

Hidden action, risk aversion and variable fines in agri-environmental schemes*

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This note analyses the design of agri-environmental schemes for risk-averse producers whose input usage is only observable by costly monitoring. The scheme penalises producers in proportion to input use in excess of a quota. A striking result is that if the scheme is designed in such a way that producers always comply with the quota, risk aversion is not relevant in determining the level of input use.

Key words: agri-environmental policy, monitoring, risk aversion.

1. Introduction

Agri-environmental schemes generally have two common features. First, because they are voluntary, participation requires compensation. Second, participation involves a management agreement or contract between the producer and regulator, in which the producer agrees to adopt some environmentally beneficial action (e.g. reducing fertiliser usage or stocking rates, or providing a public good by fencing to exclude stock from remnant bush) in return for a compensation payment. Since taxpayers provide these compensation payments, and taxation itself incurs a deadweight loss, the regulator aims to pay compensation which covers the costs of compliance and no more.

There are two well-known problems associated with input-based agri-environmental schemes: first, hidden information or adverse selection arises when individual producers have more information about the cost of compliance than the regulator, which provides an incentive for them to claim compensation payments higher than their own compliance costs; second, hidden action or moral hazard occurs if the regulator cannot monitor compliance perfectly, which provides an incentive for producers to seek rent through non-compliance.

The implications of hidden information in agri-environmental policy have been explored by Spulber (1988), Chambers (1992), Bourgeon *et al.* (1995), Wu and Babcock (1996), Latacz-Lohmann and Van der Hamsvoort (1997) and Moxey *et al.* (1999). Hidden action has been studied by Latacz-Lohmann

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(1998), Choe and Fraser (1998, 1999), Ozanne *et al.* (2001) and Fraser (2002). More recent work, by Hogan (2002), White (2002) and Ozanne and White (2007), has sought to model the two types of information asymmetry simultaneously.

Two key issues in this work relate to the treatment of producer risk preferences and the fines imposed on producers caught cheating. Ozanne *et al.* (2001) developed a principal-agent model of hidden action in agri-environmental schemes for risk-averse producers, in which producers who are caught cheating pay fixed fines. White (2002) and Ozanne and White (2007), on the other hand, assumed producers are risk neutral and face variable fines, which depend on the amount of input applied in excess of the quota. There is strong evidence that most producers are risk-averse (Bond and Wonder 1980; Bardsley and Harris 1987; Leathers and Quiggin 1991; Saha *et al.* 1994; Abadi Ghadim and Pannell 2003). In addition, fines imposed by courts generally depend on the severity of the crime; for example, fines for speeding increase according to the difference between a car's speed and the speed limit. This note therefore adapts the models for hidden action developed by Ozanne *et al.* (2001) and Ozanne and White (2007) to allow for both risk aversion and variable fines.

The contribution of this note is to analyse the design of contracts for risk-averse producers where actions are costly to monitor. The model presented below starts by assuming, that the regulator has information on producers' risk preferences. However, in an interesting special case, the risk associated with the contract is eliminated and self-compliance is ensured whatever the risk preferences of the producer. Although the primary model has the potential for achieving more abatement with lower monitoring cost, the latter may be more realistic as it does not depend upon unrealistic assumptions about the regulator being able to observe risk aversion.

2. Model

Following Laffont and Tirole (1993, p. 55) we assume that a utilitarian regulator maximises the following constrained equivalent objective function with three terms, which approximates a social welfare function:

$$E(z) = v(x) + [(1-p)w(b + \pi(x)) + pw(b + \pi(x) - \eta(x-s)) - w(\pi^*)] - (1+e)(b + mp - p\eta(x-s)) \quad (1)$$

Thus, to maximise social welfare, the regulator offers each producer a contract (s, b, p) , where s is the input quota, b is the transfer payment and p is the probability of the regulator detecting non-compliance.

The first term, $v(x)$, on the right-hand side of Equation (1) is the environmental benefit of input use, x , where $v'(x) < 0$, $v''(x) \geq 0$ and $v'(x^*) = 0$, where x^* is the profit-maximising input use. The second term, in squared brackets, gives the expected producer surplus from participating with expected utility

Table 1 Definitions of Variables, Functions and Parameters

Term	Description
Variables:	
z	Approximate social welfare function
x	Input use
\hat{x}	solution to (5) accounts for risk aversion;
\tilde{x}	first-best perfect information solution;
\bar{x}	solution to (13) special case;
x^*	profit maximising input.
s	Input quota
p	probability of monitoring
b	Transfer payment to the producer
Functions:	
$\pi(x)$	Profit as a function of input.
π^*	maximum profit
$v(x)$	Environmental cost of input use
$w(\pi)$	Is the utility function
Parameters:	
e	Shadow price of public funds
m	Monitoring cost to visit a single farm
η	Fine per unit of excess input
η^{\min}	minimum viable fine

$(1 - p)w(b + \pi(x)) + pw(b + \pi(x) - \eta(x - s))$ over non-participation $w(\pi^*)$, where $w(\pi)$ is the utility of profit, $w'(\pi) > 0$ and $w''(\pi) \leq 0$; $\pi^* = \pi(x^*)$ is unrestricted profit and the restricted profit function is defined such that $\pi(x) < \pi^*$, $\pi'(x) \geq 0$, and $\pi''(x) < 0$. The third terms gives net transfer payments adjusted for the shadow price of public funds, e . For simplicity, monitoring costs are linear, mp , where the parameter m represents the cost of monitoring a farm with certainty, $p = 1$. The payoff expected by a producer participating in the scheme depends on whether she chooses to comply with the contract, on the probability of detection if non-compliance is chosen, and on the penalty imposed for exceeding the input quota. The penalty for non-compliance is an exogenous fine of η per unit of input above the quota, s ; that is, a producer who chooses input level $x > s$ faces a possible fine of $\eta(x - s)$. All terms are summarised in Table 1.

Expected social welfare (1) is maximised subject to two behavioural constraints. First, *individual rationality* (IR) requires that producers prefer, or are indifferent between, participation and non-compliance at input level $x \geq s$ to non-participation at level x^* :

$$(1 - p)w(b + \pi(x)) + pw(b + \pi(x) - \eta(x - s)) \geq w(\pi^*) \tag{2}$$

Second, *incentive compatibility* (IC) requires that producers weakly prefer participation and non-compliance at level $x \geq s$ to participation and non-compliance at level $\tilde{x} \geq x \geq s$:

$$(1 - p)w(b + \pi(x)) + pw(b + \pi(x) - \eta(x - s)) \geq (1 - p)w(b + \pi(\tilde{x})) + pw(b + \pi(\tilde{x}) - \eta(\tilde{x} - s)) \tag{3}$$

Using a Taylor series expansion it can be shown that, in the limit $\tilde{x} \rightarrow x$, the IC constraint (3) for $x \geq s$ simplifies to:

$$(1 - p)w'(b + \pi(x))\pi'(x) + pw'(b + \pi(x) - \eta(x - s))(\pi'(x) - \eta) \leq 0 \tag{4}$$

The IR constraint ensures that the producer will participate in the scheme using an input level of, at least, x . However, this is a minimum input level, and if only constraint (2) were included in the model, the producer would have an incentive to exceed this minimum. The IC condition (4), which states that at input level x the marginal expected utility of profit must be non-positive, requires that the probability of detection is high enough to ensure that the producer does not exceed x .

The policy scheme is as follows. The regulator determines the producer’s utility function and profit function, then offers a contract based on this information which includes a monitoring probability. The producer responds by accepting the contract and deciding on an input level. If the producer is monitored and the input level is found to be above quota, a fine is levied.

The regulator’s problem, allowing for hidden action, producer risk aversion, and a variable fine for over quota input use, can now be summarised as follows. The objective function (1) is maximised subject to the non-negativity constraints, $x \geq 0$, $s \geq 0$ and $b \geq 0$, the IR constraint (2), and the IC constraint (4). The internal solution is:

$$\pi'(\hat{x}) = \frac{v'(\hat{x})}{1 + e} + \frac{A[C + (m - \eta(x - s))A]}{AD - BC} \pi''(\hat{x}) \tag{5}$$

where,

$$\begin{aligned} A &= (1 - \hat{p})w'(\hat{b} + \pi(\hat{x})) + \hat{p}w'(\hat{b} + \pi(\hat{x}) - \eta(\hat{x} - \hat{s})) \\ B &= (1 - \hat{p})w''(\hat{b} + \pi(\hat{x}))\pi'(\hat{x}) + \hat{p}w''(\hat{b} + \pi(\hat{x}) - \eta(\hat{x} - \hat{s}))(\pi'(\hat{x}) - \eta) \\ C &= w(\hat{b} + \pi(\hat{x})) - w(\hat{b} + \pi(\hat{x}) - \eta(\hat{x} - \hat{s})) \\ D &= w'(\hat{b} + \pi(\hat{x}))\pi'(\hat{x}) - w'(\hat{b} + \pi(\hat{x}) - \eta(\hat{x} - \hat{s}))(\pi'(\hat{x}) - \eta) \end{aligned}$$

Thus, the regulator offers the producer the contract $(\hat{s}, \hat{b}, \hat{p})$, the producer chooses input level \hat{x} and faces an expected fine of $\hat{p}\eta(\hat{x} - \hat{s})$. There is a trade-off between increasing abatement and increasing the cost of monitoring compliance, which is conditioned by producer risk preferences.

Assuming risk neutrality, Equation (5) simplifies to:

$$\pi'(\hat{x}) = \frac{v'(\hat{x})}{1 + e} + \frac{m}{\eta} \pi''(\hat{x}) < -\frac{v'(\hat{x})}{1 + e} \tag{6}$$

and if zero cost monitoring is assumed as well as risk neutrality it becomes

$$(1 + e)\pi'(\hat{x}) = -v'(t) \tag{7}$$

Expression (6) shows that $\hat{x} \geq \hat{x}$, that is, input abatement by a risk-neutral producer whose actions are costly to monitor will be less than that for a risk-neutral producer under perfect information. This implies that hidden action reduces the efficiency of agri-environmental schemes if producers are risk-neutral. However, the same conclusion cannot be so readily drawn from expression (5), where the trade-offs between more abatement (lower x), larger fines (lower s), and higher costs of monitoring compliance (higher p) are conditioned by producer risk preferences.

The model presented above is based on the assumption that the regulator knows the producer's attitude to risk. However, risk preferences may vary across producers, and be difficult to estimate. Thus, even if the regulator has information on the range of risk attitudes they may not know how they are distributed across producers. As Leathers and Quiggin (1991) and Isik (2002) have pointed out, this means the effects of environmental policy on input use may be ambiguous. Peterson and Boisvert (2002) have suggested one approach for dealing with this problem, which involves treating risk preferences as an additional source of hidden information and accommodating them through stochastic efficiency rules. Here, we take a simpler approach and design a special case of the above hidden-action contract in such a way that the risk associated with it is eliminated and the solution is independent of producer risk preferences.

This no-cheating, no-risk contract is obtained by setting $s = x$, so that a utility-maximising producer is induced to comply with the contract and the expected fine is zero. The social welfare function (1) simplifies to:

$$E[z] = v(x) + [w(b + \pi(x)) - w(\pi^*)] - (1 + e)(b + mp) \tag{8}$$

Setting $s = x$, the IR constraint (2) simplifies to:

$$w(b + \pi(x)) \geq w(\pi^*) \tag{9}$$

indicating that the producer prefers participation and compliance $x = s$ to non-participation $x = x^*$. Since $w(\pi)$ is assumed to be monotonic, this simplifies to:

$$b + \pi(x) \geq \pi^* \tag{10}$$

Similarly, the IC constraint (3) simplifies to:

$$p\eta w'(b + \pi(x)) \geq \pi'(x)w'(b + \pi(x)) \tag{11}$$

It can be seen immediately that the marginal utility terms in Equation (11) cancel, thus eliminating risk preferences from the optimal contract; the IC constraint becomes simply

$$p\eta \geq \pi'(x) \quad (12)$$

The solution to the regulator's objective maximisation problem, now represented by Equation (8), IR constraint (10), binding IC constraint (12), which implies $p\eta = \pi'(x)$ and the non-negativity constraints $x \geq 0$ and $b \geq 0$, is:

$$\pi'(\bar{x}) = \frac{v'(\bar{x})}{1+e} + \frac{m}{\eta} \pi''(\bar{x}) < -\frac{v'(\bar{x})}{1+e} \quad (13)$$

Expression (13) is identical to Equation (6), the solution obtained from the original model for a risk neutral producer, which shows that optimal contracts designed in this way are independent of risk preferences.

If the marginal cost of monitoring is zero, $m = 0$, or the fine rate is very large, such that $\eta \rightarrow \infty$, Equation (13) gives the same solution as Equation (7), $\bar{x} = \hat{x}$. However, because all reference to risk preferences have disappeared from Equation (13), it is impossible to achieve the optimal solution if monitoring costs depend on the frequency of monitoring, that is $m \neq 0$, and the fine rate, η , is finite. Thus, although the restricted model has the advantage that, to implement it, the regulator does not need to have information on individual producer's risk preferences, it has the corresponding disadvantage that the regulator will not account for any risk aversion within the group of farmers.

From Equation (13) the minimum feasible fine η^{\min} is defined by the point where $\bar{x} = x^*$ as $\pi'(x^*) = 0$ and the monitoring costs are given:

$$\eta^{\min} = \frac{m\pi''(\bar{x})(1+e)}{v'(\bar{x})}$$

To simplify the comparative static analysis, we define the parameter $h = (m/\eta)$ to represent the monitoring cost relative to the fine. In terms of determining the level of input, this ratio is of critical importance. Making this substitution, taking the total derivative of Equation (13) and rearranging yields:

$$\frac{dx}{dh} = \frac{(1+e)\pi''(\bar{x})}{(1+e)\pi''(\bar{x}) + v''(\bar{x}) - h\pi'''(\bar{x})(1+e)} \quad (14)$$

This derivative has an indeterminate sign unless further assumptions are imposed. If we assume $v(x)$ is linear and $\pi'''(x) > 0$ which, for instance, applies for a strictly concave profit function derived from a Cobb–Douglas production function, it follows that $dx/dh > 0$, which indicates that as the costs of monitoring increase relative to the fine, the input quota increases.

Table 2 Parameters and Initial Values for the Numerical Simulation

Parameters	Initial value	Units
p_w	220	\$ per tonne wheat
p_x	2.3	\$ per kg nitrogen
e	0.1	
v	2	\$ per kg abatement per ha
β_0	1.155	
β_1	0.30	
m	100	\$ per ha for monitoring
η	4	\$ per kg per ha excess
π^*	797.447	\$per ha return over nitrogen cost
x^*	148.593	kg per ha
θ	0.7	utility function parameter

4. Numerical examples

In this example, a producer is offered a voluntary contract to reduce the nitrogen input per hectare. Subsequently, nitrogen input is monitored, which is costly, and, if producers are found to be in excess of the quota, they pay a fine, which depends upon the level of excess. The farm's production function for wheat yield, y , is given by $y = \beta_0 x^{\beta_1}$. The producer's utility function is given by $w(\pi) = \pi^\theta$ and the benefit of input abatement is given by $v(x) = v(x^* - x)$. The initial values of the parameters used in the simulations are given in Table 2.

In the contract, the regulator directly chooses the input quota, s , the frequency of monitoring, p , and the transfer payment, b ; indirectly, the regulator induces the producer to use a particular level of input, x (the hats used in preceding sections). The most interesting result from this analysis is the difference between the general solution (5) and special case (13), as this indicates how critical it is for the regulator to account for risk aversion in contract design. The difference in the objective function between the general and special case indicates the value to the regulator of information on the producer's risk aversion.

The two solutions from Equations (5) and (13) are the same in the case where the fine is zero. As the monitoring cost tends towards zero, the second terms on the right hand sides of Equations (5) and (13) also tend towards zero and the target input and actual input converge. Similarly, as the fine is increased, the target input and actual input converge.

Table 3 shows the change in the general solution and special case as the monitoring cost increases. This has a predictable effect: in both cases, the input quota is relaxed and the probability of monitoring reduced. The monitoring probability is always higher in the special case as it is necessary to maintain an incentive for compliance with the quota.

Table 3 Optimal Solution with Monitoring Cost Increasing

m	x	s	p	b	z
<i>General Solution Equation (5)</i>					
0.00	64.65	64.65	0.45	58.62	103.39
50.00	75.58	62.94	0.34	58.66	81.70
100.00	84.45	58.61	0.27	58.52	64.91
150.00	92.07	52.01	0.22	58.14	51.54
200.00	98.82	42.88	0.18	57.63	40.75
250.00	104.88	30.03	0.14	57.37	32.03
<i>Special Case Equation (13)</i>					
0.00	64.65	64.65	0.45	58.62	103.39
50.00	75.60	75.60	0.35	41.15	81.58
100.00	84.58	84.58	0.28	29.96	64.48
150.00	92.41	92.41	0.23	22.07	50.66
200.00	99.46	99.46	0.19	16.25	39.34
250.00	105.94	105.94	0.15	11.85	30.01

The notable result from Table 3 is that the social welfare function is little different between the general case (5) and the special case (13). Thus in this numerical example there is almost no difference between the social welfare between the two cases and little is gained by the regulator from knowing producers' risk aversion.

5. Conclusion

Two models of agri-environmental policy under hidden action have been developed using an input quota/compensation payment scheme that allows for risk-averse behaviour by producers and variable fines rather than fixed fines for producers who are caught cheating. The general model assumes that the regulator has information about the risk preferences of individual producers, and shows how it can use this information to induce producers to reduce input use and reduce monitoring costs. The second model is a special, no-risk, case of the general model, which deters all cheating by producers regardless of their risk preferences. Comparative static analysis indicates the importance of the fine in relation to monitoring costs: for a viable policy under high monitoring costs the fine rate must be relatively high.

The striking result from this paper, and one which has policy significance, is that if the regulator adjusts the quota to the level of input that the producer is expected to use, the optimal input and level of monitoring is determined by a relatively simple formula which depends upon the curvature of the profit function, but not the degree of risk aversion. This result has implications for environmental and natural resource management schemes in Australia that involve input restrictions. These include the usual agri-environmental schemes and irrigation management schemes. The contracts for these schemes need to be reinforced by monitoring, and the results in this paper suggest that the

regulator should focus on assessing producers' compliance cost functions as risk preferences play a relatively minor role in designing an efficient scheme. From Table 3 the reduction in welfare from adopting the special case is increasing in the monitoring cost and lies between 0 and 6 per cent.

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