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AUTHORS	Patrice Loisel Bernard Elyakime
ARTICLE INFO	Patrice Loisel and Bernard Elyakime (2011). Private environmental incentive contract and a weather signal. <i>Environmental Economics</i> , 2(1)
RELEASED ON	Thursday, 05 May 2011
JOURNAL	"Environmental Economics"
FOUNDER	LLC “Consulting Publishing Company “Business Perspectives”



NUMBER OF REFERENCES

0



NUMBER OF FIGURES

0



NUMBER OF TABLES

0

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Patrice Loisel (France), Bernard Elyakime (France)

Private environmental incentive contract and a weather signal

Abstract

The authors of the paper are interested in an environmental incentive payment mode for risk-averse contracting farmers. The incitement joins the environmental output produced by the farmer to his effort through an environmental contract reported to be motivating. However, the authors suppose an environmental output depending on a weather signal and consider the effect of a weather variable on the incentive contract. The first and usual incentive contract studied takes into account the average effect of a weather indicator on the farmer's environmental output. The paper studies a second incentive contract taking into account the instantaneous effect of a weather indicator on the farmer's environmental output. Then in complement of the reservation farmer's utility, authors consider a minimum incentive payment given to the farmer through a constraint of a minimum payment for every point of farmer's output. It is possible to increase this minimum payment in the second type contract (compared to the first one) without reducing the expected utility of the principal and the expected utility of the farmer, by increasing the level of the farmer's environmental action. The use of such minimum farmer's payment and the increase of this minimum payment could be very conclusive to bind a farmer by an environmental contract.

Keywords: incitement, regulation, ecosystem service, minimum payment, weather, risk.

JEL Classification: Q10, Q25, Q20, Q22.

Introduction

An environmental incentive contract connects a contracting agent (a risk-averse farmer in the paper) to a principal (an aquaculture producer in the paper). The payment of such a contract depends on the environmental output of the farmer. This contract considers the farmer's effort because the farmer's environmental output depends on this effort. However, the farmer's environmental output can also depend on an exogenous risk like the weather. This is particularly true in agricultural and environmental economics.

Thus, we assume a farmland located on a hillside. At the bottom of the hillside there is a river with an aquaculture. Because of intensive farmer's agricultural practices, the surface water of the farmland is polluted and so is the river. The aquaculture producer is interested to improve the water quality by convincing the farmer to modify his agricultural practice. The aim is to obtain and to maintain a low rate of water pollution.

Obviously, the realization of such an objective is impossible without scientific studies (Noble et al., 2009), dialogues, propositions and tests with the two agents. We assume this necessary step achieved and necessary knowledge learned and known. New agricultural practices and their costs, their results and their factors of variation were learned and known.

After this first and necessary stage and in order to refine the environmental target, the setting up of financial incentives appears essential: the farmer could be bound by an environmental incentive contract proposed by the aquaculture producer with a low cost of monitoring of the environmental results (rate of pesticides in the water, for example). The results of the farmer's practices depend therefore on farmer's efforts to carry out good practices. For

example, public environmental management measures like European directives to protect river (Logan and Furse, 2002) allow the preservation of the water in the river.

The theory of incentive contracts furnishes an analytic framework (Gibbons, 1998) that appears suitable to generate incentives because the agent's payments (farmer's payment in our case) are linked to his output performance. The risk-averse agent is thus motivated to undertake efforts that will lead to a satisfactory level of environmental production. However, as this level of output will also depend on weather conditions prevailing during the implementation of the contract, it is necessary to take these climatic conditions into account while drawing up the contract.

Some authors, Grossman and Hart (1983), Holmström (1979), Milgrom and Roberts (1992), studied or demonstrated the advantage of using a signal on the agent's effort furnished in an incentive contract. First, the more information the principal has to draw up the contract, the more precise the contract will be. Second, because of incentives, the agent's utility becomes variable, (Salanié, 1997). Thus, it is possible to take into account the risk attached to an agent's contractual payment in relation with the type of the probability distribution of the agent's results.

The usual payment given to a contracting farmer (the agent) that is bound by an environmental incentive contract considers an average climatic effect on the farmer's environmental output. Actually, this is a simplification that it is possible to overrun by considering the climatic effect for every point of the farmer's output. The farmer's payment would depend simultaneously on the farmer's environmental output and on the value of a climatic signal. But in this case, it would be necessary to control the variability of the farmer's payment given by this more specific contract.

Yet, an incentive contract is not necessarily in discredit of the contracting farmer who can benefit not only a minimum utility but also a minimum payment. Our theoretical aim is to use the weather signal and a constraint of a minimum payment for every point of farmer's environmental output to improve and so to make more attractive an environmental incentive contract binding a farmer: we consider *ex ante* contracts.

First, we clarify the climatic effect in the contract in order to consider it in two different ways. The first usual way considers the climatic effect on average on the distribution of probability of the output (type 0 contract). The remuneration only depends on the environmental output. The second way considers the effect of the distribution of probabilities of output and climatic variable (type 1 contract) on a new payment function that depends on the environmental output and on the climatic variable. The contractual payment that we study is non-linear in order to cover the question as generally as possible.

Second, we consider these contracts with a minimum farmer's payment as well as a minimum farmer's utility. We want to study consequences of an increase of this minimum payment, for a given minimum farmer's utility, by an acute use of the climatic signal in a type 1 incentive contract.

The paper is organized as follows. We give the set of hypotheses relative to the modelling. We present a first model that ensures a payment that depends on the farmer's environmental performance, by considering the average effect of a weather variable on the farmer's output (type 0 contract). Then we propose to modify the contract by ensuring the farmer a payment which depends both on the farmer's environmental performance and on the value of the weather variable (type 1 contract). Then, we study these contracts theoretically by considering a constraint of a minimum payment for every point of farmer's output. The results are compared and analyzed before concluding.

1. Method: the different incentive contracts

We assume a farmer whose outdoors activity is dependent on weather conditions. We assume that this farmer is bound by an environmental incentive contract that seeks to increase farmer's environmental production. Nevertheless, we consider the two types of incentive contracts.

We consider a farmer's effort that is not observable to the principal. The principal can identify and measure the environmental production value x which is assumed to be easily and physically measurable. The cumulative distribution for result x will be a function, $F(x | y, e)$, conditioned by a weather

variable y and the effort e . We suppose: $F'_e(x | y, e) \leq 0$ and $F'_y(x | y, e) \leq 0$ with inequality on a set with a non-null measure, and the expected value of result x will be increasing in e and in y . We also define $G(y)$ as the cumulative distribution function for the weather variable y .

1.1. Contract with a standard payment. The expected principal's utility $V(\cdot)$ resulting from the production x , net of the total cost of the remuneration $(1 + \gamma)t_0(x)$ paid to the farmer (the cost of the management of one unit of private fund $t_0(x)$ is γ) and of the fixed cost c of the monitoring, is maximized under the constraints of the maximizing of the utility $U(\cdot)$ which the farmer derives from the remuneration received, taking into account its cost function $w(e)$, and the reservation farmer's utility U_0 . Functions $V(\cdot)$ and $U(\cdot)$ are increasing and non convex. Function $w(\cdot)$ is increasing and convex. We calculate a payment function $t_0(\cdot)$. Variable x is defined in $[\underline{x}, \bar{x}]$ and variable y in $[\underline{y}, \bar{y}]$.

We determine a payment function $t_0(x)$ with the utilities functions V , U and cost function w :

$$\max_{e, t_0(\cdot)} \int_y \int_x [V(x - c - (1 + \gamma)t_0(x))] dF(x | y, e) dG(y) \quad (1)$$

under the constraints, adopting a first order approach¹:

$$\int_y \int_x (U(t_0(x)) - w(e)) dF(x | y, e) dG(y) \geq U_0, \quad (2)$$

$$\int_y \int_x U(t_0(x)) dF_e(x | y, e) dG(y) = w'(e). \quad (3)$$

When the payment is dependent on the results alone, the weather conditions are treated on average with $\tilde{F}(x | e) = \int_y F(x | y, e) dG(y)$ and the former program is equivalent to:

$$\max_{e, t_0(\cdot)} \int_x [V(x - c - (1 + \gamma)t_0(x))] d\tilde{F}(x | e) \quad (4)$$

under the constraints (2) and (3) simplified.

We note λ and μ the Lagrangian multipliers associated with constraints (2) and (3). The first order condition with respect to $t(x)$ is used to calculate the transfer:

¹ By supposing the monotone likelihood ratio property (MLRP), the convexity of the distribution function (CDF) and the linearity of W , we have the following sufficient conditions: $\frac{\partial f_e}{\partial x} > 0$ and $F_{ee} > 0$.

$$(1 + \gamma) \frac{V'(x - c - (1 + \gamma)t(x))}{U'(t(x))} = \lambda + \mu \frac{f_e}{f}(x|e). \quad (5)$$

For example, and if V is the identity function, the payment function is with $\mu > 0$ (Holmström, 1979) or (Shavell, 1979):

$$t_0(x) = \left(\frac{1}{U'}\right)^{-1} \left[\frac{\lambda + \mu \frac{f_e}{f}(x|e)}{1 + \gamma} \right]. \quad (6)$$

The first order condition with respect to e , the first order conditions relative to constraints (2) and (3) are used to determine respectively the Lagrangian multipliers λ , μ and the optimal effort e . The payment will be an increasing function of x if the monotone likelihood ratio property (MLRP) of the distribution function F holds: $\frac{\partial}{\partial x} \frac{f_e}{f}(x|y, e) > 0$

(Grossman and Hart, 1983).

As well as participation constraint (2), we want a minimum payment for every point of the output. So, to the expectation constraints (2) and (3) are added the constraints: $U(t_0(x)) \geq U(\underline{t})$, $\forall x$.

To the necessary first order conditions associated with constraints (2) and (3) are added the conditions relative to these constraints (with the associated Lagrangian multiplier δ): $\delta(x) U(t_0(x)) = 0$ with $\delta(x) \geq 0$ for all x . One infers the payment:

$$t_0(x) = \left(\frac{1}{U'}\right)^{-1} \left[\max\left(\frac{1}{U'(\underline{t})}, \frac{\lambda + \mu \frac{f_e}{f}(x|e)}{1 + \gamma}\right) \right]. \quad (7)$$

In addition, using specific techniques (Carlier and Dana, 2005), one may then secure the growth in payment as a function of x , taking into account the constraint on the minimum payment. This result is of course obtained by assuming that the distribution F confirms the MLRP.

In this case, the payment only depends on the results alone, independently of the direct influence of climate on the results. So, if the climate is favorable to the farmer, the farmer could receive too high payment compared to the remuneration he would receive with a more precise contract in terms of weather and conversely¹.

1.2. Contract with a new payment mode. We determine a payment function $t(x, y)$ with the utilities

functions V , U and cost function w . As the payment depends on x and on y , this program is different from the previous one:

$$\max_{e, t(\cdot)} \int_y \int_x [V(x - c - (1 + \gamma)t(x, y))] dF(x|y, e) dG(y) \quad (8)$$

under the constraints, adopting a first order approach:

$$\int_y \int_x (U(t(x, y)) - w(e)) dF(x|y, e) dG(y) \geq U_0, \quad (9)$$

$$\int_y \int_x U(t(x, y)) dF_e(x|y, e) dG(y) = w'(e). \quad (10)$$

For example, if V is the identity function, the payment function is:

$$t(x, y) = \left(\frac{1}{U'}\right)^{-1} \left[\frac{\lambda + \mu \frac{f_e}{f}(x|y, e)}{1 + \gamma} \right] \quad (11)$$

for a payment without constraint of minimum payment and then

$$t(x, y) = \left(\frac{1}{U'}\right)^{-1} \left[\max\left(\frac{1}{U'(\underline{t})}, \frac{\lambda + \mu \frac{f_e}{f}(x|y, e)}{1 + \gamma}\right) \right] \quad (12)$$

with a minimum payment $t(x, y) \geq \underline{t}$.

This payment $t(x, y)$ depends on the result x and the climate y , while the payment given by a complete-information contract (program (8) with constraint (9)) is constant: $t_c(x, y) = \left(\frac{1}{U'}\right)^{-1} \left[\max\left(\frac{1}{U'(\underline{t})}, \frac{\lambda}{1 + \gamma}\right) \right]$.

Moreover, it is not possible to infer the effort if the principal can observe the weather and knows the distribution function $F(x|y, e)$ because x and y are random variables.

2. Theory and calculation

First, we study the theoretical property of the type 1 contract comparatively to the type 0 contract, by considering a minimum payment in the two contracts.

Secondly, we want to illustrate our result by conducting a numerical simulation of the two contracts. Our aim is to understand the link between our theoretical result and the level of the farmer's environmental effort in the two contracts.

2.1. Condition to improve the contract with a new payment mode. We note the type 0 contract with a payment $t_0(x)$ and the type 1 contract with a $t_1(x, y)$ payment.

Noted respectively $E_i(U, \underline{t})$, $i = 0, 1$ the utility expectation of the principal in the types 0 and 1 contract, for a minimum farmer's expected utility \underline{U} and a minimum payment \underline{t} for every result x .

¹ This characteristic exists with an environmental output strongly depending on the weather conditions: nitrate pollution of running water or rainfall-erosion losses in any watershed.

We fix a new payment minimum \underline{t}_0 and an farmer's expected utility \underline{U}_0 . If $e_0, t_0(\cdot)$ are the optimal solutions of the first contract, we deduce the effective expected utility of the farmer:

$$U_0 = \int_x (U(t_0(x)) - w(e_0)) d\tilde{F}(x | e_0) \tag{13}$$

with $\underline{U}_0 \leq U_0$ and of course: $E_0(\underline{U}_0, \underline{t}_0) = E_0(U_0, \underline{t}_0)$.

We have $E_0(U_0, \underline{t}_0) < E_1(U_0, \underline{t}_0)$ because the contract with an explicit acknowledgement of the indicator of the weather dominates the classic contract (Shavell, 1979).

For $U_1 > U_0$, one then gets $E_1(U_1, \underline{t}_0) \leq E_1(U_0, \underline{t}_0)$. Assuming that $E_1(U_0, \underline{t}_0)$ depends continuously on U_0 and \underline{t}_0 , there exists $\varepsilon > 0$ such that:

$$E_0(U_0, \underline{t}_0) < E_1(U_0 + \varepsilon, \underline{t}_0) \leq E_1(U_0, \underline{t}_0). \tag{14}$$

A sufficient condition of the continuity of $E_1(U_0, \underline{t}_0)$ in relation to U_0 and \underline{t}_0 is the Lagrangian concavity for the calculation $E_1(U_0, \underline{t}_0)$. In addition, a sufficient condition on this concavity is the convexity distribution function condition (CDF), $F_{ee} > 0$ if w is linear in e ($F_{e^2e^2} > 0$ if w is quadratic). We may then increase, by using a minimum farmer's payment and by switching from the first to the second contract, the farmer's expected utility without penalizing the principal. So, to make more attractive an environmental incentive contract, the simultaneous use of a minimum payment and a climatic signal is relevant.

Moreover and likewise, there is ε' such that:

$$E_0(U_0, \underline{t}_0) < E_1(U_0, \underline{t}_0 + \varepsilon') \leq E_1(U_0, \underline{t}_0). \tag{15}$$

One therefore may increase the level of the minimum farmer's payment to an identical expected utility of the farmer without penalizing the principal. We retain this result to state the following proposition about the minimum farmer payment and farmer or principal expected utility.

Proposition. If the probability distribution of x verifies MLRP and CDF conditions for all result x , the type 1 contract compared to a type 0 contract, with a minimum payment of the farmer for every point of the farmer's output, strictly may generate an increasing of the minimum farmer's payment to an identical expected utility of the farmer and without penalizing the principal.

2.2. A numerical simulation of contracts. We propose, basing ourselves on a set of theoretical hypothe-

ses, to conduct a numerical simulation of the type 0 contract and the type 1 contract, implemented with constraint on the payment to understand the level of the farmer's environmental effort in the two contracts.

The probability distribution on the weather variable and the probability distribution on the results obtained by the contracting farmer are theoretical.

The probability distribution on the results is: $F(x|y,e) = \exp(-p \frac{y+e}{x^n})$ with $p = 2.5$ and $n = 2.5$. This probability distribution verifies the MLRP and CDF conditions. The discrete probability distribution K of the weather variable associates to the values y_i : 1,1875; 2,3125; 3,4375 ; 4,5625; 5,6875 the corresponding discrete probabilities p_i : $\frac{1}{13}, \frac{3}{13}, \frac{5}{13}, \frac{3}{13}, \frac{1}{13}$. The farmer is risk-averse: $u(t) = t^{-\alpha}$. The cost function is $w(e) = k.e^2$ with $k = .01$ and $\alpha = .50$.

The results concerning the level of effort, the expected utility of the farmer and the level of principal's gross expected utility (without deduction of the cost of monitoring) are indicated in the Table 1. They were obtained by considering that parameter y is equal to .4.

Table 1. Expected utility in usual contract (type 0) and modified contract (type 1) with a constraint of minimum payment

Type of contract	Level of effort	Constraint of minimum payment	Principal's gross expected utility	Farmer's expected utility
0	0.637	1	2.147	1.054
1	0.772	1.0375	2.168	1.054

So, increasing of the level of the minimum farmer's payment to an identical expected utility of the farmer and without penalizing the principal in a type 1 contract is possible because the level of the farmer's environmental effort is higher in a type 1 contract than in type 0 contract.

Discussion and conclusion

The construction of an incentive contract is not an easy task because numerous conditions are required to make such a contract reality.

We assumed this necessary step achieved: new agricultural practices and their costs, their results and their factors of variation were learned and known. But this step is not a sufficient condition to implement an incentive contract.

Of course, during the implementation of the contract, resources to achieve the contract are supposed clearly defined and objectives are workable. More-

over, such incentive contracts correspond perfectly to the implementation of an obligation of results by the contracting agent *vis-à-vis* the principal.

The contract is built so that the utility of the contracting agent, which is always above a certain level, varies according to a law of probability because the payment is not constant. The variability of the contractor's gain is real and so can be difficult to accept by any contracting agent.

The introduction of a minimum payment assures that

the variability of the payment is balanced by the certainty of the minimum payment. Moreover, the increase of this minimum payment, of course, enables the contracting farmer to have a return on his costs more easily. So, the use of a minimum farmer's payment could be very conclusive to bind a farmer by an environmental contract.

But it is also interesting for the principal because first, the principal as an environmental agency is not losing in terms of utility and second, the environmental output becomes significantly stronger.

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