Incentive Contracts for Natura 2000 Implementation: A Mixed Model of Adverse Selection and Moral Hazard

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Abstract

The implementation of nature conservation policy in the EU is often based on contracts between public authorities and landowners. We model these contracts in the presence of adverse selection and moral hazard when the outcome is uncertain. The results show that agents, who have high probability to reach a higher level of conservation, should be offered a contract where transfers depend on the final outcome with a bonus for a high state. When conservation measures are correlated with forest management, we show that the contractual measures involve distorded tranfers. Finally, we analyze the payment mechanisms used in France and Denmark and show that these mechanisms result in overcompensation and underperformance since they do not take the problem of moral hazard and natural variability into account.

Keywords: Natura 2000, Forest, Contracts, Mixed model, Adverse selection, Moral hazard.

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1 Introduction

The majority of threatened birds and mammals are forest dwellers and forests play, therefore, an important role in nature conservation and biodiversity in the world (Birdlife International, 2000; Hilton-Taylor, 2000). Even though tropical rain forest contains most of the species, forests do also play an important role in species conservation in Europe. The EU has launched the Natura 2000 policy to increase nature protection and conservation of both individual species and habitats within the union. It is currently being implemented on public and private lands in all EU member states. The objective of Natura 2000 is to preserve and restore specific nature types and habitats of threatened species. To achieve this goal, areas are designated Natura 2000 areas based on knowledge of the biodiversity and biogeography. The Natura 2000 sites cover both marine and land areas, including forests. The habitats should be protected to conserve the related species. The implementation of the Habitats Directive[1] is based on a contractual relationship between public authorities and landowners, which determines the conservation goals, active measures and payment mechanisms of the agreement. Many EU countries, including Denmark and France, are in the process of formulating and implementing these contracts.

Using contracts as an implementation mechanism has a number of advantages. It is, in general more acceptable to the landowners, who become producers of biodiversity, a public good. It is also more flexible than legal instruments as it allows for differentiation between habitats and owner types, thereby increasing "production of biodiversity" where benefits are largest and/or costs are minimized. In the same time, it is also a demanding instrument that has to be carefully designed to avoid distortions and overcompensation. The aim of the present article is to analyze and discuss the design of Natura 2000 contracts in forests using contract and incentives theory.

When designing conservation contracts, the principal (the public authority) faces a number of different challenges: hidden information and hidden actions of the agent (the forest owner) as well as uncertainty about biological outcome of the contract. It is a well-known problem in contract theory that the agents hold private information about a range of different issues that influences the contracts directly. In the case of conservation contracts forest owners have private

[1] Council Directive 92/43/EEC.

knowledge of the conservation value of their land, their current management of the forest and their costs. The aim of the contract design is to give the agents incentive to reveal this knowledge. However, when dealing with nature conservation contracts, the problem of adverse selection is seldom alone. The outcome of the contract is most often uncertain due to the variability and complexity of biological systems, which are some of the major problems of nature conservation and preservation (Goeschl and Lin 2004). In the same time, the principal cannot observe the conservation actions of the forest owner to see whether he meets the contract. This raises the also well-known problem of moral hazard, where the agents have incentive to shirk when fulfilling the contract. In the case of Natura 2000 contracts (as in many other conservation schemes) the two information problems are intertwined and have to be handled simultaneously. In the following we present a mixed model where the principal cannot observe the type of the agents and his actions but only the variable outcome of the contract.

We also analyze another problem, which is often neglected when designing forest conservation instruments: the forest is a multiple-use resource where both economic and ecological goals can be achieved in the same forest area. Protection of some species necessitates strict conservation of the area, but often production is still possible: the conservation measures and forest management interact, thus impeding a separate analysis of the conservation measures. The design of Natura 2000 contracts should therefore be designed as a multiple-use instrument, which allows the forest owner to continue profitable management. The conservation contract can have positive or negative impact on forest management cost, thereby over- or undercompensating the real cost of fulfilling the contract. We analyze both positive and negative correlation between fulfilling the contract and general forest management in a principal-agent framework.

Finally, we discuss the different payment mechanisms used in Natura 2000 implementation in relation to the results from the model. This is particularly interesting, as different countries have chosen different payment mechanisms. We have chosen to present the French and Danish setup as examples. The Danish Forest and Nature Agency has designed payments that cover loss in land value, which is a lump-sum payment. In France, two types of payment are possible. The first builds on the principle of lump-sum payment for standardized operations. The second is based on estimates of operation costs and investments and is more flexible.

The article is organized as follows: In section 2, we give a literature review on conservation and incentive mechanisms. In section 3, we turn to the policy setup in France and Denmark and discuss the legal foundation, the contractual setting and the payment mechanisms. Section 4 is devoted to the presentation of a mixed (two-type) principal-agent model where only the uncertain outcome is observable. The agent holds private information about his capacities to reach a high outcome of the conservation activities and about the investment he undertakes. In section 5, we include the abovementioned relationship between the contracts and forest management. In section 6, we discuss the implementation of the model and relate it to the payment mechanisms found in France and Denmark. In the concluding section, we discuss the policy implications of the model and relate them to the practical issues of designing Natura 2000 contracts in forestry.

2 Related literature

Using contracts as an economic instrument within the Natura 2000 network constitutes a real novelty in the context of forest policy in Europe. In fact, the decision to use contracts for the protection of biodiversity can be understood within a general context of a changing forest policy. Forest offers quite a few interesting characteristics (e.g. long-term production and complex relationship between management and ecosystems) for which public authorities and forest owners have different objectives. The use of contracts is both a means of internalizing biodiversity and of recognizing the concept of joint production in forestry.

Even if contracting is a policy instrument, which can be used to regulate both biodiversity and environmental services (Russel, 1993; Romstad, 2004), its efficiency is conditioned on the type of functional relationship that exists between the market goods and the non-market goods (Stenger and Normandin 2003). Price support of the forest products is efficient if the relation between the two goods is known to be complementary. Otherwise, a direct subsidy of non-market goods is a better instrument, but it involves knowledge and/or observation of these non-market goods. The Natura 2000 contracts are such an instrument. When designing this instrument, it is important to realize that the incentives have to be sensitive to the producer's objective, e.g. forest owners who focus on timber production require higher compensation (Kline et al., 2000). Some empirical results confirm that the success of policy instruments, such as subsidies

in forest areas, has to take into account the different objectives and attitudes of agents. For instance a survey conducted by Serbruyns and Luyssaert (2006) shows that even if subsidies are supplied in numerous situations, forest owners tend to apply for these subsidies only when no real change in their forest management is involved. In southern Finland forest owners reject voluntary conservation contracts due to their strong feeling of property rights and to the fact that the majority appreciate non-timber aspects of their forests (Tikka 2003).

Another concern when designing incentives for nature conservation or for endangered species protection, is to deal with asymmetric information (see Smith and Shogren, 2001, 2002). Studies of contracts generally involve either moral hazard *or* adverse selection but most of the literature is concerned with the latter information problem. In most studies, authors compare conservation schemes with similar objectives or different payment mechanisms used within the same scheme. They focus on the type of payment: linear, non-linear pricing, spatially uniform or heterogeneous (Wätzold and Drechsler 2005), uniform or discriminating payments (Gren 2004). In general, menus of contracts depending on cost differentiation or available information correlated with costs are recommended (Slangen, 1997). From an efficiency point of view, conditioning payments on performance is preferable compared to conditioning them only on costs. Bazzani et al. (2000) find considerable improvements of agri-environmental policies in Italy when switching from flat rate payments per hectare to flat rate payments per unit of environmental improvement. However, making payments dependent on environmental benefits and management is not without problems due to monitoring difficulties and the uncertain correlation between conservation actions and improvements in biodiversity. This is one of the reasons why most schemes condition their payments on the cost of specific investments that are expected to increase biodiversity. Another reason is that existing knowledge of cost and benefits on individual land may not be easy to utilize directly. Whatever the type of asymmetric information, the optimal contact is not always operational due to informational requirements on rewards or sanctions or due to budget constraint (Moyle 1998).

Analyzing models that involve both moral hazard and adverse selection is in general quite complicated and the number of articles handling mixed models of conservation contracts is limited. A good example is given by Bontems and Thomas (2006) who consider a model of

agricultural pollution regulation involving hidden information and moral hazard. This model is hardened by the issue of risk sharing with risk-averse farmers. Huennemeyer and Rollins (2002) analyze conservation in Canadian public forests with private concession holders. They apply numerical simulation to analyze the magnitude of different informational problems. There are differences in conservation values between areas, and agents hold information about specific areas' conservation value. In the same time, the principal wishes to induce a costly conservation effort via the contract. However, there is no limited liability of the agents and therefore the authors find that solving the moral hazard problem is costsless.

Laffont and Martimort (2002) offer an overview of the results for mixed models. They divide these models depending on the order of the two informational problems. In our case, the adverse selection problem exists before the contract is signed and the moral hazard problem exists after, but before the outcome of the contract. Laffont and Martimort (2002) show that the introduction of moral hazard actually hardens the adverse selection problem, since the (risk neutral) agents need incentive to first reveal themselves before the contract is signed and then to make the right effort. This result depends on the existence of limited liability for the agents. Without limited liability, Guesnerie et al. (1988) show that the moral hazard problem does not lead to additional welfare loss compared to the pure adverse selection solution, since risk delegation is costless when agents are risk neutral and it therefore leads to no additional distortions compared to the first best. Theilen (2003) finds a similar result for risk averse agents in a general mixed model: the principal strictly prefers to relax the moral hazard constraints even though this increases the risk premium.

However, within environmental economics, limited liability cannot always be ignored. When there exists uncertainty about the outcome due to the natural variability of ecosystems, agents may exert a high effort but still achieve a poor outcome. In this case, it is not politically acceptable to punish him too hard. Laffont (1995) and Hiriart and Martimort (2006) have analyzed mixed models of production that entails environmental hazard where the damage costs may exceed production companies' equity base considerably. In this case it is necessary to take the limited liability into account to ensure sufficient effort to avoid damage. Laffont (1995) reaches the same solution as Guesnerie et al. (1988) when there is no limited liability. When a

limited liability constraint is included, solving the moral hazard problem is not costless, since the principal has to increase the rent to induce effort. Cost minimization is given up and low-powered incentives become optimal due to the agent's trade-off between efficiency and safety. Hiriart and Martimort (2006) explore the effect in a model where effort and cost are not directly linked. The principal still have to make trade-offs between output and care, and sellers receive a positive rent to induce optimal safety care. Also the inefficient sellers' care is reduced to decrease the moral-hazard rent of the efficient agent.

3 Natura 2000 in France and Denmark

There are two important EU directives concerning nature protection: the Birds Directive[2] and the Habitats Directive[3]. The Habitats Directive ascertains that Natura 2000 areas are to be designated in all EU Member States based on specified nature types. Europe is divided into six biogeographical areas and each area holds a range of different nature types. In the designated areas, the specified nature type should be protected against disturbances or degradation of the habitat as to restore or conserve the nature type and the endangered species within. In all designated areas a management plan should be prepared, specifying the conservation goals and specific measures. However, as the Habitats Directive does not specify how to implement the regulation, it is up to the member states to decide and it is therefore done in different ways. In the following, we present two different countries' implementation, focusing on the contractual issues of the legislation.

3.1 Denmark

In Denmark, 254 sites have been designated Natura 2000 habitat sites. They cover more than 310,000 ha or 7 % of the terrestrial area of Denmark. Approximately 60,000 ha of the designated area is forest or 12 % of total forest cover. Two thirds of this area is privately owned, the rest is publicly owned, primarily State forest. Within the Danish Natura 2000 areas in forest, an estimated 14,000 ha are assumed to be classified as one of the 10 different forest nature types

[2]Council Directive 79/409/EEC.
[3]Council Directive 92/43/EEC.

that are specified in the Natura 2000 convention. The remaining 46,000 ha are everything from cultivated agricultural land to forest areas not yet fitting the classification. The designation is flexible and reassessed continuously.

The first designations of Natura 2000 areas were made in 1998 in non-forest areas based on the legislation in the Danish Nature Protection Law[4]. However, the legislation concerning the forest areas was not in place until a new Forest Law was passed in 2004[5]. This law describes the procedure for reaching an agreement. First, the forest type's initial state and its conservation status of protected species are described. Then a forest plan is prepared, determining the conservation goals and the actions necessary to obtain or conserve the desired status of the area. The plan is reevaluated after 12 years. The public authorities negotiate a voluntary agreement with the forest owner based on the forest plan. The contract is permanent for current and all future owners and users. It can be renegotiated if the changes comply with the forest plan and both parties agree. If it is not possible to reach a reasonable agreement, forest owners are imposed to accept a set of requirements and restrictions to secure the basic forest plan.

The contract describes the measure and payment. The basic requirement of the Natura 2000 agreements is to maintain the forest as a specific nature type in the future. The implementation is based on a set of restrictions in the forest management rather than specification of active conservation measures. In addition to this, the two parties can agree on additional restrictions with the purpose of increasing general biodiversity in Danish forests. These additional measures are always voluntary and should lead to improvements that are beyond the goals of the forest plan. Table 1 shows a tentative list of restrictions that can be implemented as basic or additional measures.

Table 1: Specific restrictions in Natura 2000 contracts in Denmark

Natural forest regeneration (not planting)
No pesticides
No fertilizers
No soil preparation
No drainage
Absolute conservation (no forest management)

[4]Consolidated Act LBK nr 835 af 01/11/1997. Today replaced by Consolidated Act LBK nr 884 af 18/08/2004.
[5]Consolidated Act LOV nr 453 af 09/06/2004 (in effect).

Whether these restrictions in forest management impose cost on the forest owner depends on his previous management of the area. Economic loss that can be proved by the owner to stem from the Natura 2000 regulation is compensated as net present value. The compensation is in principle a lump-sum payment calculated from the reduction in the market value of the forest.

Every six years the state of each Natura 2000 areas is reported to EU based on a continuous monitoring system, which monitors and evaluates the biodiversity and the conservation state of the forest based on a number of biological indicators. This is done by a third party[6] and there is no cost burden on either parties of the contract to achieve this information.

3.2 France

The legislative text defining Natura 2000 implementation in France is the Circular of December 24th, 2004. In 2006, 1,674 sites (including all kinds of habitats) have been submitted to the European Commission. Now, the sites' network covers 6.5 millions hectares (except marine zones) with about one third in forested areas.

Once a site is designated, a management plan (*document d'objectifs*) is developed. From the assessment of the actual state of the site, it provides general guidance for the stakeholders involved in the management of the site. It defines the objectives of management and conservation (of natural habitats and species) together with their implementation (by way of regulation and contractual measures) and the means of financing. One or several juridical terms and conditions (*cahiers des charges)* are proposed for the future contracts, and monitoring and evaluation procedures are defined. The State's representative (*Préfet de département*) is responsible for the preparation of this document.[7] In 2005, this document was completed or in the course of drafting in 60% of the sites.

From these plans, the Natura 2000 contracts are established in agricultural, forested and marine zones. The contracts are signed between the State (via the *Préfet de département*) and a public or private owner in the Natura 2000 site. In 2005, 359 contracts have been signed

[6] The National Environmental Research Institute.

[7] A technical operator is often designated for assistance of the *Préfet de département.* The technical operator associated with all local stakeholders of the site (land owners, elected representatives,...) constitute the driving committee that meets for the plan elaboration and valuation.

including only 64 forest contracts corresponding to 1.2 million euros.[8] The Natura 2000 contract is defined by four elements: the operations that must be implemented to reach the objective of preservation, a set of commitments (some of them being eligible for a financial counterpart), the financial conditions, the documents that allow for the control of the contractual commitments.[9] For forested areas, commitments that are eligible for financing concern forestry projects with a production objective, forestry investments or actions with a protective, environmental or social objective, forestry investments or actions with an objective of conservation and restoration of the biodiversity. Thirteen measures are listed in which the conditions of eligibility are described.[10] Table 2 gives a summary of the main categories of measures in France.

Table 2: Specific measures in Natura 2000 contracts in France

Specific directed (and natural) regeneration
Development or restoration of natural habitats
Limitation of chemical or machine-made works
Cutting and trimming works without productive logic
Actions for (or against) specific species
Preservation of senescent trees

The duration of the contract is at least five years for all measures except for one concerning senescent wood (i.e. above its economic maturity, even decaying) the so-called "measure K" for which the duration is thirty years. When some contracts are dedicated to the production, the output must be left *in situ* (gain revenues from measures that are covered by a Natura 2000 contracts are forbidden). The *Préfet de Région* with the assistance of different public authorities (local representatives of the Environment and Agriculture Ministries) establishes the financial and technical conditions in each region. In particular, he specifies for each measure, the type of payment:

- either a regionally regulated amount for standardized measures and the measure K;

[8] If the management of a specific forest only requires actions from the owner classified as non compensated commitments (corresponding to the "good practices" identified in the plan of the site), then the owner has "only" the possibility to sign a charter (*charte Natura 2000*). There are no financial subsidies expected, but a charter may induce an exemption of land tax. Natura 2000 contracts are rather rare in forest because in most cases the signature of a charter is sufficient.

[9] The *Préfet de département* controls the compliance of the titular's commitments that were set in the contract. In case of noncompliance, subsidies are totally or partially cut.

[10] See Annex V of the Circular of December 24th, 2004.

- or estimated operation costs and investments, with a maximum amount per hectare.

The first type of payment is built on a principle of lump-sum payment from a legal scale. This system allows to rapidly set the level of transfer and facilitates at the same time the financial forecasts made by the departments of State. In the other cases where the principle of lump-sum payment can not be applied – typically for the majority of the operations because of their complexity – it is necessary that the *Préfet de département* approves the estimates.

4 The model

4.1 Basic framework

Consider the contractual relationship between a public authority (the principal) and forest owners (the agents, denoted A) investing I to improve the conservation value. The state of the forest S is observable. The principal has to create incentive for all agents to participate, since the legislation requires that all Natura 2000 areas are protected. But he also wants to give some agents incentive to make a higher investment to increase overall biodiversity. Therefore, the setup consists of two contracts: a basic contracts and one with additional measures. This means that all agents at least have to spend $\underline{I}$ and to maintain a minimum state S^L. Furthermore, all forest owners are offered additional measures that cost $\overline{I}$, which are voluntary for both agents and principal. These additional measures increase the probability of a higher state S^H. It is also possible to reach this state with the minimum measures, but with a lower probability. We assume that this investment is nonverifiable.

We denote S^I the initial state of forest, which is supposed to be the same for all agents. The agents are heterogeneous with respect to the probability of reaching S^H due to differences in biological aspects and ability. This probability is private knowledge held by the agents. The principal only knows that a fraction of the agents ν has a higher probability $\overline{\alpha}_i$ to reach the high state and a fraction $(1-\nu)$ has a lower probability $\underline{\alpha}_i$. Also, investment affects the probability of a given state, a higher investment increases the probability of the high state. The determination

of the final state is a stochastic process with the following probabilities and outcomes:

$$\overline{I} \text{ gives} \begin{cases} S^H & \text{with probabilities } \overline{\alpha}_1 \text{ and } \underline{\alpha}_1 \text{ according to the type} \\ S^L & \text{with probabilities } (1-\overline{\alpha}_1) \text{ and } (1-\underline{\alpha}_1) \end{cases}$$

$$\underline{I} \text{ gives} \begin{cases} S^H & \text{with probabilities } \overline{\alpha}_0 \text{ and } \underline{\alpha}_0 \text{ according to the type} \\ S^L & \text{with probabilities } (1-\overline{\alpha}_0) \text{ and } (1-\underline{\alpha}_0) \end{cases}$$

We have $\overline{\alpha}_i > \underline{\alpha}_i, \forall i = 0, 1$. Moreover $\overline{\alpha}_1 > \overline{\alpha}_0$ and $\underline{\alpha}_1 > \underline{\alpha}_0$. The agents are informed about their probabilities before they choose the level of investment, so that we are in a framework where moral hazard takes place after adverse selection. The timing of contracting is depicted in Figure 1.

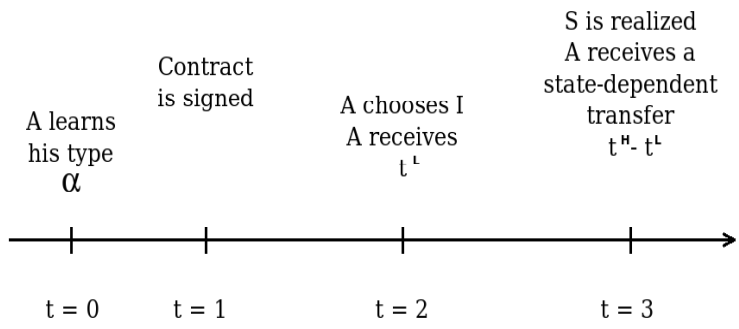

Figure 1: Timing of contracting

The principal has to offer transfers to the agents in return for their forest investments, such that participation and truth-telling are ensured. A direct revelation mechanism is a menu of two different contracts, one for each type of agent, which consists of an investment, a payment if the high-state is observed and a payment if the low-state is observed post contract

$\left\{\left(\underline{I},\underline{t}^H,\underline{t}^L\right),\left(\overline{I},\overline{t}^H,\overline{t}^L\right)\right\}$. In what follows, we assume that the principal prefers that a high-prob agent (i.e. the agent with higher probability of reaching the high state) undertakes a high investment and that the low-prob agent (i.e. the agent with lower probability of reaching the high state) makes a low investment.

All agents are profit maximizing and risk neutral with a reservation profit equal to zero.[11] Hence, the expected profit of the agents is:

$$E(\overline{\pi}) = \overline{\alpha}_1\overline{t}^H + (1-\overline{\alpha}_1)\overline{t}^L - \overline{I} \tag{1}$$

$$E(\underline{\pi}) = \underline{\alpha}_0\underline{t}^H + (1-\underline{\alpha}_0)\underline{t}^L - \underline{I} \tag{2}$$

The participation constraints are written as:

$$E(\overline{\pi}) \geq 0 \tag{3}$$

$$E(\underline{\pi}) \geq 0 \tag{4}$$

We denote the social benefit V depending on the state of the forest S. We assume that the social benefit V is increasing and concave in forest states S. For notational simplicity, we write $V^H = V(S^H)$ and $V^L = V(S^L)$. Moreover, we assume that there exists a social cost of public funds, which is strictly positive and denoted λ. Hence, the risk neutral principal considers the following expected social welfare:

$$\begin{aligned} W =& \nu\left[\overline{\alpha}_1\left(V^H-\lambda\overline{t}^H\right)+(1-\overline{\alpha}_1)\left(V^L-\lambda\overline{t}^L\right)-\overline{I}\right] \\ &+(1-\nu)\left[\underline{\alpha}_0\left(V^H-\lambda\underline{t}^H\right)+(1-\underline{\alpha}_0)\left(V^L-\lambda\underline{t}^L\right)-\underline{I}\right] \end{aligned} \tag{5}$$

Under complete information, the problem of the principal is simply to maximize the expected social welfare (5) subject to the participation constraints (3) and (4). The high-prob agents commit a high investment and the low-prob ones commit a low investment. Since rents are costly, the agents receive no rents. That is, $\overline{\alpha}_1\overline{t}^H + (1-\overline{\alpha}_1)\overline{t}^L = \overline{I}$ and $\underline{\alpha}_0\underline{t}^H + (1-\underline{\alpha}_0)\underline{t}^L = \underline{I}$.

[11] If the agents are risk averse, their program becomes the maximization of the expected (Von Neuman-Morgenstern) utility of profit.

The principal pays the same transfer whatever the final state:

$$\begin{aligned} \underline{t}^H &= \underline{t}^L = \underline{I} \\ \overline{t}^H &= \overline{t}^L = \overline{I} \end{aligned} \tag{6}$$

As we see below, this feature of the (first-best) optimal contract no longer exists in the second-best case. Before we analyze the combined problem, we are going to separately investigate the simpler pure adverse selection and pure moral hazard problems to gain some insight into the possible solutions to the mixed problem.

4.2 The pure adverse selection problem

When investments are observable and contractible there is only hidden information about the type of the agent (i.e. the probability α). The incentive compatibility constraints are:

$$\overline{\alpha}_1 \overline{t}^H + (1 - \overline{\alpha}_1)\overline{t}^L - \overline{I} \geq \overline{\alpha}_0 \underline{t}^H + (1 - \overline{\alpha}_0)\underline{t}^L - \underline{I} \tag{7}$$

$$\underline{\alpha}_0 \underline{t}^H + (1 - \underline{\alpha}_0)\underline{t}^L - \underline{I} \geq \underline{\alpha}_1 \overline{t}^H + (1 - \underline{\alpha}_1)\overline{t}^L - \overline{I} \tag{8}$$

First we consider the incentives for the low-prob agent; it can be easily argued that he has not to be rewarded for the high state: He should make the lowest possible investment $\underline{I}$ and should not be given any reward for the high state, since this would give the high-prob agent incentives to pass himself as the low-prob agent. Therefore $\underline{t}^H \leq \underline{t}^L$. In the same time, if the low state is realized the payment cannot be higher than the payment for the high state, since this would give perverse incentives to actually try to ensure the low state. Therefore the two payments have to be equal $\underline{t}^H = \underline{t}^L$. Furthermore the participation constraint (4) have to be binding and:

$$\underline{t}^H = \underline{t}^L = \underline{t} = \underline{I}$$

Hence, we can rewrite the participation constraints as:

$$E(\overline{\pi}) = \overline{\alpha}_1 \overline{t}^H + (1 - \overline{\alpha}_1)\overline{t}^L - \overline{I} \geq 0 \qquad (\overline{PC})$$

$$E(\underline{\pi}) = \underline{t} - \underline{I} = 0 \qquad (\underline{\text{PC}})$$

Moreover, this reduces the incentive contraints to:

$$\overline{\alpha}_1 \overline{t}^H + (1 - \overline{\alpha}_1)\overline{t}^L - \overline{I} \geq \underline{t} - \underline{I} = 0 \qquad (9)$$

$$0 = \underline{t} - \underline{I} \geq \underline{\alpha}_1 \overline{t}^H + (1 - \underline{\alpha}_1)\overline{t}^L - \overline{I} \qquad (10)$$

Now the participation constraint $(\overline{PC})$ and the incentive constraint (9) for the high-prob agent are the same. By rearranging and combining (9) and (10), we finally get the following adverse selection incentive constraints:

$$\overline{\alpha}_1 \overline{t}^H + (1 - \overline{\alpha}_1)\overline{t}^L \geq \overline{I} \qquad (\overline{AD})$$

$$\underline{\alpha}_1 \overline{t}^H + (1 - \underline{\alpha}_1)\overline{t}^L \leq \overline{I} \qquad (\underline{\text{AD}})$$

This means that the expected payment of the high-prob agent has to be larger than his investment $\overline{I}$ and that the expected payment of the low-prob agent posing as the other agent has to be smaller than the necessary investment $\overline{I}$. However, this solution does not determine the actual payment design. In Figure 2, we draw the constraints as function of $\overline{t}^L$ and $\overline{t}^H$, and we get the set of incentive feasible solutions.[12] Notice that since the participation constraint $(\overline{PC})$ and the adverse selection constraint $(\overline{AD})$ are the same, the constraint $(\overline{PC})$ cannot be above the constraint $(\underline{\text{AD}})$.

The set is bounded by three restrictions: $\overline{t}^L \geq 0$ (to the left), $(\underline{\text{AD}})$ (downwards) and $(\overline{PC})$ (upwards). The principal's objective is to minimize cost given the constraints. Therefore the efficient combinations are represented by the line between A and B. A is the solution where the participation constraint of the high-prob agent is binding and $\overline{t}^L = 0$.

Proposition 1 *In the case of pure adverse selection where the agent takes the entire risk, the*

[12] We do not need to take $\underline{t}$ into account since it is constant.

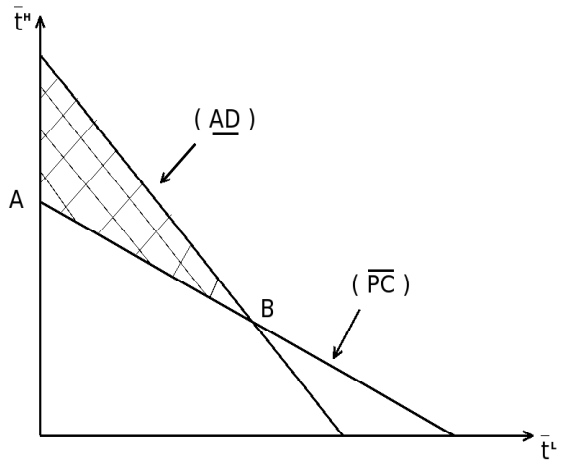

Figure 2: Incentive feasible contracts in the case of pure adverse selection

optimal contract for the type is to pay zero if the low state occurs and a payment higher than the investment $\overline{I}$ if the high state occurs:

$$\begin{aligned} \underline{t} &= \underline{I} \\ \bar{t}^L &= 0 \\ \bar{t}^H &= \tfrac{\overline{I}}{\overline{\alpha}_1} \end{aligned} \tag{11}$$

The other extreme is B in Figure 2. Here both ($\underline{\text{AD}}$) and ($\overline{PC}$) are binding and the solution is such that:

$$\begin{aligned} \overline{\alpha}_1 \bar{t}^H + (1-\overline{\alpha}_1)\bar{t}^L &= \overline{I} \\ \underline{\alpha}_1 \bar{t}^H + (1-\underline{\alpha}_1)\bar{t}^L &= \overline{I} \end{aligned}$$

Proposition 2 *In the case of pure adverse selection where the principal takes the entire risk,*

the optimal contract is to pay the same transfer whatever the final state:

$$\begin{aligned} \underline{t} &= \underline{I} \\ \bar{t}^L &= \overline{I} \\ \bar{t}^H &= \overline{I} \end{aligned} \tag{12}$$

The solution makes the agent indifferent between posing as his own type and the other type. However, if the two payments for the high-prob agent are separated a bit by ε so that $\bar{t}^L = \overline{I} - \varepsilon$ and $\bar{t}^H = \overline{I} + \varepsilon$, this is enough reward to create a separating solution for all agents.

All solutions that are a linear combination of A and B are incentive compatible and equally cost-efficient for the principal as the expected payment is constant. Notice that there is no information rent to the risk neutral high-prob agent, since the informational problem is solved simply by using the opposite incentives of the agents. So when the low-prob agent is always offered a contract with certain payment, the high-prob agent can be given incentives to reveal himself simply by adding state-dependent payments, since the high-prob agent has no incentive to choose a contract that does not reward him for his increased probability of the high state.

4.3 The pure moral hazard problem

In the case of pure moral hazard, there is no heterogeneity between agents ($\overline{\alpha}_i = \underline{\alpha}_i, \forall i$), and the investments is nonverifiable. We presume that the principal finds it valuable that the agents always make the high investment. The expected social welfare is:

$$W = \alpha_1 \left(V^H - \lambda t^H\right) + (1 - \alpha_1) \left(V^L - \lambda t^L\right) - \overline{I}) \tag{13}$$

and the participation constraint is:

$$\alpha_1 t^H + (1 - \alpha_1) t^L - \overline{I} \geq 0 \tag{PC}$$

Two types of constraints are added in the case of pure moral hazard. First, in order to have an incentive feasible contract, the expected profit of making the high investment has to be larger than the expected profit of the low investment. Hence, we have the following moral hazard

incentive contraint:

$$\alpha_1 t^H + (1-\alpha_1)\, t^L - \overline{I} \geq \alpha_0 t^H + (1-\alpha_0)\, t^L - \underline{I} \tag{14}$$

We can rewrite this constraint as:

$$(\alpha_1 - \alpha_0)t^H + (\alpha_1 - \alpha_0)t^L - \Delta I \geq 0, \tag{MH}$$

Where $\Delta I = \overline{I} - \underline{I}$.

Second, we impose limited liability constraints to avoid that the agents have to pay the principle to participate:

$$t^L \geq 0 \tag{15}$$

$$t^H \geq 0 \tag{16}$$

Figure 3 shows the set of incentive feasible combinations of t^H and t^L when the participation constraint (PC), the moral hazard constraint (MH), as well as the limited liability constraints have to be fulfilled. The grey-striped area indicates the set, which is unlimited. However, the cost-minimizing frontier is the line between A and B.

A is the solution where both (PC) and $t^L \geq 0$ are binding, that is:

Proposition 3 *In the case of pure moral hazard where the agent carries all the risk, the optimal contract is to pay zero if the low state occurs and a payment higher than the investment if the high state occurs:*

$$\begin{aligned} t^L &= 0 \\ t^H &= \tfrac{\overline{I}}{\alpha_1} \end{aligned} \tag{17}$$

Again, this solution implies that the agent's expected profit is equal to zero.

At point B, both (PC) and (MH) are binding:

$$\begin{aligned} (\alpha_1 - \alpha_0)t^H + (\alpha_1 - \alpha_0)t^L - \Delta I &= 0 \\ \alpha_1 t^H + (1-\alpha_1)\, t^L - \overline{I} &= 0 \end{aligned}$$

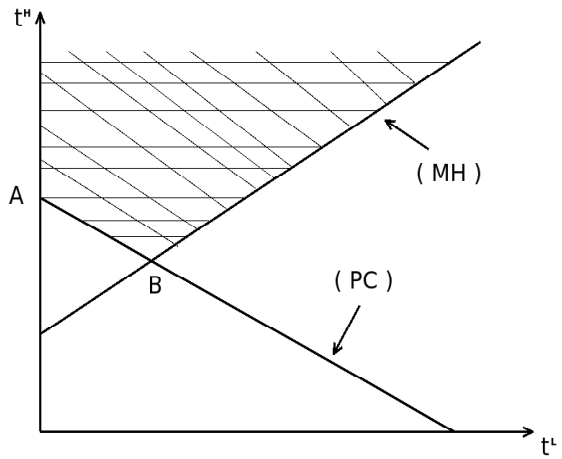

Figure 3: Incentive feasible contracts in the case of pure moral hazard

Solving this, we can state that:

Proposition 4 *In the case of pure moral hazard and risk sharing between the principal and the agent, the optimal contract covers part of the total cost of the agent in the low state and gives him a bonus in the high state:*

$$\begin{aligned} t^L &= \overline{I} - \tfrac{\alpha_1}{\alpha_1-\alpha_0}\Delta I \\ t^H &= \overline{I} + \tfrac{(1-\alpha_1)}{\alpha_1-\alpha_0}\Delta I \end{aligned} \tag{18}$$

The expected profit remains zero in this case. Again, all linear combinations of A and B are incentive compatible contracts. If (PC) is decreased or (MH) is increased, then (PC) is no longer binding and the optimal contract should only solve the moral hazard problem while respecting the limited liability constraints. When the moral hazard constraint (MH) is above the participation constraint (PC), then: $\frac{\Delta I}{\alpha_1-\alpha_0} > \frac{\overline{I}}{\alpha_1}$. Moreover, we can trivially check that this inequality is equivalent to $\frac{\Delta I}{\alpha_1-\alpha_0} > \overline{I} + \frac{(1-\alpha_1)}{\alpha_1-\alpha_0}\Delta I$. Hence, we have:

In the case of pure moral hazard when the participation constraint is not binding, the optimal contract is to pay zero if the low state occurs and to pay the agent more than when the

participation constraint is binding:

$$\begin{aligned} t^L &= 0 \\ t^H &= \tfrac{\Delta I}{\alpha_1 - \alpha_0} \end{aligned} \tag{19}$$

This solution is also maximizing the risk-sharing for the risk-neutral agent to minimize cost. The agent has a strictly positive profit:

$$E(\pi) = \frac{\alpha_0 \overline{I} - \alpha_1 \underline{I}}{\alpha_1 - \alpha_0}$$

There is no possible solution that does not involve the agent facing risk as opposed to the adverse selection solution. This is because it is necessary to reward the agent for reaching the high state to solve the moral hazard problem.

4.4 The mixed problem

Now we consider the problem where the principal cannot determine the types of agent nor observe the actual investments after the contracts have been signed. His objective function is then defined by (5):

$$\begin{aligned} W &= \nu \left[\overline{\alpha}_1 \left(V^H - \lambda \overline{t^H} \right) + (1 - \overline{\alpha}_1) \left(V^L - \lambda \overline{t^L} \right) - \overline{I} \right] \\ &\quad + (1 - \nu) \left[\underline{\alpha}_0 \left(V^H - \lambda \underline{t}^H \right) + (1 - \underline{\alpha}_0) \left(V^L - \lambda \underline{t}^L \right) - \underline{I} \right] \end{aligned}$$

For the low-prob agent, the argument from 4.2 still holds: it is still optimal that payment is not differentiated depending on state to avoid giving the high-prob agent incentives to pose as the low-prob agent. Also the limited liability prevails ($\overline{t}^H \geq 0$ and $\overline{t}^L \geq 0$) and we have the following participation constraints:

$$E(\overline{\pi}) = \overline{\alpha}_1 \overline{t}^H + (1 - \overline{\alpha}_1) \overline{t}^L - \overline{I} \geq 0 \tag{20}$$

$$E(\underline{\pi}) = \underline{t} - \underline{I} \geq 0 \tag{21}$$

However, some incentive constraints have to be altered to ensure both truth-telling and the

right investment. The moral hazard incentive constraint for the high-prob agent is:

$$\overline{\alpha}_1\bar{t}^H + (1-\overline{\alpha}_1)\,\bar{t}^L - \overline{I} \geq \overline{\alpha}_0\bar{t}^H + (1-\overline{\alpha}_0)\,\bar{t}^L - \underline{I} \qquad (\overline{MH})$$

There is no moral hazard problem for the low-prob agent, since he has no incentive to make a higher investment when he only gets the low investment covered.

The adverse selection problem for each agent can be summarized by the following constraints:

$$\overline{\alpha}_1\bar{t}^H + (1-\overline{\alpha}_1)\bar{t}^L - \overline{I} \geq \underline{t} - \underline{I} \qquad (22)$$

$$\underline{t} - \underline{I} \geq \underline{\alpha}_1\bar{t}^H + (1-\underline{\alpha}_1)\bar{t}^L - \overline{I} \qquad (23)$$

However, there also exists combinations of the two problems (here called mixed constraints, MX) where the agents both pose as each other *and* undertake the other investment that they contract on:

$$\overline{\alpha}_1\bar{t}^H + (1-\overline{\alpha}_1)\bar{t}^L - \overline{I} \geq \underline{t} - \overline{I} \qquad (24)$$

$$\underline{t} - \underline{I} \geq \underline{\alpha}_0\bar{t}^H + (1-\underline{\alpha}_0)\bar{t}^L - \underline{I} \qquad (25)$$

If we compare with (23) we see that the high-prob agent's mixed constraint can be ignored , since $\underline{t} - \underline{I} > \underline{t} - \overline{I}$.

Also, the participation constraint of the low-prob agent is binding $\underline{t} = \underline{I}$ (see equation ($\underline{\text{PC}}$)), and the principal only has to solve the optimal combination of $\bar{t}^L$ and $\bar{t}^H$. The participation and adverse selection constraints of the high-prob agent are identical. In addition to the limited liability constraints $\bar{t}^L \geq 0$ and $\bar{t}^H > 0$, the program of the principal thus has the following four constraints:

$$\overline{\alpha}_1\bar{t}^H + (1-\overline{\alpha}_1)\bar{t}^L - \overline{I} \geq 0 \qquad (\overline{PC})$$

$$\underline{\alpha}_1\bar{t}^H + (1-\underline{\alpha}_1)\bar{t}^L - \overline{I} \leq 0 \qquad (\underline{\text{AD}})$$

$$\overline{\alpha}_1\bar{t}^H + (1-\overline{\alpha}_1)\,\bar{t}^L - \overline{I} \geq \overline{\alpha}_0\bar{t}^H + (1-\overline{\alpha}_0)\,\bar{t}^L - \underline{I} \qquad (\overline{MH})$$

$$\underline{\alpha}_0\bar{t}^H + (1-\underline{\alpha}_0)\bar{t}^L - \underline{I} \leq 0 \qquad (\underline{\text{MX}})$$

This set of constraints defines the incentive feasible solution that is illustrated in Figure 4.

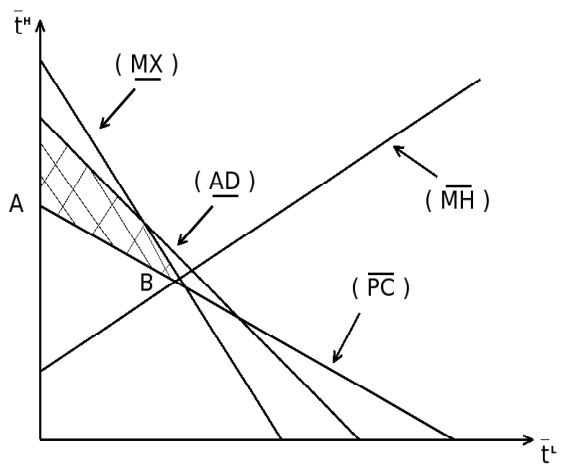

Figure 4: Incentive feasible contracts in the case of a mixed model

The mixed model is a combination of the two pure models. Therefore, the set of incentive feasible solutions is also a combination of the set of solutions of the two. Figure 4 is only an example of what this set could look like. However, the solution is rather straightforward. First, the moral hazard constraint ($\overline{MH}$) for the high-prob agent is always binding. Second, the two constraints ($\underline{\text{AD}}$) and ($\underline{\text{MX}}$) are always overruled by ($\overline{MH}$) (see Appendix A). Therefore, the optimal solutions in the mixed model is the same as the pure moral hazard case.

Proposition 5 *In the mixed model the optimal contract consists in:*

- *paying the same transfer whatever the final state to the low-prob agent;*
- *the same optimal solutions for the pure moral hazard model for the high-prob agent.*

In particular, the transfers given to the high-prob agent are greater than in the pure adverse selection case, so that preventing moral hazard hardens the adverse selection problem as in (Laffont and Martimort 2002).

5 Taking forest management into account

Up until this point, we have only looked at the Natura 2000 contracts as a decision isolated from forest management. However, the Natura 2000 contracts are not strict conservation contracts where the forest owner needs to cease his forest management altogether. Therefore, it is essential to analyze participation in Natura 2000 schemes as an integrated forest management decision.

Many of the measures of the Natura 2000 contracts affect the forest operations, e.g. removal of intruding species, natural regeneration or cessation of drainage. Some measures can have a positive effect on the economy of the forest management, either by saving the cost of operations that would otherwise have been undertaken (e.g. some cases of natural regeneration) or by making otherwise economically infeasible activities feasible (e.g. removal of intruding species) thereby increasing wood quality or production. Other measures have a negative impact on the economy of the forest management, either by having a negative effect on the productivity (e.g. stopping drainage) or by increasing the cost of operation (e.g. no fertilizers).

The forest owner is profit maximizing and will take the correlation between the Natura 2000 contracts and general forest management into account when he evaluates the contracts. The two types of agent now have the following profit functions:

$$\begin{aligned} E(\overline{\pi}) &= py - c(y, \overline{I}) + \overline{\alpha}_1 \overline{t}^H + (1 - \overline{\alpha}_1)\, \overline{t}^L - \overline{I} \\ E(\underline{\pi}) &= py - c(y, \underline{I}) + \underline{t} - \underline{I} \end{aligned}$$

The additional measures are assumed to have either a positive or negative correlation with forest management cost. For simplicity, we assume a separable cost function: $c(y, \underline{I}) = c(y) + A(\underline{I})$ and $c(y, \overline{I}) = c(y) + A(\overline{I})$. The forest owner has an extra constant cost ($A(I) > 0$) or benefit ($A(I) < 0$), which is increasing and concave in I. This new term increases both the participation constraint and the moral hazard constraint linearly, and therefore it is still the

same contraints that bind as in the mixed model. The three restrictions are:

$$\begin{aligned} \overline{t^L} &\geq 0 \\ py - c(y) - A(\overline{I}) + \overline{\alpha}_1 \bar{t}^H + (1 - \overline{\alpha}_1)\, \bar{t}^L - \overline{I} &\geq 0 \\ (\overline{\alpha}_1 - \overline{\alpha}_0) \left(\bar{t}^H - \bar{t}^L \right) - \Delta I - \Delta A(I) &\geq 0, \end{aligned}$$

where $\Delta A(I) = A(\overline{I}) - A(\underline{I})$.

Proposition 6 *Considering that the contract has an impact on the forest activities modifies the optimal contract of the mixed model. In the case of a positive correlation, the moral hazard problem is hardened as the cap between payments for the high and the low state is increased, and the participation and incentive compatible constraints are increased, which makes higher expected payments necessary. The reverse is true if the correlation is negative.*

- *For the low-prob agent, the optimal contract is:*

$$\underline{t} = \underline{I} + A(\underline{I}) \tag{26}$$

- *For the high-prob agent, the optimal contract is:*

  - *If both participation and limited liability constraints are binding:*

$$\begin{aligned} \bar{t}^L &= 0 \\ \bar{t}^H &= \tfrac{\overline{I} + A(\overline{I})}{\overline{\alpha}_1} \end{aligned} \tag{27}$$

  - *If both participation and moral hazard constraints are binding:*

$$\begin{aligned} \bar{t}^L &= \overline{I} - \tfrac{\overline{\alpha}_1}{(\overline{\alpha}_1 - \overline{\alpha}_0)} \Delta I - \tfrac{\overline{\alpha}_0}{(\overline{\alpha}_1 - \overline{\alpha}_0)} \Delta A(I) \\ \bar{t}^H &= \overline{I} + \tfrac{1 - \overline{\alpha}_1}{(\overline{\alpha}_1 - \overline{\alpha}_0)} \Delta I + \tfrac{1 - \overline{\alpha}_0}{(\overline{\alpha}_1 - \overline{\alpha}_0)} \Delta A(I) \end{aligned} \tag{28}$$

– *If only the moral hazard constraint is binding:*

$$\begin{aligned} \bar{t}^L &= 0 \\ \bar{t}^H &= \frac{\Delta I + \Delta A(I)}{(\overline{\alpha}_1 - \overline{\alpha}_0)} \end{aligned} \tag{29}$$

6 Implementation and payment mechanisms

The results from the former sections suggest a rather complicated payment mechanism, that depends both on information on the final state and general knowledge about the investment's correlation with forest management. The implementation is a menu of contracts:

- The basic contract: Agents are asked to invest $\underline{I}$ and are paid $\underline{t} = \underline{I} + A(\underline{I})$
- A contract with additional measures: Agents are asked to invest $\overline{I}$ and are given a prepayment equal to $\bar{t}^L < \underline{I} + A\left(\underline{I}\right)$ to ensure incentive compatibility. After termination of the contract, outcomes are monitored and if S^H is realized, agents are given a bonus equal to $\bar{t}^H - \bar{t}^L$.

This payment mechanism corresponds to the time line in Figure 1. The first contract has a low investment and the entire transfer is made in period 2, as there is no problem of moral hazard. The second contract involves a high investment, and the transfer is divided into two periods: before and after the state is realized. The first transfer $\bar{t}^L$ could be equal to zero, but it is not necessary to choose as low a payment, unless it is only the moral hazard constraint that is binding. If the participation constraint is also binding, $\bar{t}^L \geq 0$. When the state is realized, the bonus depends on the state. If a high state S^H is realized, the agent receives $\bar{t}^H - \bar{t}^L$, otherwise he receives nothing. It may be preferable not to retain the entire transfer until the final state have been realized, as the time laps between finalizing the contract and realizing the outcome can be long. Therefore, when possible, an initial transfer should be preferred, still maintaining the right incentives.

6.1 Payment mechanisms in Denmark and France

The results from the model can be used to evaluate the two current payment mechanisms in Denmark and France.

The French implementation involves two different payment mechanisms, which both cover the direct cost of the conservation investments. The first one is a lump-sum payment depending on a regional estimate of cost and the second one is a specific payment, where the agent gets cost reimbursement. They both lead to the same payment in our model:

$$\underline{t}^F = \underline{I} \tag{30}$$

$$\bar{t}^{L^F} = \bar{t}^{H^F} = \bar{I} \tag{31}$$

The payment mechanism is independent of outcomes and does not take private information into account at all. It does not take related forest management into account either. Therefore, there will be a difference between actual cost of implementing the contract and the transfer, even if agents are truthful and do not shirk. We still assume asymmetric information and therefore the agents will always choose the high-investment contract over the low-investment contract and then make the low investment. The profits for each type of agent is:

$$\begin{aligned}
\bar{\pi}^F &= py - c(y) + \bar{\alpha}_0 \bar{t}^H + (1 - \bar{\alpha}_0)\, \bar{t}^L - \underline{I} - A\,(\underline{I}) = \Delta I - A\,(\underline{I}) \\
\underline{\pi}^F &= py - c(y) + \underline{\alpha}_0 \bar{t}^H + (1 - \underline{\alpha}_0)\, \bar{t}^L - \underline{I} - A\,(\underline{I}) = \Delta I - A\,(\underline{I})
\end{aligned}$$

The agents participate only if $\Delta I \geq A\,(\underline{I})$, otherwise they reject the contract. In that case the welfare of the Natura 2000 scheme is $W^F = 0$. If they participate, all agents are overcompensated by $\Delta I - A\,(\underline{I})$.

We calculate the loss in welfare from this payment mechanism when the agents are accepting the contract in the appendix B and show that the loss in welfare is affected in three ways. First of all, the expected benefits decrease as the probability of the high state decreases. Secondly, the tax distortion increases due to the information rent to both agent types. Thirdly, the direct cost for the high-prob agents decreases as they no longer make the high

investment. The benefit loss is $-\nu\left[\left(\overline{\alpha}_1-\overline{\alpha}_0\right)\left(V^H-V^L\right)\right]$, the loss due to overcompensation of the low-prob agent is $-(1-\nu)\left[\lambda\left(\Delta I+A\left(\underline{I}\right)\right)\right]$ and the loss due to the high-prob agent is $-\nu\left[\overline{I}\lambda-\lambda\frac{\overline{\alpha}_1}{\overline{\alpha}_1-\overline{\alpha}_0}\left(\Delta I+A\left(\overline{I}\right)\right)\right]$. The gain from the decreased cost of the high-prob agent is $\nu\left[\Delta I+\Delta A(I)\right]$.

This means that the French payment mechanism leads to an overcompensation of agents and a loss in social benefits of the scheme. On top of that, the agents may not participate at all because the principal is ignoring the correlated cost in forest management.

The Danish Forest and Nature Agency has chosen a different payment mechanism. It is based on the net present value of the forest before and after contract implementation. This payment mechanism is well known in Denmark as it is used in cases of partly expropriation of property rights for conservation projects. This net-present-value approach solves a number of problems. First of all it, realizes that the Natura 2000 contracts are part of the general forest management by taking both direct costs and opportunity costs into account, thereby covering a larger proportion of the costs. It also takes into account the fact that the conservation costs are continuous rather than a one-time investment, as the forest plan's restrictions are permanent. However, this type of payment mechanisms does not handle the problem of moral hazard at all. The individual forest plan specifies the conservation goals of the agreement, but as there is no possible bonus, the forest owner has incentive to make the lowest possible investment or effort to reach the goals and proclaim that not fulfilling the goals is due to biological variation.

The net present value approach is equivalent to compensating the investment after making up for the correlation with forest management:

$$\underline{t} = \underline{I}+A\left(\underline{I}\right) \tag{32}$$

$$\overline{t}^L = \overline{t}^H=\overline{I}+A\left(\overline{I}\right) \tag{33}$$

None of the agents are given any incentive to make the high investment. Rather they will claim to be the high-probability agent and make the low investment and thereby decreasing the probability of the high state. Profits are:

$$\overline{\pi}^D = \Delta I + \Delta A(I)$$
$$\underline{\pi}^D = \Delta I + \Delta A(I)$$

As before, the social welfare is affected in three ways, and the calculation is given in the appendix B. The result is the following: The benefit loss is $-\nu\left[(\overline{\alpha}_1 - \overline{\alpha}_0)\left(V^H - V^L\right)\right]$, the loss due to overcompensation of the low-prob agent is $-(1-\nu)\left[\lambda\left(\Delta I + A\left(\underline{I}\right)\right)\right]$ and the loss due to the high-prob agent is $-\nu\left[\lambda\left(\overline{I} + A\left(\overline{I}\right)\right) - \lambda\frac{\overline{\alpha}_1}{\overline{\alpha}_1 - \overline{\alpha}_0}\left(\Delta I + A\left(\overline{I}\right)\right)\right]$. The gain from the decreased cost of the high-prob agent is $\nu\left[\Delta I + \Delta A(I)\right]$.

Whether the welfare loss and the overcompensation is bigger or smaller for the Danish payment mechanism compared to the French depends on two things: the correlation with the forest management and the participation of the agents in the French system. The French system leads to less overcompensation if the investment increases cost ($A(I) > 0$), even though it does so by ignoring the related cost of forest management, unless $\Delta I < A\left(\underline{I}\right)$. In this case there is no participation at all. On the other hand, if the investment actually decreases forest management cost, the Danish mechanisms is more efficient. Still they have one thing in common: none of the payment mechanisms handle either the adverse selection or the moral hazard problem, thereby leading to lower welfare than necessary.

7 Concluding comments

This article is motivated by the ongoing implementation of the Natura 2000 policy. We want to analyze the design of contracts to provide nature conservation in forest areas. Our objective is threefold. First, contract design is developed in a mixed model where adverse selection takes place before moral hazard. We use a two-type model where investments cannot be observed and are influencing the probability of biodiversity improvement. The agents differ in their probability of reaching a high state of biodiversity, this knowledge is private information. Secondly, the impact of the contract on forest management is introduced to take into account the multi-

functionality of European forests (i.e. production aspects together with conservation goals). Last, we discuss the application of Natura 2000 in France and Denmark with special emphasis on their payment mechanism.

The main results characterizing the optimal incentive contracts in mixed model are: (1) the low-probability agent should be offered a low-investment contract with a payment that is independent of the final state of the forest; (2) the high-probability agent should be offered a contract where transfers depend on the final state of the forest, thereby sharing risk with the principal. Because investment is not observable before the contract is signed, a state-dependent payment is necessary to ensure compliance with the nature conservation goals. This is done by introducing a bonus when the high state is reached; (3) for this contract, the moral hazard constraint always overrules the other constraints; (4) the high-probability agent (who undertakes high investment) is in some cases overcompensated. (5) the adverse selection problem is solved without costs, as the contracts can be separated by risk-sharing. These results provide some insight in the theoretical implementation of voluntary agreements in the Natura 2000 network.

Then, when we include the effect of these contracts on the forest management, we find that it either increases or decreases the transfer, depending on the sign of the correlation. It does not change the overall structure of the model, but neglecting the related forest management cost has a strong implication in terms of participation and efficiency.

These results are used to analyze the specific payment mechanisms in France and Denmark. We show that in both cases neither the adverse selection nor the moral hazard problem are solved. This leads to loss in benefits and overcompensation of agents, leading to increased tax distortion. The French mechanism only covers implementation costs whereas the Danish mechanism also takes related forest management cost into account. This means that the French mechanisms may not fulfill the participation constraint and explains why few forest contracts have been signed in France until now.

One of the main policy implication from our analysis is the importance of linking the Natura 2000 contracts to the observed results in biodiversity rather than to the cost of measures. It is the only way to ensure optimal behavior in forests, where it is difficult to observe the conservation investments of the forest owners. It is particularly evident as the Natura 2000 setup ensures

that a vast amount of information is gathered both before and after the implementation of the contracts. This means that the biodiversity goals can be included in the contracts without large extra transaction costs, as most of the necessary information already exists.

Further research is needed to explore some extension of model. First, some significant parameters have not been included in the model, such as the temporal aspects and especially the duration of the contract (without limit in Denmark, five years in France). Linked to this aspect, one-shot payment could be revised to include conditional payment, partitioned in time. Second, the issue of heterogeneity is also linked to different initial states of forest area and could take the form of a spatial differentiation. Finally, we assume risk-neutral agents and it could be interesting to include the case of risk aversion.

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A The moral hazard constraint of the high-prob agent

To see that the constraints for the low-prob agent are always overruled by the moral-hazard constraint, we look at the optimal contract when the moral hazard constraint is not binding.

- If it is the ($\underline{PC}$), the solution is the no-risk sharing solution, where the difference between payments is only marginal:
  $\left\{\left(\bar{t}^L = \overline{I} - \varepsilon\right), \left(\bar{t}^H = \overline{I} + \varepsilon\right)\right\}$.
  This solution cannot solve the moral hazard problem, since it does not involve the agent carrying almost any risk.

- If it is the mixed constraint that is binding, we have a new solution. The optimal contract for the high-prob agent is:
  $\left\{\left(\bar{t}^L = \frac{\overline{\alpha}_1 \underline{I} - \underline{\alpha}_0 \overline{I}}{\overline{\alpha}_1 - \underline{\alpha}_0}\right), \left(\bar{t}^H = \frac{(1-\underline{\alpha}_0)\overline{I} - (1-\overline{\alpha}_1)\underline{I}}{\overline{\alpha}_1 - \underline{\alpha}_0}\right)\right\}$.
  This solution does involve some risk-sharing, $\bar{t}^H > \bar{t}^L$, but not enough to ensure the right investment under hidden action.

Therefore, the moral hazard constraint always overrules the contraints of the low-prob agent.

B Difference in welfare

The French payment mechanism results in the following welfare:

$$W^F = \nu\left[\overline{\alpha}_0 V^H + (1-\overline{\alpha}_0)\, V^L\right] + (1-\nu)\left[\underline{\alpha}_0 V^H + (1-\underline{\alpha}_0)\, V^L\right] - \overline{I}\lambda - \underline{I}$$

If we compare this with the welfare of the mixed model including forest management, we

get:

$$
\begin{aligned}
W^F - W^{MX} &= \nu\left[\overline{\alpha}_0 V^H + (1-\overline{\alpha}_0) V^L\right] + (1-\nu)\left[\underline{\alpha}_0 V^H + (1-\underline{\alpha}_0) V^L\right] - \overline{I}\lambda - \underline{I} - A(\underline{I}) \\
&\quad -\nu\left[\overline{\alpha}_1 V^H + (1-\overline{\alpha}_1) V^L - \lambda\frac{\overline{\alpha}_1}{\overline{\alpha}_1 - \overline{\alpha}_0}\left(\Delta I + A\left(\overline{I}\right)\right) - \overline{I} - A\left(\overline{I}\right)\right] \\
&\quad -(1-\nu)\left[\underline{\alpha}_0 V^H + (1-\underline{\alpha}_0) V^L - (\underline{I} + A(\underline{I}))(1+\lambda)\right] \\
&= -(\overline{\alpha}_1 - \overline{\alpha}_0)\left(V^H - V^L\right) - \nu\left[\overline{I}\lambda - \lambda\frac{\overline{\alpha}_1}{\overline{\alpha}_1 - \overline{\alpha}_0}\left(\Delta I + A\left(\overline{I}\right)\right)\right] \\
&\quad +\nu\left[\Delta I + \Delta A(I)\right] - (1-\nu)\lambda\left(\Delta I + A(\underline{I})\right)
\end{aligned}
$$

We know that W^{MX} is the maximum welfare under the constraints of the mixed model when the forest management is taken into account. Therefore, there has to be a welfare loss. The benefit loss is $-\nu\left[(\overline{\alpha}_1 - \overline{\alpha}_0)\left(V^H - V^L\right)\right]$, the loss due to overcompensation of the low-prob agent is $-(1-\nu)\left[\lambda\left(\Delta I + A(\underline{I})\right)\right]$ and to the high-prob agent $-\nu\left[\overline{I}\lambda - \lambda\frac{\overline{\alpha}_1}{\overline{\alpha}_1 - \overline{\alpha}_0}\left(\Delta I + A\left(\overline{I}\right)\right)\right]$. The gain from the decreased cost of the high-prob agent is $\nu\left[\Delta I + \Delta A(I)\right]$.

The Danish payment mechanism gives total welfare of:

$$
\begin{aligned}
W^D &= \nu\left[\overline{\alpha}_0\left(V^H - \lambda\overline{t^H}\right) + (1-\overline{\alpha}_0)\left(V^L - \lambda\overline{t^L}\right) - \underline{I} - A(\underline{I}))\right] \\
&\quad + (1-\nu)\left[\underline{\alpha}_0\left(V^H - \lambda\overline{t^H}\right) + (1-\underline{\alpha}_0)\left(V^L - \lambda\overline{t^L}\right) - \underline{I} - A(\underline{I})\right] \\
&= \nu\left[\overline{\alpha}_0 V^H + (1-\overline{\alpha}_0) V^L\right] + (1-\nu)\left[\underline{\alpha}_0 V^H + (1-\underline{\alpha}_0) V^L\right] \\
&\quad -\lambda\left(\overline{I} + A\left(\overline{I}\right)\right) - \underline{I} - A(\underline{I})
\end{aligned}
$$

And the welfare loss compared to the mixed model is:

$$
\begin{aligned}
W^D - W^{MX} &= \nu\left[\overline{\alpha}_0 V^H + (1-\overline{\alpha}_0) V^L\right] + (1-\nu)\left[\underline{\alpha}_0 V^H + (1-\underline{\alpha}_0) V^L\right] \\
&\quad -\lambda\left(\overline{I} + A\left(\overline{I}\right)\right) - \underline{I} - A\left(\underline{I}\right) \\
&\quad -\nu\left[\overline{\alpha}_1 V^H + (1-\overline{\alpha}_1) V^L - \lambda\frac{\overline{\alpha}_1}{\overline{\alpha}_1 - \overline{\alpha}_0}\left(\Delta I + A\left(\overline{I}\right)\right) - \overline{I} - A\left(\overline{I}\right)\right] \\
&\quad -(1-\nu)\left[\underline{\alpha}_0 V^H + (1-\underline{\alpha}_0) V^L - \left(\underline{I} + A\left(\underline{I}\right)\right)(1+\lambda)\right] \\
&= -\nu\left[\left(\overline{\alpha}_1 - \overline{\alpha}_0\right)\left(V^H - V^L\right)\right] - (1-\nu)\lambda\left(\Delta I + \Delta A(I)\right) \\
&\quad -\nu\left[\lambda\left(\overline{I} + A\left(\overline{I}\right)\right) - \lambda\frac{\overline{\alpha}_1}{\overline{\alpha}_1 - \overline{\alpha}_0}\left(\Delta I + A\left(\overline{I}\right)\right)\right] + \nu\left[\Delta I + \Delta A(I)\right]
\end{aligned}
$$

The benefit loss is $-\nu\left[\left(\overline{\alpha}_1 - \overline{\alpha}_0\right)\left(V^H - V^L\right)\right]$, the loss due to overcompensation of the low-prob agent $-(1-\nu)\left[\lambda\left(\Delta I + A\left(\underline{I}\right)\right)\right]$ and to the high-prob agent is $-\nu\left[\lambda\left(\overline{I} + A\left(\overline{I}\right)\right) - \lambda\frac{\overline{\alpha}_1}{\overline{\alpha}_1 - \overline{\alpha}_0}\left(\Delta I + A\left(\overline{I}\right)\right)\right]$. The gain from the decreased cost of the high-prob agent is $\nu\left[\Delta I + \Delta A(I)\right]$.