Does Government's Biofuel Incentive Payment Program Work in the Presence of Asymmetric Information?

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Abstract

Since combustion of fossil fuels can release a large amount of greenhouse gases into the atmosphere thereby accelerate the rate of climate change, biofuel from biomass has been suggested as a fuel of the future. We argue that if biofuel is to become a fuel of the future, the principal (government or social planner) should make monetary incentive payments to farmers willing to dedicate their farm land to growing bioenergy crops. The problem arises when the principal does not have information on whether these biofuel farmers are actually low-cost types or high-cost types. The idea of a biofuel incentive payment program is to distribute more incentive payments to high-cost farmers so as to induce them to participate in the program. Principal-agent model is used to study the effect of hidden information on the government's incentive payments to biofuel farmers. Results show that with complete information both low-cost and high-cost type farmers have incentives to produce biofuel crops under the government contract. When information asymmetry is considered, low-cost farmers earn extra payments, but their optimal productivity level remains unchanged. In this second-best outcome with asymmetric information, high-cost farmers' optimal level of productivity and incentive payments that they received depend on the marginal costs of raising tax revenue. Generally, our results suggest that the government's biofuel incentive payment program may not be an effective tool in inducing biofuel crop production if asymmetric information is present and marginal costs of raising tax revenue are high.

1. Introduction

Biofuel from biomass is often suggested as a future replacement for fossil fuel. According to the U.S. Environmental Protection Agency (EPA)[1], fossil fuels burned to run cars and trucks, heat homes and businesses, and power factories are responsible for about 98% of U.S. carbon dioxide emissions, 24% of methane emissions, and 18% of nitrous oxide emissions. Combustion of these fossil fuels is considered to be the largest contributing factor to the release of greenhouse gases into the atmosphere. Increasing concentrations of these greenhouse gases are likely to accelerate the rate of climate change. Biomass can play an important role in reducing greenhouse gas emissions and air pollution. Biomass fuels recycle atmospheric carbon, minimizing global warming impacts since zero net carbon dioxide is emitted during biomass combustion. Other environmental benefits of using biomass energy include provision of wildlife habitats and consequent improved biodiversity - energy crops may provide increased habitat diversity within the agricultural landscape. By utilizing biomass energy, society can also benefit from an improvement in rural economies due to the development of local industries in forestry and agriculture.

The production of biofuel feedstocks from agricultural and forestry sources has been considered for many years, particularly after the 1970's energy crisis. The sustainability of bioenergy in the future will depend on fossil fuel prices. The international price of fossil fuels is in many cases kept artificially low by government subsidies aimed at protecting domestic fuel security and regional employment (Hall and Scrase, 1998). So long as fossil fuels are cheaply available in the market due to government subsidies, it is unlikely that biofuel will be considered as a viable source of

[1] http://yosemite.epa.gov/oar/globalwarming.nsf/content/climate.html

energy. In order to combat the global climate change and air pollution, incentive payment programs may be needed to encourage bioenergy producers to produce biofuels not only for use in transportation but also in electricity generation. With the help of government, such incentive programs can be implemented. If biomass is to become a fuel of the future, cost reductions must be given a high priority. We can think of biofuels as new and potentially marketable products. In order to produce these new products, producers may have to adopt new technologies that require unique human capital skills, monitoring of the production processes, high quality inputs and capital equipments, etc. Since it is costly to incorporate new technologies into the biofuel production process, producers may need monetary incentives. Government incentive payments could induce biofuel producers to adopt and incorporate new technologies in their production processes, provided that the subsidies are higher than the cost of adoption.

The objective of this paper is to design an optimal contract that can increase the welfare of both the government (i.e. the society) and the producers of bioenergy crops. By utilizing biofuels, the society can gain its welfare from the reduction in greenhouse gases and air pollution. With the help of government subsidies, biofuel producers can also increase their welfare by reducing their production costs and increasing their market shares. Principal-agent model is used to construct an optimal contract. The principal in this case is the government or social planner, and the agents are producers or farmers who grow bioenergy crops. Since the agents have private information, i.e. they know whether they are high-cost types or low-cost types, there will be asymmetry of information between them and the principal.

2. Literature Review

Previous studies which include Wu and Babcock (1995), Ahouissoussi (1995), Goodhue et al. (2003), and Segerson (1988) have used principal agent models to examine situations where information asymmetries are important. Wu and Babcock (1995) use the model to design a green payment program which pays farmers directly for the environmental benefits they provide. Their green payment program is designed for irrigated corn production in the Oklahoma high plains. The program presents farmers with a policy menu that consists of combinations of the type of production practices permitted (for example, input use and tillage practices) and an accompanying government payment. The asymmetry of information between the government and farmers play an integral role in program design. Wu and Babcock assume that the government knows only the distribution of farmers' type, but unable to discriminate a particular farmer's type. Given this information asymmetry, farmers may have an incentive to cheat and misrepresent their types to obtain favorable combinations of production practices and payments. Their green payment program is designed to provide an incentive for farmers to choose or reveal their true types. Hence the program is second best because of this constraint.

Ahouissoussi (1995) examines the regional pest control that can lessen the externalities associated with mobile pests and pesticide drift with the resulting potential enhancement of producers' net returns. The principal in his case is the Animal and Plant Health Inspection Service (APHIS), and the agents are cotton producers. APHIS is interested in inducing producers to adopt the regional pest control program. The problem arises when producers' gain in rents from regional pest control will be relatively less for those producers experiencing high economic rents without regional pest control. An

incentive payment scheme has to be designed to induce producers of different types to participate in the program. The principal has limited information on the type of producers. Thus, the principal must design an incentive scheme that does well on average whatever type of agent is involved.

According to Goodhue et al. (2003), "green payment programs are designed to pay farmers for their production of goods other than agricultural output, such as wildlife and sustainable practices, and in some cases, to induce them to increase their production of these goods". Goodhue et al. use the principal-agent framework to analyze two controversies regarding agricultural green payment programs: 1) whether farmers should be paid for their provision of environmental inputs, such as wildlife habitat or paid for outputs, such as wildlife populations, and 2) whether programs designed to promote the use of sustainable agricultural practices should pay all users, or only new adopters. They find that under most conditions it is socially more desirable to pay farmers for inputs than for outputs. They also find that for many practices, the social cost of paying only new adopters is small. But, for some practices it may be socially preferable to pay both new adopters and current users. Segerson (1988) employs an incentive scheme that could be used to control non-point pollution in the presence of uncertainty and monitoring difficulties. Her design mechanism is discussed in the context of both a single suspected polluter and multiple suspected polluters.

3. The Model

The theoretical model of this paper will be similar to Wu and Babcock's (1995). It will be an adverse selection problem where the principal does not know the agent's private information, but the probability distribution of this information is common knowledge.

We will assume that the principal and the agent both adopt an optimizing behavior and maximize their individual utility. Moreover, the principal is assumed to be a Bayesian expected utility maximizer. In designing the agent's payoff rule, the principal moves first as a Stackelberg leader under asymmetric information anticipating the agent's subsequent behavior and optimizing accordingly within the set of available contracts (Laffont and Martimort, 2002).

For simplicity, suppose that there are two types of farmers dedicated their land to growing bioenergy crops such as switchgrass, willow or poplar: low-cost farmers and high-cost farmers. Following Chambers (1992), low-cost farmers have lower marginal and total costs over all output levels. Given the existence of information asymmetry, the incentive payment program, which is intended for the high-cost farmers, will not be able to discriminate between the low-cost and high-cost types. Thus, low-cost farmers may have an incentive to imitate the high-cost types and obtain favorable combinations of production practices and payments. To solve this problem, the principal must design and use the payment scheme to induce farmers to reveal their true types.

3.1 Farmer's utility without the contract

In order to gain a better understanding of changes in a biofuel farmer's utility when he/she accepts the contract, we first determine the farmer's utility without the contract. Let x_i be the productivity of farm land acres dedicated to growing bioenergy crops, and $a_i \in [a_1, a_2]$ be farmer's private cost for using a unit of land to grow bioenergy crops, where i = 1 represents low-cost type farmers and 2 represents high-cost type farmers. Specifically, we may think of a_i as the marginal or opportunity cost of biofuel farmers. Clearly, $a_2 > a_1$ since low-cost type biofuel farmers are assumed to be more productive

than the high-cost types. The parameter a_i varies among farmers and defines the type of farmers. The distribution of a_i is common knowledge, i.e. that the principal knows the farmer's type a_i with some probabilities, υ for the low-cost farmers and $(1-\upsilon)$ for the high-cost farmers. Farmers know their own private cost a_i, but it is not specifically known to the principal. Therefore, a_i is considered to be exogenous.

Each farmer maximizes his/her utility with respect to the land available for biofuel crop production. Farmer's utility or profit function may be expressed as follows,

$$\pi_i = py(x_i) - a_i x_i \qquad i = 1, 2$$

where y is defined as the production function and p as the production price. The function $y(x_i)$ has the regular properties of a neo-classical production function with $y'(.) > 0$, $y''(.) < 0$. x_i and a_i are as defined above. Each farmer maximizes his/her own utility with respect to x_i. The first order condition (FOC) to farmer's maximization problem can be written as,

$$py'(x_i) - a_i = 0 \quad \Rightarrow \quad py'(x_i) = a_i \tag{1}$$

Each farmer equalizes his/her marginal productivity of land with his private opportunity cost of using land for biofuel production. From (1), the optimal productivity of land can be obtained and be denoted as x_i^*. Hence, the optimal level of farmer's utility can be expressed as: $\pi_i^*(a_i, x_i) = py(x_i^*) - a_i x_i^*$. If $\pi_i^*(a_i, x_i) < 0$, farmers will not have incentives to grow biofuel crops. According to Schneider and McCarl (2003), the U.S. biofuel production has not proven to be economically feasible without subsidies. They argue that there are four possible political justifications for subsidizing biofuels. First,

biofuel subsidies serve to support agricultural prices by adding to demand for feedstock commodities and in turn supporting agricultural incomes. Second, the biofuel product has desirable environmental/health attributes relative to fossil fuels. Third, increased biofuel use reduces dependence on petroleum extending the life of existing stocks. Fourth, biofuel combustion substantially offsets net GHG emissions relative to fossil fuel combustion. Farmers' profit from growing biofuel crops would likely be negative without government subsidy payments.

3.2 Farmer's utility with the contract

The contract includes the productivity of land that farmers dedicated to raising biofuel crops, x_i and the subsidy or transfer payment, T_i , offered to farmers by the social planner. Under the incentive payment contract, the social planner presents farmers with the policy menu: $[x_i, T_i]$, where both the x_i and T_i are specified for each type of farmer. In order to compensate farmers for the loss of incomes due to the production of biofuel crops, the social planner needs to know the farmer's profit function. With the contract, the farmer's profit function becomes,

$$\pi_i^c(a_i, x_i) = py(x_i) - a_i x_i + T_i \qquad i = 1, 2$$

where $\pi_i^c(a_i, x_i)$ is the farmer's optimal profit with the contract, i.e. with the monetary transfer payment, T_i. It must be true that $\pi_i^c(a_i, x_i) \geq 0$, otherwise farmers will not participate in the payment program.

3.3 Principal's objective and utility function

The principal's social objective is to support rural employment and reduce the GHG emissions through the use of biofuels. With the contract, the principal's goal is to

maximize its social surplus. In expected utility form, the social surplus (SS) can be written as,

$$SS = \upsilon[\tilde{B}(x_1) + \pi_1^c(a_1, x_1) - \lambda T_1] + (1-\upsilon)[\tilde{B}(x_2) + \pi_2^c(a_2, x_2) - \lambda T_2]$$

where $\tilde{B}(x_i)$, i =1, 2 in reduced form[2] is the social benefit associated with the use of biofuel crops. And it is assumed that $\tilde{B}(0) = 0$, $\tilde{B}'(.) > 0$ and $\tilde{B}''(.) < 0$. υ and $(1-\upsilon)$ are the probabilities that farmers will be low-cost types with private cost, a_1 and high-cost types with private cost a_2, respectively. Following Wu and Babcock (1995), λ (where $\lambda > 0$) is denoted as the marginal cost of raising tax revenue to support the government's transfer payments.

3.4 The first best case with full information

In the first best condition, the principal is assumed to be able to observe the productivity of each type biofuel farmers, i.e. she knows exactly what each type of farmers' private marginal cost is. Thus, the information is complete. The following principal maximization problem determines the first best outcome (FB),

$$\underset{x_i, T_i}{Max}\ SS = \upsilon[\tilde{B}(x_1) + \pi_1^c(a_1, x_1) - \lambda T_1] + (1-\upsilon)[\tilde{B}(x_2) + \pi_2^c(a_2, x_2) - \lambda T_2]$$

subject to each farmer's individual rational or participation constraint (IRC) i.e.

IRC1 $\pi_1^c(a_1, x_1) \geq 0$

IRC2 $\pi_2^c(a_2, x_2) \geq 0$

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[2] As suggested by Richard Woodward, $\tilde{B}(x_i)$ is written in reduced form. The reduced form is derived because the principal is only interested in the aggregate production of biofuels. In aggregate form it may be written as, $B[y(x_1) + y(x_2)] = B[y(x_1)] + B[y(x_2)]$, and by taking the derivative with respect to x_1 and x_2 yields $B'[y(x_1)]$ and $B'[y(x_2)]$. From here, the individual benefit function in the reduced form can be expressed as $\tilde{B}(x_1)$ for the low-cost types and $\tilde{B}(x_2)$ for the high-cost types.

To induce farmers to participate, the payment scheme must satisfy IRCs, i.e. the farmers' utility with the contract, $\pi_i^c(a_i, x_i)$ must be at least as great as their reservation utility, $\pi_i^*(a_i, x_i)$. For the sake of simplicity, reservation utilities for IRC1 and IRC2 are normalized to zero.

With complete information, the above IRC1 and IRC2 will bind, because there is no reason for the social planner to pay the monetary transfer more than she has to. The principal will pay just enough so that IRC1 and IRC2 will bind. Thus, to solve the above maximization problem, the principal would maximize her objective function subject to each of the two binding IRCs. The first order conditions (FOCs) for the first best outcome (FB) of each type of farmers can be expressed as follows,

For the low-cost type:

$$FOC_1^{FB}: \ \frac{\partial \tilde{B}(.)}{\partial x_1} - \lambda[a_1 - p\frac{\partial y(.)}{\partial x_1}] = 0 \quad \Leftrightarrow \quad py'(x_1) = a_1 - \frac{1}{\lambda}\tilde{B}'(x_1) \tag{2}$$

From (2), the optimal level of land productivity can be obtained and denoted as: x_1^{*FB}

The first-best optimal transfer payment for the low-cost type can be obtained and written as,

$$T_1^{FB}(a_1, x_1^{*FB}) = a_1 x_1^{*FB} - py(x_1^{*FB}) \tag{3}$$

For the high-cost type:

$$FOC_2^{FB}: \frac{\partial \tilde{B}(.)}{\partial x_2} - \lambda[a_2 - p\frac{\partial y(.)}{\partial x_2}] = 0 \quad \Leftrightarrow \quad py'(x_2) = a_2 - \frac{1}{\lambda}\tilde{B}'(x_2) \tag{4}$$

From (4), the optimal level of land productivity can be obtained and denoted as: x_2^{*FB}.

The first-best optimal transfer payment for the high-cost type can be obtained and written as,

$$T_2^{FB}(a_2, x_2^{*FB}) = a_2 x_2^{*FB} - py(x_2^{*FB}) \tag{5}$$

Through the contract with full information, equations (2) and (4) suggest that each type of biofuel farmers equalizes his/her marginal productivity of land with his/her private opportunity cost minus the social opportunity cost derived from producing bioenergy crops. By comparing equations (2) and (4) with equation (1), we may conclude that with the contract and complete information, farmer's marginal productivity decreases by a positive amount $\frac{1}{\lambda}\tilde{B}'(x_i)$ (since $\tilde{B}'(x_i) > 0$ and $\lambda > 0$). This can be illustrated graphically as follows,

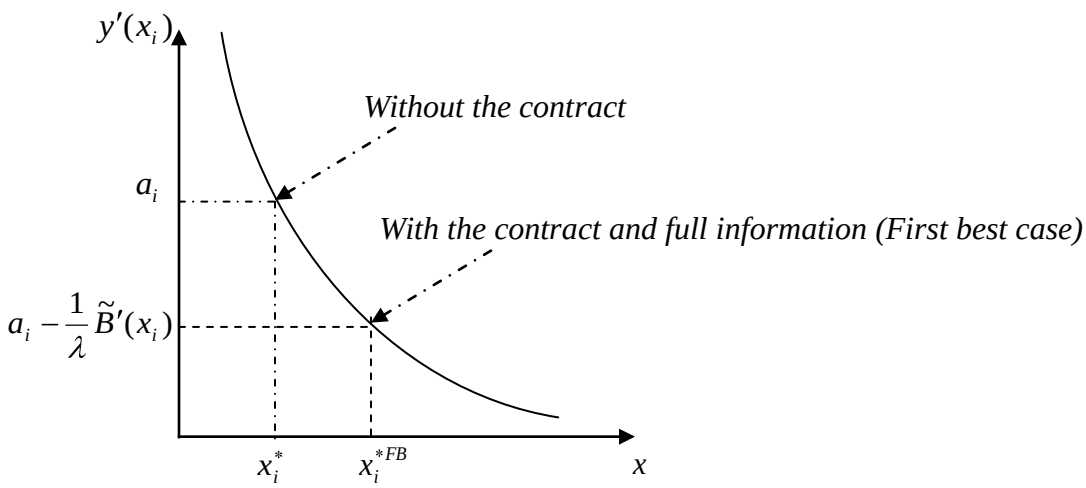

Figure 1. Optimal land productivity with and without the contract

The above figure suggests that with the contract and full information, both low-cost and high-cost type farmers (i = 1, 2) can raise their optimal level of land productivity from x_i^* to x_i^{*FB}. Hence, the first-best optimal transfer payments (equations 3 and 5) may induce farmers to produce more biofuel crops.

3.4 The second best case with asymmetric information

In the second best condition, the principal is assumed to be unable to observe the productivity of each type of biofuel farmers. Since farmers have private information which cannot be observed by the principal, they have incentives to imitate each other and obtain favorable combinations of production practices and payments. To prevent that from happening, the principal needs to use the incentive compatible constraints (ICCs) to induce biofuel farmers to reveal their true types. As a result of asymmetric information, two additional ICCs are added in the second best case as described below. The following principal maximization problem determines the second best outcome (SB),

$$\underset{x_i, T_i}{Max}\ SS = \upsilon[\widetilde{B}(x_1) + \pi_1^c(a_1, x_1) - \lambda T_1] + (1-\upsilon)[\widetilde{B}(x_2) + \pi_2^c(a_2, x_2) - \lambda T_2]$$

subject to both the IRCs and the ICCs,

IRC1 $\pi_1^c(a_1, x_1) \geq 0$

IRC2 $\pi_2^c(a_2, x_2) \geq 0$

ICC1 $\pi_1^c(a_1, x_1) \geq \pi_1^c(a_1, x_2)$

ICC2 $\pi_2^c(a_2, x_2) \geq \pi_2^c(a_2, x_1)$

ICCs require that each type of biofuel farmers prefers the policy option intended for them to the option intended for the other type. Wu and Babcock (1995) indicate that the payment program is feasible if it satisfies both the IRCs and ICCs. When the principal uses a feasible program, farmers voluntarily choose the policy option intended for them. Therefore, by maximizing the above objective function subject to IRCs and ICCs, the principal will be able to find a feasible program. The Lagrangian Mutlipier method can be used to solve the above maximization problem but rather difficult to handle. In this two-type agent model, the number of constraints calls for more practical path, where we

first guess which constraints are binding, then solve the model assuming these constraints bind and check ex post that the omitted constraints are strictly satisfied (Laffont and Martimort, 2002).

The incentive compatibility problem implies that ICC1 will bind but not ICC2. Because it is not feasible for high-cost (a_2) type farmers to imitate low-cost (a_1) types, there is no incentive exists and thus ICC2 will not bind. The participation problem implies that IRC2 will bind. This simplification in the number of constraints leaves us only with two remaining constraints, IRC2 and ICC1. Both constraints must be binding at the optimum of the principal's problem[3]. The principal problem now is to maximize her objective function subject to the binding IRC2 and ICC1. By solving the principal's maximization problem, the FOCs for the second best outcome (SB) of each type of farmers are obtained as follows,

For the low-cost type:

$$FOC_1^{SB}: \qquad py'(x_1) = a_1 - \frac{1}{\lambda}\tilde{B}'(x_1) \tag{6}$$

From (6), the optimal level of land productivity can be obtained and denoted as: x_1^{*SB}.

The second-best optimal transfer payment for the low-cost type can be obtained and written as,

$$T_1^{SB}(a_1, x_1^{*SB}) = (a_2 - a_1)x_2 + a_1 x_1^{*SB} - py(x_1^{*SB}) \tag{7}$$

For the high-cost type:

$$FOC_2^{SB}: \qquad py'(x_2) = a_2 - \frac{1}{\lambda}\tilde{B}'(x_2) - \frac{\upsilon}{(1-\upsilon)}\frac{(1-\lambda)}{\lambda}(a_2 - a_1) \tag{8}$$

From (8), the optimal level of land productivity can be obtained and denoted as: x_2^{*SB}.

[3] Proof of binding constraints can be seen in Laffont and Martimort (2002) (page 42).

The second-best optimal transfer payment for the high-cost type can be obtained and written as,

$$T_2^{SB}(a_2, x_2^{*SB}) = a_2 x_2^{*SB} - py(x_2^{*SB}) \tag{9}$$

4. Discussion of Second Best Outcome in Comparison to First Best Outcome

Equations (2) and (6) indicate that low-cost farmers' optimal level of productivity is the same with or without full information i.e. $x_1^{*FB} = x_1^{*SB}$. However, equations (3) and (7) suggest that with asymmetric information low-cost type farmers receive more transfer payments, since $T_1^{SB}(a_1, x_1^{*SB}) - T_1^{FB}(a_1, x_1^{*FB}) = (a_2 - a_1)x_2 > 0$[4]. Hence, with hidden information, low-cost farmers can earn an extra payment of $(a_2 - a_1)x_2$. This extra payment or information rent is paid to low-cost farmers to induce them to reveal their private information.

When equation (8) is compared to equation (4), the high-cost farmers' marginal productivity may decrease or increase depending on whether $0 < \lambda < 1$ or $\lambda > 1$. If $0 < \lambda < 1$, then the marginal productivity of high-cost farmers will decline. On the other hand, if $\lambda > 1$ then the marginal productivity of high-cost farmers will rise. Graphically, this can be demonstrated as follows,

[4] Because $x_1^{*FB} = x_1^{*SB}$, $(a_2 - a_1) > 0$, and $x_2 > 0$ which must be true for bioenergy crop production to take place.

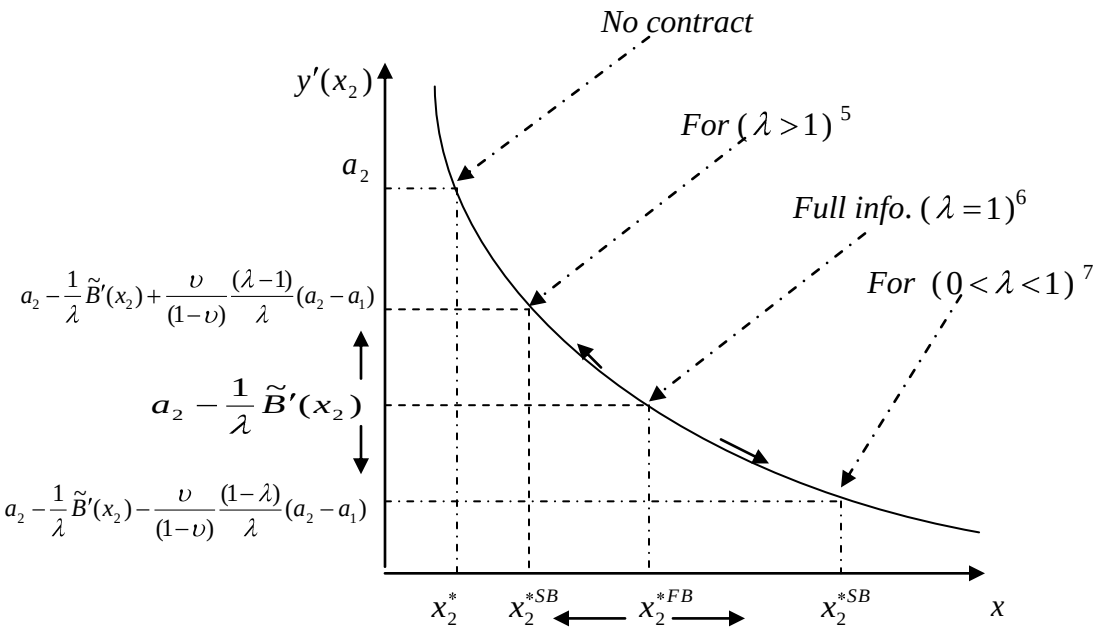

Figure 2. Optimal land productivity with and without full information

As can be seen in figure 2, the marginal productivity of high-cost farmers will either decline or rise depending on whether $0 < \lambda < 1$ or $\lambda > 1$. These results suggest that when $\lambda > 1$, the optimal level of land productivity will be distorted upward , i.e. $x_2^{*SB} < x_2^{*FB}$ as shown in the figure above. In contrast, when $0 < \lambda < 1$, the optimal level of land productivity will be distorted downward, i.e. $x_2^{*SB} > x_2^{*FB}$. Thus, with the present of asymmetric information, high-cost farmers' second-best optimal level of land productivity will be lower than their first-best full information level if $\lambda > 1$, and the reverse will be true if $0 < \lambda < 1$. Equations (5) and (9) illustrate that

[5] $\lambda > 1$ implies that the marginal costs of raising tax revenue to support the government transfer payments are higher than the marginal transfer payments given to the farmers.

[6] $\lambda = 1$ implies that the marginal costs of raising tax revenue to support the government transfer payments are equal to the marginal transfer payments given to the farmers.

[7] $0 < \lambda < 1$ implies that the marginal costs of raising tax revenue to support the government transfer payments are lower than the marginal transfer payments given to the farmers.

$T_2^{SB}(a_2, x_2^{*SB}) >,< or = T_2^{FB}(a_2, x_2^{*FB})$ only if $x_2^{*SB} >,< or = x_2^{*FB}$. And this can only be true if $0 < \lambda < 1$, $\lambda > 1$ or $\lambda = 1$. Hence, for the high-cost farmers, whether the optimal second-best transfer payments are higher, lower, or equal to the optimal first-best transfer payments will depend on the marginal costs of raising tax revenue to support the principal's transfer payments given to biofuel farmers. If the marginal costs of raising tax revenue are high (i.e. if $\lambda > 1$), then high-cost farmers for whom the transfer payments are mainly intended are worse off due to the effect of information asymmetry. The reverse will be true if the marginal costs of raising tax revenue are low (i.e. if $0 < \lambda < 1$). In order to distribute the transfer payments efficiently, the principal needs to consider the effect of hidden information and design the contract in such a way that low-cost farmers have no incentives to imitate high-cost farmers. In this type of contract design, there is a tradeoff between the cost of obtaining biofuel farmers' private information and the social benefits associated with the production of bioenergy crops.

5. Conclusion

The purpose of this paper is to apply the principal-agent model to determine an optimal contract in the context of information asymmetry between biofuel crop farmers and the social planner. The model allows us to take into account that farmers have private information on the marginal cost of using land for biofuel crop production. Thus, it intends to investigate the effect of this information asymmetry on the optimal level of land productivity and social planner's transfer payments.

We consider firstly the farmer's utility without the contract. Given the current situation of bioenergy crop production in the U.S., it is unlikely that farmers will generate profits without any monetary help from the social planner. Transfer payments are needed

to provide farmers with incentives to grow biofuel crops and gain profits at the same time. But the problem arises when farmers have private information. In this case, the principal has to design a contract to encourage farmers not only to participate but also to reveal their types truthfully using the incentive compatible constraints.

Comparisons are made between biofuel farmers' utilities with and without contract. Results show that with the contract and complete information, both low-cost and high-cost type farmers raise their optimal level of productivity. Hence, the social planner transfer payments may induce farmers to produce more bioenergy crops when the information is complete. When the information asymmetry is considered in the model, low-cost farmers' optimal level of productivity remains the same as it is in the first-best full information case. However, the transfer payments to low-cost types have increased in the second-best case due to the effect of hidden information. The increased amount of transfer payments are given to low-cost type farmers to induce them to reveal their true types.

Finally, in the second-best outcome with asymmetric information, high-cost farmers' optimal level of productivity depends on the marginal costs of raising tax revenue to support the government incentive payments. If the marginal costs of raising tax revenue are high, the optimal level of productivity will be distorted upward, i.e. the second-best high-cost farmers' productivity will be lower than its first-best level. The reverse will be true if the marginal costs of raising tax revenue are low. The second-best optimal incentive payments made to high-cost farmers also depend on the marginal costs of raising tax revenue. With high marginal costs of raising tax revenue, high-cost type farmers would receive comparatively low optimal second-best incentive payments.

In terms of policy implications, if asymmetric information is present and marginal costs of raising tax revenue are high then the government's biofuel incentive payment program may not be an effective tool in inducing biofuel crop production because this would result in rewarding low-cost farmers with extra payments while leaving high-cost farmers, who should be the main recipients of incentive payments in the first place, to be worse off. For future research, it will be beneficial if we could find a way to empirically test the effect of asymmetric information on the government's biofuel incentive payment program.

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