PERFORMANCE-BASED VOLUNTARY GROUP CONTRACTS FOR NONPOINT SOURCE POLLUTION

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Introduction

Pollution from nonpoint sources (NPS), and agriculture in particular, remains as one of the largest sources of water quality impairments in the United States. As is well known in the literature, there are many difficulties with designing regulations for reducing nonpoint source pollution (i.e., Tomasi, Segerson, and Braden, 1994). Uncertainty and asymmetric information are the key regulatory difficulties that have been identified for developing effective economic mechanisms to control nonpoint source pollution. The main goal of this paper is to describe a potential incentive mechanism that can be applied in limited information situations, such as nonpoint source pollution. The incentive mechanism involves a contract written between a point source of pollution and a small group of other nonpoint polluters in the watershed to reduce a specific load of pollution. The contract allows the nonpoint sources to enter the contract voluntarily. To handle the incentive problems typical in many principal agent problems, it incorporates joint liability, and peer pressure/monitoring to induce the nonpoint sources of pollution to meet their contractual obligations.

The contract proposed here is built upon the ideas of Stiglitz (1990) and Varian (1990) that were originally applied to micro-lending arrangements in developing countries. As we hypothesize with nonpoint source pollution, joint liability contracts for micro-lending assume that individuals have more information about each other than the principal has about them. Given the likelihood for moral hazard in contracts with asymetric information, the contract proposed in this paper takes advantage of joint liability and peer pressure to eliminate or reduce the moral hazard problem. Joint liability contracts have been shown to be successfully applied in practice in several situations (Ghatak and Guinnane, 1999; Van Tassel, 1999).

For our purposes, a principal (a point source of pollution) offers a contract that specifies a price for each ton of pollution abated by individuals who participate. The contract is offered to individual farmers in a specified sub-watershed upstream from the discharge point. Farmers in the watershed decide whether or not to participate, and if they decide to participate, they bid into the contract the level of abatement services they will provide. The principal will form the group from these bidders, and will agree to pay the farmers if they meet the group's overall target. The bids determine the sharing rule for payments at the end of the season.

To show how a group contract with peer pressure could be applied to the non point source pollution, three contracts are explored. The paper begins with a simple problem that ignores asymetric information. This model is then contrasted with a second model that incorporates asymetric information and a third model that allows for peer pressure. The results show that without peer pressure, one of the incentive compatability constraints is not met, suggesting that individual farmers would revert to low effort in most cases. Increase in fixed payment can also induce farmers to shirk. The results suggest that contracts that incorporate peer pressure and take advantage farmer interactions among their neighbors can avoid the typical problems associated with moral hazard. Without peer pressure, farmers have little to no incentive to achieve pollution abatement goals. We speculate that peer pressure is more likely to evolve in situations where farmers are all located in the same small watershed and where they have frequent interactions with each other, and potentially can observe their neighbors actions during the year.

In addition to exploring the role of peer pressure in avoiding the moral hazard problems associated with non point source pollution control contracts, we also explore the trade-offs between participation in the contract and shirking. At one extreme, existing voluntary incentive programs involve fixed payments with no requirements for performance. They will thus lead to high levels of participation, but likely to large levels of shirking as well. For example, in a typical year all of the money available for existing federal conservation programs is used by farmers, but there is little evidence available to prove that pollution declines as a result. The second contract explored in this paper shows how large fixed payments, as currently used, are likely to lead to small improvements in pollution. At the other extreme, one could write a contract that specifies that payments will only be made if the target is met, following Holmstrom (1982) or Segerson (1988). Such an extreme, nonlinear contract such as this likely would eliminate most shirking, but it may lead to little participation among farmers. In this paper, it is shown that it is possible to increase the fixed payment in order to increase participation if peer pressure is a viable component of the contract.

Results also indicate that fixed payment proportion from the total payment can be larger in regions where farmers have high costs and high reservation utilities. Moreover, peer monitoring can be lower in regions where there are high nonpecuniary penalties and future revenue loss from the contract, or vice versa.

MODEL

To date, performance-based programs have rarely been used to control non point source pollution. For the most part, controls rely on voluntary incentive programs that make payments regardless of the actual reductions in pollution attained. This is problematic for point sources who may wish to purchase pollution abatement reduction credits from nonpoint sources. There are few contract mechanisms available to provide point sources with assurances that pollution abatement will actually occur if they make payments for technological improvements in nonpoint sources. This study shows that under certain circumstances, it is possible to develop performance-based approaches that can be the basis for contracting between point and non-point sources.

To show this, a group contract is proposed with voluntary participation. The basic idea behind this mechanism is to delegate individual monitoring and enforcement to the group members since they live in close proximity and have more knowledge about each other than principal. Once the principal convinces the agents to participate in this contract by providing an adequate incentive, the contract operates to eliminate the moral hazard problems typical in many contracts with asymmetric information. The principal's job is to offer a contract with enough incentives and form a group, to monitor the pollution abatement that arises from group efforts, and to make payments based on that.

I. Symmetric Information Contract/Individual Contract

The paper first shows a contract under perfect conditions where principal and agents* have the same information available to each other. Such would be the case if the individual contributions and cost functions from each source could be observed perfectly.

* The terms principal and agents refers to point source polluter and farmers, respectively.

In this case agent doesn't have any information advantage to use against the principal, i.e., no moral hazard and adverse selection problems. Since the principal can observe/verify the individuals' actions/efforts, the contract can be an individual contract and based on the effort level. The principal must decide both the effort that she demands from the agent, and subsidy/payment that will be paid based on the result. The results from this kind of contract will show us what the optimal payment mechanism is under different risk preferences.

Principal's Problem:

$$\underset{[e,\{s(a_i)\}_{i=1,....,n}]}{Max} \sum_{i=1}^{n} p_i(e)\, U[mc^* a_i - s(a_i)]$$

Subject to :

$$\sum_{i=1}^{n} p_i(e)\, u(s(a_i)) - c(e) \geq \overline{U} \quad \rightarrow \text{Participation Constraint}$$

Where,

There are 'n' possible discrete outcomes with a given effort level.

$p_i(e) = \Pr ob[a = a_i \mid e]$, for $i \in \{1,2,.....,n\}$. The probability that the result will be a_i, given the agent's effort level 'e'.

U: Principal's utility/benefit function. U'>0, U''<=0 (Risk-neutral or risk-averse)

mc: marginal cost of abatement for the point source

a_i**:** Level of abatement/output i by agent, and $a_i = (a_1, a_2, \ldots\ldots, a_n)$

$s(a_i)$: Agent's payment/subsidy as a function of abatement level

$u(s(a_i))$: Agent's utility from payment. u'>0, u''<=0 (concave)

e: Effort

$c(e)$: Cost of effort/abatement to the agent. c'>0, c''=>0 (convex)

$\overline{U}$: Agent's reservation utility

This problem establishes that the principal maximizes the surplus that she obtains from the relationship, under one condition which is called *participation constraint*, or the *individual rationality condition*. This condition says that the agent can always reject the contract if what he gets by signing it is not at least equal to what he can obtain from the alternatives in the market.

Lagrangian Function :

$$L(\{s^o(a_i)\}, e^o, \lambda^o) = \sum_{i=1}^{n} p_i(e^o)U[mc * a_i - s^o(a_i)] + \lambda^o \left[\sum_{i=1}^{n} p_i(e^o)u(s^o(a_i)) - c(e^o) - \overline{U} \right]$$

F.O.C. (with respect to $(s(a_i))$

$$-p_i(e^o)U'[mc * a_i - s^o(a_i)] + \lambda^o p_i(e^o)u'(s^o(a_i)) = 0$$

$$\lambda^o = \frac{U'[mc * a_i - s^o(a_i)]}{u'(s^o(a_i))}, \ for \ \forall \ (i = 1, ..., n)$$

When we apply the Kuhn-Tucker theorem, we can see that the multiplier associated with participation condition must be strictly positive, given our assumptions. That means participation constraint binds, which is intuitive. If it didn't bind, then the principal would be paying 'too much' to the agent. In this case, the principal can reduce the payment to the agent in such a way that the agent would still accept the contract, and the principal would get greater utility, which is called Pareto Optimum.

Optimal Payment Mechanism

$$\frac{U'[mc * a_i - s^o(a_i)]}{u'(s^o(a_i))} = constant$$

This equation indicates that the ratio of marginal utilities of the principal and the agent should be constant whatever the final result is. In order to better understand the implications of this condition, let's take a look at following four cases:

i. If U'(.)=constant, that is, the principal is risk-neutral, the efficiency condition above requires that $u'(s^o(a_i))$=constant for all i. If the agent is risk-averse, the only possible way in which the marginal utilities at two points can be the same is if the two points are the same. In other words, $u'(s^o(a_i)) = u'(s^o(a_j))$ requires that $s^o(a_i) = s^o(a_j)$. Therefore, at the optimal contract the agent receives a pay-off that is independent of the result. The optimal distribution of risk when the principal is risk-neutral is for her to accept all the risk, completely insuring the agent. The agent receives the same payment in all contingencies, and this payment will only depend on the effort demanded. So, the exact payment will be: $s^o = u^{-1}(\overline{U} + c(e^o))$, since we know that participation constraint binds.

ii. If both the principal and the agent are risk-neutral, the result will be very similar to the previous one. The agent can still get the fixed payment, since both U'(.) and $u'(s^o(a_i))$ are constants. By the same token, the payment will be: $s^o = \overline{U} + c(e^o)$

iii. If the agent is risk-neutral, u'(.)=constant, and the principal is risk-averse, U''(.)<0, then we are in the opposite situation. The optimal contract will require that $U'(mc^*a_i - s^o(a_i))$=constant for all i. That means, $mc^*a_i - s^o(a_i) = mc^*a_i - s^o(a_j)$. this time the principal's profit is independent of the result. Consequently, the agent accepts all the risk, insuring the principal against variation in the result. The optimal contract is of the form: $s^o(a_i) = mc^*a_i - k$.

We can interpret this as a 'franchise' contract: the agent keeps the result a_i and pays the principal a fixed amount k, independent of the result. In order that the participation constraint be saturated, the constant k must satisfy

$$\sum_{i=1}^{n} p_i(e^o)\,(mc^*a_i - k) = \overline{U} + c(e^o)$$

$$k = \sum_{i=1}^{n} p_i(e^o)\,(mc^*a_i) - \overline{U} - c(e^o)$$

The amount that the principal sets as the price for the agent to keep the result is the difference between the expected profit from the activity and the amount required for agent to accept the relationship.

iv. If both the principal and the agent are risk-averse, each one will need to accept a part of the variability (risk) of the result. Exactly how much will depend on their degrees of risk-aversion. The optimal contracts in this case can be very complicated. A rather attractive, for simplicity, contract format is the set of linear contracts: $s^o(a_i) = k + b(mc^*a_i)$

II. Asymmetric Information Case

The second model in this paper explores the effect of moral hazard on the problem. In this case, the principal cannot observe/verify the agents contributions or cost functions so that contract cannot based on the effort level. The principal can, however, observe total abatement level. That makes the group contract more suitable for nonpoint source pollution. The principal's job will be to specify the payment mechanism, offer the contract and observe the total output. Agents will decide whether to participate or not. If they participate, they must additionally decide whether to exert high or low effort.

For the rest of the paper we will assume that both principal and agents are risk neutral. However, since we have a moral hazard problem within the group, we cannot offer a full fixed payment as in the symmetric information case. If the principal offers just fixed payment, no matter the result is, then it is obvious that agents will put the lowest effort. The payment mechanism we offer will be linear and depend on the group performance. This is more like when both principal and agents are risk-averse case in symmetric case. When the group meets the target, they will get fixed payment plus some bonus; otherwise they will get just the fixed payment.

1. Joint Liability Group Contract Model without Peer Pressure

Here is step by step how this joint liability group contract works:

1. Principal offers the contract to the agents in a particular watershed. The contract specifies the price per ton abatement, payment mechanism and total ambient level abatement required.
2. Agents are free to accept or reject the contract. It is completely voluntary. If an agent rejects the contract, he will be out of group and will not be responsible for any abatement or payment. However, if an agent agrees to the contract, then he is going to bid how many tons he is willing to abate. So all the agents who want to join the contract will bid the amount they will produce.
3. Principal will form a group amongst these bidders up until he reaches the total amount he is looking for. If he cannot get enough amounts of bids, then he can form a group with those bidders, or he can just withdraw the contract. If he gets more total bids than he is looking for, then he can develop a mechanism to form a group. For example, he can randomly choose group members, or start from the

highest bidder or lowest bidder until he meets his target level abatement. Or those bidders can self-select the group members they want to be and form the group.

4. Now the season starts, and farmers are free to obey their bids or they can produce less or more than they bid. Off course, producing more means extra cost to farmers, or vice versa. But producing more is also increasing the probability of meeting the target as a group since it may cover the random weather effect, or part of shirking members' portion. It is obvious that an agent can only produce more up to some point where his marginal cost equals his marginal revenue, i.e., per ton abatement price.

   On the other hand, farmers need to consider several issues when they want to produce less, i.e., moral hazard. First of all, his payment is also depent on group performance. So if he shirks, that means there is a less chance for group to meet the target and get the payment. He will be worse off doing that when he had some abatement costs. If he didn't do anything and had no abatement cost, then he will be indifferent.

5. Once everybody in the group decide how many tons to produce at the beginning (I assume that all decisions made before the season starts since most abatement practices are one time applications such as filter strips or no-till), season will start and they will start using abatement practices they believe best fits for them.

6. At the end of the season, principal will measure the ambient abatement level. If it is more than or equal to target level, then everybody will get the payment. Payment for each agent will be some fixed payment plus his bid amount times the price per ton of abatement. So it is a deterministic payment for each agent. No

matter what they produce they will get the same payment as long as they meet the target. However, if they cannot meet the target as a group, then group will only get some fixed payment. The reason for having this kind of payment mechanism is the difficulty of distributing the total payment among the group members. It is very hard to come up with a sharing rule in this kind of situation where you cannot verify the individual contributions.

As can be seen from the structure of the contract, principal doesn't have any moral hazard problem. They cannot cheat as a group over principal. However, moral hazard problem exists within the group.

As for adverse selection problem, we believe that having bidding notion in the contract can sort out that problem because only those farmers who have abatement costs less than price per ton abatement will bid in. That means, only those farmers who doesn't currently use available or best abatement practices or technology will join the contract. This is what principal is looking for.

Even if there is still some adverse selection problem exists, we would like to ignore it because only solution to adverse selection problem is to offer separate contract for each type of agent. Let say we have more than one contract offered to the farmers. Some will accept the one, some will the other's. That means we have more than one group in one watershed area. This will take back to the same problem we had at the first place, which is identifying the individual contribution. In this case we need to identify the contribution of each group in order to decide their performance and payment. So having more than one group in a watershed is similar to having individual contracts for NPS, which is not applicable.

Assumptions:

For simplicity, one principal and two identical agent case will be analyzed in this paper. Principal has the all the bargaining power, i.e., he offers the contract to the agents and agents are free to take it or leave it. In this contract principal is going to specify the payment mechanism and total abatement he is looking for from the group.

Other Assumptions:

- All decisions are made before the season starts.
- Everybody in the group has the same probability of success and failure.
- Principal and agents are risk-neutral
- Individuals who are not in the group will behave the same as before the contract. So there is no negative or positive effect of non-group members.
- Group member can produce abatement from zero to some positive numbers but not negative, i.e., they won't pollute more than before.
- Two outcomes: 1) Desired and above, 2) Less than desired
- Two effort level: High and Low
- Random weather effect
- No adverse selection problem

Payment Mechanism

Although both principal and agents are risk-neutral, existence of moral hazard problem within the group prevents the principal from offering agents all fixed payments (independent from the outcomes), as in the symmetric case above. If he does that, agents will get the fixed payment with lowest possible effort. That is why the payment has to be somehow based on the outcome. For simplicity, linear payment scheme, i.e. fixed payment plus bonus, has been used in this paper. This is more like similar to both the principal and agent are risk-averse case in symmetric information model. We have two outcomes, and two states that payments depend upon: If the total ambient abatement level is equal to or more than the target level (i.e., group is successful), each agent will get some fixed payment plus bonus. Otherwise, they will only get the fixed payment.

$$s_k = \begin{cases} F_k + B_k & \text{if } A - A^b \geq 0, \text{ (Desired level or above)} \\ F_k & \text{Otherwise, (Less than Desired level)} \end{cases}$$

$$F_k = q * p * a_k^b$$
$$B_k = (1-q) * p * a_k^b$$
$$S_k^T = F_k + B_k = p * a_k^b$$
$$A^b = \sum_{k=1}^{n} a_k^b$$
$$0 \leq q \leq 1$$

Where,

s_k: Total payment to the agent k.

S^T: Total maximum payment that an agent can get

F_k: The amount of fixed payment to the agent k.

B_k: The amount of bonus payment to the agent k.

A: Aggregate actual ambient abatement level

A^b: Total bid amount of the group

p: Price of abatement per ton

a^b: abatement bid amount of an agent

ω: Random variable (i.e., weather)

q: Proportion allocated to fixed payment from total maximum payment (S^T).

Agent 1's expected utilities (EU):

- **When both choose HIGH effort:**

$$EU_1^{HH} = [F_1 + \Pr^{HH} * B_1] - C_1^H(a)$$

- **When he chooses HIGH effort and the other LOW effort:**

$$EU_1^{HL} = [F_1 + \Pr^{HL} * B_1] - C_1^H(a)$$

- **When he chooses LOW effort and the other HIGH effort:**

$$EU_1^{LH} = [F_1 + \Pr^{LH} * B_1] - C_1^L(a)$$

- **When both choose LOW effort:**

$$EU_1^{LL} = [F_1 + \Pr^{LL} * B_1] - C_1^L(a)$$

Where,

$\Pr^{ij}$: The probability of being successful as a group when both agents exerts efforts i and j, respectively. Where i, j = H, L

$C_k^H(a) > C_k^L(a)$

$C_k^i(a)$: Cost of abatement for agent 'k' when he exerts effort 'i', k = 1,2 and i = H, L.

Agent 1's Maximization Problem:

$$\underset{H,L,\overline{U}}{Max} \begin{Bmatrix} [F_1 + \Pr^{HH} * B_1] - C_1^H(a), [F_1 + \Pr^{HL} * B_1] - C_1^H(a), [F_1 + \Pr^{LH} * B_1] - C_1^L(a), \\ [F_1 + \Pr^{LL} * B_1] - C_1^L(a), \overline{U} \end{Bmatrix}$$

$$EU_1^{ij} = [q * p * a_1^b + \Pr^{ij} * (1-q) * p * a_1^b] - C_1^i(a), (i, j = H, L)$$

$$F.O.C.$$

$$1) \frac{\partial EU_1^{HH}}{\partial q} = p * a_1^b (1 - \Pr^{HH})$$

$$2) \frac{\partial EU_1^{HL}}{\partial q} = p * a_1^b (1 - \Pr^{HL}) = \frac{\partial EU_1^{LH}}{\partial q}$$

$$3) \frac{\partial EU_1^{LL}}{\partial q} = p * a_1^b (1 - \Pr^{LL})$$

The results above show the effect of change in proportion allocated to fixed payment (q) on the expected utilities of the agent 1. When the constraint (8) is applied to these results, it can easily be seen that change in q affects the most equation 3 and then 2, and finally 1. That means, any increase in fixed payment (i.e., decrease in bonus payment) will increase expected utility the most when both agents puts low efforts compare to other cases. In other words, after some point, any increase in q will encourage agents to choose low effort, free-riding problem. This clearly shows how increase in fixed payment lead to free-riding.

Principal's Maximization Problem:

$$Max \{[\Pr^{HH}(mc * A^s - B_T) + (1 - \Pr^{HH})(mc * A^f)] - F_T\}$$

Where,

mc: Marginal cost of abatement for point source

A^s: Aggregate actual ambient abatement level if the group is successful ($A^s \geq A^b$)

A^f: Aggregate actual ambient abatement level if the group fails ($A^f < A^b$)

B_T: Total bonus payment to the group

F_T: Total fixed payment to the group

Incentive Compatibility (IC) Constraints:

(1) $EU_1^{HH} \geq EU_1^{HL} \rightarrow [F_1 + \Pr^{HH} * B_1] - C_1^H(a) \geq [F_1 + \Pr^{HL} * B_1] - C_1^H(a)$

(2) $EU_1^{HH} \geq EU_1^{LH} \rightarrow [F_1 + \Pr^{HH} * B_1] - C_1^H(a) \geq [F_1 + \Pr^{LH} * B_1] - C_1^L(a)$

(3) $EU_1^{HH} \geq EU_1^{LL} \rightarrow [F_1 + \Pr^{HH} * B_1] - C_1^H(a) \geq [F_1 + \Pr^{LL} * B_1] - C_1^L(a)$

(4) $EU_1^{HL} \geq EU_1^{LL} \rightarrow [F_1 + \Pr^{HL} * B_1] - C_1^H(a) \geq [F_1 + \Pr^{LL} * B_1] - C_1^L(a)$

(5) $EU_1^{HL} \geq EU_1^{LH} \rightarrow [F_1 + \Pr^{HL} * B_1] - C_1^H(a) \geq [F_1 + \Pr^{LH} * B_1] - C_1^L(a)$

$\rightarrow \quad C_1^H(a) \leq C_1^L(a)$

Participation Constraint:

(6) $EU_1^{HH} \geq \overline{U} \rightarrow [F_1 + \Pr^{HH} * B_1] - C_1^H(a) \geq \overline{\mathrm{U}}$

Other Constraints

(7) $C_k^H(a_k) > C_k^L(a_k)$

(8) $\Pr^{HH} > \Pr^{HL} = \Pr^{LH} > \Pr^{LL}$

Note that constraints 5 and 7 contradicts. That means constraint 5 will never be met. So agent will not have enough incentive to choose high effort when the other agent chooses low effort. In this case he would prefer to put low effort, too. This shows us that a rational agent will never choose to exert high effort without knowing that the other agent also exerts high effort. Another important point to make is that even if the principal gives agents zero fixed payment, without having some kind of enforcement within the group such as peer monitoring, they will not have enough incentive to put high effort. Positive fixed payment especially important for agents' participation.

This result is similar to current Command and Control programs and Best Management Practices. Farmers are forced/agreed upon applying some practices in their farm, but there is no strict monitoring on farmers. So, they have incentive to get the subsidy and shirk.

2. Joint Liability Group Contract Model with Peer Pressure

Previous model suggests that moral hazard within the group cannot be solved without some form of enforcement occurring within the group. As proposed in development finance, peer pressure and social sanctions can potentially be a useful form of peer enforcement within a region. The idea of having monitored and using nonpecuniary penalties by the group members will discourage agents to shirk and eliminate/reduce the moral hazard problem in the group.

Similar kind of joint liability group contracts have also been successfully used in micro-finance in developing countries, called group lending. The underlying idea of group lending is to delegate monitoring and enforcement activities to borrowers themselves. Borrowers who know a lot about each other, such as those live in close proximity or socialize in the same circles, are the most promising candidates for group lending. They can be better able to apply social pressure on potential defaulters (Prescott, 1997). A major source of market failure in credit markets is that a bank cannot apply financial sanctions against poor people who default on a loan, since by definition they are poor. Poor people's neighbors, on the other hand, may be able to impose powerful non-financial sanctions at low cost.

We believe that this kind of mechanism can be successfully applied in nonpoint source pollution, as well. The reasons for that are first of all it is obvious that farmers have more information about each other than the principal. Second, they live in close proximity and can monitor each other more easily and cheaply. They have relatively stronger social ties that they don't want to lose. The main difference between group lending and nonpoint source pollution is that in group lending each agent has independent production activity and at the end of the period s/he reveals his/her success or failure. During this period of time agents monitor each other since they have jointly liable. Each agent gets a credit from the bank at the beginning of the period. If he is successful at the end, he pays his debt plus some portions of the other agent's debt who fails.

On the other hand, in nonpoint source pollution, there is a joint production, and agents' payment depends on the total group production. If the group is successful, everybody gets fixed payment plus bonus at the end. If the group fails, just the fixed payement.

Having said that, the only difference between previous model and this model is that agents use peer pressure by monitoring each other during the season and using some social sactions (cutting out from the group, losing reputation, losing future income from the contract) if they catch someone shirking. In this section, we will show that peer pressure can make this group contract work by solving the moral hazard problem within the group. So it is crucial to have some kind of peer pressure in order group contract to work. Otherwise, it will return to the previous case where moral hazard exists.

Additional Assumptions:

- Peer monitoring decisions are taken before the realization of returns.
- Agents who put low effort get punished, if they get caught, by some exogenous nonpecuniary penalty (M) and lose their future revenues (V) from the project by not being in the group for future seasons.

- Shirking agents will be punished, if they get caught, even if the group is successful.

Agent 1's expected utilities (EU):

- **When both choose HIGH effort:**

  $EU_1^{HH} = [F_1 + \Pr^{HH} * B_1] - C_1^H(a)$

- **When he chooses HIGH effort and the other LOW effort:**

  $EU_1^{HL} = [F_1 + \Pr^{HL} * B_1] - C_1^H(a)$

- **When he chooses LOW effort and the other HIGH effort:**

  $EU_1^{LH} = [F_1 + \Pr^{LH} * B_1] - C_1^L(a) - \gamma(M + V)$

- **When both choose LOW effort:**

  $EU_1^{LL} = [F_1 + \Pr^{LL} * B_1] - C_1^L(a) - \gamma(M + V)$

Where,

M: Monetary value of peer pressure on agent 'k' by other agents.

V: Future revenue loss of the agent by shirking and being out of the group for next seasons. For static model we are going to assume that this is a exogenous variable.

γ : Probability of being monitored and getting caught.

Agent 1's Maximization Problem:

$$\underset{H,L,\overline{U}}{Max} \begin{Bmatrix} [F_1 + \Pr^{HH} * B_1] - C_1^H(a), [F_1 + \Pr^{HL} * B_1] - C_1^H(a), [F_1 + \Pr^{LH} * B_1] - C_1^L(a) - \gamma(M + V), \\ [F_1 + \Pr^{LL} * B_1] - C_1^L(a) - \gamma(M + V), \overline{U} \end{Bmatrix}$$

Principal's Maximization Problem:

$$Max \left\{ [\Pr^{HH}(mc * A^s - B_T) + (1 - \Pr^{HH})(mc * A^f)] - F_T \right\}$$

Incentive Compatibility (IC) Constraints:

(1) $EU_1^{HH} \geq EU_1^{HL} \rightarrow [F_1 + \Pr^{HH} * B_1] - C_1^H(a) \geq [F_1 + \Pr^{HL} * B_1] - C_1^H(a)$

(2) $EU_1^{HH} \geq EU_1^{LH} \rightarrow [F_1 + \Pr^{HH} * B_1] - C_1^H(a) \geq [F_1 + \Pr^{LH} * B_1] - C_1^L(a) - \gamma(M+V)$

(3) $EU_1^{HH} \geq EU_1^{LL} \rightarrow [F_1 + \Pr^{HH} * B_1] - C_1^H(a) \geq [F_1 + \Pr^{LL} * B_1] - C_1^L(a) - \gamma(M+V)$

(4) $EU_1^{HL} \geq EU_1^{LL} \rightarrow [F_1 + \Pr^{HL} * B_1] - C_1^H(a) \geq [F_1 + \Pr^{LL} * B_1] - C_1^L(a) - \gamma(M+V)$

(5) $EU_1^{HL} \geq EU_1^{LH} \rightarrow [F_1 + \Pr^{HL} * B_1] - C_1^H(a) \geq [F_1 + \Pr^{LH} * B_1] - C_1^L(a) - \gamma(M+V)$

$$\rightarrow \quad C_1^H(a) \leq C_1^L(a) + \gamma(M+V)$$

Note that when the constraint 5 is met, the other 4 IC constraints automatically met, too. So, it is enough for us to take only 5 as an IC constraint. Another point to worth mention is that as long as the group has big enough peer pressure, the agents will have enough incentive to put high effort no matter what other agents do.

Participation Constraint:

(6) $EU_1^{HH} \geq \overline{U} \rightarrow [F_1 + \Pr^{HH} * B_1] - C_1^H(a) \geq \overline{\mathrm{U}}$

Other Constraints

(7) $C_k^H(a_k) > C_k^L(a_k)$

(8) $\Pr^{HH} > \Pr^{HL} = \Pr^{LH} > \Pr^{LL}$

Lagrangian Function :

$$L(\{q,\lambda,\mu) = \{[\Pr^{HH}(mc*A^{s}-2(1-q)p*a^{b})+(1-\Pr^{HH})(mc*A^{f})]-2q*p*a^{b}\}$$
$$+\lambda\Big[[q*p*a^{b}+\Pr^{HH}*(1-q)*p*a^{b}]-C_{1}^{H}(a)-\overline{\mathrm{U}}\Big]+\mu\Big[C_{1}^{L}(a)+\gamma(M+V)-C_{1}^{H}(a)\Big]$$

F.O.C. (w.r.t. (q)

$$\Pr^{HH}2p*a^{b}-2p*a^{b}+\lambda\Big[p*a^{b}-\Pr^{HH}*p*a^{b}\Big]=0$$

$$\lambda=\frac{2p*a^{b}(1-\Pr^{HH})}{p*a^{b}(1-\Pr^{HH})}=2>0$$

(w.r.t. (λ)

$$[q*p*a^{b}+\Pr^{HH}*(1-q)*p*a^{b}]=C_{1}^{H}(a)+\overline{\mathrm{U}}$$

Eq.1) $q=\dfrac{C_{1}^{H}(a)+\overline{\mathrm{U}}-\Pr^{HH}*p*a^{b}}{p*a^{b}(1-\Pr^{HH})}$

OR

Eq.2) $p=\dfrac{C_{1}^{H}(a)+\overline{\mathrm{U}}}{q*a^{b}+\Pr^{HH}*(1-q)*a^{b}}$

(w.r.t. (μ)

$$C_{1}^{L}(a)+\gamma(M+V)=C_{1}^{H}(a)$$

Eq.3) $\gamma=\dfrac{C_{1}^{H}(a)-C_{1}^{L}(a)}{(M+V)}$

These results suggest that joint liability group contracts can be applied under some conditions. (Eq.1) gives us the optimum portion that needs to be allocated for fixed payment. As can be seen from the equation, any increase in $C^{H}(.)$ and reservation utility, increases q, too. This is very intuitive. If an agent has higher abatement cost and reservation utility, proportion that allocated for fixed payment (q) expected to be higher, too. On the other hand, increase in the price per ton abatement (p) will decrease q. This is also very logical because increase in price also increases the fixed payment. However, in order to have stable fixed payment increase in the price (p) can be adjusted by decreasing the portion of the fixed payment (q).

(Eq.2) gives us the optimum price per ton. This is basically restatement of the equation 1. Equation 2 shows that increase in $C^H(.)$ and reservation utility, increases p, as well. This is also an expected result since a high cost and reservation utility agent will demand higher amount of price from the principal in order to join the contract. p and q relation is the same as explained before.

As for the (Eq.3), minimum required monitoring rate supposed to be the ratio of difference between high and low cost, and total social sanctions imposed (M+V). This equation show that increase in $C^H(.)$, increases monitoring rate (γ), too. That is, high cost agents will have more incentive to monitor other agents in order to discourage them from shirking. On the other hand, an increase in $C^L(.)$, decreases monitoring rate (γ). The idea behind this can be very well the agent who put low effort but has higher cost relative to those who put low effort and lower cost would prefer lower rate of monitoring because if he gets caught he will be worse off (his loss will be more because of both higher abatement cost and social sanctions compare to the low cost agent). Finally, an increase in social sanctions (M+V) will decrease the rate of monitoring (γ). This makes sense since having very high social sanctions will have more effect on the agents for not to shirk, which makes required monitoring less needed.

Summary and Conclusions

This paper demonstrates a mechanism that works better for nonpoint source pollution. First of all it is based on the performance not design-based approach. This will lead to direct effect on the water quality improvement. Second of all, this will be a voluntary contract. So whoever thinks that it is profitable and are willing to put effort, will join the contract. Third, it is a group contract. This is very appropriate when individual contributions cannot be determined such as nonpoint sourse pollution. Fourth, it has a fixed payment. One of the most important parts of this kind of contract is to have enough incentive to participate. Having fixed payment can increase the participation but also cause the free-rider problem. Fifth, in order to prevent free-rider problem, we have included peer pressure and social sanctions concepts in our model. Basically, joint liability in payments leads agents to peer monitoring/pressure. Peer monitoring can discourage agent to shirk and induce them to put high effort. This can allow the principal to have some fixed payment in the contract without having any moral hazard problem in order to increase the participation. Results show that this kind of mechanisms may work under some conditions. Once the principal carefully analyze the case and specifies the variables correctly, agents can have enough incentive for not to shirk and put always high effort. This will make both the principal and the agents better off.

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