Afforestation Subsidy under Asymmetric Information and Transaction Cost in Developing Countries: Does rural capital market imperfection matter?

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Abstract *This paper deals with the design of voluntary contract of afforestation subsidy in developing countries where heterogeneity among farmers abounds in terms of land value. The heterogeneity in the land value is due to capital market imperfection in rural areas of these countries where the rate of return to land and other assets is endogenously determined by household rate of time preference. Farmers' rate of time preference is not observed by public agency that intends to regulate land use through subsidy. However, it is private information and hence information asymmetry problem. We therefore, developed a mechanism design model to evaluate the efficacy of afforestation subsidy policy under such information setting in developing countries. We show that capital market imperfection undermines the efficiency of subsidy measures in these countries. The efficiency loss is also further compounded by transaction (e.g. dead weight loss of tax to raise fund) of the policy. Specifically, we found that afforestation level under asymmetric information (capital market imperfection) is lower as compared to symmetric information scenario. Furthermore, unlike previous studies, we found that the absence of transaction cost of subsidy doesn't necessarily guarantee the first best solution in the presence of capital market imperfection, but yield results relatively closer to the first best outcome than what would be the case otherwise.*

Key words*: Information asymmetry, transaction cost, mechanism design, afforestation subsidy*
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Introduction

In addition to timber demand, there is a growing demand for non-timber standing forest services such as carbon sequestrations, biodiversity protection, watershed management and amenity services world wide. While forest production for timber is often based on market mechanism, national governments and international NGOs have followed different approaches to supply non-timber services of standing forests. PES programs have become increasingly popular as a means to induce landowners to undertake environmentally beneficial activities such as biodiversity protection, soil conservation etc.

PES programs involves a contract between the regulator (the state) and individual landowner which specifies the type and level of conservation practices that the landowner is required to undertake on his/her land as well as the amount of money s/he receives in

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compensation. Participation is voluntary such that for the landowner to signs the contract, the amount that is offered in compensation should at least cover the extra costs s/he incurs. However, PES contractual relationships are subjected to asymmetric information between the landowner and the regulator. It is likely that the landowner have private information about the cost of providing environmental services than the regulator (Wu and Babcock, 1995 and 1996). In the presence of such an information asymmetry, landowners may use their information advantage to extract information rent from the regulator. Information rent results the regulation policy inefficiency as it leads to the attainment of fewer environmental services per unit of compensation (per unit of dollar) than in the symmetric information scenario. This implies a typical mechanism design problem which has been stated before. Early literature includes Smith (1995), Smith and Tomasi (1995), Wu and Babcock (1995; 1996). An important finding from these past studies is that uniform compensation of the farmers leads to an efficiency loss. Social welfare can be maximised under such a scenario if the regulator can offer a menu of contracts specifying the conservation activities and associated compensation payments.

Another finding is that the absence of transaction cost of subsidy policies yields the first best outcome regardless of information distribution (i.e. whether it is asymmetrically distributed or not).

Studies of mechanism design problems usually assume that farmers differ with respect to a certain characteristic which is assumed to determine the marginal benefit or cost of the input to be regulated. For instance, Wu and Babcock (1996) assume that farmers differ with respect to the quality of land and the regulated input is the amount of polluting input used in agriculture. Anthon and Thorsen (2006) considered differences in utility derived from afforetstation projects across farmers and Motte et.al (2004) considered heterogeneity of cost of expanding agricultural land into protected areas as a source of information asymmetry.

However, we find no mechanism design literature in the context of developing countries agriculture where farmers differ in terms of prices of inputs to be regulated in addition to differences in resources quality and other characteristics. This paper contributes to the literature by applying mechanism design theory to afforestation subsidy in a developing country where land prices differ across farmers due to heterogeneity of the farmer's rate of time preference. In the perfect competitive market, the price of the stock of land is determined, inter alia, by market rate of interest which equals the intertemporal rate of substitution (rate of time preference (RTP)). However, in rural areas of developing countries markets are far from perfect (Holden, et.al, 1998, de Janvry, et.al 1991). Importantly, capital or credit markets are missing or at best rationed in which case the market rate of interest doesn't equal rate of time preference (RTP) for all households (de Janvry and Sodoulet, 1995; Holden et.al, 1998). The prices of assets such as land in such a case are rather farmer specific (endogenous) owing to differences of rate of time preferences across household.

The rate of time preference is private information for the farmer and therefore not observable by the public environmental agency which intends to compensate farmers for afforestation effort. This poses a typical mechanism design problem. The study account for the heterogeneity in the rate of time preferences and analyze whether the socially optimal contract menus of afforestation are uniform (pooling) or separating under such

information regime. We demonstrate the efficiency loss to asymmetric information in terms of the difference between afforestation level under separating equilibrium policy (second best outcome) and that of first best outcome. Also we analyze how efficiency loss varies with cost of subsidy denoted as transaction cost (the cost tax distortion and or opportunity cost of subsidy).
We find that information asymmetry due to rate of time preference undermines the efficiency of PES. The important policy implication of the finding is that development of credit markets in rural areas of developing countries can complement PES scheme of afforestation.

The remainder of the papers is organized as follows: the model of first best and symmetric information is presented in section 2. In section 3 we show if the optimal subsidy policy are uniform or separating. In addition, we present the results of asymmetric information and compare with first best outcomes. The role of transaction cost is also presented in this section. Section 4 concludes the paper.

The model

In this paper, we model a contract where a regulator (environmental agency) presents farmers with a policy menu that comprise of a combination of the afforestation level and corresponding compensation payment. The policy menu specify as many combinations as there are distinct rates of time preference (farmers type) or a single menu for all types of farmers. The choice between the two depends on their efficiency gain in the second best world and the former is most often superior to the latter in that regard. In the first best world, the former is always opted for as long as there exist heterogeneity among farmers.

In any case, participation of the farmer in the program is voluntary, thus farmers may choose a combination or none of them. We make some simplifying assumptions: First, we abstract from heterogeneity of other characteristics except the rate of time preferences or the regulator can observe all other heterogeneity except that of rate of time preference. Second, we assume that though the regulator cannot observe farmer's type (rate of time preferences), he has a priori belief about each type in terms of its probability distribution. Finally we assume that both the regulator and the farmer are risk-neutral.

The basic tenet of this paper is that private decision of land use do not account for forest's positive externalities. Forest stocks are multi-functional. In addition to timber products, they provide biodiversity conservation, carbon sequestration services, flood protection services etc. These additional services (externalities) are public goods and hence characterized by market failure in which case forest managers don't account for them in the decision of land allocation and harvesting time of forests. More importantly, when timber benefit falls short of benefit of alternative land use, commonly agriculture, farmers don't allocate their land to forest plantation and hence zero supply of forest services. It is thus, in the interest of social planner to device and implement incentive policies to regulate farmers land use to internalize these externalities to improve social welfare.

In what follows, we formulate a model of benevolent social planner, which accounts for these externalities and yield socially optimal outcome (first best solution).That is the model yields the first best land use policy (a combination of afforested area and agricultural land use) that maximize social welfare. This solution will thus serve as a bench mark against which we compare the results of second best world[3].

Let the sum of discounted stream of benefits from forest and agriculture are given as

$$V(x) = \int_{t=0}^{\infty} B(x)e^{-\delta t}dt \quad \text{and} \quad \pi(\overline{X} - x) = \int_{t=0}^{\infty} \psi(\overline{X} - x)e^{-\delta t}dt \tag{1}$$

respectively. And the cost of tree planting at the beginning of the period is given as $h = h(x) = kx,\ h_x = k$

Where $B(x)$ is the society's instantaneous benefit from forestry , $\Psi(\overline{X} - x)$ is instantaneous benefit from agriculture, x is the land allocated to forestry, $\overline{X} - x$ is the land allocated to agriculture and $\overline{X}$ represents the total area of land available for forestry and agriculture land uses..

A social planner problem that maximizes the sum of benefits from forestry and agricultural land use is given as follows:

$$\max_x \omega = V(x) + \pi(\overline{X} - x) - h(x) \tag{2}$$

F.O.C

$$\frac{\partial \omega}{\partial x} = V_x + \pi_x - h_x = 0,\ \pi_x \prec 0$$
$$\Rightarrow V_x = \pi_x + h_x \tag{3}$$

The socially optimal afforestation x^* and the corresponding agricultural land use, $\overline{X} - x^*$ is determined from 3. The result shows that socially optimal combination of afforested land and agricultural areas are attained at a point where the marginal value of forest services, V_x equals its marginal opportunity cost, π_x ; the foregone per hectare benefit of agricultural land use and marginal cost of afforestation. Henceforth, we call the latter the marginal cost converting land into forestry.

Afforestation under symmetric information and transaction cost

In this case, the social planner's problem is to maximize social welfare out of afforestation and agricultural land use decisions by providing a farmer incentive, $s(\theta)$ and

determining the area to be afforested $x(\theta)$, where $\theta \in [0, \infty]$ is the farmer's rate of time preference. The incentive payment should cover the opportunity cost of forgone land use decision and the cost of planting trees (afforestation). This cost is given as[4]:

$$\hat{\pi}(\overline{X} - z), \theta) + h(x) = \hat{\pi}(x, \theta) + h(x) = \int_0^t \Psi(x) e^{-\theta t} dt + h(x) \qquad (4)$$

Where $\overline{X}$ is the total land holding size of a farmer, z is the amount of land allocated to agriculture, and hence $\overline{X} - z = x$ is the amount of land to be allocated to afforestation[5]. Here it should be noted that the regulator assigns the level of afforestation of land based on their rate of time preference; $x(\theta)$ which means that the level of afforestation land x is assigned to farmer type θ. Similarly the compensation payment is also based on farmers type and specified as

$$s(\theta) = \hat{\pi}(x(\theta), \theta) + h(x(\theta)) \qquad (5)$$

However, this payment comes at a cost and hence it entails transaction cost of afforestation. Transaction cost in this case arises from tax distortion of raising subsidy fund for afforestation and the opportunity cost of diverting public expenditure to afforestation at expense of other competing public investment needs.

For ease of exposition, we assume that there are two types of farmers in terms of their rate of time preference: low rate of time preference type $\underline{\theta}$ and high rate of time preference type θ^+. The analysis can be extended straight forwardly to N farmers. The rate of time preference of each farmer is public information (symmetric information). This means that the social planner can observe the farmer's rate of time preference. The utility function of the farmer type θ is specified as:

$$U(\theta) = \pi(\overline{X} - x(\theta), \theta\ ) + s(\theta) \quad \text{where } \theta \in [\underline{\theta} \quad \theta^+] \qquad (6)$$

The arguments of farmer's utility function are the income from farming practices $\pi(\overline{X} - x(\theta), \theta)$ and a transfer from a regulator $s(\theta)$ in exchange for afforesting part of his/her land. The social welfare function is a utilitarian type with arguments being society's benefit from forestry and farmers utility function; It is given as:

$$\omega = V(x(\theta)) + \pi(\overline{X} - x) + (1 + \lambda)s(\theta) \qquad (7)$$

Where λ is the cost of raising fund for afforestation subsidy through distorted tax or part

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[4] Note that for those farmers whose rate of time preference differ from that of society we have $\theta \neq \delta \Rightarrow \hat{\pi} \neq \pi$ *and* $\hat{\pi}_x \neq \pi_x$ but for some farmers who has the same rate of time preference as society's rate of time rate of time preferences , we have $\theta = \delta \Rightarrow \hat{\pi} = \pi$ *and* $\hat{\pi}_x = \pi_x$

[5] Note that we can express the size of land allocated to agriculture as $z = \overline{X} - x$

of the raised fund lost to corruption or the opportunity cost of afforestation through subsidy. We henceforth call this cost a transaction cost of afforestation subsidy policy. The social welfare maximization problem is thus:

$$\max_x \omega = V(x(\theta)) + \hat{\pi}(\overline{X} - x(\underline{\theta}),\ \underline{\theta}) + \hat{\pi}((\overline{X} - x(\theta^+), \theta^+) - \lambda s(\theta^+) - \lambda s(\underline{\theta}) \quad (8)$$

s.t $\hat{\pi}(\overline{X} - x(\theta^+), \theta^+) + s(\theta^+) = \hat{\pi}(\overline{X}, \theta^+)$ (9)

$$\hat{\pi}(\overline{X} - x(\underline{\theta}),\ \underline{\theta}) + s(\underline{\theta}) = \hat{\pi}(\overline{X}, \underline{\theta}) \quad (10)$$

where 7 and 8 are participation constraint for type $\underline{\theta}$ *and* θ^+ individuals respectively[6].

The corresponding Lagrangian function is specified as:

$$\begin{aligned} L = {} & V(x(\theta) + \hat{\pi}((\overline{X} - x(\theta^+), \theta^+) + \hat{\pi}(\overline{X} - x(\underline{\theta}), \underline{\theta}) - \lambda(s(\underline{\theta}) - s(\theta^+)) \\ & + \eta(\hat{\pi}((\overline{X} - x(\theta^+), \theta^+) + s(\theta^+) - \hat{\pi}(\overline{X}, \theta^+) \\ & + \gamma(\hat{\pi}((\overline{X} - x(\underline{\theta}), \underline{\theta}) + s(\underline{\theta}) - \pi(\overline{X}, \underline{\theta}) \end{aligned} \quad (11)$$

F.O.C

$$x(\theta^+) : \frac{\partial L}{\partial x} = V_x - \hat{\pi}_x + \eta \hat{\pi}_x = 0 \Rightarrow V_x = (1+\eta)\hat{\pi}_x$$

$$x(\underline{\theta}) : \frac{\partial L}{\partial x} = V_x - \pi_x + \gamma \hat{\pi}_x = 0 \Rightarrow V_x = (1+\gamma)\hat{\pi}_x$$

$$s(\theta^+) : \frac{\partial L}{\partial s} = -\lambda + \eta = 0 \Rightarrow \lambda = \eta)$$

$$s(\underline{\theta}) : \frac{\partial L}{\partial s} = -\lambda + \gamma = 0 \Rightarrow \lambda = \gamma$$

by transitivity

$$V_x = (1+\gamma)\hat{\pi}_x = (1+\eta)\hat{\pi}_x = (1+\lambda)\hat{\pi}_x \quad (12)$$

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[6] We assume that all the constraint hold with equality as the regulator minimizes expense of compensation payment. We also assume that, as long as their participation constraint is satisfied all the farmers participate in the afforestation program. Moreover, we assume that $\theta^+ \succ \underline{\theta}$ and from 3 we see that $s(\underline{\theta}) \succ s(\theta^+)$. This implies that farmer type $\underline{\theta}$ is high cost type and need to be assigned lower level of afforestation as compared to that assigned farmer type θ^+. Note that compensation payment is costly because it entails tax distortion, corruption loss or has opportunity cost.

Comparing 11 with 2 (first best solution), we see that afforestation level in 11 is different from the first best solution in 2. For farmers who has $\theta = \delta$ and hence $\hat{\pi}(\overline{X} - x(\theta), \theta) = \pi(\overline{X} - x(\delta), \delta)$ *and* $\hat{\pi}_x = \pi_x$, the differences emanates from the presence of transaction cost of subsidy payment, λ. But for farmers who has $\theta \neq \delta$ and hence $\hat{\pi}(\overline{X} - x(\theta), \theta) \neq \pi(\overline{X} - x(\delta), \delta) \Rightarrow \hat{\pi}_x \neq \pi_x$, the difference results from the presences of λ and the fact that $\hat{\pi}_x \neq \pi_x$. In fact, for both types of farmers, the afforestation level is lower compared with first best solution.

Asymmetric information-uniform or separating policies

In this section, we analyze the situation where the regulator cannot observe farmers' opportunity cost of providing environmental services. The problem results from credit or capital market imperfection where rate of return is not determined by the market but by the farmers rate of time preference. When missing or rationed credit market abounds, each farmer discounts stream of farm income (land value) on the basis of subjective discount rate resulting from farmer's rate of time preference. The rate of time preference thus, defines the type of farmers and is not observable by the public environmental agency which intends to compensate farmers for afforestation effort, but is private information for the farmer.

In what follows, we provide that farmer's rate of time preference (RTP) is indeed unobservable. This would mean that it differs from rate of interest which is opportunity cost of capital under competitive credit market.

Suppose that a household maximize intertemporal utility function given as

$$MaxU = \int v(c_t) e^{-\delta t} dt \qquad (13)$$

Where δ stands for pure rate of time preference. If we consider household choice among alternative bundles of consumption (c_0, c_1) at times $t = 0$ and $t = 1$ and keep consumption in all other periods fixed, the total differential of (13) can be written as;

$$dU = v'(c_0) dc_0 + v'(c_1) e^{-\delta} dc_1 = 0 \qquad (14)$$

RTP defined as marginal rate of substitution of consumption across the two period given can be derived as;

$$\left. \frac{dc_1}{dc_0} \right|_{U = constant} = \frac{v'(c_0)}{v'(c_1)} e^{\delta} \qquad (15)$$

We now return to derivation of RTP at optimal bundle of consumption over the two periods.

$$MaxU = \int v(c_t) e^{-\delta t} dt \qquad (16)$$

s.t $c_0 + c_1 e^{-rt} = A_0 + y_0 + y_1 e^{-rt}$ or $c_0 e^r + c_1 = A_0 e^r + y_0 e^r + y_1$ (17)

Where A_o, c_0 , y_0, r and y_1 stand for initial period($t=0$) asset stock, consumption and income, interest rate and period ($(t=1)$ income of a household. In addition to this constraint, the household faces a borrowing constraint as the result of which the first period consumption is bounded from above (Dasgupta, 1993) and expressed as:

$$c_0 \leq \bar{c} \tag{18}$$

Where $\bar{c}$ is the maximum that a household can consume during initial period.
The corresponding Lagrangian function is thus given as:

$$L = v(c_0) + v(c_1)e^{-\delta} + \lambda(A_0 + (y_0 - c_0)e^{rt} + y_1 - c_1) + \phi(\bar{c} - c_0)$$

F.O.C and manipulations yields:

$$\begin{aligned} v'(c_0) &= \phi + \lambda e^r \\ v'(c_1)e^{-\delta} &= \lambda \end{aligned} \tag{19}$$

From (19), we can derive that;

$$v'(c_0) = \phi + v'(c_1)e^{-(\delta - r)} \tag{20}$$

RTP is thus derived as;

$$-\frac{dc_1}{dc_0}\bigg|_{U=\text{constant}} = e^{\theta} = \frac{v'(c_0)}{v'(c_1)}e^{\delta} = e^r + \frac{\phi}{v'(c_1)}e^{\delta} \tag{21}$$

From (21), it is evident that RTP; e^{θ} is different from market rate of return (interest rate return) ((e^r) if Lagrangian multiplier ϕ is not zero i.e. credit constraint is binding.
Now by taking absolute value and transforming every terms (21) into log form, we can rewrite (21) as;

$$\theta = r + \delta \ln(\frac{\phi}{v'(c_1)}) \tag{22}$$

Equation (22) shows that consumption rate of time preferences differ from interest rate. This concludes the proof of the statement that households rate of time preferences is not observables as long as it is different from interest rate. It is rather private information of the household leading to information asymmetry.

In face of the asymmetry of information, the regulator should either pay farmers uniformly or design alternative contract.
Farmers essentially differ in their opportunity cost of providing the environmental

services (afforestation) and the amount of compensation under uniform payment is larger for most farmers than is strictly necessary. It is therefore, not consistent with regulator's objective of maximizing the sum of public and private benefits while incurring transaction cost (tax distortion of raising fund for subsidy, corruption loss and opportunity cost of subsidy). Alternatively the incentive compatible contract can be used to reduce the total amount of compensation. Under incentive compatible contract, a regulator presents farmers with a policy menu that comprise of a combination $(x(\theta), s(\theta))$, where $x(\theta)$ is the afforestation level and $s(\theta)$ is a corresponding compensation payment per hectare if x ha of afforestation is chosen by farmer type θ. We also now relax the assumption of two farmers to N farmers. The policy design is such that a farmer has no incentive to choose the menu intended for other types of farmers. It amounts to mean that $(x(\theta)\ s(\theta))$ must be optimal choice for farmer type θ. This is a self-*selection* or *incentive compatibility* constraint in mechanism design literature and we specify it as follows:

Suppose that if type-θ farmer chooses the menu intended for type-θ^+ farmer, $[x(\theta^+),\ s(\theta^+)]$ his utility function is[7]:

$$U(\theta^+|\theta) = \hat{\pi}(\overline{X} - x(\theta^+), \theta) + s(\theta^+) \qquad (23)$$

and if he chooses the menu intended for him $[x(\theta),\ s(\theta)]$, his utility function is given:

$$U(\theta) = \hat{\pi}(\overline{X} - x(\theta), \theta) + s(\theta) \qquad (24)$$

It thus follows that the policy menu, $[x(\theta),\ s(\theta)]$ satisfy *incentive compatibility* (*self-selection*) constraint if and only if

$$U(\theta) \geq U(\theta^+|\theta) \qquad (25)$$

Given self-selection conditions above, we now formulate the regulator optimization problem. It is noted that the regulator cannot observe the types of the farmers. However, s/he has a belief in terms of probability density, $\phi(\theta)$. The optimization problem of regulator problem is thus given as:

$$\max_{x,s} E\omega = \int_0^1 [V(x(\theta) - (1+\lambda)s + U(\theta)]\phi(\theta)d\theta \qquad (26)$$

s.t $x'(\theta) \geq 0$

This specification is equivalent to theorem 3, equation 3.2 of Guesnerie and Laffont (1984). In addition to these conditions, as the farmers' participation in the mechanism is

[7] Note farmers maximize utility function by strategically reporting their type and hence $\theta \in [0, \infty]$ is the argument of the utility function.

voluntary, the contract menu should also satisfy the individual rationality constraint. This constraint is given as:

$$U(\theta) \geq \bar{u}(\theta)$$

where $\bar{u}(\theta)$ is the minimum benefit that the farmer could gain without the contract that is the opportunity cost of participating into the contract. The condition can be satisfied if

$$U(\underline{\theta}) \geq \bar{u}(\underline{\theta}) \qquad (27)$$

where $\underline{\theta}$ is the least rate of time preference which equals zero in the set $[0,\infty]$. The equation hold with equality as the regulator minimizes expense of compensation. In other words, once the participation constraint of the farmer with the least rate of time preference is satisfied, the rest of farmers with rate of time preference greater than that (zero) can voluntarily participate into the contract (mechanism).
We can now reformulate the utility function of a farmer as:

$$\max_{\theta} U(\theta) = \bar{u}(0) + \int_0^1 U'(\theta)d\theta = \bar{u}(0) - \int_0^1 \hat{\pi}_\theta d\theta = \hat{\pi}(x(\theta),\theta) + s(\theta) \qquad (28)$$

Solving for $s(\theta)$ from this equation, we find that:

$$s(\theta) = \bar{u}(0) - \hat{\pi}(x(\theta),\theta) - \int_0^1 \hat{\pi}_\theta d\theta . \qquad (29)$$

Inserting this expression into the social planner objective function in 18 and integrating by parts yields:

$$\max_{x} E\omega = \int_0^1 [V(x(\theta) + (1+\lambda)\hat{\pi}(\overline{X} - x(\theta),\theta) + \lambda\hat{\pi}_\theta (\frac{1-\Phi(\theta)}{\phi(\theta)})]\phi(\theta)d\theta - \lambda\bar{u}(0) \qquad (30)$$

Proposition 1: *Compared with afforestation level of first best world and that of symmetric information scenario, afforestation level under asymmetric information scenario is lower.*

Proof: Taking the F.O.C of equation (30) and manipulating yields:

$$V_x = (1+\lambda)\hat{\pi}_x + \lambda\hat{\pi}_{x\theta}(\frac{1-\Phi(\theta)}{\phi(\theta)}) \qquad (31)$$

The second term on RHS of (31) represents information rent. It is defined as the payment above the minimum payment necessary to induce farmers' participation in the mechanism (afforestation contract scheme). The optimal contract is therefore such that it limit the information rent to cause the farmer to be indifferent between mimicking and revealing his true type and hence a revelation mechanism. It is the information rent that is responsible for attaining lower level of afforestation as compared to symmetric information scenario.

Corollary 1: *The first best afforestation level can be approached, when transaction cost (tax distortion, opportunity cost of afforestation subsidy) is minimal;* $\lambda \to 0$

Proof: From equations (12) and (31), $\lambda = 0$ implies $V_x = \hat{\pi}_x$ which yields the first best afforestation level x^* regardless of information regime for a farmer or group of farmers that has $\theta = \delta$ and hence $\hat{\pi} = \pi$ *and* $\hat{\pi}_x = \pi_x$.

The intuitive interpretation of this solution is that subsidy is a zero-cost transfer from a social planner to a farmer and hence paying too much subsidies is not socially costly which leads to attaining socially optimal level of afforestation and consequently the optimal level of agricultural land use. The immediate implication of this claim is that, the lower are the transaction cost, the closer is the afforestation level to the first best world afforestation level for this group of farmers. However, for farmers that have no same rate of time preference as society's rate of time preference, there is no guarantee that the absence of transaction cost can yield the first best solution as $\hat{\pi}_x \neq \pi_x$.

Nevertheless, $\lambda \to 0$ produces relatively closer outcome to first best solution than the outcomes that would obtains otherwise (i.e. outcomes under larger values λ).

The transaction cost varies from country to country and it is therefore the ability to minimize it that enables to attain the result closer to socially optimal outcomes for a given contractual mechanism. Particularly, low income countries have high opportunity cost of such subsidy policy where there are a lot of pressing public investment demands. Moreover, in countries where corruption is rampant, efficiency loss with asymmetric information is likely to be significant. This obviously limits the level of afforestation under such scheme. In other context where distortion of tax is high, similar results will also obtain. It is also to be noted that countries can attain different level of afforestation under such policy for the same amount of subsidy expenditure because of differences in the transaction cost.

Conclusion

Previous studies have applied a mechanism design models to Payment for Environmental Services (PES) in the context of developed countries where capital market is competitive. They considered heterogeneity among farmers mainly in terms of quality of the inputs to be regulated. In this paper we however, apply a mechanism design model to the afforestation subsidy contract in developing countries where heterogeneity among the farmer abounds in terms of the prices of input (land) to be regulated. The model assumes that heterogeneity among farmers in terms land quality and other characteristics are observable by the regulator. However, the regulator cannot observe farmer's rate of time preference and hence unobservability of the discounted land value of the farmer.

We find that information asymmetry due to inability to observe farmer's rate of time preferences limit the efficiency of subsidy policy for afforestation under Payment for Environmental Services. Particularly, afforestation level under asymmetric information is lower as compared to symmetric information scenario. Moreover, there is no guarantee that the subsidy under symmetric information results in first best (socially optimal) afforestation level in the presence of the cost of subsidy policy. These costs are the cost

of tax distortion of subsidy, corruption misappropriation or opportunity cost of subsidy and is called transaction cost of the policy. Countries do differ in terms of these cost and consequently likely to attain different afforestation level for the same amount of subsidy expenditure. Unlike previous studies, we find that the absence of transaction cost of subsidy doesn't necessarily guarantee the first best solution, but yield results closer to the first best outcome than what would be the case otherwise.

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