Enforcement Aspects of Conservation Policies:

Compensation Payments versus Reserves

Sandra ROUSSEAU[1]

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ABSTRACT

This model explicitly incorporates the dynamic aspects of conservation programs with incomplete compliance and it allows landholders' behaviour to change over time. A distinction is made between initial and continuing compliance. We find that incomplete enforcement can have a significant impact on the choice between subsidy schemes and reserves for conservation policies. The results suggest that it is useless to design a conservation scheme for landholders, if the regulator is not prepared to back the program with a monitoring and enforcement policy. In general, if the cost of using government revenues is sufficiently low and the environmental benefits are equal, the regulator will prefer to use compensation payments since the total compliance costs as well as the inspection costs will be lower. If the use of government funds is too costly, the reserve-type instruments will be socially beneficial.

Keywords: Monitoring and enforcement; Policy instruments; Conservation policy

[1] Centre for Economic Studies, K.U.Leuven, Naamsestraat 69, B-3000 Leuven, Belgium
Tel: 32 16 32 66 36, Fax: 32 16 32 67 96, E-mail: sandra.rousseau@econ.kuleuven.be

1. INTRODUCTION

For more than a decade some major European biodiversity policies, such as the Habitats and Birds Directives (Council Directives 92/43/EEC and 79/409/EEC)[2], have been in place. The two most relevant instruments used in the EU conservation policy are reserves and compensation payments for conservation practices. These instruments are often complements but can also be used separately. The policy choice between using reserves or compensation payments can be reformulated as selecting to directly regulate the activity under scrutiny or to fix transfer prices. As Weitzman (1974) already showed, there is a close connection between these two modes of control. In ideal circumstances with perfect information, either policy instrument can obtain the same results. In general exactly the same information is necessary to name the right prices or to determine the right quantities. Unfortunately, policy decisions are never made under perfect circumstances: the available knowledge is imperfect and often asymmetrically distributed, outcomes of policy actions show elements of randomness and are influenced by stochastic processes, and human behaviour is not always rational.

When the benefits and costs of policies are uncertain due to imperfect information, Weitzman (1974) showed that the ideal instrument, which is contingent on the state of the world revealed at each time, is infeasible. Therefore he determined the optimal instrument under uncertainty as the instrument that maximizes the expected benefits minus the expected costs. He found that a quantity instrument should be used if the marginal benefit curve is steeper than the marginal cost curve; otherwise, a price instrument should be used. This is because the price instrument leads to lower expected costs while the quantity instrument implies higher expected benefits. Jensen and Vestergaard (2003) have generalised Weitzman's analysis to fisheries. If the cost function is additively separable in

[2] The two directives are designed to create a coherent network of protected areas known as NATURA 2000.

stock size and catches, they find that the analysis holds for a schooling fishery (i.e. the fish stock size does not influence the cost of fishing), but it might not hold for a search fishery (i.e. the fish stock size influences the cost of fishing).

Besides uncertainty with respect to the costs and benefits associated with environmental policies, it is also often uncertain whether firms and individuals will in effect comply with the appropriate legislation. Imperfect monitoring and incomplete enforcement have proved to be very important factors in the practice of environmental regulation. For this reason, Montero (2002) studies whether incomplete enforcement has any impact on the choice between price and quantity instruments. If the benefit and cost curves are uncertain, he shows that the quantity instrument performs relatively better than the price instrument. The reason is that the effective amount of control under the quantity instrument is no longer fixed, which makes this instrument come closer to a non-linear instrument.

Turning to conservation policies, Gibson et al. (2005) state that the factors which influence the outcome of conservation programs can be divided into four groups: *(i)* the characteristics of the resource, *(ii)* the characteristics of the group, *(iii)* the institutional arrangement and *(iv)* the external environment. Based on data collected by International Forestry Resources and Institutions (IFRI) network, they find that rule enforcement is a necessary condition in order to obtain successful outcomes from local resource management. Also the European Commission acknowledges the need for enforcing environmental legislation and has recently (February 2007) adopted a proposal for a directive relating to the protection of the environment by criminal law. Certain acts, such as illegal damage to protected habitats and the trade in endangered species, will thus qualify as penal offences, when they are committed in a deliberate fashion or by grave negligence, whether it be a case of physical or moral responsibility (Eckstein, 2007).

However, in the literature little consideration is given of landholders' actions once they have joined a conservation scheme. Therefore, in our model we allow landowners to imperfectly comply with a program's requirements. The reason behind the imperfect compliance is that landholders' actions cannot be directly observed and these actions can only be verified through costly monitoring, resulting in asymmetric information. Data also corroborate the assumption that compliance with currently implemented conservation schemes is less than perfect. Choe and Fraser (1998 and 1999) mention the available evidence on the non-compliance with conservation schemes for the UK. For instance, in relation to the Countryside Stewardship Scheme, Land Use Consultants (1995) found that on 24 percent of the sites visited, farmers were not fulfilling their contractual obligations. Giannakas and Kaplan (2005) discuss compliance with the US program stimulating the adoption of on-site resource conservation activities on highly erodible lands. Since the inception of the policy, over 11000 producers have been cited for violations on approximately 281000 acres with a total of nearly 16 million dollars in denied benefits (Claassen, 2000).

Ellefson et al. (2007) describe the results of a comprehensive assessment of state government, forest practice regulatory programs in the US. The programs focus on a wide range of forestry practices applied to private forests. The program administrators estimated that only in a very few instances forest practices were always being correctly applied. Practices such as timber harvesting, roads and trails and chemical application practices tended toward more correct application, while cultural, protection and administrative practices were more inclined to be sometimes or never correctly applied. With respect to the effectiveness of the programs, administrators judged educational and technical assistance programs to be most effective in obtaining correct application of forestry practices generally, while tax incentive programs were rated least effective.

Financial incentive programs were rated slightly more effective than regulatory programs (2.81 versus 2.60 on a scale from 1 = least effective to 5 = most effective).

Previous models considering compliance to conservation programs, such as Choe and Fraser (1998 and 1999) and Giannakas and Kaplan (2005), did so in a static framework and they focussed on one policy instrument. We, however, explicitly incorporate the dynamic aspects of conservation programs into the model and allow landholders' behaviour to change over time. We also make a distinction between initial compliance and continuing compliance and focus on the difference in monitoring and enforcing compensation schemes or reserves. We find that incomplete enforcement can have a significant impact on the selection of conservation instruments. The results suggest that it is useless to design a conservation scheme for landholders, if the regulator is not prepared to back the program with a monitoring and enforcement policy. In general, if the cost of using government revenues is sufficiently low and if the associated environmental benefits are similar, the regulator will prefer to use compensation payments over reserve-type instruments, since the total compliance costs (cost efficiency) as well as the inspection costs will be lower. If the use of government funds is too costly, the reserve-type instruments will be socially beneficial.

Section 2 discusses the model and derives the conditions under which landholders comply with conservation policies. In section 3 we describe the selection of policy instruments under incomplete compliance. Section 4 concludes.

2. Model

We analyse a multi-period model with a finite horizon. This policy horizon is exogenously determined and is denoted by *T*. Typically *T* represents the minimal number of years a particular conservation practice must be implemented in order to comply with the regulation; e.g. the number of years a forest cannot be cut down. Landholders are subject to a conservation policy, which might be based on a command-and-control approach (e.g. reserves) or a market-based approach (e.g. compensation payments).

2.1 Assumptions

We assume that landholders are risk neutral and that they maximise the net benefit from their land. The surface of each site is assumed to be equal to unity. However, the same person can own several plots of land. Initially none of these lands have been put to a conservation use and no conservation practices are being implemented. The start-up cost of changing land use practices in order to enhance biodiversity for landholder *i* is equal to I_i and continuing compliance costs in later periods equal $c_i \leq I_i$. These start-up costs tend to be higher than continuing compliance costs because they include learning and conversion costs, changes in suppliers or fixed investment costs such as building fences or planting trees. These costs of land conversion or of changing management practices vary between different landowners: $c_i \in [\underline{c}, \overline{c}]$ and $I_i \in [\underline{I}, \overline{I}]$ with (continuous) density functions $g(c_i)$ and $h(I_i)$ and cumulative density functions $G(c_i)$ and $H(I_i)$. We assume that these functions are commonly known to both government and landowners, but that only the landholders themselves know their real values. Due to these cost differences, it is necessary to explicitly distinguish between initial and continuing compliance with conservation policies. Previously, Harford (2000) has incorporated the notions of initial and continuing compliance in order to determine the quantity of abatement capital a firm installs when confronted with pollution standards.

In order to implement a conservation policy the regulator chooses between two instruments: reserves (quantity instrument) and compensation payments (price instrument). When reserves are used, this fixes the number of sites that have to take certain conservation measures: $q = \overline{q}$ where $0 \leq q \leq 1$ denotes the percentage of the total land area that is sustainably managed. A compensation scheme determines a payment of s for each landowner who implements a particular conservation practice in each period.

The regulator is also responsible for ensuring the landholders' compliance with the policy. To this end, the regulator randomly performs inspections with a probability *p* in each period *t*. Every audit costs *v* and this inspection cost is high enough so that full compliance is not socially optimal. Further we assume that an inspection can perfectly determine the compliance status of the landowner; in other words, there are no measurement errors. A violator who is caught in period *t* has to pay a fine $F(t)$. For a compensation payment scheme, this fine is equal to the cumulative sum of all subsidies[3] that were already paid to the violator in previous periods: $F(t) \equiv \sum_{k=1}^{t} s = s.t$. The sanction also implies that the violator cannot receive any future subsidies. The fine cannot exceed the cumulative subsidy amounts since this would imply less (voluntary) participation by the target group[4]. The restitution of all subsidies received so far means that fines are increasing in time and thus deterrence is also mounting over time. This increasing penalty also implies that not all participants would choose to violate in the last period *T* even tough monitoring is imperfect. When a reserve-type instrument is chosen, the fine is exogenously fixed in the legislation and equals $F(t) = \overline{F}$.

[3] An example where such a penalty scheme is used is the compensation scheme for afforestation on agricultural land in Flanders (ABG, 2003).

[4] A policy with a fine exceeding the cumulative subsidy amounts can always be reformulated as a policy with a lower nominal subsidy and a fine equal to the cumulative subsidy amounts. The model can thus be viewed as a normalisation.

2.2 Compliance with compensation payments

In this scenario a landholder is faced by a subsidy scheme that offers a payment of s in each period t for T periods in return for the implementation of certain conservation measures. In each period t, each landowner i is assumed to maximise the expected net income Y_{it} of the land from t until the end of the policy horizon T. In the initial period, $t = 0$, an individual will decide whether or not to participate in the conservation program by optimising the following objective function:

$$\max_z Y_{i0} = \max_z \left(\left[1 - z \right] Y_{i0}^{NP} + z Y_{i0}^{P} \right)$$

with $z = 1(0)$ if the landholder decides (not) to participate in the program, Y_{i0}^{NP} is the expected net income from not participating and Y_{i0}^{P} is the expected net income from enrolling in the program. We assume that the landholders can only decide to take part in the conservation scheme in period 0 and that is impossible to subscribe in a later period. The expected net income from taking part in the conservation program will depend on the future decisions concerning compliance with the requirements necessary for receiving the subsidy payment. In this model, we distinguish the initial decision to participate from continuing compliance with the program. Thus we have to examine the compliance decision in the last period $(t = T)$ and, through backward induction, we can subsequently optimise the compliance decision of the landowners in the previous periods and the participation decision in period 0.

In the last period T a landholder who participates in the program decides to comply with the requirements if:

$$Y_i^{C} + s - c_i \geq Y_i^{NC} + s - pF\left(T\right)$$

with Y_i^C the revenue if the land is sustainably managed and Y_i^{NC} the income from the land if the conservation measures are not implemented. These revenues are assumed to be constant over time and hence we drop the time index[5]. This gives:

$$Y_i^C - Y_i^{NC} - c_i \geq -pF(T)$$

The net cost of compliance with the program's obligations has to exceed the expected fine for owners to comply. This condition can be rewritten as:

$$p \geq -\frac{Y_i^C - Y_i^{NC} - c_i}{F(T)} \equiv \tilde{p}_{iT}$$

If a landholder decides to participate in the conservation program, we find that his compliance decision can be described by proposition A. First, however, we define the following set of parameters:

$$\tilde{p}_{it} \equiv -\frac{Y_i^C - Y_i^{NC} - c_i}{F(t)} \quad \forall t$$

These parameters are always ordered as follows: $\tilde{p}_{i1} > \tilde{p}_{i2} > ... > \tilde{p}_{iT}$ for all *i*, since per definition $F(1) < F(2) < ... < F(T)$.

Proposition A

The compliance decision of the landowners who participate in the conservation program is described as follows:

If $c_i \leq Y_i^C - Y_i^{NC} \equiv \tilde{c}_i$,

then the landholder will comply in each period t, $0 < t \leq T$ *(case I).*

If $\tilde{c}_i < c_i \leq \tilde{\tilde{c}}_i \equiv Y_i^C - Y_i^{NC} + F(T)$ *(case II), and*

[5] As Wätzold and Schwerdtner (2005) mention, the costs and benefits of conservation programs often exhibit variations over time and space. In this model we do not specifically deal with this.

a) if $p \geq \tilde{p}_{i1}$*, then the landholder will be compliant in each period t,* $0 < t \leq T$

b) if $\tilde{p}_{it} \leq p < \tilde{p}_{it-1}$ *for* $1 < t \leq T$*, then the landholder will comply from period t onwards until period T and violate before period t*

c) if $p < \tilde{p}_{iT}$*, then the landholder will never comply.*

If $c_i > \tilde{\tilde{c}}_i$*, then the landholder will never comply (case III).*

The proof of the proposition is given in appendix A.

In case I, it is always profitable for the landholders to implement the conservation measures even without compensation payments. Indeed the conservation costs $\left(c_i\right)$ are already covered by the increase in private land revenues (e.g., fewer fertilizers are needed or the recreational benefits increase) after implementation $\left(Y_i^C - Y_i^{NC}\right)$. Thus, the compliance decisions of these low-cost landowners are independent of the monitoring and enforcement policy. Rational landholders in a world with perfect information would already have implemented these moneymaking measures. However, in reality due to, for instance, incomplete information, these profitable opportunities are not always realised.

The high-cost landowners in case III will always decide to violate the program's rules, if they choose to participate in it, since the costs of compliance are always higher than the highest possible fine that can be imposed, corrected for the change in land revenues. Even with perfect monitoring, $p = 1$, it is not optimal for these landholders to comply.

The compliance decisions of the medium-cost landowners (case II) depend on the monitoring policy. The level of the probability of inspection has to be high enough $\left(p \geq \tilde{p}_{i1}\right)$ to convince these landholders to fulfil the program's requirements during the complete time horizon. If the monitoring stringency is not sufficiently high, these landowners will only execute the necessary management changes when the product of the inspection frequency and the fine (i.e. the expected sanction) is high enough. Due to the increasing fines, landholders decide to comply once the expected penalty exceeds a certain threshold. If the probability of detection is lower than $\tilde{p}_{iT}$, these medium-cost owners will never comply with the program if they to decide to participate.

Once we know the landholders' compliance decisions after they decide to participate in the program, we can derive the conditions under which it is optimal for them to actually join the conservation program. We examine the participation decision at $t = 0$ for each case mentioned above. Remember that we assume that the initial compliance cost I_i is always higher than the cost c_i for continuing compliance once the program is started. The discount rate is equal to δ. The landholder's participation decision is formally described in proposition B.

Proposition B

If $c_i \le \tilde{c}_i$ (case I) or if $\tilde{c}_i < c_i \le \tilde{\tilde{c}}_i$ and $p \ge \tilde{p}_{i1}$ (case IIa), then

a) if $I_i \le \tilde{I}_i \equiv Y_i^C - Y_i^{NC} + s + \sum_{t=1}^{T} \delta^t \left(Y_i^C - Y_i^{NC} + s - c_i \right)$, the landholder will participate in the program and will always comply

b) if $I_i > \tilde{I}_i$, the landholder will not participate in the program

If $\tilde{c}_i < c_i \le \tilde{\tilde{c}}_i$ and $\tilde{p}_{i\tilde{t}} \le p < \tilde{p}_{i\tilde{t}-1}$ (case IIb), then

a) if

$$I_i \le \tilde{\tilde{I}}_i \equiv Y_i^C - Y_i^{NC} + s + \sum_{t=1}^{\tilde{t}} \delta^t \left(1-p\right)^{t-1} \left(s - pF\left(t\right) \right) + \sum_{t=\tilde{t}}^{T} \delta^t \left(1-p\right)^{\tilde{t}-1} \left(Y_i^C - Y_i^{NC} + s - c_i \right),$$

the landholder will participate in the program and will comply from period $\tilde{t}$ onwards

b) if $I_i > \tilde{\tilde{I}}_i$, the landholder will not participate in the program.

If $\tilde{c}_i < c_i \le \tilde{\tilde{c}}_i$ *and* $p < \tilde{p}_{iT}$ *(case IIc) or if* $c_i > \tilde{\tilde{c}}_i$ *(case III),* *then the landholder will not participate in the program.*

For cases I and IIa, the landholder opts to participate in the program under condition that the initial compliance cost I_i is not too high. If the initial compliance cost is higher than the net present value of all future profits from the program $\left(I_i > \tilde{\tilde{I}}_i\right)$, the land manager will not take part in the conservation scheme, even tough he would implement the required land use practices once he would have been enrolled in the program. If the landowner would never comply with the program's obligations (cases III and IIc), he would also opt not to take part in it, since the initial compliance cost is even higher than the cost of continuing compliance $\left(I_i \ge c_i\right)$. If the monitoring policy is such that medium-cost landowners only start complying after a certain time (case IIb), we find that these landowners will participate in the conservation program if their initial compliance costs are sufficiently low.

Note that the level of the subsidy s does not influence the parameter $\tilde{c}_i$ and thus the number of landowners in case I is fixed. However, the subsidy level s does have an impact on the parameter $\tilde{\tilde{c}}_i$ via the fine $F(T)$. This implies that increasing the level of s allows the regulator to shift owners from case III to case II and, depending on the probability of detection, more landholders will participate in the program.

Without monitoring and enforcement, only 'case I' landholders would be compelled to take part in the conservation scheme, no matter how high the subsidies are. In that case, an information campaign would suffice since these landowners always profit from the implementation of the conservation measures. So the results suggest that it is useless to design a conservation scheme for landholders, if the regulator is not prepared to back the program with a monitoring and enforcement policy.

Moreover, we find that it is possible to increase participation rates in our model if the subsidy in the start-up period is set at a higher level provided that the probability of detection is sufficiently high. This would allow the regulator to compensate landowners for the higher start-up costs, which is indeed a common characteristic in compensation payment schemes in reality. For example, the subsidies for afforestation of agricultural lands in Flanders are higher in the first period in order to pay for the costs of planting trees (ABG, 2003).

2.3 Compliance with reserves

When the regulator decides to use reserves (CAC) as a policy instrument, the landholders in a particular region are legally obliged to implement certain conservation measures. The percentage of plots that need to be sustainably managed is set equal to $\overline{q}$. The landowners who are targeted by the policy can choose to comply with the rules or not. With a probability p landowners are inspected and, when a violation is detected, the violator has to pay a fine $\overline{F}$ and he is forced to comply in that period, which costs him I_i or c_i. Again it initially costs more to start implementing the required practices than to continue compliance with the regulation $\left(I_i \geq c_i, \forall i\right)$.

The compliance behaviour of the landholders with a reserve instrument is described in proposition C.

Proposition C

Landholder i's compliance behaviour when faced with reserve-type regulation can be described as follows:

If $I_i \le \hat{I}_i \equiv \frac{1}{1-p}\left(Y_i^C - Y_i^{NC} + p\overline{F}\right)$*, then the landholder will always comply (case 1).*

If $I_i > \hat{I}_i$ *and* $c_i \le \hat{c}_i \equiv \frac{1}{1-p}\left(Y_i^C - Y_i^{NC} + p\overline{F}\right)$ *(case 2), then*

a) if $I_i \le \hat{I}_i + \sum_{t=1}^{T} \delta^t (1-p)^t \left[Y_i^C - Y_i^{NC} - c_i + p\left(\overline{F} + I_i\right)\right]$*, the owner always complies*

b) if $I_i > \hat{I}_i + \sum_{t=1}^{T} \delta^t (1-p)^t \left[Y_i^C - Y_i^{NC} - c_i + p\left(\overline{F} + I_i\right)\right]$*, the landholder is noncompliant until he gets caught and is compliant afterwards*

If $I_i > \hat{I}_i$ *and* $c_i > \hat{c}_i$ *(case 3), then*

a) if $I_i \le \hat{I}_i + \sum_{t=1}^{T} \left[\delta^t (1-p)^t \left(I_i - c_i\right)\right]$*, the landholder complies in period 0 and is in violation afterwards*

b) *if* $I_i > \hat{I}_i + \sum_{t=1}^{T} \left[\delta^t (1-p)^t \left(I_i - c_i\right)\right]$*, the landholder never complies.*

The proof of proposition C can be found in appendix B.

A low-cost landholder (cases 1 and 2a) is always compliant since implementing the conservation measures is less costly than paying the expected fine. Medium-cost owners (case 2b) will postpone initial compliance until the violation is detected and they are forced to incur the initial compliance costs. Afterwards, because continuing compliance costs are lower than initial compliance costs, they continue to adopt the mandated conservation practices. The second group of medium-cost landowners (case 3a) start by complying with the policy in period 0 because they can save paying the expected fine for one period (corrected for the change in private land revenues with and without conservation). For this group of owners, these expected savings exceed the expected costs of having to pay I_i in period 0 rather than later. The high-cost landholders (case 3b) will never comply since they find it less expensive to pay the expected fine(s) than to pay the compliance costs.

3. CHOICE OF POLICY INSTRUMENTS

The regulator announces the conservation policy at time $t = 0$ and commits to a monitoring and enforcement strategy. The policy instrument that is used is either a compensation payment scheme or a reserve. The selection of policy instruments for conservation policies has already been extensively studied in various settings (e.g. Sterner, 2003; Moons and Rousseau, 2007; Wätzold and Schwerdtner, 2005; Boyce, 2004 or Crepin, 2005). However, the influence of incomplete compliance on the instrument choice has not yet been examined in detail for conservation policies[6]. The monitoring and enforcement policy is determined by the probability of detection *p* and the fine *F(t)*. Note that the fine is exogenous when the regulator uses reserves, while it is endogenous in the case of subsidies. We also assume that the inspection frequency is constant over time.

The regulator chooses the type and level of the policy instrument that maximises the expected benefits minus the expected costs (i.e. expected change in social welfare) associated with a particular conservation goal $\hat{q}$ $\left(0 \leq \hat{q} \leq 1\right)$ for a region. This criterion for selecting policy instruments is also used in, among others, Weitzman (1974) and Montero (2002). We assume that the conservation goal $\hat{q}$ is the result of the political process, which is exogenous to our model.

In order to be able to compare the two policy instruments, we need some additional simplifying assumptions. Firstly, we assume that the government only knows the expected value of the private revenues from the land with or without conservation measures even

[6] Studies looking at the choice of policy instruments under incomplete compliance for pollution reduction policies include, among others, Montero (2002), Sandmo (2002) and Rousseau and Proost (2005).

tough in reality they vary over the sites (Babcock et al., 1997; Wätzold and Schwerdtner, 2005):

$$E\left[Y_i^C\right] = Y^C \quad and \quad E\left[Y_i^{NC}\right] = Y^{NC} \qquad \forall i$$

Further we assume that c_i is uniformly distributed between $\left[\underline{c}, \overline{c}\right]$ with mass one and, equivalently, that I_i is uniformly distributed between $\left[\underline{I}, \overline{I}\right]$. The minimal compliance cost $\underline{c}$ is such that $\underline{c} > Y^C - Y^{NC}$. This means that the landholders have already implemented all profitable measures and no one falls under case I. The maximal initial compliance cost $\overline{I}$ is smaller than $Y^C - Y^{NC} + \sum_{t=1}^{T} \delta^t \left(Y^C - Y^{NC} - \overline{c}\right)$ and this implies that all landowners falling under case IIa will participate in the conservation program (see proposition B). Finally, we assume that the fines are equal for both policy scenarios so as to facilitate the comparison between the two instruments:

$$F(t) = \overline{F} = sT \qquad \forall t$$

Since the sanction is now constant over time, case IIb will not be applicable.

3.1 Compensation payments

In order to attain the policy goal $\hat{q}$ using subsidies, the regulator will need to simultaneously determine the compensation payment *s* and the probability of detection *p* such that a share $\hat{q}$ of all landholders participate in the program and comply with its requirements. This implies that, using proposition A,

$$Y^C - Y^{NC} + psT \geq \underline{c} + \hat{q}\left(\overline{c} - \underline{c}\right)$$

Thus the variables *s* and *p* have to fulfill the following conditions in order to reach the conservation goal:

$$ps \geq \frac{\underline{c} + \hat{q}\left(\overline{c} - \underline{c}\right) - \left(Y^C - Y^{NC}\right)}{T} \text{ and } 0 \leq p \leq 1 \qquad (1)$$

In order to reach the policy goal $\hat{q}$, the expected fine psT has to exceed the compliance costs c_i corrected by the change in private land revenues $\left(Y^C - Y^{NC}\right)$ for all landholders with continuing compliance costs below $\underline{c} + \hat{q}\left(\overline{c} - \underline{c}\right)$.

3.2 Reserve

If the regulator chooses to use reserves as a policy instrument, the size of the reserve equals $\hat{q}\left(=\overline{q}\right)$. Remember that the fine $\overline{F}$ in this instance is set equal to the fine $\left(sT\right)$ associated with the compensation payment scheme[7]. In order to make all landholders in the policy area comply, the monitoring policy has to be sufficiently stringent. From proposition C we find that the probability of detections needs to fulfil the following condition:

$$\overline{I} \leq \frac{1}{1-p}\left(Y^C - Y^{NC} + p\overline{F}\right)$$

We can rewrite this expression as:

$$p\left(\overline{F} + \overline{I}\right) \geq \overline{I} - \left(Y^C - Y^{NC}\right)$$

The monitoring probability must be such that the expected costs of non-compliance exceed the expected costs of compliance (corrected for the change in private land revenues). Thus:

$$p \geq \frac{\overline{I} - \left(Y^C - Y^{NC}\right)}{sT + \overline{I}} \qquad (2)$$

Since the probability of inspection cannot exceed one, it is possible that condition (2) cannot be satisfied and thus that the policy goal $\hat{q}$ cannot be reached without increasing the fine.

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[7] Fines will be limited in reality because the wealth of individuals and firms is limited (Polinsky and Shavell, 1991).

As an alternative to setting the policy's objective $\overline{q}$ equal to $\hat{q}$, it is also conceivable to set the policy goal equal to one $\left(\overline{q}=1\right)$. This implies that the regulator formally forces all landholders in the complete region to adopt certain conservation practices. However, through the choice of the monitoring and enforcement strategy, the percentage of owners that actually comply can be set equal to $\hat{q}$. The probability of detection that achieves this goal is determined by equation (1) (for $\overline{F}=sT$) and the violators who are caught should not be forced to comply. This policy scenario is in effect an environmental tax scheme since landholders can choose to comply or to pay a fine with a certain probability (see Sandmo, 2002). Such an environmental tax scheme is likely to be politically infeasible. Moreover the credibility of the policy is questionable because the regulator will be perceived as accepting non-compliance behaviour from a sizable proportion $\left(1-\hat{q}\right)$ of the landowners. Therefore we do not discuss this policy scenario any further.

3.3 Impact on social welfare

The expected change in social welfare from the conservation policy consists of the sum of *(i)* the expected environmental benefits, *(ii)* the landholders' net income and *(iii)* the social cost of government expenditures. Both policy instruments have a different impact on the three components of social welfare.

Due to the assumptions we make, all participants with the compensation payment scheme fall under case 2a (proposition A). Thus, the change in social welfare equals:

$$\begin{aligned}\Delta SW_S = &\sum_{i\in P}\sum_{t=0}^{T}\delta^t B_i + \sum_{i\in P}\left(Y_i^C - I_i + s + \sum_{t=1}^{T}\delta^t\left(Y_i^C - c_i + s\right)\right) + \sum_{i\notin P}\sum_{t=0}^{T}\delta^t Y_i^{NC} \\ &+ MCPF\left(\sum_{i\in P}\sum_{t=0}^{T}\delta^t\left(-\nu p_S - s\right)\right)\end{aligned} \qquad (3)$$

with B_i the conservation benefit of plot i, ν the cost of inspecting a landowner, *MCPF* the marginal cost of public funds[8] and $p_S \equiv \frac{\underline{c} + \hat{q}\left(\overline{c} - \underline{c}\right) - \left(Y^C - Y^{NC}\right)}{sT}$. Note that none of the landholders will have to pay a fine since all program participants $\left(i \in P\right)$ comply in this scenario. It is, however, still necessary to inspect them on a regular basis because otherwise they would start violating the program's obligations.

The expected change in social welfare associated with a reserve program is:

$$\begin{aligned} \Delta SW_R = &\sum_{i \in R} \sum_{t=0}^{T} \delta^t B_i + \sum_{i \in R} \left(Y_i^C - I_i + \sum_{t=1}^{T} \delta^t \left(Y_i^C - c_i \right) \right) + \sum_{i \notin R} \sum_{t=0}^{T} \delta^t Y_i^{NC} \\ &+ MCPF \left(\sum_{i \in R} \sum_{t=0}^{T} \delta^t \left(-\nu p_R \right) \right) \end{aligned} \tag{4}$$

with $p_R = \min\left[\frac{\overline{I} - \left(Y^C - Y^{NC}\right)}{sT + \overline{I}};1\right]$ and all landholders that are subject to the regulation belong to the subgroup *R* $\left(i \in R\right)$. The monitoring policy is set so that all landholders in *R* fall under case I (in proposition C). Under the assumptions we made the probability of detection associated with a reserve policy will exceed the inspection frequency related to a subsidy scheme $\left(p_R \geq p_S\right)$, since it also has to deter high-cost owners from violating the regulation. The monitoring and enforcement strategy associated with compensation payments has to deter only the landholders with low compliance costs

[8] The marginal cost of public funds *(MCPF)* measures the distortions caused by the collection of tax revenue that is spend on public goods that do not influence private consumption. Each euro of collected taxes leads to a direct cost for the taxpayers (that one euro) as well as an indirect cost due to the less efficient functioning of the economy. After all, the transfer from taxpayers to government alters the consumption and labour decisions of these taxpayers and influences market behaviour.

$\left(c_i \in \left[\underline{c}, \underline{c} + \hat{q}\left(\overline{c} - \underline{c}\right)\right]\right)$. Again no fines are paid by the landholders because the monitoring strategy is such that all owners comply.

3.4 Discussion

The impact on social welfare by the conservation policy consists of three parts: *(i)* the impact on the environment, *(ii)* the effect on the landholders' income and *(iii)* the change in the regulator's budget. Compensation payment schemes and reserves each have a different impact on the three welfare components.

The effect on environmental quality depends on the variation in conservation benefits over the different sites. For this reason, we cannot draw any general conclusions about the relative effect of both instruments. If the regulator knows which plots are likely to provide higher conservation benefits, reserve schemes can be targeted toward those plots. This would imply that reserves can yield a higher environmental benefit than compensation payments. The use of reserves in settings with high conservation benefits is indeed something we observe in reality. In a situation where a failure to act has irreversible consequences (e.g. a particular species of bird becomes extinct) or where conservation is incompatible with human actions (e.g. the conservation of biodiversity hotspots or wilderness areas), reserves are probably the most appropriate instrument to use. Compensation schemes can be used, for instance, to stimulate conservations actions in an established agricultural landscape (e.g. to promote the planting of hedgerows or the creation of pools). In order to keep the analysis tractable, we, however, assume that the conservation benefits are equal across the land:

$$B_i \equiv \overline{B} \qquad \forall i$$

This implies that both policies have exactly the same effect on the environmental quality since they both reach the target $\hat{q}$ and hence the first terms of equations (3) and (4) are equal. The same situation would hold true if there is no information on the individual environmental benefits but only on the distribution of conservation benefits. The regulator would then assign the same expected benefit to conservation measures for each plot in the region: $E\left(B_i\right) \equiv \bar{B}; \forall i$.

Total landholders' revenues under a compensation payment scheme will always be larger than under a reserve scheme. Firstly, the landowners are compensated – at least in part – for the conservation costs and, secondly, only the lowest cost landholders will participate in the program since compensation schemes are cost efficient while reserve schemes are not. This implies that the sum of the second and third terms in equation (3) will always exceed the sum of the second and third terms in equation (4).

In order to rank the two policy instruments, we also need to consider their impact on government revenues. To this end we have to compare $\sum_{i \in P} \sum_{t=0}^{T} \delta^t \left(-\nu p_S - s\right)$ with $\sum_{i \in R} \sum_{t=0}^{T} \delta^t \left(-\nu p_R\right)$. The compensation scheme will cost the regulator more than a reserve policy if $s > \nu\left(p_R - p_S\right)$. This condition is always fulfilled if $s > \nu$ since $p_R - p_S$ is always positive and smaller than one.

Depending on the cost of government resources, we distinguish two cases. If the compensation payments are costless transfers $\left(MCPF = 1\right)$, a compensation scheme will always result in a higher level of social welfare than the use of reserves, since the total compliance costs (cost efficiency) as well as the inspection costs will be lower. In the second case, government funds are costly to use $\left(MCPF > 1\right)$ because they are financed by distortionary taxes. Then the regulator will still prefer to use compensation payments if the marginal cost of public funds is sufficiently low. For a high *MCPF,* the use of reserves will become socially beneficial.

4. CONCLUDING REMARKS

This paper shows that incomplete enforcement has great significance in the regulator's choice between compensation schemes and reserve-type instruments. Compliance with regulations cannot be guaranteed without effort from the regulator and this has implications for the government budget. We show that is pointless to develop conservation policies if they are not complemented with a monitoring and enforcement strategy. If there is no information on the conservation benefits associated with each plot or if these benefits are equal across the region, the regulator will weigh the efficiency and enforcement benefits of compensation schemes with the costs of using government resources to pay the compensation payments. The results indicate that the regulator will prefer compensation schemes if the cost of using government revenues is sufficiently low, since the total compliance costs as well as the inspection costs will be lower. If the use of government funds is too costly, the reserve-type instruments will be welfare improving.

Obviously other considerations besides enforcement should be taken into account when modelling the instrument choice of the regulator. However, this is not the main focus of this paper. The current model could be extended by explicitly specifying the distribution and variation of conservation benefits over space and time. If the regulator knows which lands provide higher conservation benefits, reserve-type instruments have an additional benefit compared to compensation schemes since the former can be targeted towards these high-benefit sites. It would also be desirable to consider additional enforcement strategies. One possibility would be to allow fines to increase with the size of the violation. Another would be to allow learning from the part of the regulator and allow the regulator to adapt its monitoring and enforcement strategy over time in response to new information with respect to the landowners' compliance costs. Finally it is also important to note that in this model we assume that the costs of monitoring and enforcement are equal for both instruments. In reality this is not likely to be true.

APPENDIX A: Proof of proposition A

We take as given that the landholders participate in the conservation program and investigate their continuing compliance decisions, using backward induction. A landholder will comply in period T, if $Y_i^C - Y_i^{NC} - c_i \geq -psT$ or if:

$$p \geq -\frac{Y_i^C - Y_i^{NC} - c_i}{sT} \qquad (5)$$

If $c_i \leq Y_i^C - Y_i^{NC}$, condition (5) is always fulfilled and these landholders comply in period T. Looking at their decision in period T-1, we find that these landholders comply if:

$$Y_i^C + s - c_i \geq Y_i^{NC} + s - ps(T-1)$$

The decision in period T is not relevant for the compliance decision in T-1 since it is independent from it. Since $c_i \leq Y_i^C - Y_i^{NC}$, these low-cost landholders will always comply once they participate in the program. The same reasoning can be applied to periods $t < T-1$. This proves case I.

If $c_i > Y_i^C - Y_i^{NC} + sT$, condition (5) never holds, since $p \leq 1$ per definition. These landholders will violate the regulation in period T. Since $F(T) > F(T-1) > ... > F(1)$, these high-cost owners will always violate the program's requirements. This proves case III.

If $Y_i^C - Y_i^{NC} < c_i \leq Y_i^C - Y_i^{NC} + sT$, condition (5) holds and the landholders comply in period T if:

$$p \geq -\frac{Y_i^C - Y_i^{NC} - c_i}{sT} \equiv \tilde{p}_{iT}$$

Analogously these medium-cost landholders comply in period $t < T$ if:

$$p \geq -\frac{Y_i^C - Y_i^{NC} - c_i}{st} \equiv \tilde{p}_{it}$$

Since $F(1) < F(2) < ... < F(T)$, we have $\tilde{p}_{i1} > \tilde{p}_{i2} > ... > \tilde{p}_{iT}$ for all *i*. This implies that

a) if $p \geq \tilde{p}_{i1}$, then the landholder will be compliant in each period t, $0 < t \leq T$

b) if $\tilde{p}_{it} \leq p < \tilde{p}_{it-1}$ for $1 < t \leq T$, then the landholder will comply from period t onwards until period T

c) if $p < \tilde{p}_{iT}$, then the landholder will never comply.

This proves cases IIa, IIb and IIc.

APPENDIX B: Proof of proposition C

We look at the compliance decisions of landholders when they are confronted with a reserve-type regulation. Again we use backward induction.

In the last policy period T, we distinguish two cases: (i) the landholder has invested I (forced or voluntary) in a previous period and (ii) the landholder has in past never complied with the regulation and his violation has not been detected.

For (i), the owner will comply in period T if:

$$Y_i^C - c_i \geq Y_i^{NC} - p\left(\overline{F} + c_i\right) \text{ or if } c_i \leq \frac{1}{1-p}\left(Y_i^C - Y_i^{NC} + p\overline{F}\right) \tag{6}$$

Else the landholder will violate the regulation in period T.

For (ii), the owner will initially comply in period T if

$$Y_i^C - I_i \geq Y_i^{NC} - p\left(\overline{F} + I_i\right) \text{ or if } I_i \leq \frac{1}{1-p}\left(Y_i^C - Y_i^{NC} + p\overline{F}\right) \equiv \hat{I}_i \tag{7}$$

Else the landholder will violate the regulation in period T.

The compliance decision in period 0 can be described for three cases. Note that if condition (7) is true this also implies that equation (6) holds (since $c_i < I_i$), while the reverse does automatically not hold true.

Case 1: conditions (6) and (7) both hold

This implies that in period 0 the landholder will comply if

$$\begin{aligned} & Y_i^C - I_i + \sum_{t=1}^{T} \delta^t \left[Y_i^C - c_i\right] \geq \\ & Y_i^{NC} - p\left(\overline{F} + I_i\right) + \sum_{t=1}^{T} \delta^t \left[\left(1-(1-p)^t\right)\left[Y_i^C - c_i\right] + (1-p)^t \left[Y_i^{NC} - p\left(\overline{F} + I_i\right)\right]\right] \end{aligned}$$

This condition is always satisfied for this case. Thus these owners will always comply with the regulation (in all periods).

Case 2: condition (6) holds and condition (7) does not hold

This implies that in period 0 the landholder will comply if

$$Y_i^C - I_i + \sum_{t=1}^{T} \delta^t \left[Y_i^C - c_i \right] \geq$$

$$Y_i^{NC} - p\left(\overline{F} + I_i\right) + \sum_{t=1}^{T} \delta^t \left[\left(1-(1-p)^t\right)\left[Y_i^C - c_i\right] + (1-p)^t \left[Y_i^{NC} - p\left(\overline{F} + I_i\right)\right]\right]$$

Thus if $I_i \leq \hat{I}_i + \sum_{t=1}^{T} \delta^t (1-p)^t \left[Y_i^C - Y_i^{NC} - c_i + p\left(\overline{F} + I_i\right)\right]$, the landholder always complies.

If $I_i > \hat{I}_i + \sum_{t=1}^{T} \delta^t (1-p)^t \left[Y_i^C - Y_i^{NC} - c_i + p\left(\overline{F} + I_i\right)\right]$, the landholder is noncompliant until he gets caught and is compliant afterwards since condition (6) holds.

Case 3: conditions (6) and (7) both don't hold

This implies that in period 0 the landholder will comply if

$$Y_i^C - I_i + \sum_{t=1}^{T} \delta^t \left[Y_i^{NC} - p\left(\overline{F} + c_i\right)\right] \geq$$

$$Y_i^{NC} - p\left(\overline{F} + I_i\right) + \sum_{t=1}^{T} \delta^t \left[\left(1-(1-p)^t\right)\left[Y_i^C - p\left(\overline{F} + c_i\right)\right] + (1-p)^t \left[Y_i^{NC} - p\left(\overline{F} + I_i\right)\right]\right]$$

Thus if $I_i \leq \hat{I}_i + \sum_{t=1}^{T}\left[\delta^t (1-p)^t \left(I_i - c_i\right)\right]$, the landholder complies in period 0 and is in violation afterwards. If $I_i > \hat{I}_i + \sum_{t=1}^{T}\left[\delta^t (1-p)^t \left(I_i - c_i\right)\right]$, the landholder never voluntarily complies. Only if the violator is caught and forced to comply, he will incur compliance costs for that period.

This proves proposition C.

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