

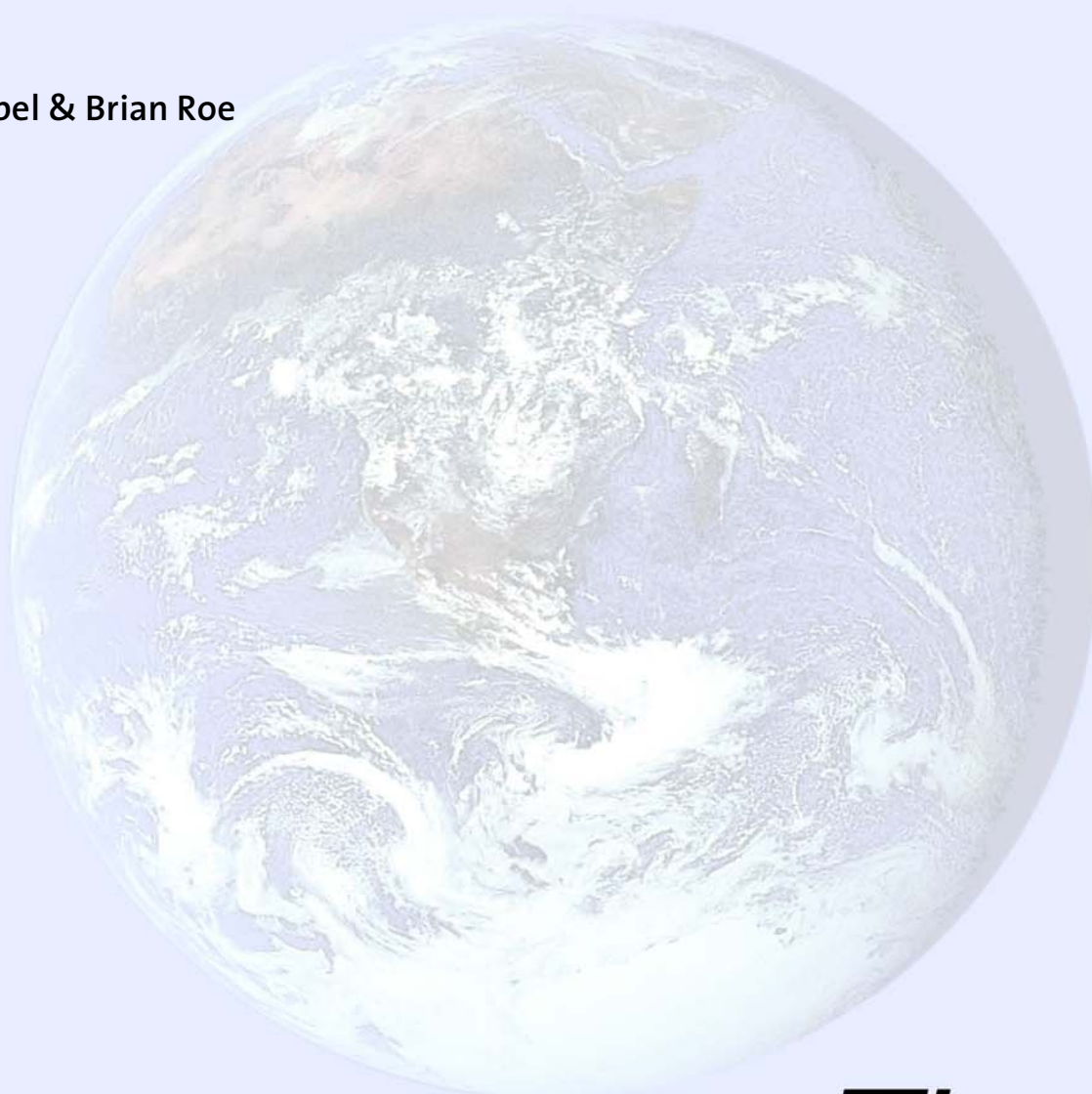
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Performance payments for environmental services: Lessons from economic theory on the strength of incentives in the presence of performance risk and performance measurement distortion

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Abstract

Payments for environmental services (PES) schemes have become an increasingly accepted and popular mode for governmental and non-governmental agencies to use in addressing local and regional declines in ecosystem services. A defining characteristic of performance payments, a sub-category of PES schemes, is the linking of individual payments to environmental outputs themselves rather than to the inputs that affect the production of environmental services. Such a focus raises several practical issues during implementation. We review and translate key aspects of the economic theory of incentives into the context of performance payments schemes with special attention paid to two practical issues. The first is that of structuring individual incentives to account for risks outside the individual's control such as weather that can affect the level of environmental services generated. The second deals with the possibility of distortion in the measurements of environmental services used to determine individual payments under PES schemes. Each challenge is accompanied by a discussion of advice based upon economic theory and a discussion of examples from different countries where such implementation issues arise.

JEL classification: Q20

Key words: Optimal Incentive Contracts, Payments for Environmental Services, Performance Incentives, Distortion

1 Introduction

Payments for environmental services (PES) schemes have become an increasingly accepted and popular mode for governmental and non-governmental agencies to use in addressing local and regional declines in ecosystem services (Landell-Mills and Porras, 2002; Millennium Ecosystem Assessment, 2005; Wunder et al., 2008). Following Wunder (2005) we define a PES plan as a scheme that involves a voluntary transaction for a well-defined environmental service that is being purchased by one or more buyers

from one or more suppliers, where the transfer of payment from buyer to seller is contingent upon provision of the service by the supplier.

Performance payments for environmental services are a sub-category of the larger group of PES. A key characteristic which differentiates them from other PES schemes is their focus on outputs rather than inputs. Most other PES approaches tie individual incentives to activities and prac-

tices that are inputs into the processes that generate environmental services. In contrast, performance payment approaches tie individual incentives to the level of environmental services actually created. In other words, performance payments are the most direct payment approach (Ferraro and Kiss, 2002). To use an analogy from the business world, the performance payment strategy looks more like paying a salesperson a commission for completed sales while an input-based approach to service provision would be equivalent to paying an hourly wage for time spent interacting with potential buyers.

Such an output focus is seen as a tremendous advantage of performance payment schemes, because it allows the suppliers of environmental services to find the best way of combining inputs in their particular location to meet the overarching goals of generating a desired level of environmental services. Such localized knowledge may not be available to those designing input-focused approaches and may frustrate attempts to efficiently generate the desired level of services. Indeed, previous discussions of performance payment approaches often highlight that output-based incentives provide flexibility and room for innovation in service provision (Musters et al., 2001), which allows a greater cost-effectiveness or 'bang for the buck' in delivering services (Casey and Boody, 2007; Ferraro and Simpson, 2002; Wätzold and Drechsler, 2005; Wunder, 2005).

Although there are many calls for an increased application of the performance payment approach (Albers and Ferraro, 2006; Ferraro and Kiss, 2002; Nyhus et al., 2005;

Zechmeister et al., 2003), this payment system is not a panacea and it is important to be aware of its drawbacks. In particular, the question arises how to address potential risk and noise in the production process of the environmental good to prevent sub-optimal incentive design. Furthermore, the dollars paid to scheme participants are tied to observable and often distorted indicators of environmental services rather than to perfect, undistorted measures. An important question is thus how the incentives provided through the scheme can be adjusted to the degree of distortion in the indicators to avoid making payments without receiving the desired environmental good.

In this paper, we address these two major practical issues that arise when implementing performance payment schemes and present possible solution strategies. All proposed policy approaches are followed up by tables listing various examples of existing performance payment schemes. The presentation of case studies is an effort to increase awareness of existing schemes that, due to their small or medium size, so far mostly have only been presented in the grey literature.

The remainder of this paper is organized as follows: Section 2 briefly reviews the literature on incentives for PES schemes. Section 3 presents the basic framework of performance payment schemes and discusses issues of risk and distortion. Section 4 examines four alternative policy options to accommodate for risk and distortion and closes with considerations on when performance payments may not be the first-best policy choice. Section 5 discusses the main findings.

2 Previous work

Shifting from input-oriented to individualized, output-focused approaches requires a shift in mindset during policy design. While environmental economists have customized established theories of public economics to formulate effective guidelines for implementing command-and-control regulations and taxes to deal with environmental externalities (e.g., Baumol and Oates, 1988), efforts to critically translate economic theories of incentives for use in developing effective PES schemes are more limited.

Goldsmith and Basak (2001) discuss problems of risk and distortion in connection to making incentive payments to agents in a firm based on environmental performance indicators. Since compliance with environmental standards is mandatory for firms, the solutions proposed by the authors focus particularly on risk sharing strategies between the firm's principal and its agent. Risk, i.e. environmental noise, in contracts for general PES is examined by Rojahn and Engel (2005). They use a model by Holmström and Milgrom (1990) as a framework to investigate the effects of alternative environmental service production functions as well as cooperation among agents on optimal contract design. In a recent paper Ferraro (2008) discusses the difficulties of maximizing the additionality (i.e. the production of environmental services that would not have been supplied without payments) of a budget-limited PES scheme under conditions of asymmetric information. Three policy options to cope with asymmetric information

are presented and evaluated: procurement auctions, screening contracts, and the acquisition of information about agents' opportunity costs.

Apart from these contributions, the current PES literature still lacks a more in-depth discussion of the advantages, disadvantages as well as applicability of different incentive payment approaches for direct payment schemes.

In the principal-agent and labor economics literature many models have been developed that account for risk and uncertainty in the derivation of optimal incentive contracts (e.g. Holmström and Milgrom 1987, 1991; Mirrlees 1975). The trade-off of risk and incentives deduced from these models has more recently been questioned by Prendergast (2000, 2002) who suggests that there may be a positive relationship between uncertainty and incentives.

Considerable attention has also been paid to analyzing the effects of distortion in incentive contracts (e.g. Kerr 1975; Baiman and Noel, 1985; Bushman and Indjejikian, 1993; Feltham and Xie, 1994; Datar et al., 2001; Baker 2002).

This paper contributes by translating key findings from the established literature to the specific PES context. Strategies to cope with risk and distortion in incentive design are pinpointed and backed-up by examples from the field.

3 Framework

Models have been established that examine the optimal provision of incentives (Laffont and Martimort, 2002) when the two parties involved have conflicting goals, e.g. the environmental service buyer wants a greater level of service provision and the service supplier wants to exert less costly effort to meet the demands of the buyer. Buyers of environmental services typically are governments, NGOs, or private companies (Engel et al., 2008). They can, in their role as buying agency, define the details of the environmental good or service that is to be purchased through the performance payment contract. This can be virtually any good or service, e.g. increase of biodiversity in agricultural landscapes, conservation of certain endangered species, reduction of groundwater nitrification, etc. The more specific and quantifiable the goal is, the easier it will be to design the appropriate incentives.

In general, the paying agency is assumed to be risk neutral and will be indifferent between two options with the same expected payoff. Risk neutrality is plausible in case the paying agency has a diversified investment strategy rather than a single focus on one contract. Suppliers of environmental services, in contrast to buyers, are assumed to be risk averse. Furthermore, we cannot assume that suppliers in general are altruistic. This means that without additional incentives they will only produce as much of the environmental service as is necessary to optimize their own welfare. Society's benefit of the goods produced is not of importance for their initial private production decision.

The success or failure of an initiative for a performance payment scheme may also depend on the prevailing institutional framework conditions. Both buyers and sellers will want to be certain that the terms of the contract are verifiable by a third party in case of a dispute. Equivalently, enforceability of the contract through the legal system is an important precondition (Ferraro and Kiss, 2002). Both parties may be reluctant to sign a contract if essential framework conditions are lacking. This may hamper efforts to install performance payment schemes in countries with deficient legal systems.

3.1 Basic structure of performance payment approach

Typically models of performance-based payment schemes presented in labor economics consist of two parts: a base payment and a variable incentive payment. The base payment can be set so that the participant's expected utility of scheme participation always at least equals his reservation utility (Datar et al., 2001). In the PES context, this means that it must be equal to the participant's opportunity cost of producing the environmental good. Providing such a base payment is an option, in particular if risk is to be shared between the paying agency and the participant. Providing a monetary base payment weakens the conditionality concept which is at the core of performance payment schemes. To strengthen conditionality, the paying agency may choose to work with variable incentive payments and only provide a non-monetary base payment, e.g. training opportunities or certificates for participation. This type of in-kind base payment could be altered by program administrators in concert with the strength of the optimal variable payment. Monetary payments to cover initial investment costs can be issued on a separate basis.

The variable payment serves as a contingent bonus which depends on the environmental outcome. The environmental outcome can be measured by one or several performance indicators. The major challenge for the paying agency is to determine the optimal variable payment that will induce scheme participants to maximize the environmental outcome. In Figure 1, the dotted line indicates the incentive payment. In terms of the figure, finding the optimal incentive power means determining the optimal slope for the dotted line.

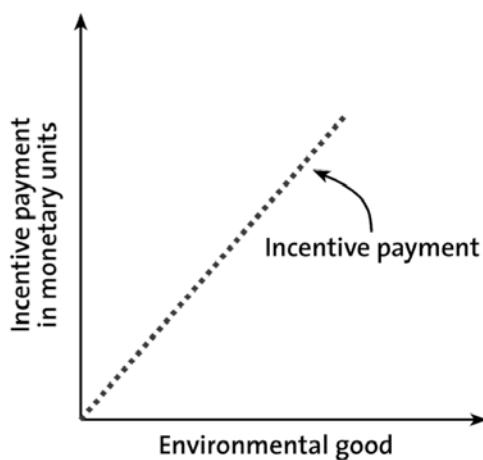


Figure 1: Outline of a performance payment scheme

3.2 Risk and distortion

Designing optimal contracts is fairly simple under conditions of certainty. However, 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 (Rojahn and Engel, 2005). 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, numerous external shocks can give rise to uncertainty, e.g. changes in the natural environment, market price fluctuations, or political upheavals.

Apart from production risks, distortion in the performance indicator is an important issue. Labor economists and accounting scholars regularly study problems of tying incentives to distorted indicators, e.g. Kerr's (1975) classical article "On the folly of rewarding A, while hoping for B" (see also Baiman and Noel, 1985; Datar et al., 2001; Feltham and Xie, 1994). Distortion in our context means that a scheme participant can conduct certain activities that will increase the good measured by the performance indicator without simultaneously adding to the attainment of the environmental goal.

As a key feature, the production process of the good is not prescribed in a performance payment scheme. Naturally, there will often be several ways to produce the good measured by the performance indicator, but not all may necessarily increase the environmental goal. If the distorted production processes are more cost efficient, the scheme participants will opt for these. An article published in the New York Times in 1898 provides anecdotal evidence of such a case in point: "The bounty given by the Indian Government for snakes' heads in order to exterminate these reptiles, has led to a few of the dishonest natives breeding them for a living" (The New York Times, 23.01.1898).

Distortion can also arise due to a badly chosen performance indicator which for all possible production processes simply has no, or very low, correlation with the environmental goal. Tying payments to inputs which are only loosely correlated with the desired outputs can be interpreted as a special case of distorted performance indicators (Baker, 2002). This applies to many input-based PES approaches.

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 the goal and the performance measure. Utilizing distorted measures provides dim prospects for goal attainment.

4 Alternative incentive design options

Assume a paying agency would like to obtain more of an environmental good, E , e.g., clutches of a rare bird in a field. For simplicity, the agent, in this case the owner of the field, can only pursue two actions which will help reach the paying agency's goal: a_1 , reduction of chemical use and, a_2 , planting of special fruit trees. A third action, a_3 , has no impact on the production of the environmental good. The production function for the environmental good is assumed to be

$$E(a, \varepsilon) = a_1 f_1 + a_2 f_2 + a_3 f_3 + \varepsilon \quad (1)$$

where f_1, f_2, f_3 are the marginal impacts of the actions on the goal with $f_1, f_2 \neq 0$ and $f_3 = 0$. Certain external environmental effects, ε (with variance σ_ε^2 and mean 0), also impact the number of bird clutches on the field.

The field owner's expense is assumed to be certain and to be expressed by a quadratic function

$$D(a) = \frac{1}{2} (a_1^2 + a_2^2 + a_3^2)$$

The paying agency rewards the field owner through a linear payment scheme

$$b + c_e E \quad (2)$$

which, as discussed above, consists of the base payment, b , and the variable incentive payment, $c_e E$.

As in Bolton and Dewatripont (2005), for a risk averse agent with a coefficient of absolute risk aversion, η , utility can be modeled in a standard way by a negative exponential utility function

$$-e^{-\eta(b + c_e E - D(a_i))}$$

The scheme participant's expected utility can be expressed as a function, ψ , of utility

$$\psi(-e^{-\eta(b + c_e E - D(a_i))})$$

The paying agency's task is now to determine the optimal incentive payments.

The payment scheme in the model, as well as in Figure 1, is linear. Although the linearity assumption is tied to the restrictive assumptions of normally distributed environmental noise terms and a constant absolute risk aversion utility function for the scheme participant (Bolton and Dewatripont, 2005), it is chosen due to its convenience and simplicity.

4.1 Single performance indicator

Building on the basic model presented above, in this first scenario it is assumed that the paying agency would like to make use of only one performance indicator. Either the agency has an overall environmental goal that can easily be quantified and directly used as performance measure or it must make use of a distorted proxy indicator. In both cases, the performance measures 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. The paying agency is advised to take this into account when designing the scheme.

The optimal weight for an undistorted performance measure, in our example bird clutches in the field, is found by maximizing the expected net benefit to the paying agency subject to the constraint that the participant chooses activities that maximize his utility and the constraint that the total payment to the agent must be higher than his reservation utility. The expected net benefit to the paying agency is computed as the difference between the constant per unit value of the environmental good minus the payment to the scheme participant. For simplicity the derivations are omitted here but they can e.g. be found in detail in Holmström and Milgrom (1991) or Bolton and Dewatripont (2005, pp. 137-139).

The resulting optimality condition is:

$$c_e = \frac{1}{1 + \eta \sigma_e^2}$$

This condition tells the paying agency that the optimal incentive payment should decrease with (i) an increase in the participant's risk aversion, and (ii) an increase in the variance of the environmental noise.

Eventually, the paying agency will not have the opportunity to employ an undistorted performance measure but rather will have to settle for a distorted proxy, G . In our example, the agency may not want to search the field for clutches to avoid disturbing the birds. As an alternative it may choose to assess the number of rare birds by acoustically measuring the intensity of their songs. If the birds' chirps are difficult to distinguish between species, this performance measure runs the risk of becoming distorted. The field owner has the possibility to attract many different bird species to his field by laying out birdfeed. Obviously this action is significantly cheaper than planting special fruit trees or reducing chemical usage and it will increase the intensity of bird chirps.

More formally, this distorted performance measure's sensitivity to the agent's actions is indicated by the respective marginal impacts, g_i . The new production function is $G(a, \phi) = a_1 g_1 + a_2 g_2 + a_3 g_3 + \phi$, where ϕ are the external environmental effects with variance σ_ϕ^2 and mean 0. Note that the third action, a_3 , which did not have an impact on the production of the environmental good now has an impact, $g_3 \neq 0$ on the performance measure G . The paying agency will now want to determine the optimal incentive payment, c_g for the linear payment scheme

$$b + c_g G \quad (3)$$

It is particularly important to understand that agents will adjust their actions to optimize their payoff based on the given performance indicator. The scheme's overall goal statement does not necessarily influence their actions. Participants may appreciate and approve of the overall goal but the performance measure is the decisive incentive that steers the individuals' actions.

Contract theory literature suggests several similar approaches to measure distortion. Feltham and Xie (1994) square the difference between the relative impact of two actions on an undistorted and a distorted performance measure. Provided there is no distortion the relative impacts of the two measures will be equal and the term is zero. Datar et al. (2001) assess distortion as the squared difference between the actions' marginal impacts on outcome and the sensitivity of the distorted performance measure to these actions. Instead of directly calculating the difference between marginal impacts, Baker (2002) measures the cosine between the two vectors indicating the sensitivity of the performance measures to the agent's actions. No distortion means that the angle between the vectors is zero and thus the cosine equals one. Making use of this last approach, the optimality condition is:

$$c_g = \frac{\|f_i\| \|g_i\| \cos \theta}{\|g_i\|^2 + 2\eta \sigma_\phi^2}$$

where f_i and g_i are vectors of the actions' marginal impacts and $\|f_i\|$ and $\|g_i\|$ represent the respective norms. θ is the angle between the vectors which measures distortion.

The analysis of the optimal weight for a distorted performance measure, c_g , (in the absence of alternatives) renders rather intuitive results. It should decrease as distortion increases, decrease as environmental noise in the production process increases, as well as decrease as risk aversion increases (Baker, 2002).

The models presented above identify optimality conditions for the design of scheme incentives. The comparative statics showed how the incentives should be adjusted in reaction to a marginal change in one of the parameters. In reality, a scheme designer is however unlikely to have full information on all the parameters that are necessary to compute optimal incentives. Oftentimes the incentives may rather be established in an iterative trial-and-error approach. The examples listed in the table below are thus of less analytical nature but showcase how schemes have been designed and, in particular, which type of indicators have been chosen.

Table 1 below provides an overview of fourteen performance payment schemes from around the world that each makes use of a single performance indicator. The first column indicates the geographical location of the scheme. The second column lists the environmental good that is to be produced. In terms of the models presented above, this refers to the environmental good, E , in equation 1. The

incentive payments, $c_e E$ (Eq. 2), respectively $c_g G$ (Eq. 3) of each particular scheme are given in column three. It is interesting to note that none of the schemes listed in Table 1 offer a monetary base payment. This indicates that the scheme designers opted for strong conditionality of the payments.

Table 1: Schemes with a single performance indicator

Program location (Source)	Goal(s) to be achieved	Incentives
1 Germany (Pürckhauer, 2007)	Conservation of Montagu's harrier (<i>Circus pygargus</i>)	Payment per aerie, calculated to compensate crop loss from setting aside 50x50 m area around aerie
2 Germany (Roßkamp, 2007)	Conservation of certain bird species [black-tailed godwit (<i>Limosa limosa</i>), peewit (<i>Vanel-lus vanellus</i>), redshank (<i>Tringa totanus</i>), and pied oystercatcher (<i>Haematopus longirostris</i>)]	Payment per protected clutch ¹
3 Nebraska, USA (NGPC, 2005)	Conservation of mountain plovers (<i>Charadrius montanus</i>)	Payment of \$100 per nest to farmers (farmers required to assist in locating and flagging of nests prior to weed control tillage)
4 Argentina (IUCN-SSC Crocodile Specialist Group, 2004)	Caiman (<i>Caiman latirostris</i> , <i>Caiman yacare</i>) conservation and ranching	Payments (US\$7) for each nest located and marked by locals
5 Sweden (Zabel & Holm-Müller, 2008)	Increase of wolverine (<i>Gulo gulo</i>) population	Payments (approx. US\$ 33,450) per carnivore offspring
6 Sweden (Zabel & Holm-Müller, 2008)	Increase of lynx (<i>Lynx lynx</i>) population	Payments (approx. US\$ 33,450) per carnivore offspring
7 Kenya (Ferraro, 2007)	Release of turtles caught in fishing nets	Payments (approx. US\$7) for the release of adult and sub-adult turtles and (approx. US\$4) for smaller turtles
8 Esperanza (Rojas & Aylward, 2002)	1. forest protection in watershed 2. avoidance of potential land invasions 3. Managing of forest and forest guards 4. Economic viability for conservation	Payment (US\$10) per ha and year multiplied by relationship of real to projected energy production in water powerplant and an inflation correction term
9 Seychelles (Ministry of Environment Seychelles, 2008)	Eradication of alien Indian House Crow (<i>Corvus splendens</i>) Program was successful; complete eradication achieved	Payment (approx. US\$100) per killed crow
10 Montana, USA (Pokorny & Krueger-Mangold, 2007)	Eradication of dyer's woad (<i>Isatis tinctoria</i>) from Montana	Payment (US\$50) for notification of new infestation located at least 1km from known site
11 Oregon, USA (Porter, 2008)	Control of 7 specified noxious weeds	Payment of \$200 for the reporting of a new infestation site within a designated area
12 Louisiana, USA (Louisiana Department of Wildlife and Fisheries, 2007)	Protection of coastal ecosystem through harvest of up to 400,000 nutria (<i>Myocaster coypus</i>) annually	Payment (US\$5) per nutria tail
13 India (The New York Times, 1898)	Decrease of snake population	Payment per snake head
14 Samoa (Shine et al., 2000)	Control of alien African Snails	"a few cents per snail killed"

¹ Funding of the program is provided by a local beer brewery. For each crate of beer sold during 7 designated weeks the brewery invests approx. US\$0.3 into environmental protection projects.

The level of distortion varies across the indicators chosen in the different schemes. The first six schemes focus on the conservation of certain wildlife species. Their performance indicators measure wildlife population increases, e.g. bird and caiman nests or carnivore offspring. One of the schemes listed in Table 1 is situated in Kenya and issues payments to fishermen for each turtle released from a fishing net. Theoretically, this scheme provides incentives to intentionally fish for turtles, though no such distortionary activities have been reported (Ferraro, 2007). The last six case studies in Table 1 are all examples of bounty schemes to eradicate or control invasive species. The Seychelle's bounty program is stated to have been very successful and resulted in a complete eradication of the invasive Indian House Crow (*Corvus splendens*) (Ministry of Environment Seychelles, 2008). Performance payment schemes that make use of bounties are however prone to give rise to distortion. Explicit breeding of invasive species as a result of a bounty scheme was discovered in India (case 13) many years ago and more recently in Samoa (case 14) (Shine et al., 2000; The New York Times, 1898). Explicit monitoring systems, such as control visits or requirements to map the trapping sites (Louisiana Department of Wildlife and Fisheries, 2007) may help prevent such perverse incentives.

4.2 Several performance measures

Eventually the paying agency may not want to rely on only one performance measure. For example, goods such as biodiversity conservation are likely to call for a plurality of indicators (Duelli and Obrist, 2003). A set of several measures in combination may be convenient. In a noiseless environment, the performance indicators would be direct functions of the agent's actions. The optimal weights for alternative indicators could be determined by regressing, without intercept, the marginal impacts of the undistorted measure on the marginal impacts of the distorted measures (Datar et al., 2001). The resulting regression coefficients would provide the optimal weights.

However, in reality it is unlikely to come across completely noiseless performance measures. A comparison of suitable indicators will most likely reveal a tradeoff between risk and distortion. Assume for simplicity that two indicators are to be used: one undistorted but with substantial noise and one distorted but less risky. Referring to our previous notation this implies that $\sigma_\varepsilon^2 < \sigma_\phi^2$. A question of

interest is how the distorted performance measure should be weighted relative to the undistorted measure. Baker (2002) does analysis on these relative weights and finds that an increase in distortion leads to a decrease in the relative weight of the distorted performance measure. As noise in the undistorted performance measure increases, the relative weight of the distorted performance measure increases. The effect of an increase in noise of the distorted performance measure is ambiguous.

While Baker (2002) focuses on changes in the noise of the production functions, Datar et al. (2001) analyze changes in the marginal impacts of actions. In their sense, an undistorted measure is a function of some number of actions and the distorted measure is a function of merely a subset of these actions. The incongruent measure, in this model, is not sensitive to any additional actions. Again referring to our previous notation, the undistorted performance measure is $E(a, \varepsilon) = a_1 f_1 + a_2 f_2 + \varepsilon$ with $f_1, f_2 \neq 0$ whereas the distorted measure now can be noted as $G(a, \phi) = a_1 g_1 + \phi$ with $g_1 \neq 0$.

Assume the first action's impact on the undistorted measure increases, Δf_1 , for some exogenous reason. Datar et al. (2001) find that the optimal reaction to this change depends on the size of the first action's impact on the environmental goal relative to the second action's impact. Provided the first action's new marginal impact remains much smaller than that of the second action, it is optimal to directly target an increase in the first action by means of increasing the weight on the distorted measure, G . An increase in the performance payment based on the environmental good, E , would induce the agent to increase the second action more than the first, since the second action's marginal impact is relatively larger. This increased engagement in the second action, would provoke the agent to request an increased risk premium. The paying agency can avoid this cost by directly targeting the first action.

In case the new marginal impact of the first action is much larger than that of the second it is optimal to increase the weight of the undistorted performance measure. This will directly lead to the desired increase of the first action. Table 2 summarizes the effects of changes in the parameters (first column) on the optimal incentive payments (top row).

Table 2: Effects of selected parameters on optimal incentive power

	Incentive payment for undistorted indicator, c_e	Incentive payment for distorted indicator, c_g	Incentive payment for undistorted indicator relative to payment for distorted indicator, c_e/c_g
Variance of noise in production function of undistorted indicator, σ_e^2	↓		↓
Variance of noise in production function of distorted indicator, σ_ϕ^2		↓	↓↑
Scheme participant's coefficient of absolute risk aversion, η	↓	↓	
Distortion, $\cos\theta$		↓	↑
Marginal impact of action 1 on undistorted indicator, f_1			↑, for $ f_1 + \Delta f_1 < f_2 $ ↓, for $ f_1 + \Delta f_1 > f_2 $

Examples of performance payment schemes that employ several indicators simultaneously are listed in Table 3. The construction of this table is identical to that of Table 1. The first column states the program location, followed by a description of the environmental goal and the incentive payments in columns two and three respectively. The first case in Table 3, a turtle nest protection project of the Kiunga Marine National Reserve, Kenya, is an example of a scheme that follows the indications of the economic theory. This project is run by WWF and the Kenya Wildlife Service and is especially targeted at women (Ferraro, 2007). The goal is to conserve marine turtles. A performance payment of 500 Kenyan Shillings (approx. US\$7.5) is paid to local women for each certified turtle nest discovered on the beach. An additional payment of 20 Shillings (approx. US\$0.04) is paid for each successfully hatched turtle egg and 10 Shillings (approx. US\$0.02) 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 theory of incentives 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 than 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 recommendation derived from theory would be to shift relatively more weight on the distorted measure discovery of nests.

A further example in Table 3 is the silvopastoral ecosystem management project in Nicaragua (case 3). In this scheme a battery of different land uses are indexed according to their carbon sequestration and biodiversity conservation characteristics (Pagiola et al., 2007). From this data a special environmental services index is computed. Land owners receive payments based on net increases of their environmental services index relative to their base index at the time of contracting. The Nicaraguan scheme is also a rare example of a scheme that made an upfront payment. It was issued based on the environmental services index at the time of contracting to prevent land owners from cutting all their trees prior to the program's initiation (Pagiola et al., 2007).

Table 3: Schemes with more than one performance indicator

Program location (Source)	Goal(s) to be achieved	Incentives
1 Kenya (Flintan, 2002; Ferraro, 2007)	Turtle conservation	Payment (approx. US\$7.5) per reported turtle nest and payment (approx. US\$0.04) for each successful hatching and (approx. US\$0.02) for each unsuccessful (rotten) egg
2 Tanzania (Ferraro, 2007)	Turtle conservation/ Reduction of poaching by locals	Payment (approx. US\$2.5) per reported turtle nest and payment (approx. US\$0.03) for each successful hatching and (approx. US\$0.02) for each unsuccessful (rotten) egg
3 Nicaragua (Pagiola et al., 2007)	Adoption of silvopastoral practices	Payment (US\$75) per annual point increase in program's environmental services index
4 Germany (Stapelholmer Naturschutzvereine, 2007)	Conservation of four endangered bird species [black-tailed godwit (<i>Limosa limosa</i>), peewit (<i>Vanellus vanellus</i>), redshank (<i>Tringa totanus</i>), and curlew (<i>Numenius arquata</i>)]	Payments per hectare and differentiated according to single breeding birds and entire colonies Certain management rules while birds present
5 Iowa, USA (Morton et al., 2006)	Water quality improvement	P-index, Soil Conditioning Index (SCI), and cornstalk nitrate test

4.3 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 (RPE) may be a solution. An essential precondition for this approach is that several participants face production noise that is correlated (e.g., $\sigma = \sigma_s + \sigma_i$ where σ_s is the systematic portion of risk faced by all participants and σ_i is the idiosyncratic portion that represent separate individual draws from a common distribution of production noise). The greater the systematic portion of the production risk, the more effective are RPE approaches. RPE here means linking individual compensation to the individual's performance relative to other participants' performance. Both continuous schemes and discrete schemes (e.g., a rank-order tournament where discrete prizes are awarded for performance levels that are the highest, second-highest, etc.) can be used.

It is important that an individual cannot influence the value of the benchmark. Otherwise RPE may provide incentives for agents to influence the benchmark by sabotaging other's work (Lazear, 1989). Similarly, incentives for collusive shirking, i.e. making agreements within the reference

group on low performance, may arise. Also, some potential scheme participants may be muscled out by others in an attempt to influence the composition of the reference group (i.e., group composition risk). For example, there may be an effort to remove potential curve-wreckers. Finally, production externalities can complicate the creation of an exogenous benchmark (Gibbons and Murphy, 1990).

Often agents in an RPE scheme are assumed to be homogeneous. Relaxing this assumption, i.e. allowing for heterogeneous agents in terms of marginal investment costs (Lazear and Rosen, 1981) or variance in agents' abilities (Tsoulouhas and Marinakis, 2007) can, to a certain extent, compromise the benefits of RPE. Tsoulouhas and Marinakis (2007) show how the variability of individual's output increases along with heterogeneity which in turn is found to reduce the benefits of RPE over direct performance payments. However, very large numbers of scheme participants can cancel out the drawbacks of heterogeneity.

Examples for the use of RPE 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 and Attenberger, 1999). 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 other scheme participants (Mangelsdorf and Attenberger, 1999).

4.4 Performance thresholds

Rather than measuring performance on a continuous scale or comparing it to that of others, some agri-environmental schemes make use of performance thresholds. The participant thus receives a payment once his environmental service production is equal to, or larger than, a given threshold. How this threshold is set can be of importance for scheme success. With an externally given static threshold, scheme participants will have incentives to produce just enough of the environmental good to receive the bonus. There will be no incentives to produce more of the good than to meet the threshold level.

Alternatively, the threshold can be flexible over time and adjusted to past performance. For example, the current year's threshold may be defined as either the past year's threshold or the past year's true performance level, whichever was larger. This mode of setting a threshold is called the ratchet effect (Weitzman, 1980; Murphy, 2001). Ratcheting the threshold level may give rise to incentives for the scheme participant to smooth her performance between years to prevent a large increase in the threshold (Murphy, 2001). Assume for example a biodiversity scheme that defines its ratcheted performance threshold as a certain number of selected plant species on a given field. In a year with plant abundance beyond the threshold level, a farmer may have incentives to intentionally reduce the plant species prior to monitoring to avoid an increase in the threshold for the coming period.

An example of a scheme with an externally given threshold is the German MEKAll 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 payment if they meet the threshold of hosting at least four out of a given list of 28 special plant species on their fields (Oppermann, 2003). Providing 5 or even all 28 of the specified plant species will however not increase the payment. The payment is thus capped from above.

A similar 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). As in the MEKAll scheme, the focus here is on whether selected plant species grow on the field. The first threshold is set at four out of a list of specified plants. If a second threshold (two additional plant species from the list) is passed, the payment is nearly doubled.

An interesting question concerns the conditions under which making use of thresholds is preferable to using continuous performance measures. In their model, Arnaiz and Salas-Fumás (2008) find that if the distribution of the undistorted performance measure's noise term has semi-heavy tails a scheme with thresholds may become optimal. Compared to a normal distribution, a distribution with semi-heavy tails has relatively more noise in the performance measure at extreme values. Thus, thresholds set around the mode of the distribution could be used instead of continuous measures to avoid the noisy extreme values. Based on a different model Levin (2003) notes that contracts that are difficult for a third party to enforce may rely upon threshold payments rather than continuous payments to maximize incentives. Table 4 summarizes the key characteristics of three schemes that make use of performance thresholds. It is interesting to note that all three schemes provide for base payments. In the first case, the base payment is conditional on certain action-oriented criteria. In the Mongolian scheme (case 3) the base payment consists of a guaranteed purchase of defined amounts of handicrafts.

Table 4: *Payment schemes with performance thresholds*

Program location (Source)	Goal(s) to be achieved	Incentives
1 Germany (Ministerium Ländlicher Raum, 2000)	Compensation for agricultural services in particular preservation and maintenance of the cultural landscape, environmental protection, and market relief. Secure existence of sufficient numbers of farms to preserve and maintain the cultural landscape	Payment (max. approx. US\$80 per ha and year) for at least four out of a given list of 28 plant species
2 Switzerland (Schweizerischer Bundesrat, 2001)	Preservation and advancement of biodiversity on farmland used as ecological buffer area with exceptional biological quality	Payment (approx. US\$500 per ha & year) for at least 6 out of given lists of plant species (different plant lists for different regions)
3 Mongolia (Mishra et al., 2003)	Snow leopard (<i>Uncia uncia</i>) conservation	20% top up on price of handicrafts if no violations to the contracted program rules (ban on hunting snow leopards and their prey)

4.5 When not to use performance payment schemes

The sections above discussed various types of incentive payment schemes and conditions under which they may be recommendable policy options. There are however certain general conditions under which implementing an incentive payment scheme is not advisable. Most obviously this is the case if a clear-cut goal statement is lacking. Also, an incentive payment scheme should not be set up if no adequate performance indicators with reasonable levels of risk and distortion can be identified.

Provided suitable performance indicators are available, a method to link the performance value to the scheme participant who is responsible for the outcome is necessary. 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 indi-

viduals. However, this approach requires collective action among the beneficiaries (Rojahn and Engel, 2005; Zabel and Holm-Müller, 2008). In cases where success of collective action is doubtful, alternatives to performance payments may be more promising.

The installation of a performance payment scheme within a defined geographical area may induce people to migrate to this region to benefit from the scheme. Especially in developing countries, if the stakes are high enough, such a welfare magnet effect could cause perverse effects for environmental conservation.

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. Provision of long-term financing is often mentioned to be a crucial determinant of success, in particular if major investments are required (Meinzen-Dick et al., 2002; Pagiola et al., 2007). Unlike eco-tourism or eco-labeling performance payments are not self-sustained. They rather need a continuous source of funding.

5 Discussion

Performance payments are a relatively new environmental policy instrument with rather few well-established schemes. With respect to creating incentives for the production of a defined environmental goal, 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 (Ferraro 2001; Ferraro and Kiss, 2002; Ferraro and Simpson 2002; Engel et al. 2008). 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. If not controlled for, the flexibility of production processes may, however, also induce distortion due to moral hazard.

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 rather is to use agri-environmental 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). Although WTO green-box compatible, performance payments are not likely to be a good policy choice for general income support.

The two major questions raised in this paper are how to optimally adjust incentives in a performance payment scheme in the presence of (i) risk, i.e. external environmental noise, in the production process and (ii) distortion

in the performance indicators. By reviewing findings presented in the accounting and contract theory literature solution strategies could be identified. In particular these are: when using only one indicator, the incentive payment should decrease as external noise, as well as the scheme participant's coefficient of absolute risk aversion increase. Relative performance evaluation is a viable approach to back-out risk. Two important preconditions for relative performance evaluation are that (i) an individual cannot influence his benchmark and (ii) all participants' performance is subject to a highly correlated source of external environmental noise. Finally, issuing threshold payments instead of continuous payments is a strategy to cope with noise which is not normally distributed but rather has semi-heavy tails.

Concerning distorted indicators, the literature supports the intuition that the incentive payment should decrease as distortion increases. In some cases two indicators may be used which contain a trade-off between risk and distortion. An interesting finding is that it is optimal to increase the relative weight of the distorted but less risky indicator as the noise in the less distorted indicator 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 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 and to omit the creation of unintentional adverse incentives. Since the response to an incentive may substantially vary, e.g. between people of different cultural groups, it would be unsound to suggest any universally optimal per-

formance indicators. For example, in some countries providing bounties as incentive to harvest invasive species is well-accepted, whereas in others eradication efforts have been stopped by animal rights activists (Bremner and Park, 2007).

Performance payment schemes require a number of conditions to be met, but under given circumstances they have the potential to be a very powerful pro-conservation policy tool.

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