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Coping with risk and distortion in performance-based payment for environmental services schemes

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Abstract

Around the world, ecosystems are in decline and as human population increases new policy mechanisms to counteract this trend are increasingly being sought-after. A growing group of policy makers and practitioners are gaining interest in the new conservation performance payment approach. This policy approach falls within the larger group of payments for environmental services.

This paper applies findings from a model developed by Baker (2002) on distortion and risk in performance-based employment contracts to conservation performance payments. Guidelines for the optimal design of pro-conservation incentives are identified. The theoretical considerations are backed-up by reviews of case studies on existing performance payments for water quality management and biodiversity conservation.

1 Introduction

Humans greatly depend on ecosystem services, but to meet the needs of the growing population many ecosystems have been exploited beyond sustainable levels. The loss of ecosystem services may result in a serious constraint to achieving the Millennium Development Goals (MEA 2005). In recent years, payments for environmental services (PES) have received much attention as new strategy to align poverty alleviation goals with ecosystem conservation (Landell-Mills, Porras 2002; Pagiola, Platais 2005).

While many PES schemes are action based, i.e. remunerate a certain activity, a small number of innovative performance-based schemes has emerged. These performance-based schemes offer periodic payments contingent on clearly defined environmental outcomes. It is only the quantifiable outcome that counts, the action or procedure that led to the outcome is not of interest. Although limited in number, some countries and private enterprises are already experimenting with performance-based contracts especially in the fields of water quality management and biodiversity conservation. Calls to expand the use of performance-based agri-environmental schemes are increasingly being voiced (Zechmeister et al. 2003; Bulte, Rondeau 2005; Ferraro, Albers 2005; Nyhus et al. 2005; BUND 2007).

Typically performance-based payment schemes consist of two parts: a base payment and a variable incentive payment that depends on the environmental outcome. The higher the environmental outcome, the higher the payment the participant receives. This incentive mechanism is what is acknowledged to be the great advantage of performance payments. Scheme participants are provided with incentives to produce the desired environmental outcome in the most efficient way. The actions to achieve the environmental goal are not specified and thus there is room for flexibility and innovations. The second advantage is that compared to more indirect payment mechanisms, such as subsidies to enhance eco-tourism, direct payments are also presumed to be more cost-effective (Ferraro, Simpson 2002; Wätzold, Drechsler 2005; Casey, Boody 2007), they render a greater "conservation bang for the buck" (Wunder 2005). To optimally exploit the incentive power of this type of scheme it is important to know how to weight the variable payment relative to the base payment. To assess this question, this paper applies established lessons from contract theory to the field of environmental policy design.

The paper builds on a model developed by Baker (2002) for the design of optimal incentive-based employment contracts. The model explicitly takes production risks and distortion of performance measures into account and lies out rules for the optimal design of incentives. The model helps create a theoretical framework to explain the diversity in the design of already existing performance payment schemes and may also serve as a framework for the design of new schemes.

The following section deals with problems of risk and distortion. In section 3 Baker's (2002) model is reviewed and backed up by an examination of existing performance-based agri-environmental and PES schemes. Section 4 discusses and concludes the main findings of the paper.

2 Distorted performance measures and production risks

When designing a performance payment scheme, the paying agency obviously needs to define exactly what the goal and target of the scheme is (Batie, Ervin 1999). It can be virtually any goal, e.g. increase of biodiversity in agricultural landscapes, conservation of certain endangered species, reduction of groundwater nitrification, increase in groundwater quantity etc. Next to the goal statement, Casey and Boody (2007) suggest that the development of a performance payment scheme should comprise four steps. The first step should be the design, testing and evaluation of one or several performance measures to adequately quantify the success or degree of goal attainment. The second step concerns the establishment of a cost-effective monitoring and evaluation system. They further suggest that the definition of the payment level should be the third step. Finally, an administration system needs to be set up. Throughout the various design phases of a new scheme, it is important to realize that the scheme participants will adjust their actions to optimize their payoff based on the given performance measures. The performance measure is what the participants strive to optimize since this is what they are being paid for. The scheme's overall goal statement does not necessarily influence their actions. Participants may appreciate and approve of the overall goal but the performance measures are the decisive incentives that steer the individuals' actions.

A study conducted in New Zealand on how water quality could be improved found that farmers explicitly asked for performance measures but preferred to have a free choice on methods. The New Zealand farmers are quoted to have consistently pointed out *"Tell us (as farmers) what water quality standards we need to achieve, and help us work out for* *our own farms what we need to do to achieve them. But don't tell us what to do and how to do it."* (OECD 2004).

Whether a performance payment scheme is an expedient solution to attain the overall goal will to a large extent depend on the degree of congruence between goal and performance measure. Utilizing distorted measures provides dim prospects for goal attainment.

Assessing the risk connected to the procurement of the performance measure is of equal importance for optimal contract design. Provided the participation in the scheme is voluntary, the tradeoff between risk and payment needs to be perceived as appropriate. The production of many environmental goods is both a function of human activities and environmental factors that often occur at random and may be very difficult to control. In the majority of cases the exact production function may not even be known. Some production processes may involve great investments which entail path dependencies for the land owner, e.g. the plantation of hedges to reduce soil erosion or afforestation to stabilize groundwater flows. These measures can be very costly but there is no guarantee that they will truly foster the environmental outcome that is being paid for. Additionally, extreme environmental hazards such as fires, storms, or floods can destroy such investments. The classic tradeoff between risk and incentive pay is discussed in Holmström and Milgrom (1991) and reviewed in Bolton and Dewatripont (2005). Rojahn and Engel (2005) discuss this tradeoff for PES schemes. Their analysis focuses on an application of the Holmström and Milgrom (1990) model but they do not take problems of distorted performance measures into account. The application of Baker's model to the design of conservation performance payment schemes adds to the literature since it allows for a consideration of the well-established lessons on risk and incentive payments but incorporates issues on distortion in performance measures.

3 Baker's model applied to agri-environmental schemes

In Baker's model the paying agency has decided to provide incentives for farmers to produce more of the environmental good E. The environmental good is produced as a function of the participant's actions and random environmental effects, ε (with variance σ_ε^2). $\vec{a}$ is an n-dimensional vector of the participant's possible actions. $\vec{f}$ is also an n-dimensional vector and stands for the marginal products of the participant's actions on the environmental good. The production function for the environmental good can be expressed as:

$$E(\vec{a},\varepsilon) = \vec{f}\vec{a} + \varepsilon$$

As stated in the previous section, the payment scheme is linear and consists of a base payment, denoted s, and a variable top-up, denoted $b_e E$, that depends on the environmental outcome. The base payment is set so that it meets the participant's reservation utility.

The paying agency is assumed to be risk neutral whereas the participant is risk averse. The participant's coefficient of absolute risk aversion is denoted as h. The participant derives utility from the expected payment and disutility both from the variance of the payment and the effort she invests in actions. Her net expected utility can thus be expressed as:

Net expected utility = $U(s + b_e E) - h\,\mathrm{var}(s + b_e E) - \sum_{i=1}^{n} \frac{a_i^2}{2}$

The question now is how the paying agency should set b_e to weight the variable payment share relative to the base payment so that the scheme participant will have incentives to maximize the environmental outcome.

In the next section, three different scenarios will be discussed. The first is a situation in which the paying agency can dispose of a risky but undistorted performance measure. The second scenario deals with a situation in which the paying agency employs two performance measures, one undistorted but risky and the other less risky but distorted. The last scenario discusses a situation in which the paying agency applies a relative performance evaluation approach.

3.1 Derivation of optimal slope for risky but undistorted performance measure

In this first scenario it is assumed that the paying agency has an overall environmental goal that can easily be quantified and directly used as performance measure. The measure thus provides perfectly undistorted incentives.

However, the performance measure may not accurately reflect the participant's efforts in the production process. This is due to the random environmental events that also impact the performance measure. The scheme participant consequently perceives the performance measure as risky. To derive the optimal weight for the performance measure, the participant's net utility function is optimized subject to the constraint that the participant chooses activities that maximize her utility.

The solution, which (in a similar form) is derived in detail in Bolton and Dewatripont (2005) is

$$b_e^* = \frac{F^2}{F^2 + 2h\sigma_\varepsilon^2}$$

F is the length of the vector of marginal products, $\vec{f}$. The value of F provides information on the impact of the participant's actions on the desired outcome relative to the impact of the random environmental events. In other words, the larger F i.e., the greater the human impact relative to nature's impact, the larger the optimal slope of the incentive share.

Baker's result here is the same that Holmström and Milgrom (1991) obtain in their model. It implies that the slope of the incentive share increases with F. Furthermore, the equation makes explicit that the slope of the optimal incentive share decreases with an increase in the participant's coefficient of absolute risk aversion h. Equivalently, it decreases with increasing variance σ_ε^2.

An example of a performance payment scheme which makes use of a risky but undistorted performance measure is the Swedish carnivore conservation program offered to reindeer herding Sami villages (Zabel, Holm-Müller 2007). The Swedish government has declared that its goal is to increase the population sizes of certain endangered carnivores (Regeringens Prop. 2000/01:57). The carnivores, foremost wolverines and lynx, roam the wilderness areas of northern Sweden and cause great economic damage by preying on the indigenous Sami peoples' semi-domesticated reindeer (Persson 2005; Swenson, Andrén 2005; Danell et al. 2006). The government set up a performance payment scheme in 1996 that remunerates the reindeer herders based on the number of carnivore offspring that are certified on the reindeers' grazing grounds. The government wants an increase in the carnivore population and hence population increases is what it pays for. The foremost impact that the herders can have on carnivore population growth is to refrain from (illegal) poaching. Wolverines and lynx do not hibernate and especially during the winter they essentially depend on the abundance of reindeer to survive (Pedersen et al 1999). Providing reindeer as prey or at least tolerating predation can thus also be counted as an active support of carnivore conservation.

Although undistorted, there is a certain risk in the carnivore offspring 'production function'. It has been found that the proportion of females in a population that successfully rear young is smaller than the percentage of females that is pregnant (Persson 2006). Reproductive success is suggested to depend to a large extent on a female's condition during the lactation phase. The condition during this phase is in itself assumed to be determined by the biological costs of the previous year's reproduction and the availability of food during the current winter (Persson 2005). The availability of food can to a certain extent also depend on the occurrence of other large carnivores in the area. Intra-species predation is also an important issue which greatly impacts wolverine population dynamics (Persson 2003). Thus refraining from poaching and letting reindeer room free as potential food source for wolverines is not a guarantee for wolverine offspring in the next year.

It is interesting to note that the Swedish scheme only consists of the variable payment, i.e. no base payment is offered. In terms of the model, this cannot be optimal since the reindeer herders are not risk neutral ($h \neq 0$) nor is the variance of the external environmental effects zero $\sigma_{\varepsilon}^{2} \neq 0$. Reindeer herders have only recently complained that payments greatly depend on external effects. (Personal communication Oct. 2007). In response considerations on revising the scheme and introducing a base payment that can be counted on, as predicted by the model, have been taken up.

Another example of performance payments for wildlife conservation is a local bird protection scheme in the Eider-Treene-Sorge river basin area, Germany (Stapelholmer Naturschutzvereine 2007). The goal of the scheme is to conserve four endangered bird species that all build their nests in meadows (black-tailed godwit, peewit, redshank, and curlew). Each year farmers and staff of the local conservation agency are on the look-out for birds in the fields. Once it is certified that a bird is breeding in a certain meadow, the farmer can apply for a performance payment. Payments are per hectare and differentiated according to single breeding birds and entire colonies. To obtain the payment the farmer must abide to certain management rules while the birds are present and may only revert to his usual farming practices once the birds have left.

3.2 Derivation of optimal slopes for scheme with several performance measures (undistorted but risky, and distorted but less risky)

Eventually the paying agency may not want to rely on only one performance measure. It may rather want to use a set of several measures in combination. In particular, goals such as biodiversity conservation call for a plurality of indicators (Duelli, Obrist 2003).

For the model assume the paying agency employs the undistorted but risky performance measure, E, as well as a distorted but less risky performance measure, P. Both performance measures are assumed to be linear functions of the participant's actions and the effects of random environmental events on the respective performance outcome.

$$E(\vec{a},\varepsilon) = \vec{f}\vec{a} + \varepsilon$$

$$P(\vec{a},\phi) = \vec{g}\vec{a} + \phi$$

$\vec{g}$ is an n-dimensional vector and stands for the marginal products of the participant's actions on the distorted performance measure. ϕ represents the impact of random environmental effects on the distorted performance measure and has the variance σ_ϕ^2. Distortion is measured as $\cos\theta$, with θ signifying the angle between the vector of the environmental goal E and the vector of the distorted performance measure P. The less distorted and thus the closer the two vectors are, the higher the value of $\cos\theta$. The more distorted the performance measure P, and thus the larger the angle between E and P, the lower the value of $\cos\theta$.

In the model it is assumed that $\sigma_\varepsilon^2 \geq \sigma_\phi^2$ since all of the variability in P is assumed to be contained in E. The covariance between P and E is $\text{cov}(E,P) = \sigma_{\phi\varepsilon}^2$. In this scheme the participant receives an amount of money that is the sum of a base payment, s, and the variable shares of both the undistorted $b_e E$ and the distorted $b_p P$ incentive payments. So the payment to a participant is $s + b_e E + b_p P$.

The paying agency now needs to find the optimal slopes for b_e and b_p. Baker (2002) arrives at the following optimality conditions:

$$b_e^* = \frac{F^2 G^2 (1-\cos^2\theta) + 2h\sigma_\phi^2 F(F - G\cos\theta)}{(G^2 + 2h\sigma_\phi^2)(F^2 + 2h\sigma_\varepsilon^2) - (FG\cos\theta + 2h\sigma_\phi^2)^2}$$

$$b_p^* = \frac{2hF\left(G\cos\theta\sigma_\varepsilon^2 - F\sigma_\phi^2\right)}{\left(G^2 + 2h\sigma_\phi^2\right)\left(F^2 + 2h\sigma_\varepsilon^2\right) - \left(FG\cos\theta + 2h\sigma_\phi^2\right)^2}$$

G is the length of the vector of marginal products, $\vec{g}$. The value of G provides information on the impact of the participant's actions on the distorted performance measure relative to the impact of the random environmental events.

A question of interest is how the distorted performance measure should be weighted relative to the undistorted measure. Baker (2002) performs comparative statics on the ratio $R = \frac{b_p^*}{b_e^*}$ to assess this question. He finds that, provided $\cos\theta$ is positiv, an increase in distortion leads to a decrease in the relative weight of b_p. As noise in the undistorted performance measure σ_ε^2 increases, the relative weight of the distorted performance measure increases. The effect of an increase in noise of the distorted performance measure σ_ϕ^2 is ambigous.

An example of a scheme that follows the indications of the model is the turtle nest protection project of the Kiunga Marine National Reserve, Kenya. This project is run by WWF and the Kenya Wildlife Service (Ferraro 2007). The goal is to conserve marine turtles. A performance payment of 500 Kenyan Shillings is paid to locals for each certified turtle nest discovered on the beach. An additional payment of 20 Shillings is paid for each successfully hatched turtle egg and 10 Shillings for an unsuccessful hatchment (Flintan 2002). An average nest counts about 115 eggs. These payments provide incentives to not only look for turtle nests but also to monitor and protect them from predators. The analogy to the model is straightforward. The more distorted but less risky performance measure is the discovery of a turtle egg nest. The less distorted but more risky performance measure is the actual hatchment of a baby turtle. The actual hatchment of a turtle naturally happens after the eggs were laid in the nest. Consequently, all the risk factors that played a role up to the point when the adult turtle lays the eggs are also included in the risk connected to the hatchment. However there are additional risk factors that may cause embryo mortality such as predation or problems with gas exchange in the nest (Ackerman 1980). Thus due to these supplementary risks, the hatchment of a baby turtle can be counted as more risky that the creation of a turtle egg nest by an adult turtle.

Assume the noise in the undistorted performance measure 'turtle hatchments' were to increase for some given exogenous reason. In this case, the policy recommandation derived from the model would be to shift relatively more weight on the distorted measure discovery of nests.

Another example from the field of wildlife conservation is from Madhya Pradesh, India. The National Park authorities want to promote the conservation and thus population growth of certain bird species that breed in tall grass. Around the Van Vihar National Park farmers are paid a certain base payment if they abstain from haying for a certain time and let their grass grow tall. A second payment is issued when the specified birds are sighted in the tall grass. A third payment is granted once successful hatchments are observed in the grass (Chauhan 2008, pers. comm.). As in the Kenyan turtle conservation scheme, the analogy to the model is clear. Bird abundance in the tall grass is a less risky performance measure than successful hatchments but since conservation is the goal, bird sightings are more distorted than actual successful hatchments.

Assume that for some given reason the distorted performance measure ‘bird abundance in tall grass’ had to be replaced by an even more distorted measure such as proximity to the next waterhole. The model’s policy implication for such a scenario is to increase the relative weight on the undistorted measure and to decrease it for the new more distorted measure.

In Europe there are agri-environmental schemes that make use of several performance measures but the analogy to the model is not quite as clear. An example is the German MEKAII scheme in Baden-Wuerttemberg. Farmers receive a base payment conditional on certain action oriented criteria. Additional to the base payment they can apply for a performance-based surplus. The performance payment is issued if the farmer’s field hosts at least four out of a given list of 28 special plant species (Oppermann 2003).

A similar agri-environmental scheme is currently being planned in Lower Saxony, Germany. The explicit goal of this scheme is to support grasslands that are valuable with respect to diversity in plant genetics (Niedersächsisches Umweltministerium 2007). Four out of a list of selected plant species must exist on the field in order to receive a base payment. Provided two more plant species from the list also grow on the field, the farmer can apply for a bonus that nearly doubles the base payment.

Both of these German schemes use various plant species as performance measures but in terms of payment there is no explicit differentiation between the plants. Referring to the model this would mean that all plants are equally undistorted indicators of goal attainment and equally risky in their procurement. Whether this hypothesis is true or if all plants are rather valued equally due to simplification reasons is difficult to assess.

3.3 When to use relative performance evaluation

Wätzold and Schwertner (2005) argue that a major disadvantage of performance payments in agri-environmental schemes is that an individual’s performance also depends on external environmental effects such as weather influences. In cases when external noise seems unacceptably high, relative performance evaluation may be a solution. An essential precondition for this approach is that the external effects cause variation in the performance of all participants. Relative performance evaluation means comparing an individual’s degree of goal attainment to a certain benchmark, e.g. the average attainment of a group of participants. The optimality conditions for b_e^* and b_p^* in section 3.2 can be used to discuss this approach.

Vector P which was the distorted performance measure in the previous model is now defined to be the benchmark. It is important that an individual cannot influence the value of the benchmark (Baker 2002). In an agri-environmental scheme this is rather easy to secure by calculating an individual benchmark for each participant consisting of the average of all other participants' performance values. Under this precondition $G = 0$, i.e the length of the vector of marginal products of a participant's actions on P is zero. Consequently, $P = \phi$ and $b_e^* = -b_p^*$. The implication of this result is that an individual will not receive a surplus payment if her level of goal attainment exactly equals the average of the others. If $E > P$. i.e her value is better than average, she will receive a surplus payment of $b_e^*(E - P)$. Equivalently she will be penalized with a payment reduction of $b_e^*(E - P)$ provided $P > E$, i.e. her value is below average.

Examples for the use of relative performance payments in agri-environmental schemes are nitrate leaching reduction programs around watersheds. In Germany there are many schemes designed by water utility companies that offer payments to farmers who reduce the amount of nitrogen runoff from their fields (Mangelsdorf, Attenberger 1999; Zabel 2007). Annually a soil sample is collected from each participant's field during a certain time period, typically in fall after the post-harvest fertilization. The amount of nitrogen in each sample is then determined. Weather influences, such as temperature and rain fall, have a great impact on nitrogen evaporation as well as run-off. In other words, weather conditions have significant influence on the amount of nitrogen that remains in the soil after fertilization. Hence, the amount of nitrogen in a soil sample from the same field may vary greatly from year to year even if all other factors were held constant. To back out the weather 'noise', the performance measure is defined as the amount of nitrogen found in each participant's soil sample relative to the average of all scheme participants (Mangelsdorf, Attenberger 1999). As stated above, an important precondition in relative performance evaluation is that an individual cannot influence the benchmark.

4 Discussion

Performance payments are a relatively new environmental policy instrument with rather few well-established schemes. The advantages of performance payments as opposed to more indirect conventional approaches, such as area-based payments, eco-labeling, or eco-tourism, may seem enticing. In particular, their conditionality concept and direct incentives seem promising. Maximum flexibility and room for innovations is provided to scheme participants with respect to methods to achieve the desired environmental outcome.

However, before starting to design an agri-environmental or PES scheme, policy makers must make clear-cut decisions on exactly what their goal is, e.g. whether the sole goal is to procure a defined environmental outcome or whether the goal is to use PES schemes as policy tool to provide income support to a large number of farming households. In the former case performance payments may be an interesting option whereas in the second case other policy options may be more suitable (Claassen et al. 2001).

The review of Baker's model on optimal incentive design for risky and distorted performance measures underlined the need for clearly defined environmental goals and undistorted performance indicators. Defining suitable performance indicators is one of the largest challenges that need to be resolved when designing a performance payment scheme. The model suggests that a vastly distorted performance measure should receive very little or no weight at all. However, as illustrated by the examples, the choice of indicators is often accompanied by a tradeoff between distortion and risk. In the model with one undistorted indicator, theory suggests that the slope of the incentive payment share should decrease as the noise in the indicator as well as the participants' risk aversion increase. In case the noise in the indicator is appreciated to be too high to be able to convince farmers to participate in the scheme, relative performance evaluation may be an alternative. The model in section 3.3 laid out the theoretical framework for this approach. Two important preconditions are that (i) an individual cannot influence his benchmark and (ii) all participants' performance is subject to the same external environmental noise. For schemes with two different indicators, as in the model in section 3.2, the policy recommendations are to (i) decrease the relative weight on the distorted measure if distortion increases, and (ii) to increase the relative weight on the distorted measure if the noise in the undistorted measure increases.

Currently much research is being done on different indicator development approaches. Apart from risk and distortion some general criteria for indicators are that they should be quantifiable, transparent, and easily understood by practitioners. See Casey and Boody (2007) for an overview of recent approaches to measure environmental performance in the US at the national and regional scale as well as at the farm level.

The indicator selection process should always be accompanied by an assessment of the local scheme participants' decision making processes. Such an assessment should take into account all relevant socio-economic and cultural factors that may guide scheme participant's decision making. The proposed assessment may aid to anticipate how the participants are likely to respond to incentive payments. This is important to omit the creation of unintentional adverse incentives.

Once suitable performance indicators have been identified a method to link the performance value to the appropriate scheme participant needs to be determined. In some cases the link may be obvious, e.g. if a performance indicator such as number of trees is directly measured on someone's land. In developing countries where property rights are often lacking, even immobile indicators such as trees may be difficult to assign to individuals. Mobile indicators such as wildlife or water are likely to be confronted with difficulties in allocation. A solution is to collectively reward groups of people or communities instead of individuals. However, this approach requires collective action among the beneficiaries (Zabel, Holm-Müller in press; Rojahn, Engel 2005).

A further issue that needs to be considered is whether the expenses of monitoring and managing a performance payment scheme can be met. Next to the actual payments issued to scheme participants these transaction costs are likely to be substantial.

Although certainly not a panacea, performance payment schemes with well-designed performance indicators may in many cases be an interesting alternative to more conventional PES approaches.

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