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Use of Penalties and Rewards in Agri-Environmental Policy

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Abstract

Achieving high compliance rates in incentive-based agri-environmental schemes is an important issue. This paper explores the use of a mixed penalty-reward approach under heterogeneous compliance costs. Specifically, we examine the use of a "compliance reward" under asymmetric information and output price uncertainty. Using a budget-neutral approach, three possible sources of financing are considered: 1. funds obtained by reducing monitoring effort; 2. the proceeds of fines collected from participating farmers who are inspected and found not to be in compliance; and 3. money saved by reducing the number of farmers enrolled. We discuss the advantages and disadvantages of each source of funding and analyze them numerically for both risk-neutral and risk-averse farmers. We show that under certain conditions a mixed penalty-reward system can increase the likelihood of compliance without increasing programme costs. For risk-averse farmers, however, conditions that ensure a positive outcome from compliance rewards become more restrictive. The implications of these findings are outlined for the future design of agri-environmental schemes with reference to cost-share working lands programmes such as EQIP in the United States.

Keywords: Agri-environmental policy, moral hazard, penalties, payments for compliance

JEL codes Q12 Q20 Q28 Q57

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1. Introduction

Agri-environmental schemes are receiving increasing attention as a means of enhancing the supply of environmental public goods or reducing negative externalities associated with agricultural activities. Many schemes offer incentive payments to encourage farmers to adopt environmentally-friendly farming methods. In the United States, the National Resources Conservation Service (NRCS) and the Farm Service Agency (FSA) of the U.S. Department of Agriculture manage voluntary agri-environmental programmes (conservation programmes) such as the Conservation Reserve Program (CRP), the Environmental Quality Incentives Program (EQIP), and the Conservation Security Program (CSP). Although the focus in the United States was originally on taking environmentally-sensitive land out of production, emphasis has been broadened to working-land programmes, in which payments are made to farmers to adopt production practices that improve water and air quality, and protect wildlife habitat. Agri-environmental schemes that involve these broader objectives are increasingly popular in many other countries, for example, the Environmentally Sensitive Areas Scheme (ESAS) and the Countryside Stewardship Scheme (CSS) in the United Kingdom.

Asymmetric information poses a challenge in the design of incentive-based agri-environmental schemes. The difficulty originates from the fact that the agri-environmental agency does not have accurate information on farmers' characteristics (raising the issue of adverse selection) and/or can only observe their actions imperfectly after a contract is signed (raising the issue of moral hazard[2]). Adverse selection arises when low-cost farmers have an incentive to disguise themselves as high-cost farmers in order to obtain higher payments under a scheme. This can result in overcompensation, lower environmental benefits and reduced cost effectiveness. Moral hazard arises if some farmers receive payments without fulfilling their contractual obligations. In summary, information asymmetry is likely to result in reduced outcomes and it is important to address the issue in designing agri-environmental programmes.

Many authors that have addressed information asymmetry have focused on adverse selection (Spubler 1988; Chambers 1992; Bourgeon et al. 1995; Wu and

[2] In general, continuous actions, such as the amount of manure applied to farmland, are harder to monitor than discrete actions, such as the installation of equipment to handle animal waste. However, lack of maintenance or improper use of such equipment can also result in low environmental performance.

Babcock 1996; Latacz-Lohmann and Van der Hamsvoort 1997; Moxey et al. 1999). Choe and Fraser (1999) observe that far less attention has been devoted to the problem of moral hazard and compliance monitoring[3]. Ozanne et al. (2001) and Fraser (2002)[4] examine the likelihood of compliance and conclude that risk aversion among farmers can diminish the moral hazard problem in agri-environmental programmes[5]. Hart and Latacz-Lohmann (2005) investigate the implications of variations in compliance costs, assuming a uniform distribution. The role of penalties has been considered in the literature, but for political reasons, the actual use of penalties in agri-environmental programs is often limited and the inspection rate may be low.

One possibility for increasing the effectiveness of environmental schemes is to use "compliance rewards", i.e., payments made to farmers who, when inspected, are found to be in compliance with the terms of a scheme. Although not currently applied in the agricultural area, this approach is being advocated by the U.S. Environmental Protection Agency (EPA) through its National Environmental Performance Track Program[6]. A limited amount of economic analysis exists on the effect of this type of pecuniary reward. Falkinger and Walther (1991) use a detailed theoretical model to investigate the role of compliance rewards, focusing on tax compliance behaviour. Other recent papers (e.g., Alm et al., 1992; Torgler, 2003) use an experimental approach in laboratory experiments. Feld et al. (2006) discuss the impact of compliance rewards in the context of self-declared taxation obligations and provide a design mechanism for field experiments.

In this paper we build upon the work of Fraser and Hart et al. to examine the effect of introducing compliance rewards on compliance rates in agri-environmental programmes, focusing on the model used in working land payment programmes such as EQIP. That programme provides an initial cost-share payment to farmers who agree

[3] Cohen (1999) also points out that enforcement and monitoring have received far less attention than other issues in the general environmental economics literature.

[4] Fraser includes output price uncertainty in his model. He also shows that the likelihood of compliance can be increased by changing inversely penalties and the probability of detection, keeping the expected penalty unchanged.

[5] Stranlund, J.K. (2006) analyzes the effects of risk aversion on compliance choice in markets for pollution control. Yano and Blandford (2008) consider simultaneous output price and production uncertainty and examine the impact of risk aversion among farmers on the likelihood of compliance. They find that if a conservation practice has a risk increasing effect, moral hazard is more problematic.

[6] Under the National Environmental Performance Track Program (NEPTP), EPA pays rewards to firms that achieve or exceed minimum regulatory requirements and use additional measures to improve environmental performance.

to adopt environmentally-friendly production practices[7]. Using a budget-neutral approach[8] we consider three possible sources of financing for rewards: 1. funds obtained by reducing the inspection rate (monitoring expenditures); 2. use of the proceeds from fines imposed on farmers who violate contractual obligations; and 3. money saved by reducing the number of farmers enrolled in the programme (total initial cost-share payments). The advantages and disadvantages of each source are examined theoretically and numerically for both risk-neutral and risk-averse farmers. In addition, we investigate the conditions that determine the preferred choice between monitoring effort and compliance rewards when budgetary savings or additional budgetary resources are available.

Our results suggest that under certain conditions, the introduction of compliance rewards can increase compliance rates for both risk-neutral and risk-averse farmers. We conclude that if the cost of monitoring per farmer is quite high, reducing monitoring effort to fund compliance rewards is effective. However, a relatively large reduction in the probability of inspection will result in lower compliance rates among risk-averse farmers. Proceeds from fines can also be used in conjunction with that approach if non-compliance rates are initially high. Money saved by reducing programme enrolment should be used only when the agri-environmental agency is able to estimate each farmer's potential contribution to environmental quality, as in the case under some U.S. programmes[9]. Additionally, if extra budgetary resources are made available, the compliance reward is a preferred instrument if monitoring costs per farmer are high.

In the next section we develop a basic model for compliance monitoring in the context of cost sharing. In section 3 we develop a theoretical model to examine the role of compliance rewards in agri-environmental schemes, and discuss the advantages and disadvantages of each source of funding. Section 4 presents the results of numerical analysis using the Monte Carlo method to illustrate the main findings in sections 2 and 3. The final section of the paper presents our conclusions and their implications for the

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7 Lump sum incentive payments are also associated with EQIP but we focus on its cost sharing aspects in this paper.

8 The environmental agency may be able to increase its budget, but since the issue is frequently one of deciding how to allocate existing financial resources, our primary focus is on a budget-neutral approach to funding compliance rewards. We assume that the environmental agency seeks to allocate funds optimally to maximize environmental performance subject to its budget constraint.

9 For example, the NRCS uses an "offer index" to estimate farmers' potential contribution to environmental quality in EQIP.

design and implementation of agri-environmental policies in the United States and other countries.

2. The Basic Model of Compliance Monitoring under Cost Sharing

We begin with a cost sharing model. There is a working lands programme providing a pre-specified cost share payment to farmers for the adoption of specific production practices, as is the case under the EQIP programme in the United States. Each farmer can take one of two decisions: non-participation or participation. It is assumed that the cost share rate, $\gamma \in (0,1)$, is based on expected compliance costs (fixed and variable) that are unrelated to production, denoted by I^e. For ease of exposition we use the term "direct" compliance costs for such costs in the remainder of the paper. In addition, we assume that implementing required practices reduces the level of output. Since a cost share payment does not cover these costs completely, we assume that there are expected (monetary) compliance benefits, B^e, to farmers from adopting the proposed conservation practice. Denoting the expected profit foregone by Φ^e, a farmer chooses to participate in the programme if $B^e - (1-\gamma)I^e - \Phi^e > 0$. Note that if the expected compliance benefit exceeds the expected direct compliance cost plus expected profit foregone, the agri-environmental agency does not have to provide a cost share payment to induce a farmer to enter the scheme. Therefore, it is reasonable to assume that $B^e < I^e + \Phi^e$, that is, cost sharing is an incentive for participation (not for compliance).

Again, following the design of the EQIP programme, after a contract is signed, the farmer faces three possible choices: 1) contract withdrawal[10]: the farmer cancels the contract; 2) compliance: the farmer abides by terms of the contract; and 3) non-compliance (cheating): the farmer takes the cost share payment, but does not fulfil the contractual obligations. Now let I^a, B^a, and Φ^a denote the actual compliance cost (*ex post*), actual private benefits from compliance, and profit foregone, respectively. We assume that there is uncertainty in profit due to random output price variation. If $B^a - (1-\gamma)I^a - \Phi^a < 0$, and there is no penalty for cancellation, the farmer chooses contract withdrawal.

[10] The contract withdrawal phenomenon in the EQIP programme is examined by Cattaneo (2003) using a logit model.

Let us focus on N participating farmers adopting an identical practice. Assuming that the expected direct compliance cost and the cost share rate is the same for all farmers, the i^{th} farmer's expected payoff[11] under each choice can be expressed as:

$$E_p \pi_i^c = B_i^a - I_i^a + \gamma I^e + (\bar{p} - c_i)\tilde{y}_i \tag{1}$$

$$E_p \pi_i^{nc} = \gamma I^e + (\bar{p} - c_i) y_i \tag{2}$$

where $\bar{p}$ is expected output price, c_i is unit cost of output, and y_i represents the level of output that the i^{th} farmer produces $y_i > \tilde{y}_i$ for all $i = 1, \ldots, N$. The superscripts c and nc indicate compliance and non-compliance respectively. E_p is the expectation operator defined over p, which has a cumulative distribution function, $\Theta : \Re \to [0,1]$.

If there is no monitoring and no penalty, the risk-neutral farmer chooses non-compliance when $B_i^a < I_i^a + \Phi_i^a$ and vice versa ($\Phi_i^a = (y_i - \tilde{y}_i)(\bar{p} - c_i)$). Since we assume $B^e < I^e + \Phi^e$ initially, the likelihood of $B_i^a < I_i^a + \Phi_i^a$ is high. In that case the i^{th} farmer will choose not to comply with terms of the contract.

We now introduce the probability of inspection and penalties into our model. We assume that the (objective) probability of inspection determined by the agri-environmental agency is known with certainty by all farmers and independent of farmers' previous behaviour (i.e., there is state-independent auditing)[12] and independent of output price. Monitoring is assumed to be perfect in the sense that once a participating farmer is inspected, any violation of the terms of the contract will be discovered. The expected payoff from compliance and non-compliance can now be expressed as:

$$E\pi_i^c = B_i^a - I_i^a + \gamma I^e + (\bar{p} - c_i)\tilde{y}_i \tag{3}$$

$$E\pi_i^{nc} = \gamma I^e + (\bar{p} - c_i) y_i - \theta F \tag{4}$$

where $\theta \in (0,1]$ represents the objective probability of inspection and F is the size of penalty for non-compliance, which is assumed to be greater than the initial cost share payment. E is the expectation operator defined over p and θ. The risk-neutral farmer selects compliance if:

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[11] Fixed (production) cost is not included, but does not affect farmers' compliance behaviour.

[12] Harrington (1988), Friesen (2003), and Fraser (2004) investigate state-dependent monitoring schemes using a dynamic game model which can provide cost savings for an agri-environmental agency. This aspect is not discussed in this paper.

$$I_i^a + \Phi_i^a - B_i^a < \theta F \;. \tag{5}$$

This means that if the expected penalty is greater than net total compliance cost, the risk-neutral farmer will comply with the scheme. If the net total compliance cost, $\Gamma_i = I_i^a + \Phi_i^a - B_i^a$ is distributed according to the distribution function $g(\Gamma)$ with associated cumulative $G(\Gamma)$, then the compliance rate will be $\Omega = G(\theta F)$. An increase in the expected penalty results in an increase in the number of farmers in compliance because $\partial\Omega / \partial\theta = F \cdot G' \geq 0$, and $\partial\Omega / \partial F = \theta \cdot G' \geq 0$.

However, the variance of payoffs should be taken into account for risk-averse farmers. The variance of the payoff from compliance (π_i^c) is:

$$\sigma^2_{\pi_i^c} = \int_p \{\pi_i^c - E\pi_i^c\}^2 d\Theta(p) = \tilde{y}_i^2 \sigma_p^2 \tag{6}$$

and the variance of the payoff from non-compliance is given by:

$$\begin{aligned}\sigma^2_{\pi_i^{nc}} &= \int_p (1-\theta)\{\gamma I^e + (p - c_i) y_i - E\pi_i^{nc}\}^2 d\Theta(p) \\ &\quad + \int_p \theta\{\gamma I^e + (p - c_i) y_i - F - E\pi_i^{nc}\}^2 d\Theta(p)\end{aligned} \;. \tag{7}$$

Equation (7) can be re-expressed as[13]:

$$\sigma^2_{\pi_i^{nc}} = y_i^2 \sigma_p^2 + (\theta - \theta^2) F^2 \,. \tag{8}$$

The variance of the payoff from non-compliance is greater than from compliance since:

$$\sigma^2_{\pi_i^{nc}} - \sigma^2_{\pi_i^c} = (y_i^2 - \tilde{y}_i^2)\sigma_p^2 + (\theta - \theta^2) F^2 > 0 \,. \tag{9}$$

Because an increase in the variance of the payoff has a negative impact on expected utility, risk-averse farmers are more likely to comply with the scheme[14]. Moral hazard becomes less problematic for risk-averse farmers under output price uncertainty.

3. The Compliance Reward Model

We now extend the model to include compliance rewards. As indicated in the introduction, three possible sources of financing rewards are considered[15]. Before analyzing the implications of each of these, a general framework for the compliance

[13] The derivation is in Appendix A.

[14] This result is consistent with the model developed by Fraser (2002).

[15] Money saved by reducing the initial payment level (cost share rate) could also be used. However, this increases the probability of non-participation and contract withdrawal discussed in section 2. A reduction in the initial level of payment is quite risky for the agri-environmental agency. Thus, we exclude this possibility.

reward model is developed. The i^{th} farmer's expected payoff under compliance and non-compliance is specified by:

$$E\pi_i^c = B_i^a - I_i^a + \gamma I^e + (\overline{p} - c_i)\tilde{y}_i + (\theta - \Delta\theta)R \tag{10}$$

and

$$E\pi_i^{nc} = \gamma I^e + (\overline{p} - c_i)y_i - (\theta - \Delta\theta)F \ , \tag{11}$$

where R represents the compliance reward per farmer and $\Delta\theta$ is the difference between the initial and new objective probabilities of inspection. The latter term is introduced to reflect the option of reducing the inspection rate in order to conserve resources for the payment of rewards. The difference between the expected payoff from compliance and non-compliance is:

$$E\pi_i^c - E\pi_i^{nc} = B_i^a - I_i^a - \Phi_i^a + (\theta - \Delta\theta)(R + F) \, . \tag{12}$$

If this difference is positive, the risk-neutral farmer will comply with the scheme. The compliance rate will be $\Omega = G((\theta - \Delta\theta)(R + F))$. Therefore, if the following condition is satisfied, the compliance rate among risk-neutral farmers is higher than before (with the pure penalty system):

$$(\theta - \Delta\theta)R > \Delta\theta F \ . \tag{13}$$

Now let us consider the case when farmers are risk-averse. Again, we need to take account of the variance of payoffs to examine the effect of rewards on compliance. The variances of payoff from non-compliance and compliance are:[16]

$$\sigma_{\pi_i^{nc}}^2 = y_i^2 \sigma_p^2 + (\tilde{\theta} - \tilde{\theta}^2)F^2 \tag{14}$$

and

$$\begin{aligned} \sigma_{\pi_i^c}^2 &= \int_p (1 - \tilde{\theta})\{\gamma I^e + (p - c_i)\tilde{y}_i - E\pi_i^c\}^2 d\Theta(p) \\ &\quad + \int_p \tilde{\theta}\{\gamma I^e + (p - c_i)\tilde{y}_i + R - E\pi_i^c\}^2 d\Theta(p) \end{aligned} \tag{15}$$

or

$$\sigma_{\pi_i^c}^2 = \tilde{y}_i^2 \sigma_p^2 + (\tilde{\theta} - \tilde{\theta}^2)R^2 \, , \tag{16}$$

where $\tilde{\theta} = \theta - \Delta\theta$. The sign of the difference between two variances, (14) and (16) is ambiguous. Given the size of penalty, the decision on compliance by the risk-averse farmer depends on the amount of the compliance reward per farmer.

[16] These variances are derived using the same procedure as in Appendix A.

Table 1: The amount of compliance reward per farmer and change in the inspection rate

	Source for compliance reward	Compliance reward per farmer	Reduction in the inspection rate
1	Funds obtained from reducing the inspection rate	$\frac{N\Delta\theta k}{\tilde{\theta}\alpha N} = \frac{\Delta\theta k}{\tilde{\theta}\alpha}$	$\Delta\theta$
2	Fines collected in the previous period	$\frac{A}{\theta\alpha N}$	0
3	Funds obtained by reducing the number of farmers enrolled in the scheme	$\frac{n\gamma I^{e}}{\theta\alpha(N-n)}$	0

Table 1 summarizes the compliance reward per farmer, *R*, and the reduction in the probability of inspection for each source. It is not difficult to derive results for a combination of financing sources. Details on the determination of the compliance reward are given in Appendix B.

In the table, *A* represents the revenue collected from fines in the previous (initial) period, $\alpha \in (0,1]$ is the expected proportion of farmers that are in compliance (expected compliance rate)[17], and *n* is the number of farmers excluded from the scheme.

To assess how compliance rewards might be used, we list the pros and cons associated with each source of funding.

i) *Money from reducing monitoring effort*

Decreasing the level of monitoring effort can increase the likelihood of compliance only if the cost of monitoring per farmer is sufficiently high. However, the new inspection rate has to be set a sufficiently high level to influence behaviour by risk-averse farmers to yield the desired environmental outcome. A large reduction in monitoring effort relative to the initial inspection rate[18] is likely to result in low compliance rates and unintended low environmental performance because the variance

[17] α is assumed to be the same for the inspected group and the non-inspected group.

[18] The variance of the payoff from compliance depends on relative reductions in inspection rates rather than absolute reductions. It increases quadratically as the objective probability of inspection declines. In particular, over 80% reductions in the inspection rate results in a high variance of the payoff from compliance. Consequently, the risk-averse farmer has less incentive to comply with the terms of the contract.

of the payoff from compliance will be high. This issue is examined through numerical analysis in the next section.

ii) *Proceeds obtained from fines*

Use of the revenue collected from fines can increase compliance rates for both risk-neutral and risk-averse farmers since it increases the expected payoff (utility) from compliance. However, a critical shortcoming of this approach is that if farmers comply, accumulated proceeds will run out at some point regardless of how these are distributed over time. The amount of fines collected involves an endogeneity problem – we need the revenue from fines to pay rewards, but the payment of rewards reduces the revenue obtained from fines. As a result, variability is introduced into the payment of rewards and this creates variability in compliance rates over time. Despite this weakness, wise use of this source of funding can increase compliance rates. This is explored further in subsequent numerical analysis.

iii) *Money saved by reducing the number of farmers enrolled*

Although stable high compliance rates can be achieved using this source of funding, lower total environmental performance can result if the agri-environmental agency cannot measure accurately the contribution of each farm to environmental quality. Producers whose participation in a scheme could potentially generate large environmental benefits may be excluded. Moreover, even if the agency can rank all applicants in terms of their potential contribution, use of this source of funding does not guarantee cost-effectiveness. The agri-environmental agency may exclude more farmers from the scheme than is necessary to achieve maximum compliance. This issue is also analyzed through numerical analysis.

Thus far, we have focused on the case where the agri-environmental agency reallocates existing funds to finance compliance rewards. However, the revenue collected from fines and savings from reducing the number of farmers enrolled could also be allocated to increasing monitoring effort. In the rest of this section, we explore the trade-off between payments for compliance and monitoring effort and derive conditions that determine the preferred instrument.

Let T be the total amount realized from budgetary savings (this could also relate to additional budgetary resources allocated to an agency). If the agri-environmental agency spends this amount to increase the inspection rate, the new probability of inspection, $\tilde{\theta}$ can be expressed as:

$$\tilde{\theta} = \theta + \frac{T/v}{N} \quad , \tag{17}$$

where the cost of monitoring per farmer is v. The difference between the expected payoff from compliance and non-compliance is:

$$E\pi_i^c - E\pi_i^{nc} = \left(\theta + \frac{T}{vN}\right)F + B_i^a - I_i^a - \Phi_i^a \,. \tag{18}$$

The compliance rate can be written as: $\Omega = G((\theta + (T/vN))F)$. If money is spent on compliance rewards, the expected payoff from compliance becomes:

$$E\pi_i^c = B_i^a - I_i^a + \gamma I^e + (\bar{p} - c_i)\tilde{y}_i + \theta(T/\alpha\theta N) \,. \tag{19}$$

The difference between the two expected payoffs is:

$$E\pi_i^c - E\pi_i^{nc} = \left(\frac{T}{\alpha N} + F\right)\theta + B_i^a - I_i^a - \Phi_i^a \tag{20}$$

and in this case, $\Omega = G(((T/\alpha N) + F)\theta)$. Therefore, if the following condition is satisfied, spending money on compliance rewards has a larger positive impact on the compliance rate than spending additional resources on monitoring:

$$\left(\frac{T}{\alpha N} + F\right)\theta > \left(\theta + \frac{T}{vN}\right)F \,, \text{ or } \frac{v}{\alpha} > F \quad . \tag{21}$$

Since α lies between zero and one, if the cost of monitoring per farmer is greater than the size of the penalty, a compliance reward is the preferred instrument for risk-neutral farmers for $\forall\alpha$, and vice versa.

Again, for risk-averse farmers, it is necessary to compare the expected utility of these options. If money is spent to increase the inspection rate, the difference between the variance of payoffs from non-compliance and compliance can be written as:

$$\sigma^2_{\pi_i^{nc}} - \sigma^2_{\pi_i^c} = y_i^2\sigma_p^2 + (\tilde{\theta} - \tilde{\theta}^2)F^2 \,. \tag{22}$$

When the agri-environmental agency spends money on compliance rewards, the difference between the two variances becomes:

$$\sigma^2_{\pi_i^{nc}} - \sigma^2_{\pi_i^c} = y_i^2\sigma_p^2 + (\theta - \theta^2)(F^2 - R^2) \,. \tag{23}$$

The former (22) is larger than the latter (23). Hence, the risk-averse farmer has a greater incentive to comply with the scheme when monitoring effort is increased compared to the case where compliance rewards are provided. The larger the degree of risk aversion, the higher the threshold value for monitoring costs to make monitoring equally effective as the compliance reward. We examine the trade-off using numerical analysis.

4. Numerical Simulation

This section provides the numerical analysis to illustrate some of the key findings in sections 2 and 3. It is assumed that the farmer's utility function can be approximated by a second-order Taylor series expansion about the expected payoff:

$$E(u(\pi)) = u(E\pi) + \frac{1}{2}u''(E\pi)\cdot\sigma_\pi^2 . \tag{24}$$

We employ the power utility function following Fraser (2002) so that constant relative risk aversion (CRRA) represents farmers' attitude to risk:

$$u(\pi) = \frac{\pi^{1-\delta}}{1-\delta},\quad u'(\pi) = \pi^{-\delta},\ \text{ and }\ u''(\pi) = -\delta\pi^{-\delta-1}. \tag{25}$$

Therefore, the Arrow-Pratt coefficient of constant relative risk aversion is:

$$-\frac{u''(\pi)\pi}{u'(\pi)} = \delta,\quad \delta \in [0,1). \tag{26}$$

Under these assumptions, we calculate values for the expected utility under each set of parameters. The hypothetical parameter values used are given in Table 2.

Table 2: Hypothetical parameter values for the base case

$\overline{p}$	y	$\tilde{y}$	c	γ	I^e	θ	F	α
100	100	80	30	0.5	1800	0.1	1500	0.7

All parameter values are set so as to satisfy all inequalities discussed in previous sections (e.g., the participation constraint). Drawing on a report on monitoring methodologies in the Countryside Stewardship Scheme in U.K. (Little et al, 2001), we set the inspection rate $\theta = 0.1$ and the cost share rate at 50%, which is typical in EQIP. Other parameters, which do not affect our principal conclusions, are determined arbitrarily. In addition, we assume that there are 100 farmers (*N*=100) whose net total compliance costs are heterogeneous. Using the Monte Carlo method, 100 random values of $B_i^a - I_i^a$ are generated from the normal distribution with mean, $\mu = 1200$, and standard deviation, $\sigma = 50$. Applying the central limit theorem, we generate random values for 30 experiments to obtain mean values which are reasonable approximations to the true compliance rates. Following Fraser (2002), the coefficient of variation for the price of output is set at CV=0.2.

Table 3 reports the impact of reductions in the inspection rate on the compliance rates when the cost of monitoring per farmer is higher than the size of penalty. For risk-neutral farmers, the larger the reduction in the probability of inspection, the higher the compliance rate. This is due to the fact that risk-neutral farmers do not care about an increase in the variance of the payoff from compliance. Meanwhile, the highest compliance rates (in bold type) can be achieved when reductions in inspection rates are 70% ($\delta = 0.25$), 60% ($\delta = 0.5$), and 50% ($\delta = 0.75$) for risk-averse farmers. As the degree of risk aversion increases the effect of changes in the variance of the payoff also increases. Since the attitude to risk is private information for farmers, over 70% reduction is quite risky for the agri-environmental agency.

Table 3: Reductions in monitoring effort and compliance rates

Reduction in the inspection rate (%)	Total compliance rewards	Compliance rate (%)			
		Risk neutral	δ=0.25	δ=0.5	δ=0.75
0	0	16	32	50	70
10	2000	24	41	60	78
20	4000	33	51	69	84
30	6000	42	60	77	88
40	8000	52	69	82	91
50	10000	62	76	86	**92**
60	12000	73	81	**87**	91
70	14000	81	**83**	85	86
80	16000	87	79	68	56
90	18000	**92**	44	5	0

The cost of monitoring: k =2000

To examine the impact of changes in the initial inspection rate[19], table 4 gives the results when $\theta = 0.08$. The impact of changes in the degree of risk aversion on compliance rates are similar to the case where $\theta = 0.1$. This implies that the relative magnitude of reductions in the inspection rate is important, rather than the absolute reduction.

[19] The initial budgetary resources also change.

Table 4: Effect of reductions in monitoring effort on compliance rates with an initial inspection rate of θ= 0.08

Reduction in the inspection rate (%)	Total compliance reward	Compliance rates (%)			
		Risk neutral	δ=0.25	δ=0.5	δ=0.75
0	0	5	13	28	46
10	1600	8	19	34	53
20	3200	12	25	42	60
30	4800	17	31	49	66
40	6400	23	38	54	71
50	8000	30	44	60	**72**
60	9600	38	50	**61**	71
70	11200	46	**52**	57	63
80	12800	55	48	41	34
90	14400	**64**	20	3	0

The cost of monitoring: k =2000

Table 5 shows the effects of using the revenue collected from fines on compliance rates over time for risk-neutral and risk-averse farmers. The use of this source can increase compliance rates. As indicated in section 3, however, if the revenue obtained from fines is spent on compliance rewards in a single period, compliance rates are unstable over time. Distributing collected fines over time can stabilize compliance rates (in this case over three periods), but only a rate of 54% can be achieved. Nevertheless, wise use of this source could be complementary to other sources of funding. For instance, a combination of funding sources for compliance rewards (e.g., reducing monitoring effort plus fines) will result in a better outcome.

Table 5: Effects of the use of funds collected from fines on the compliance rate over time

Time	Compliance rate (%)					
	Spent at once		Distributed over three periods		Distributed over three periods with reduction in monitoring effort	
	Risk Neutral	δ=0.25	Risk Neutral	δ=0.25	Risk Neutral	δ=0.25
0	16	32	16	32	73	81
1	99	100	54	74	78	85
2	16	32	54	74	78	85
3	99	100	54	74	78	85
4	16	32	16	32	73	81
5	99	100	54	74	78	85
6	16	32	54	74	78	85
7	99	100	54	74	78	85
	Unstable		Short, sharp, shock (relatively stable)		Higher and more stable	

The cost of monitoring: k =2000 and $\triangle\theta$= 0.06

Table 6 summarizes the impact of using savings from limiting enrolment in the scheme on compliance rates. These increase dramatically for both risk-neutral and risk-averse farmers. However, over exclusion of farmers from the scheme leads to a lower total number of farmers in compliance. In our numerical example, when the Arrow-Pratt measure of relative risk aversion is 0.5, the most efficient exclusion level is eight farmers (eight percent of eligible farmers, if these results are interpreted in terms of percentages). Although compliance rates (99%) are not 100%, the number of farmers in compliance is the highest (91). The agri-environmental agency needs to choose carefully the number of farmers enrolled in a scheme, paying attention to budget allocation.

Table 6: The effects of reductions in the number of farmers enrolled in the scheme on the number of farmers in compliance

Number of farmers excluded	Total compliance reward	Number of farms in compliance (compliance rate (%))			
		Risk neutral	δ=0.25	δ=0.5	δ=0.75
0	0	16 (16)	32 (32)	50 (50)	70 (70)
2	1800	32 (33)	50 (51)	69 (70)	83 (85)
4	3600	50 (52)	67 (70)	83 (86)	91 (95)
6	5400	69 (73)	82 (87)	89 (95)	**92 (98)**
8	7200	81 (88)	**88 (96)**	**91 (99)**	92 (100)
10	9000	**87 (97)**	89 (99)	90 (100)	90 (100)
12	10800	87 (99)	88 (100)	88 (100)	88 (100)

Table 7 shows compliance rates for different costs of monitoring[20] monitoring effort and compliance rewards when additional budgetary resources or budgetary savings are available ($T = 4500$). Since $\alpha F = 0.7 * 1500 = 1050$, compliance rates are the same for both instruments for risk-neutral farmers if the cost of monitoring is 1050. If the cost of monitoring is greater than 1050, a compliance reward is the preferred instrument, and vice versa. For risk-averse farmers, however, the threshold value for the cost of monitoring which equates compliance rates for the two instruments is higher than 1050. For instance, when the Arrow-Pratt measure of relative risk aversion is 0.25, monitoring and compliance rewards are equally efficient instruments (same compliance rate of 78 %). In our numerical example, we set $\alpha = 0.7$, but the agri-environmental agency should carefully determine its budget allocation since the expected proportion of farmers in compliance is private information. At any rate, if the cost of monitoring is expected to be much higher than the possible size of penalty, it is more efficient to devote money to compliance rewards.

[20] Again, different monitoring costs imply different levels of the initial budgetary resources since the probability of inspection is fixed. Although we can also change the probability of inspection to correspond to the level of monitoring cost, this does not affect our key findings.

Table 7: Monitoring versus compliance rewards for different costs of monitoring

	Compliance rate (%)							
	Risk neutral		δ=0.25		δ=0.5		δ=0.75	
Cost of monitoring	M	CR	M	CR	M	CR	M	CR
1000	62	60	81	78	92	90	97	96
1050	**60**	**60**	79	78	91	90	97	96
1100	58	60	**78**	**78**	**90**	**90**	97	96
1150	56	60	76	78	89	90	**96**	**96**
1200	53	60	74	78	88	90	**96**	**96**
1250	52	60	73	78	87	90	95	96

M: spending funds in increasing the inspection rate; CR: spending funds in financing compliance rewards; T=4500

5. Conclusion

This paper investigates the potential use of compliance rewards in agri-environmental schemes and examines trade-offs among possible sources for funding these under asymmetric information and output price uncertainty. Under the assumption of heterogeneous net compliance costs, theoretical models are developed and numerical analysis is conducted.

We find that whether compliance rates can be increased by reducing monitoring effort to finance compliance rewards depends on the level of monitoring costs. If the cost of monitoring is high, compliance rewards financed by reducing monitoring effort, can increase the likelihood of compliance for both risk-neutral and risk-averse farmers. However, if monitoring effort is reduced substantially, the variance of the payoff from compliance will be high and low compliance rates will result for risk-averse farmers. The revenue collected from fines can be used with other sources of financing for compliance rewards. Funding by reducing the number of farmers enrolled in the scheme will be effective only if the agri-environmental agency can measure the contribution of each farm to environmental quality accurately.

We also examine the trade-off between instruments (monitoring or compliance rewards) when extra budget and/or budgetary savings are available. We find that the preferred choice of instrument depends on the level of monitoring costs. Higher risk aversion among farmers leads to higher threshold values for monitoring costs which equalizes compliance rates for the two instruments.

In conclusion, under certain conditions the use of a compliance reward can mitigate the problem of moral hazard in agri-environmental programmes. In particular, if there are constraints on the size of penalties that can be imposed, and/or the monitoring cost per farm is high, the compliance reward is a preferred instrument. In addition, the agri-environmental agency needs to allocate limited budgetary resources between initial payments and enforcement efforts efficiently. In the light of these results it is clear that further consideration of the design and implementation of incentive-based agri-environmental schemes is merited.

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Appendices

A. Deriving the variance of the payoff

The variance of the payoff from compliance (6) can be rewritten as:

$$\sigma^2_{\pi_i^c} = \int_p \{(p-\overline{p})\tilde{y}_i\}^2 d\Theta(p) = \tilde{y}_i^2 \int_p (p-\overline{p})^2 d\Theta(p) \,. \tag{6-A}$$

Because

$$\int_p (p-\overline{p})^2 d\Theta(p) = \sigma^2_p \quad , \tag{6-B}$$

we have $\sigma^2_{\pi_i^c} = \tilde{y}_i^2 \sigma^2_p$. Meanwhile, the first term of equation (7) is:

$$\begin{aligned}
&\int_p (1-\theta)\{(p-\overline{p})y_i + \theta F\}^2 d\Theta(p) \\
&= (1-\theta)\int_p \{(p-\overline{p})^2 y_i^2 + 2(p-\overline{p})y_i\theta F + \theta^2 F^2\} d\Theta(p) \\
&= (1-\theta)\left[y_i^2 \int_p (p-\overline{p})^2 d\Theta(p) + 2 y_i \theta F \int_p (p-\overline{p}) d\Theta(p) + \theta^2 F^2 \int_p d\Theta(p) \right]
\end{aligned} \tag{7-A}$$

where $\int_p (p-\overline{p}) d\Theta(p) = 0$ and $\int_p d\Theta(p) = 1$. Therefore, (7-A) can be rewritten as:

$$(1-\theta) y_i^2 \sigma^2_p + (1-\theta)\theta^2 F^2 \,. \tag{7-B}$$

Similarly, the second term is given by:

$$\theta\, y_i^2 \sigma^2_p + \theta(1-\theta)^2 F^2 \,. \tag{7-C}$$

From (7-B) and (7-C) we obtain:

$$\sigma^2_{\pi_i^{nc}} = y_i^2 \sigma^2_p + [(1-\theta)\theta^2 + \theta(1-\theta)^2] F^2 \,. \tag{7-D}$$

Rearranging this equation yields equation (8).

B. Determining the amount of compliance reward per farmer

The amount of (expected) compliance reward per farmer is dependent on the expected proportion of farmers in compliance (expected compliance rates), α , the objective probability of inspection, θ, and the total number of farmers in the scheme, *N*. Because the farmer can only receive a compliance reward if inspected, the amount of the (expected) compliance reward per farmer should be determined by dividing total funding available for compliance rewards, T , by the expected number of those who are in cell A in the table below.

	θ (inspected)	1-θ (not-inspected)
α(compliance)	A	B
1-α(non-compliance)	C	D

Thus, the amount of (expected) compliance reward per farmer is given by:

$$R = \frac{T}{\theta \alpha N} .$$