Ecological Economics 134 (2017) 49–56

Contents lists available at ScienceDirect

Ecological Economics

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

Performance of Input- and Output-based Payments for the Conservation of Mobile Species

Martin Drechsler

UFZ-Helmholtz Centre for Environmental Research, Department of Ecological Modelling, Permoserstr. 15, 04318 Leipzig, Germany

ARTICLE INFO

Article history:
Received 18 May 2016
Received in revised form 16 August 2016
Accepted 7 December 2016
Available online 19 January 2017

Keywords:
Conservation
Ecological-economic model
Feedback loop
Metapopulation
Output-based payment
Spatio-temporal dynamics

ABSTRACT

A conceptual model is presented for the comparison of input-based payments (where conservation measures are rewarded) and output-based payments (where conservation outcomes are rewarded) in a spatially structured landscape. The landscape consists of a grid of land parcels, each managed by a land user. The objective of the conservation agency is the survival of an endangered mobile species in the landscape. The comparison of the two payment schemes is made with regard to cost-effectiveness (maximizing species survival for given total conservation costs) and budget-effectiveness (maximizing species survival for given conservation budget). The model is a grid-based dynamic stochastic ecological-economic simulation model. In the model analysis it is found that within the considered model parameter ranges the output-based payment outperforms the input-based payment, except for the cases of risk-averse land users and spatial spill-overs. The comparative advantage of the output-based payment increases with increasing viability and decreasing dispersal range of the species, and with decreasing spatial variation of the conservation costs. In the light of these results, output-based payments appear as a promising policy option even for mobile species where the local outcome (presence of the species in the land parcel) of a local conservation measure is uncertain.

1. Introduction

Payments for ecosystem services (Engel et al., 2008; Engel, 2016) are one of the most promising policy instruments to conserve biodiversity in agricultural landscapes. Their advantage compared to legal regulations is, among others, that they are voluntary (leading to higher acceptance of conservation among land users) (Sorice et al., 2013) and that they are more cost-effective because under the assumption of profit-maximizing land users only those whose cost are below the payment take part in the scheme while land users with high costs reject.

In Europe the most frequently applied type of payment scheme are homogenous payments for conservation measures where all land users in a region are offered the same payment (Vegamini et al., 2015). This implies that some land users (those with very low costs) receive higher payments than actually necessary to induce them to conserve their land (so-called producer rents). Therefore these payment schemes are not perfectly budget-effective in the sense that for a given conservation budget the level of biodiversity is maximized.

An alternative to homogenous payments are spatially differentiated payments (Armsworth et al., 2012; Wünscher et al., 2006) where each land user is offered a payment that just covers his or her costs.[1] This alternative is, however, problematic because, first, it may be regarded as unfair if some land users get a higher payment for the same conservation measures than others, and second, it would require that the conservation agency knows the land users' conservation costs, which is usually not the case (the agency is confronted with the problem of asymmetric information).

Another alternative is to pay land users not for carrying out a particular conservation measure but to pay if a particular ecological outcome, such as the presence of an endangered species, is achieved on the land (Burton and Schwarz, 2013; Engel et al., 2008; Ferraro, 2011, and references below). Such payments are termed performance-based or output-based payments to distinguish them from the above-mentioned schemes which are termed action-based or input-based payments. In an output-based payment the conservation agency does not need to know the costs of the conservation measures — it does not even need to know which measures are taken to achieve the desired outcome.

Despite these advantages, output-based payments also have their disadvantages which include that they function less well in the presence

E-mail address: martin.drechsler@ufz.de.

[1] Another scheme which effectively involves spatially heterogeneous payments to land users is the agglomeration bonus (Parkhurst et al., 2002) and will be taken up in the Discussion section.

http://dx.doi.org/10.1016/j.ecolecon.2016.12.022
0921-8009/

of risk. Risk in this context means that the outcome of a conservation measure is highly variable, unpredictable and not entirely controllable by the land user. This may be, e.g., due to variability in weather conditions that lead to variable presence of an endangered plant species on the land — despite the application of conservation measures. As a consequence the income of the land users will be variable because the payment is received only upon presence of the species.

Several studies have investigated the pros and cons of input-based and output-based payments. Derissen and Quaas (2013) analyzed the effects of different degrees of asymmetric information and different risk attitudes of regulator and land users on the optimality of different payment schemes. They compared input-based payments, output-based payments and mixtures of both and found, among other things, that for a risk-neutral regulator a combination of input- and output-based payments is optimal in the majority of cases. In an empirical study by White and Sadler (2012) an output-based payment turned out to be more cost-effective for the conservation of biodiversity than an input-based payment. White and Hanley (2016) investigated the role of adverse selection and moral hazard on the optimal choice of payment scheme. They also extended the static model to a dynamic model with two time periods. Among other things they found that if the regulator is able to measure the ecosystem service output and contract on it, then they can provide an incentive for an optimal level of the unobservable effort and informational rent.

A solution of the above-mentioned problem of output-based payments – risk – has been proposed by Zabel and Roe (2009). The authors introduced the relative performance which measures the performance of a particular land user compared to that of other land users in the region. The payment is made dependent on this relative performance. If all land users perform poorly a land user who performs slightly better than the others will receive the payment. This approach buffers the risk induced e.g., by weather variability because weather affects all land users in the same way. If the weather conditions are poor so will be the performances of all land users but the land user who invests in conservation will perform slightly better.

The relative-performance approach is well suited to buffer spatially correlated risks such as weather variability. It will, however, fail if the performance risk is not correlated but depends on local but uncontrollable conditions.[2] A prominent example for this type of risk is the presence of a mobile species in a conserved land parcel if the local population of the species in that land parcel can go extinct by chance and species presence can be achieved only through dispersal of individuals and recolonization from neighboring local populations. The risk whether the species is present on the conserved land parcel or not is specific to the land parcel and uncontrollable by the land user.

In ecological research the processes of local extinction, dispersal and recolonization are summarized in the so-called metapopulation theory (Hanski, 1999; Levins, 1969). A metapopulation is an ensemble of local populations, each inhabiting a habitat patch. Environmental or demographic factors can lead to the extinction of a local population. However, existing local populations emit dispersing individuals that may reach an empty habitat patch and recolonize it. Thus the metapopulation as a whole will generally survive much longer than an individual local population. Metapopulation theory has become one of the most important paradigms for the description of species dynamics in spatially fragmented landscapes (Driscoll and Lindenmayer, 2012; Wu, 2013).

Metapopulation theory has also been employed to describe species dynamics in dynamic landscapes where in each time period some land parcels may be conserved to create habitat while other habitats are destroyed and converted to agricultural land use (e.g., DeWoody et al., 2005; Wintle et al., 2005). These processes are also relevant in the present context, because the decision of a land user (conservation or agriculture) is likely to depend on the probability that his or her conserved land parcel will be occupied, which depends on the presence of the species in the neighborhood, as explained above. Altogether we can expect coupled ecological-economic dynamics where the spatio-temporal species dynamics affect the spatio-temporal land-use dynamics and vice versa.

The purpose of the present paper is to analyze the coupled species-land-use dynamics that are induced by an output-based payment if the output is measured by the presence of an endangered species that is structured as a metapopulation. While previous analyses of output-based payments (see references above) ignored spatial structure, dynamics (as an exception White and Hanley (2016) consider a simple dynamic problem with two periods) and feedback loops the present analysis is the first to take these issues into account. In the analysis I am interested in the cost-effectiveness and the budget-effectiveness of output-based payments compared with those of homogenous input-based payments that were introduced above. Budget-effectiveness here means that the expected number of land parcels occupied by the species is maximized for a given conservation budget while cost effectiveness means that the expected number of occupied land parcels is maximized for a given level of total cost accruing to the land users in the study region. Budget-effectiveness is relevant in the face of limited conservation budgets while cost-effectiveness is relevant for the assessment of socially optimal policies.

In particular I am interested how the two payment schemes perform in dependence of the characteristics of the endangered species (such as local extinction rate and dispersal range), the spatial heterogeneity of the conservation costs in the study region and the risk attitude of the land users. In addition I will consider the possibility that even unconserved land parcels may be occupied by the species as long as there is enough immigration from neighboring occupied land parcels — which represents an example of spatial spill-over.

The model that is used for the analysis is a generic grid-based stochastic ecological-economic model. Models of this type have developed, e.g., by Groeneveld et al. (2005), Mouysset et al. (2011) and Nalle et al. (2004). The present model and its analysis will be described in the following Section 2. Section 3 presents the results of the model analysis while Section 4 discusses the results and derives conclusions.

2. Model Description

2.1. Introductory Remarks and Initialization of the Model

The model considers a stylized agricultural landscape structured as a square grid with 10 by 10 grid cells (land parcels), each grid cell being owned by a single land user. A small proportion q of land parcels is legally protected as reserves and occupied by an endangered species. Each of the remaining land parcels can be used for agriculture or for conservation of the endangered species. Conservation of a land parcel i incurs forgone agricultural profits, in the following also termed conservation costs, z_i. The conservation costs are assumed to be independent uniformly distributed random numbers in the range between $1-\sigma$ and $1+\sigma$, where σ represents the cost variation. The costs are assigned to the land parcels in the beginning of the model simulation and are kept fixed during the simulation.

2.2. Economic Module

First I describe the economic module for input-based payments and then the module for output-based payments. To start with the input-based payments, consider for the moment a particular payment level p offered to all land users if they use their land parcels for conservation. Then all land users whose conservation costs z_i are smaller than the payment p conserve their land parcel while the others carry out agriculture. This determines the land-use pattern which remains constant in time and is the basis of the ecological module described below.

[2] Another difficulty with the approach of Zabel and Roe (2009) is the possibility of moral hazard, because land users may collude to underperform so that for the regulator it is not possible to distinguish whether the collective underperformance is due to adverse exogenous factors or to the decisions of the land users.