Ecological Economics 85 (2013) 77–84

Contents lists available at SciVerse ScienceDirect

Ecological Economics

journal homepage: www.elsevier.com/locate/ecolecon

Analysis

# Combining performance-based and action-based payments to provide environmental goods under uncertainty

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ARTICLE INFO

*Article history:*
Received 16 March 2012
Received in revised form 31 October 2012
Accepted 3 November 2012
Available online 27 November 2012

*JEL classification:*
Q28
Q18
H41

*Keywords:*
Conservation contracts
Payments for ecosystem services
Payments for environmental services
Biodiversity
Uncertainty

ABSTRACT

Payments for environmental services (PES) are widely adopted to support the conservation of biodiversity and other environmental goods. Challenges that PES schemes have to tackle are (i) environmental uncertainty and (ii) information asymmetry between the provider of the service (typically a farmer) and the regulator. Environmental uncertainty calls for action-based payment schemes, because of the more favorable risk allocation if the farmer is risk-averse. Information asymmetry, on the other hand, calls for a performance-based payment, because of the more direct incentives for the farmer. Based on a principal-agent model, we study the optimal combination of both, performance-based and action-based payments under conditions of environmental uncertainty and asymmetric information. We find that for a risk-neutral regulator a combination is optimal in the majority of cases and that the welfare gain of the combined scheme over a pure action-based (performance-based) payment increases with information asymmetry (environmental uncertainty). We further show that for a regulator who is risk-averse against fluctuations in environmental goods provision the optimal performance-based payment is lower than for a risk-neutral regulator. We quantitatively illustrate our findings in a case study on the enhancement of the butterfly Scarce Large Blue (*Maculinea teleius*) in Landau/Germany.



## 1. Introduction

The protection and enhancement of environmental assets are objectives shared by many governments around the globe. Often these assets depend on how farmers manage their private land, but as they typically have characteristics of public goods, farmers have little incentives to make socially optimal decisions (Bardsley and Burfund, 2008). For this reason policy instruments such as payments for environmental or ecosystem services (PES) have been advocated to create incentives similar to those that would be provided by market prices, if markets for environmental services would exist (e.g. Bulte et al., 2008; Corbera et al., 2007; Vatn, 2009).

Two types of payment schemes are used in practice: Action-based payments are bound to a predefined action or measure, whereas performance-based payments are directly bound to the outcome of a desired ecosystem good or service.[1]

Performance-based payments have the advantage that they set the direct incentive to provide ecosystem services efficiently (Matzdorf, 2004; Zabel and Roe, 2009). A drawback of performance-based payment schemes is that the risk of producing an ecosystem good comes at the expense of the farmer, since the quantity of environmental service also depends on external influences beyond the farmer's control. If the farmer is risk-averse, and the regulator is risk-neutral, a pure performance-based payment scheme thus leads to an inefficient risk allocation.[2] As a result, most existing schemes are action-based, although performance-based payments are sometimes applied for the conservation of an already given state or of existing biodiversity (Hampicke, 2001; Osterburg, 2006). Action-based payments may be a cost-effective alternative if there is a clear action that is required to provide the environmental good, known and observable by the regulator (Gibbons et al., 2011). If there is informational asymmetry between farmer and regulator, however, a pure action-based payment is likely to lead to an inefficient outcome.

In this paper, we consider payment schemes that combine performance-based and action-based payments. We set up a principal-agent model to study what combination of both is optimal when there is both environmental uncertainty affecting the provision of the environmental good and asymmetric information about how

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[1] Many labels for these payment schemes can be found within the literature. Other common names for action-based payments are e.g. input- or measure-based payments, for performance-based payments the terms output-oriented, outcome- or result-based payments are also common.

[2] An efficiency improvement in the risk-allocation could be obtained by shifting risk from the risk-averse farmer to the risk-neutral regulator. One way of doing this (the one considered in this paper) is to combine a pure performance-based payment to some extent with an action-based payment.

0921-8009/$ – see front matter 
http://dx.doi.org/10.1016/j.ecolecon.2012.11.001

**Table 1**
Table showing the optimal PES scheme for a risk-neutral regulator.

| | Asymmetric information between farmer and regulator | Both perfectly informed |
|---|---|---|
| Environmental risk | Combination | Action-based |
| No environmental risk | Performance-based | Any |

productive a management action is for providing the environmental good.

We find that the optimal payment typically will be a combination of performance-based and action-based payments (see Table 1). A pure performance-based payment is optimal for a risk-neutral regulator (the principal) only if either there is no environmental risk or if the farmer (the agent) is risk-neutral. A pure action-based payment is optimal only if the regulator has full information about the marginal productivity of the actions for providing the environmental good. The performance-based fraction of the optimal payment increases with environmental uncertainty, while the action-based fraction increases with information asymmetry. These findings are also reflected in the welfare gains of the combined scheme over the pure performance-based or action-based schemes: the welfare gain, measured as the payoff of a risk-neutral regulator, of the optimally combined scheme over an optimally chosen, pure action-based (performance-based) payment increases with information asymmetry (environmental uncertainty).

The assumption of a risk-neutral regulator may be inappropriate, because society's marginal willingness to pay for the environmental asset may increase if an environmental asset becomes increasingly scarce. For this reason we also consider a regulator who is risk-averse against fluctuations in environmental goods provision. As the argument for an action-based payment scheme is the more favorable allocation of risk if the farmer is risk-averse but the regulator is risk-neutral, one might expect that the performance-based fraction of the optimal payment might be relatively higher when the regulator is risk-averse. We find, however, that the optimal performance-based payment actually decreases with the regulator's degree of risk aversion.

We apply our analysis to the case study on the enhancement of the butterfly Scarce Large Blue (*Maculinea teleius*) in Landau/Germany, based on data from the literature (Drechsler et al., 2007; Wätzold et al., 2008). Results indicate that the optimal combination of the performance-based and action-based payments may lead to a welfare gain of several thousand euros per hectare.

## 2. Principal-Agent Model of Environmental Good Provision Under Uncertainty

We consider a principal-agent setting where a regulator (the principal) offers a PES to a single, representative farmer (the agent), who chooses an action that contributes to the production of an environmental good. This means, we assume that all farmers share the same characteristics with respect to preferences and production technology.[3] We thereby extend the approach of Zabel and Roe (2009), allowing for a combination of a performance-based payment with an action-based payment, and risk aversion on the regulator's side.

The temporal structure of the problem is that, first, the principal announces the payment scheme. Second, the agent decides on whether or not he would like to participate in the program. If he participates, he receives (or pays) a base-payment. Third, the agent chooses his action, and fourth, nature adds stochastic disturbance. Finally, the agent receives performance-based and action-based payments from the principal, and society enjoys the environmental good.

[3] The question how to deal with heterogenous farmers (for example by designing adequate auction schemes such as, e.g., Latacz-Lohmann and Van der Hamsvoort, 1997) is beyond the scope of this paper.

The quantity $y$ of the environmental good is produced according to

$$y = \phi x + \varepsilon. \quad (1)$$

The provision of the environmental good can be increased by the farmer's action $x$ with a constant marginal productivity $\phi$. For example, $x$ can be thought of as the area of farmland set aside for biodiversity protection. We consider $y$ to be the *additional* environmental goods provided, i.e. $y$ is the (net) growth of the environmental good. This growth is also affected by a stochastic disturbance $\varepsilon$, capturing environmental noise, which is independent and identically normally distributed with zero mean and standard deviation $\sigma_\varepsilon$.[4]

Marginal productivity $\phi$ of the action $x$ is known to the farmer, but not to the regulator. This information asymmetry arises, because the farmer knows the peculiarities of his farmland while the regulator does not. The regulator only knows a prior probability distribution over $\phi$. We assume that this is any probability distribution with a mean $\bar{\phi}$ and variance $\sigma_\phi^2$. The quantity $x$ of the action exerted by the farmer is common knowledge of both farmer and regulator.

Some important and restrictive assumptions about the production of the environmental good are embodied in Eq. (1), which we shall discuss in the following.

(i) Taking asymmetry with regard to the observability of the farmer's action into account has similar effects as the information asymmetry with regard to marginal productivity and could be included in the model in a straightforward way. In either case the essential assumption is that the farmer may have more information about his contribution to the provision of the environmental good than the regulator.
(ii) Assuming *perfect* information on $\phi$ on the farmer's side is rather strong. However, the crucial aspect of this assumption is that the farmer has *better* information about what he is doing than the regulator. Assuming perfect information only simplifies the analysis. Environmental uncertainty, captured by $\varepsilon$ in Eq. (1), is an aspect of incomplete information about the production of $y$ faced by the farmer and the regulator to an equal extent.
(iii) As we are considering a representative farmer, assuming production of the environmental good according to Eq. (1) means that either there are no external effects between farmers, or that all external effects are internalized, for example by a farmer's association that negotiates about the PES contract with the regulator.

We consider a payment $\omega$ for the provision of the environmental good that is composed of a base payment $b$, a payment for the action, $a\,x$, and of a payment for the performance, i.e. the provision of the environmental good, $p\,y$,[5]

$$\omega = b + ax + py. \quad (2)$$

Because of environmental uncertainty, $y$ may be negative. In such a case the performance-based payment $p\,y$ will be negative as well, although typically the *expected* performance-based payment will be positive. The base payment $b$ is chosen such that the farmer nevertheless has an incentive to participate in the PES scheme. Using the base payment to meet the participation constraint is in line with the recent literature on PES that has adopted this approach from labor economics (Zabel and Roe, 2009).[6]

[4] Note that the net growth of the environmental good may be negative even with a positive effort $x$, due to environmental uncertainty.

[5] We restrict our analysis to linear combinations of the three payment parts here. An analysis of more general payment structures is left for future research.

[6] One example for combined payment schemes can be found in Switzerland: Here the schemes contain site-specific direct payments, similar to the base payment considered here. Additional payments are bound to the condition that 7% of the farm area are managed in line with specific ecological standards, corresponding to the action-based payment considered here. Finally, the Swiss authority adds a performance-based payment when biodiversity is sufficiently high.