Agri-environment Policy Design
With Hidden Information and Hidden Action:
Input Quotas vs Input Charges

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Abstract

Moxey, White and Ozanne (1999) have shown how transfer payments coupled with input quotas can be used to design optimal truth-telling mechanisms for voluntary agri-environmental schemes under hidden information about compliance costs. Ozanne, Hogan and Colman (2001) adapted the Moxey et al. model to analyze hidden action in such schemes, analyzing the relationships between input abatement, the cost of monitoring compliance and farmers' risk preferences. White (2002) extended the Moxey et al. model to analyze the design of contracts under both hidden action and hidden information, but used an input charge/transfer payment approach rather than the original input quota/transfer payment one. In addition, he assumed that farmers caught cheating face a variable fine, related to the amount of input they apply in excess of the amount agreed in the contract, rather than a fixed fine as assumed by Ozanne et al. White argues that his results show that an input charge/transfer payment policy is more efficient than a quota when the regulator cannot observe compliance costs of individual farmers. This paper integrates the previous work, developing a model of both hidden action and hidden information in agri-environmental schemes based on the input quota/transfer payment approach of Moxey et al. (1999) and Ozanne et al. (2001), rather than the input charge/transfer payment approach of White (2002), but the variable fine of the latter rather than the fixed fine assumed by Ozanne et al. This integrated model shows that, contrary to White (2002), the input quota and input charges approaches lead to identical outcomes in terms of abatement levels, compensation payments, monitoring costs, probabilities and social welfare.

1. Introduction

Moxey, White and Ozanne (1999) use a principal-agent model to show how transfer payments coupled with input quotas can be used to design optimal truth-telling mechanisms for voluntary agri-environmental schemes such as Countryside Stewardship, Nitrate Sensitive Area Scheme and Environmental Sensitive Area Scheme. The solution results in a menu of contracts specified in terms of transfer payments and input quotas. Producers choose the contract for their type: high compliance cost producers choose a high input quota and low transfer payment contract while low compliance cost producers choose a low quota and high transfer payment contract.

Moxey *et al.* only considered the hidden information (or adverse selection) aspect of asymmetric information problem facing a regulator. However, if the regulator cannot observe post-contractual input use and therefore has to incur monitoring costs to ensure that farmers comply with contracts, there is a hidden action problem as well. Ozanne, Hogan and Colman (2001) adapted the Moxey *et al*. model to analyze hidden action in such schemes, showing that, because of the trade-off between increased environmental benefit and increased cost of monitoring compliance, only a second-best solution can be obtained. Taken together these two papers provide a theoretical framework that covers both types of information asymmetry in agri-environmental policy, but treating them separately. White (2002) extended the Moxey *et al*. model to analyze the design of contracts under both hidden action and hidden information, but used an input charge/transfer payment approach rather than the original input quota/transfer payment one. In addition, he assumed that farmers caught cheating face a variable fine, related to the amount of input they apply in excess of the amount agreed in the contract, rather than a fixed fine as assumed by Ozanne *et al*. White argues that his results show that an input charge/transfer payment policy is more efficient than a quota when the regulator cannot observe compliance costs of individual farmers.

This paper integrates the previous work, developing a model of both hidden action and hidden information in agri-environmental schemes. The model is based on the input quota/transfer payment approach of Moxey *et al*. (1999) and Ozanne *et al*. (2001), rather than the input charge/transfer payment approach of White (2002), but the variable fine of the latter rather than the fixed fine assumed by Ozanne *et al.*.[1] This integrated model shows that, contrary to White (2002), the input quota and input charges approaches lead to identical outcomes in terms of optimal abatement levels, compensation payments, monitoring costs and probabilities of detection, and social welfare.

2. The model

Agri-environmental policy is modeled as a social welfare maximization problem that recognizes the constraints facing policy-makers due to information asymmetry and the costs of monitoring contracts with farmers. The following sections use principal-agent theory to model agri-environmental contracts between a regulator and farmers, progressing from a situation where the regulator has perfect information, through separate models for hidden information and hidden action, to an integrated model which includes hidden information, hidden action and the cost of monitoring compliance.

2.1 Perfect information

Adopting the approach and notation used by Moxey *et al.* (1999), it is assumed that the regulator aims to maximize a social welfare function with three terms:

$$z_i = v(x_i^* - x_i) + (b_i - c_i(x_i)) - (1+e)b_i \qquad i=1,2 \qquad (1)$$

where farmer *2* is assumed to be more efficient than farmer *1*.

The first term on the right hand side of equation (1) represents the benefit of input abatement, where x_i* is the optimal input level used by farmer *i* if he or she does not participate in the scheme, x_i is the agreed input quota if she participates, and *v* measures the environmental benefit per unit of input abatement. The second term, $(b_i – c_i(x_i))$, gives the *i*'th farmer's monetary

[1] Note that, in amalgamating the models, it has been necessary, for the sake of consistency, to make minor notational adjustments when summarizing the models presented in Ozanne *et al*. and White. These adjustments are not always pointed out, but have no significant impact on the results and should not present any difficulty to the careful reader.

utility (or rent) as the difference between the transfer payment, b_i, offered to induce participation and the cost of compliance, $c_i(x_i)$, where the latter function is defined as the profit forgone,

$$c_i(x_i) = \pi_i(x_i^*) - \pi_i(x_i) \qquad (2)$$

with $c_i'(x)<0$, $c_i''(x)>0$, $c_1(x)>c_2(x)$ and $c_1'(x)>c_2'(x)$ by definition (see Moxey *et al.*, 1999, for a more detailed discussion of the properties of the compliance cost function).

The final term on the right-hand side is the net social cost of the transfer payment, where e represents the shadow costs of public funds in terms of the distortionary effects of general taxation. This specification of objective function assumes that the scheme applies to a small area relative to the total agricultural area, so that price effects are zero. It also assumes that the benefits from contracting with one farm do not depend on any other farms joining the scheme; this enables us to use a linear benefits of abatement function.

If the regulator has perfect information about the farmer's compliance cost function and the farmer's actions *ex post*, the objective function (1) is maximized subject to the individual rationality (IR_i) constraints,

$$b_i - c_i(x_i) \geq 0 \qquad i=1,2 \qquad (3)$$

and non-negativity constraints, $x_i \geq 0$ and $b_i \geq 0$. The internal solution is given by,

$$c_i'(\hat{x}_i) = -\frac{v}{1+e} \qquad (4)$$

where $\hat{x}_i$ is the optimal input quota for the i'th farmer when the regulator has perfect information and the corresponding transfer payment is $\hat{b}_i = c_i(\hat{x}_i) = \pi_i^* - \pi(\hat{x}_i)$. Together, the contracts $(\hat{x}_i, \hat{b}_i)$ represent the first-best solution to the problem facing the regulator. Equation (4) indicates that these contracts ensure that the marginal cost of compliance is equal to the marginal benefit of abatement to society. These contracts, arrived at using the input quota/transfer payment approach, are effectively identical to perfect information contracts obtained by White (2002, equation (7)) using the input charge/transfer payment contract approach:

$$t_i = \frac{v}{1+e} \qquad (5)$$

where t_i is the input charge, since social welfare is maximized when $t_i = - c_i'(x_i)$.

2.2 Hidden information with first-best contracts

If the regulator offers the first-best contracts $(\hat{x}_i, \hat{b}_i)$ but cannot observe farmer type, there is an incentive for the less efficient farmer, type 1, to be declare that he or she is a more efficient farmer, since obtaining contract $(\hat{x}_2, \hat{b}_2)$ by this deception earns rent:

$$\hat{b}_2 - c_1(\hat{x}_2) > 0 \quad \text{since } IR_2 \text{ is binding and therefore} \quad c_1(\hat{x}_2) < c_2(\hat{x}_2) = \hat{b}_2$$

Note, however, that a similar incentive to be "economical with the truth" does not exist for the more efficient farmer, who would be worse of if he or she obtained contract $(\hat{x}_1, \hat{b}_1)$:

$$\hat{b}_1 - c_2(\hat{x}_1) < 0 \quad \text{since } IR_1 \text{ is binding and therefore} \quad \hat{b}_1 = c_1(\hat{x}_1) < c_2(\hat{x}_1)$$

Thus, offering the first-best menu of contracts when there is hidden information is costly to the regulator since total transfer payments increase while overall abatement decreases. The regulator may reduce the cost of the scheme by only offering contract $(\hat{x}_1, \hat{b}_1)$. However, this will only attract the less efficient farmers and abatement will be lower than desired.

2.3 Hidden information: second-best contracts

The Moxey *et al.*, 1999, model was based on the assumption that, although the regulator is unable to observe whether individual farmers are more or less efficient, it does have subjective prior probabilities, γ_i, for the two types as well as being able to observe farmer's actions *ex post*. The regulator's aim is therefore to maximize expected social welfare,

$$\bar{z} \;=\; \sum_{i=1}^{2} \gamma_i [v(x_i^* - x_i) + (b_i - c_i(x_i)) - (1+e)b_i] \qquad (6)$$

subject to the individual rationality constraints (3) and hidden information incentive compatibility ($HIIC_i$) constraints,

$$b_i - c_i(x_i) \geq b_j - c_i(x_j) \qquad i, j = 1,2;\ i \neq j. \qquad (7)$$

which ensure that there is no incentive for either producer to choose the wrong contract. Moxey *et al.* show that IR_2 and $HIIC_1$ are binding, and that the second-best contracts, $(\hat{\hat{x}}_i, \hat{\hat{b}}_i)$, are given by:

$$c_1'(\hat{\hat{x}}_1) = -\frac{v}{1+e} \qquad (8)$$

$$c_2'(\hat{\hat{x}}_2) = -\frac{v}{1+e} - \frac{\gamma_1 e}{\gamma_2 (1+e)}\left[c_2'(\hat{\hat{x}}_2) - c_1'(\hat{\hat{x}}_2)\right] > -\frac{v}{1+e} \qquad (9)$$

$$\hat{\hat{b}}_1 - c_1(\hat{\hat{x}}_1) = \hat{\hat{b}}_2 - c_1(\hat{\hat{x}}_2) \qquad (10)$$

$$\hat{\hat{b}}_2 - c_2(\hat{\hat{x}}_2) = 0 \qquad (11)$$

From equation (8) it can be seen that the input quota offered to the less efficient farmer is the same as under perfect information, i.e. $\hat{\hat{x}}_1 = \hat{x}_1$. However, equation (9) shows that, since $c_1'(x) > c_2'(x)$ by definition, the quota offered to the more efficient farmer is higher than in the first-best solution; i.e. abatement is reduced, $\hat{\hat{x}}_2 > \hat{x}_2$. Furthermore, although equation (11) shows that the transfer payment offered the more efficient farmer equals his or her cost of compliance, equation (10) shows that the less efficient retains some rent.

The corresponding hidden information contracts obtained by White, 2002, equations (10) and (11)) using the input charge/transfer payment contract approach are defined by the following:

$$t_i = \frac{v}{1+\lambda} \tag{11}$$

$$t_2 = \frac{v}{1+\lambda} + \frac{\gamma_1 e}{\gamma_2 (1+e)} \left[\frac{x_2(t_2) - x_1(t_2)}{x_2'(t_2)} \right] \tag{12}$$

White does not point this out, but, as in the perfect information case, these second-best contracts under hidden information - using the input quota/transfer payment approach and input quota/transfer payment approaches respectively - are effectively identical. For the less efficient farmer, this is obvious from equations (8) and (11). It is less obvious, from comparison of equations (9) and (12), for the more efficient farmer, but nevertheless true, since it is simple to show that as $c_i'(t_j) = x_i(t_j)$,

$$c_2'(x_2) - c_1'(x_2) = \frac{x_2(t_2) - x_1(t_2)}{x_2'(t_2)} \tag{13}$$

Thus, when hidden information alone is considered, the input abatement levels, compensation payments, social welfare and informational efficiency losses are exactly the same whether agri-environmental contracts are designed using an input charge or input quota approach.

2.4 Hidden action

If the regulator observes the farm type but not the farm's input use without monitoring, there is an incentive for both types of farmers to accept the appropriate contract, but exceed the input quota stipulated in the contract (or implied by the input charge), whilst claiming the full transfer payment. Ozanne *et al.*, 2001, and White, 2002, both show monitoring can reduce this hidden action problem, but that, because there is a trade-off between input abatement and the monitoring costs borne by the taxpayer, input abatement is lower than under perfect information. However, there are differences in how they model the situation.

Both assume that the regulator monitors input use and fines any farmer found not be complying with the terms of the agreed contract. Monitoring is assumed to be perfectly accurate in the sense that when a farm is monitored the regulator observes the input level without error. The fine level is exogenous, but the regulator can determine the probability of detection by varying the frequency of monitoring.[2] However, White assumes farmers caught cheating face a variable fine, which is proportional to the quantity of input they apply in excess of the reported amount, whereas Ozanne *et al.* assume a fixed fine. In addition, Ozanne *et al*. assume the compensation payment is confiscated, while White does not.

Here, a mixture of the above approaches is followed. The input quota/transfer payment approach is used, as in Moxey *et al*. and Ozanne *et al*. However, transfer payments are not confiscated and fines are not fixed; rather, as in White's model, it is assumed, that the penalty for non-compliance is a fine of η per unit of input in excess of the agreed quota, where η is the same for both types of farmer. The regulator offers farmers a menu of contracts, comprising of input quotas, transfer payments and monitoring regimes. The probability of detecting non-compliance for the *i*'th farmer, corresponding to the respective monitoring frequency, is set at p_i. In addition, for simplicity, monitoring costs are assumed to be linear, mp_i, where the parameter m representing the cost of monitoring a farm with certainty, $p=1$, is the same for both farm types. Thus, the regulator's objective function is:[3]

$$z_i = v(x_i^* - x_i) + (b_i - c_i(x_i)) - (1+e)(b_i + mp_i) \qquad i=1,2 \qquad (14)$$

[2] It is a standard result that regulators prefer high penalties as this reduces the frequency of monitoring and thus monitoring costs. However, penalties for non-compliance have tended to be low and the legislation establishing agri-environmental schemes has not allowed regulators to set their own penalties (National Audit Office, 1997).

[3] White's original specification does not allow for the net social cost of monitoring to the taxpayer by multiplying the final term in the social welfare function, mp_i, by $(1+e)$. Here we follow Ozanne *et al*., who do.

White demonstrates that, to ensure incentive compatibility, monitoring must be set such that $t_i = p_i\eta$, that is the input charge is equal to the expected fine per unit of input, and replaces the last term in the objective function with mt_i/η. For, if $t_i > p_i\eta$ risk neutral producers would have an incentive to under report input use. On the other hand, if $t_i < p_i\eta$ monitoring costs would be excessive, since setting p_i such that $t_i = p_i\eta$ is sufficient to ensure compliance. Using the input quota/transfer payment approach, this is equivalent to introducing the explicit hidden action incentive compatibility ($HAIC_i$) constraints,

$$p_i\eta \geq -c_i'(x_i) \qquad (15)$$

into the model. These $HAIC_i$ constraints state that, to deter cheating, the expected fines per unit of abatement must be at least as great as the marginal profits foregone (recalling equation (2)) for the respective farm types. They follow directly from White's characterization of the monitoring regime, since $t_i = -c_i'(x_i)$. They may also be derived by noting that, in order to deter cheating, the certain return from compliance must not be less than the expected return from non-compliance:

$$\begin{aligned}\hat{\hat{b}}_i - c_i(\hat{\hat{x}}_i) &\geq (1-p_i)(\hat{\hat{b}}_i - c_i(x_i)) + p_i(\hat{\hat{b}}_i - c_i(x_i) - \eta(x_i - \hat{\hat{x}}_i)) \\ &\geq \hat{\hat{b}}_i - c_i(x_i) - p_i\eta(x_i - \hat{\hat{x}}_i)\end{aligned}$$

$$\therefore \quad p_i\eta \geq -\frac{c_i(x_i) - c_i(\hat{\hat{x}}_i)}{x_i - \hat{\hat{x}}_i} \qquad \text{for all} \quad x_i \geq \hat{\hat{x}}_i$$

In the limit $x_i \to \hat{\hat{x}}_i$ the fraction in the last equation becomes the marginal cost of compliance, $c_i'(\hat{\hat{x}}_i)$.

The hidden action model can now be solved by maximizing social welfare (14) subject to the IR_i constraints (3), the $HAIC_i$ constraints (15), the non-negativity constraints, $x_i \geq 0$ and $b_i \geq 0$, and the probability of detection constraints, $0 \leq p_i \leq 1$. The internal solution for the regulator, yielding the optimal input quotas, transfer payments and detection probabilities respectively for the two types of farmer, is given by the following:

$$c_i'(\hat{\hat{x}}_i) = -\frac{v}{1+e} + \frac{m}{\eta} c_i''(\hat{\hat{x}}_i) > -\frac{v}{1+e} \tag{16}$$

$$\hat{\hat{b}}_i = c_i(\hat{\hat{x}}_i) \tag{17}$$

$$\hat{\hat{p}}_i = -\frac{c_i'(\hat{\hat{x}}_i)}{\eta} \tag{18}$$

Equation (16) confirms that, since $c_i''(x_i)>0$ by definition, the quota offered to the more efficient farmer is higher than in the first-best solution; i.e. abatement is reduced, $\hat{\hat{x}}_i > \hat{x}_i$, for both types of farmer. Once again, taking account of minor notational adjustments and the fact that here we have allowed for the social cost of monitoring to the taxpayer, it can be seen that the above is identical to the solution obtained by White, 2002, using the input charge/transfer payment approach,

$$t_i = \frac{v}{1+e} + \frac{m}{\eta x_i'(t_i)}$$

since social welfare is maximized when $t_i = -c_i'(x_i)$ and $\frac{1}{x_i'(t_i)} = \frac{dt_i}{dx_i} = -\frac{dc_i'(x_i)}{dx_i} = -c_i''(x_i)$.

The model presented above adopts the variable fine approach of White, 2002, rather than the fixed fine approach of Ozanne *et al.*, 2001. For the sake of completeness, it can be readily shown that the above solution is identical to that obtained by Ozanne *et al.*. For, if instead of specifying a fine per unit input, η, the regulator imposes fixed fines, F_i, where,

$$F_i = -\frac{\eta c_i'(\hat{\hat{x}}_i)}{c_i''(\hat{\hat{x}}_i)}$$

equation (16) can be rewritten as,

$$c_i'(\hat{\hat{x}}_i) = -\frac{v}{(1+e)\left(1+{}^{m}\!/\!_{F}\right)}$$

which is the Ozanne *et al.* solution for risk neutral farmers and linear monitoring cost and environmental benefit functions. It will be noted that this requires differing fines for the two types of farmer, $F_1 \neq F_2$, whereas the variable fine approach assumes the two types of farmer face the same fine per unit of input in excess of the quota, η, if they are found in breach of contract.

2.5 Hidden information and hidden action

If the regulator observes neither the farm type nor their actions there is potential for a combination of both hidden information (adverse selection) and hidden action (moral hazard) problems to occur. Amalgamating the models presented in sections 2.3 and 2.4, the regulator's problem is then to maximize the expected social welfare function:

$$\bar{z} = \sum_{i=1}^{2} \gamma_i [v(x_i^* - x_i) + (b_i - c_i(x_i)) - (1+e)(b_i + mp_i)] \tag{19}$$

subject to the IR_i constraints (3), $HIIC_i$ constraints (7), $HAIC_i$ constraints (15), non-negativity, $x_i \geq 0$ and $b_i \geq 0$, and probability of detection (or monitoring frequency) constraints, $0 \leq p_i \leq 1$. Assuming a separating solution holds, so that IR_2 and $HIIC_1$ and both the $HAIC_i$ constraints are binding, the second-best contracts, ($\hat{\hat{x}}_i, \hat{\hat{b}}_i, \hat{p}_i$), are given by:

$$c_1'(\hat{\hat{x}}_1) = -\frac{v}{1+e} + \frac{m}{\eta} c_1''(\hat{\hat{x}}_1) > -\frac{v}{1+e} \tag{20}$$

$$c_2'(\hat{\hat{x}}_2) = -\frac{v}{1+e} + \frac{m}{\eta} c_2''(\hat{\hat{x}}_2) - \frac{\gamma_1 e}{\gamma_2 (1+e)} \left[c_2'(\hat{\hat{x}}_2) - c_1'(\hat{\hat{x}}_2)\right] > -\frac{v}{1+e} \tag{21}$$

$$\hat{\hat{b}}_1 - c_1(\hat{\hat{x}}_1) = \hat{\hat{b}}_2 - c_1(\hat{\hat{x}}_2) \tag{22}$$

$$\hat{\hat{b}}_2 - c_2(\hat{\hat{x}}_2) = 0 \qquad (23)$$

$$\hat{p}_i = -\frac{c_i'(\hat{\hat{x}}_i)}{\eta} \qquad i = 1,2 \qquad (24)$$

Once adjustments have been made for minor changes in notation and treatment of the social cost of monitoring, it can be seen that the above is identical to White's separating solution obtained using the input charge/transfer payment approach,

$$t_1 = \frac{v}{1+e} + \frac{m}{\eta\, x_1'(t_1)}$$

$$t_2 = \frac{v}{1+e} + \frac{m}{\eta\, x_2'(t_2)} + \frac{\gamma_1 e}{\gamma_2(1+e)}\left[\frac{(x_2(t_2) - x_1(t_2))}{x_2'(t_2)}\right]$$

since social welfare is maximized when $t_i = -c_i'(x_i)$ and, as shown in sections 2.3 and 2.4,

$$\frac{1}{x_i'(t_i)} = -c_i''(\hat{x}_i) \qquad \text{and} \qquad c_2'(x_2) - c_1'(x_2) = \frac{x_2(t_2) - x_1(t_2)}{x_2'(t_2)}$$

3. Conclusion

Using principal-agent theory, agri-environmental policy has been modeled as a social welfare maximization problem that recognizes the constraints facing policy-makers due to information asymmetry and the social costs of monitoring contracts with farmers. Previous work by Moxey *et al*. (1999), Ozanne *et al*. (2001) and White (2002) has been combined to provide a model of both hidden action and hidden information in agri-environmental schemes. The model utilizes the input quota/transfer payment approach of Moxey *et al*. (1999) and Ozanne *et al*. (2001), rather than the input charge/transfer payment approach of White (2002), but the variable fine of the latter rather than the fixed fine assumed by Ozanne *et al*. It has been shown that, contrary to White (2002), the input quota and input charges approaches lead to identical outcomes in terms of optimal abatement levels, compensation payments, monitoring costs, detection probabilities and social welfare.

It is intended that further work will extend the model to allow for farmer risk aversion, as in Ozanne *et al*. (2001), and use numerical simulations - based on plausible representations of production technology, farmer's risk preferences and monitoring costs - to analyze the relative importance of hidden information and hidden action in the design of agri-environmental contracts. Other possible areas include the effects of income uncertainty (as in Fraser, 2002) and repeated contracts (as in Hogan, 2002), and extending the two-producer type model to a continuum of producer types (as in White and Ozanne, 1997).

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