Policy Mechanisms". *Amer. J. Agr. Econ.* 74 (August 1992): 646-53.

[5] Claassen, R., L. Hansen, M. Peters, V. Breneman, M.Weinberg, A. Cattaneo, P. Feather, D. Gadsby, D. Hellerstein, J. Hopkins, P. Johnston, M. Morehart, and M. Smith. "Agri-Environmental Policy at the Crossroads: Guideposts on a Changing Landscape," ERS/USDA, AER No. 794, January 2001.

[6] Dasgupta, P., P. Hammond, and E. Maskin. (1979). The implication of social choice rules: Some Results on Incentive Compatibility. *Review of Economic Studies* 46: 185-216.

[7] Guesnerie, Roger and Jean-Jacques Laffont. "A Complete Solution to a Class of Principal-Agent Problems with an Application to the Control of a Self-Managed Firm", *Journal of Public Economics.* 25 (1984): 329-369.

[8] Hueth, Brent. "The Goals of U.S. Agricultural Policy: A Mechanism Design Approach". *Amer. J. Agr. Econ.* 82 (February 2000): 14-24.

[9] Laffont, Jean-Jacques, Eric Maskin, and Jean-Charles Rochet. "Optimal Nonlinear Pricing with Two-Dimensional Characteristics", in *Information, Incentives, and Economic Mechanisms—Essays in honor of Leonid Hurwicz*, edited by Theodore Groves, Roy Radner, and Stanley Reiter. University of Minnesota Press, Minneapolis, 1987.

[10] Mercier, Stephanie, "Commodity Program Principles and Proposals: A View from the Senate", *Agricultural Outlook Forum*, February 2002.

[11] Myerson, R. (1979). Incentive compatibility and the bargaining problem. *Econometrica* 47: 61-74.

[12] Smith, Rodney B.W. "The Conservation Reserve Program as a Least-Cost Land Retirement Mechanism", *Amer. J. Agr. Econ.* 77 (February 1995): 93-105

[13] The U.S. Congress, "Farm Security and Rural Investment Act", May 2002.

[14] Veneman, Ann M. (as the U.S. Secretary of Agriculture), Remarks at the 2002 Agricultural Outlook Forum February 2002,
http://www.usda.gov/news/releases/2002/02/0057.htm.

[15] Wu, Junjie and Bruce A. Babcock. "Optimal Design of a Voluntary Green Payment Program under Asymmetric Information", *J. Agr. and Res. Econ.* 20(2): 316-327.

[16] Wu, Junjie and Bruce A. Babcock. "Contract Design for the Purchase of Environmental Goods from Agriculture", *Amer. J. Agr. Econ.* 78 (November, 1996): 935-945.