Improving the ecological and economic performance of agri-environment schemes: payment by modelled results versus payment for actions

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Abstract

Researchers and policy designers have become increasingly interested in re-designing agri-environmental policy to improve both economic efficiency and ecological effectiveness. One idea within this debate has been payments for results (outcomes) rather than payment for actions. Payment for result policies have been argued to have some important advantages, but two key disadvantages are the higher risks faced by land owners, leading to low participation rates; and the potentially high costs of monitoring outcomes. Bartkowski et al (2021) propose an alternative policy design of payment for modelled results, which claims to avoid these two problems. Our paper provides the first empirical test of the economic and ecological consequences of applying such a payment for modelled results policy to farmland biodiversity in England. We compare payment for modelled results findings with approximately equivalent payment for actions schemes designed to deliver increases in the same biodiversity indicators. Key insights from the work are that payment for modelled results delivers superior ecological outcomes for the same budgetary cost as payment for actions, whilst economic surpluses to farmers are also higher.

1 Introduction

Agri-Environment Schemes (AES) have been mainstreamed in agricultural policies across the globe as a means to financially incentivise farmers to undertake nature-protecting activities and to mitigate environmental damage (Batary et al, 2015; Prager, 2015). At their core, AES schemes aim to compensate land managers for the additional costs and income foregone incurred in farming with higher environmental and ecological quality standards (Tyllianakis & Martin-Ortega 2021). However, evidence is emerging world-wide that the dominant design of AES – payment for actions – often fails to achieve desired environmental outcomes, such as halting the decline of farmland biodiversity (Bertoni et al., 2020; Pe'er et al, 2020; although see Walker et al, 2018).

Payments for actions, alongside results-based payments sit within the general class of incentive-based AES and are the two main policy design alternatives that have been analysed (Derissen and Quaas 2013; Wuepper and Huber, 2021). Payment for action schemes offer farmers a (typically uniform) payment for adopting defined management practices within a specified region or nation state (Engel 2016). These actions – such as reductions in fertiliser use, or reductions in stocking rates – are intended to achieve an environmental policy target, such as an improvement in river water quality or an increase in the population of a farmland bird species. In contrast, results-based payment schemes offer payment conditional on achieving a specified ecological outcome, creating an incentive for those farmers who can provide the ecological benefit at a low cost to join the AES (Chaplin et al, 2021; Birge et al, 2017; Gibbons et al 2011). Within Europe, the majority of AES schemes are action-based, partly because of the assumption that these contracts are easier to observe and may be considered fairer than results-based alternatives (White and Hanley 2016). However, interest is growing in the use of results-based incentives as part of the on-going reforms of the Common Agricultural Policy (Herzon et al, 2018; Wuepper and Huber, 2021; Hasler et al, 2022).

A key drawback of many action-based schemes is that payments do not reflect the spatial heterogeneity in economic costs and potential ecological benefits, which significantly hinders the cost-effectiveness of such schemes in achieving an ecological target. Furthermore, paying for specific actions does not allow farmers to make use of private information they may hold on how best to produce the desired environmental output (Wätzold and Drechsler 2005). Consequently, payments for results schemes are being increasingly discussed in the academic literature and policy circles in Europe and the UK as a promising alternative.

From a theoretical perspective, results-based payments are often considered to be potentially more cost-effective than action-based payments (White and Hanley 2016; Derissen and Quaas, 2013). Payment-for-result schemes have a number of advantages over payment-for-actions AES policies, which are that (i) society pays for the desired results, rather than the actions intended to produce these results, (ii) farmers have an incentive to innovate to reduce the private costs of producing the contracted-for results, whilst (iii) farmers can use private information to determine how best to produce these results (Burton and Schwarz 2013; White and Hanley 2016). Monitoring costs could be higher or lower than payment for action schemes, depending on the relative observability of effort versus outcomes. However, a key concern of payments for results is that such schemes transfer risk from the buyer (the government) to the seller (farmers), since farmers cannot be sure that a particular set of actions will deliver a particular result (Russi et al 2016; Bartkowski et al, 2021). Many factors determining ecological outcomes such as a change in populations for a specific bird species are out with farmers' control (for example the weather; the behaviour of neighbours; migration patterns) (Fleury et al, 2015). This means that payment for result schemes may have lower participation rates than equivalent payment for action schemes.

Recent reviews show that few "pure" payment for outcome schemes operate in Europe (Tanaka et al, 2022). This is potentially due to the perceived problems of low participation due to the relatively higher risk to farmers (compared to payment for action schemes), and high monitoring costs for the regulator (Herzon et al, 2018). Bartkowski et al (2021) offer a novel

solution to these twin problems which they call "payments by modelled results". Payments would be made to farmers based on predicted environmental results using a model-based online decision support tool. Farmers choose between different bundles of actions which deliver a specific modelled outcome in terms of the regulators environmental target (such as a reduction in nitrate levels in a river). From the farmer's perspective, the risks associated with such a contract are lower than the risks of a pure payment for results contract, since the farmer willingly contracts to undertake a set of actions from a portfolio of options which the model predicts will yield the desired environmental outcome. From the regulator's perspective, monitoring costs are lower than with a pure payment for results, since the payment for each farmer is based on the predicted rather than actual outcome. Of course, over time, the regulator must check that the model does a good job of making predictions.

In this paper, we develop an ecological-economic model to test the performance of this "payment for modelled results" policy, comparing it with a standard payment for actions policy designed to achieve the same environmental target. Moreover, we compare both of these policies with what we refer to as a hybrid policy, which uses a more flexible or spatially-differentiated payment for action approach. This hybrid approach is intended to capture, in a simple, realistic way, the spatial heterogeneity in biodiversity outcomes associated with this farm management action. This is important, since a key advantage of payment for results (or modelled results) policies over payment for actions is their ability to reflect the underlying spatial variability in the ecological productivity of land with respect to the targeted environmental outcome. We compare ecological and economic outcomes of all three policies based on a fixed overall policy cost to the regulator. As far as we are aware, this is the first empirical test of Bartowksi's et al proposal.

There are relatively few empirical studies that examine payment for results schemes. A systematic review by Nthambi et al (2022) identified 31 studies exploring payment for results schemes in Europe. The majority of the studies covered stakeholder discussions with farmers on how best to design schemes. These discussions focused on how to measure outcomes,

including the indicator choice (e.g. Birge et al 2017), how to determine sufficiently high levels of payment to achieve target levels of participation (e.g. Wezel et al 2016), how to structure these payments (e.g. Fleury et al 2015), as well as the advice, support and training needed to implement a payment for results scheme (Wezel et al 2018) and the use of nudges to improve predicted uptake (Massfeller et al, 2022).

Chaplin et al (2021) provide one of the few studies comparing action and results-based schemes. The environmental performance of two objectives was measured: provision of winter bird food for farmland birds, and provision of pollen and nectar resources for pollinating insects in arable farming systems. Results showed that the payment by results measures were more effective than a conventional payment for actions AES. In addition, farmers' self-assessment of results (environmental outcomes) was highly correlated with the experts' assessment of the results, although it should be noted extensive training was undertaken with farmers on the monitoring of the intended results. Wuepper and Huber (2021) compare an action-based scheme with a results based scheme in Switzerland, and find that both the conservation outcome and return on investment was higher for the results-based scheme. However, neither of these papers evaluate the modelled results policy option proposed by Bartkowski et al (2021), which is the principal objective of the present work.

2   Methods

We use an integrated ecological-economic modelling approach to understand the landscape-scale outcomes of alternative AES policies, comparing payment for actions with payment for modelled results[1]. Our landscape is divided into 1 by 1 km land parcels (100 ha), and each landowner is assumed to manage a single parcel. We assume that the landowner is a profit maximiser. The model follows a two-stage approach. Firstly, ecological regression models are used to predict changes in the distribution and abundance of species based on the prescribed

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[1] Elsewhere we used similar models to examine the implications of offset banking where a market trading mechanism allocates contracts to farmers to produce conservation benefits on their land (e.g., *reference withheld for blind review*)..

AES policy (i.e., payment for actions, payment for modelled results, or hybrid policy). The baseline for this modelling is the current landscape. Secondly, economic simulation models integrate data on agricultural values within the landscape to determine the profitability of each land parcel under the alternative AES policies. From this, we can determine which farmers would sign up for (i) a payment for actions scheme ii) a hybrid, spatially targeted payment for actions scheme and iii) a payment for modelled results scheme. We then analyse these decisions spatially to understand the resulting impacts on both habitats and species, and the economic effects on farmers.

2.1 Case study area

We apply our model to a UK case study region known as the Tees Valley, Pennine Uplands and North York Moors (Figure 1). The case study region covers an area of approximately 5400 km^2 and encompasses a range of habitats and land use types, from upland moors in the west of the region, low lying agricultural land throughout the central region and increasing urbanization in the east at the coastal margin. Farming systems in the upland areas are characterised by low-intensity livestock farming, principally hill sheep and beef cattle: farm incomes are marginal and depend heavily on farm support and agri-environment payments[2]. Farming in the low-lying eastern parts of the case study region is focussed on arable and dairy.

The region encompasses three Special Protection Areas (SPAs) designated under the EU Birds Directive and three Special Areas for Conservation (SACs) designated under the EU Habitats Directive. Coastal habitats of the Teesmouth and Cleveland Coast SPA are classified for the assemblage of over 20,000 wintering warders, including Eurasian curlews (*Numenius arquata*), Northern lapwings (*Vanellus vanellus*) and oystercatchers (*Haematopus ostralegus*) (JNCC, 2020). These species are classified as 'Near Threatened' on the international IUCN Red List of Threatened Species (Bird Life International, 2019) and are considered as regional and national conservation priorities. Our target species of interest for the AES policy options

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[2] See, for example, https://www.highnaturevaluefarming.org.uk/case-studies/grasslands-of-the-north-pennines/.

is lapwing, although we also model the effects of each AES policy on "off-target" species, namely curlew and oystercatcher. Lapwing appears on the Red-List (species in most urgent need of conservation action) of threatened bird species in the UK (Eaton et al 2015). Lapwing populations have declined by 54% in the UK in the past 50 years, partly due to changing farmland management. We use statistical regression on observed lapwing numbers across UK farmland to describe the relationship between the current land use and the current abundance of birds within a land parcel (Simpson et al. 2022). Ecological modelling shows that lapwing numbers can be increased by farmers replacing the current land use on a parcel with an ecologically-preferred land management practice, in particular low-intensity grassland. Such grassland is more beneficial to lapwing population abundance than the alternative agricultural practices of crop and/or more intensive livestock production (Simpson et al, 2022).

2.2 Agri-environment schemes to be simulated

To allow us to explore landscape-scale outcomes, we need a payment for modelled results policy that aligns with the payment for actions policy. We achieve this by setting the budgetary spending of the alternative approaches to be roughly equal. Our payment-for-actions policy is equivalent to the dominant type of contact under Pillar 2 of the Common Agricultural Policy, which we set as the restoration or creation of low-grazing intensity grassland. Low-intensity grassland is restored in our case study by farmers reducing livestock stocking rates on currently grazed grassland or ceasing arable cropping practices and creating new low-intensity grassland. To ensure additionality, this change in land management practice in the model can only take place on agricultural land patches currently farmed for crops or more intensive livestock. A hybrid, spatially-differentiated payment for actions policy varies this uniform payment rate based on landscape-level, non-agricultural features which modelling shows to be important co-determinants of lapwing populations. The payment for modelled results policy is specified as payments for predicted population changes at a given location in lapwing numbers, based on our ecological model linking land management to lapwing distribution and abundance.

2.3 Data development

As noted above, we divided the case study region into $1km^2$ land parcels (100 ha). Each land parcel contains data from four spatially referenced datasets covering land classification and crop distribution, as well as lapwing, oystercatcher and curlew abundance and distribution. Land use was classified into 33 types including urban, improved grassland, arable and horticulture (Rowland et al 2015). This classification allowed us to identify agricultural land parcels which could provide environmental gains, as proxied by increases in predicted lapwing, curlew and oystercatcher abundance.

2.4 Ecological-Economic Modelling

An agent-based model was developed in Stata MP (Version 16) to model farmers' choices based on the relative economic returns of undertaking low-intensity grassland restoration under the payment for actions, payment for modelled results and hybrid AES policies. Firstly, a species abundance model (SAM) is employed to predict the abundance of lapwing, curlew and oystercatcher across the case study region based on current land use (Simpson et al, 2022). Secondly, the SAM is used to predict changes in the abundance of the species where landowners restore their agricultural land to low-intensity grassland. This allows us to calculate the subsidy farmers would receive under a payment for actions or payment for modelled results.

Economic decisions were modelled based on the economic rent (profit) generated by each land parcel. We calculated the gross margin (rent or profit) of agricultural parcels by combining crop coverage with the associated gross margin data available in the Farm Management Handbook (Beattie 2019). We assumed that for a farmer to be willing to enter any AES scheme, they must be offered a subsidy payment equal at a minimum to the agricultural rent forgone. Under the payment for actions policy, the subsidy paid to farmers was calculated based on the average opportunity cost per ha of restoring agricultural land to low-intensity grassland across the catchment. For our case study, this gave a payment rate of £585 per hectare. Under the payment for modelled results, we compared three subsidy payments: £10,000 per lapwing, £12,600 per lapwing, and £15,000 per lapwing, based on model estimates of the costs of generating additional lapwings by changing land management.

Under the spatially-differentiated payment for actions scheme, all agricultural land parcels were offered the base payment rate of £585 per ha to convert to low intensity grassland. Land parcels that met the inclusion criteria of (i) no urbanisation within the parcel and (ii) no electricity pylons running through the land parcel, were offered a bonus payment of an additional £40 per ha giving a total payment of £620 per ha. These landscape attributes were chosen based on results from the SAM, whilst the £40 addition was calculated as the

maximum payment give predicted sign-up rates which met the budgetary cost constraint. This constraint was implemented by calibrating all three policy options to have approximately the same overall budgetary cost of £1.6 million per year across the whole case study area.

The agent-based model then determines the profitability of each land parcel under continuing agricultural production compared to the payment for actions policy, payment for modelled results policy or the hybrid spatially-differentiated payment for actions policy. We then map the resulting economic and ecological landscape-scale outcomes in ArcGIS.

3   Results

3.1   Payment for Actions

Our payment for actions scheme was the restoration of agricultural land to low-intensity grassland. We find that under this scheme, 39 farmers would choose to restore agricultural land parcels (Table 1). This results in the restoration of 2792 hectares of low-intensity grassland at a cost to the policy maker of £1.6 million. Under this scheme, there is a 2.8% increase in the number of lapwings above the current predicted abundance on agricultural land parcels (with a cost of approximately £17,945 per lapwing).

3.2   Hybrid Policy (Spatially Weighted Payments for actions)

We designed an alternative payment for actions policy that provided two alternative payment rates for low-intensity grassland creation depending on the characteristics of the land parcel. These payments were related to the expected suitability of the land parcel in terms of its contribution to the species of interest (lapwing), in terms of landscape-level characteristics that the SAM showed to be important to predicted lapwing distributions. Some 37 farmers choose to sign up to the hybrid scheme. This results in the restoration of 2721 hectares of low-intensity grassland and a 1.6% increase in the abundance of lapwing compared to the current landscape (Table 2). This costs approximately £16,300 per increase in lapwing.

3.3   Payment for Modelled Results

Our payment for modelled results scheme was based on predicted increases in lapwing for an agricultural land parcel switched to low-intensity grassland from its current use. Using our ecological-economic modelling framework we were able to derive a farmer's opportunity cost for increasing the abundance of a single lapwing and rank these from lowest to highest for all land parcels that could restore agricultural land parcels to low intensity grassland (Figure 2). The opportunity cost varied from £6,300 up to £100,300 per additional lapwing. We were also able to derive the cumulative policy cost and cumulative lapwing gain for all land parcels that could restore from agricultural land to low intensity grassland, ranked from farmers with the lowest to highest opportunity cost (Figure 3). From this we can see for the parcel with the lowest opportunity cost, it would cost the policy maker £21,000 to subsidise the farmer for a modelled increase of three lapwing.

Using the opportunity cost curves derived for lapwing, and the cumulative policy costs (Figures 2 and 3) we were able derive that for a subsidy budget of £1.6 million farmers could be offered a payment rate of £12,800 per modelled lapwing. At this rate, we predict that 32 farmers would choose to join the scheme, and this results in the restoration of 2168 hectares of low-intensity grassland (Table 3). There is a 2.8% increase in the number of lapwings above the current predicted abundance.

To demonstrate that the sign-up of farmers to payment for results scheme in non-monotonic in terms of increasing payments we also modelled the sign-up rate under two alternative payment levels of £10,000 per lapwing and £15,000 per lapwing (Table 3). There is a clear step change in the participation rates at three modelled payment rates with 9 farmers choosing to participate at the lowest rate (£10,000 per lapwing) and 90 farmers choosing to participate at £15,000 per lapwing. This result is directly attributable to the variations in famers opportunity costs for restoring agricultural land to low-intensity grassland and the spatial heterogeneity in predicted increases in lapwing abundance across the landscape. For our landscape, we find

a significant, positive correlation between the farmers' gross margin and the predicted increase in lapwings, r (2569) = 0.54, p <0.001.

3.4 A Comparison of the three alternative AES scheme designs

Our final set of results compares the landscape scale outcomes in terms of farmer participation, change in lapwing numbers and change in non-target species (curlew and oystercatcher) across the three alternative AES designs (Figure 5). The total subsidy cost to the policy maker is fixed at £1.6 million for each of the three schemes, however, the surplus to farmers participating in the schemes was greatest under payment for modelled results. Under this scheme, farmers received a surplus of £256,000 compared to £131,000 under the hybrid scheme and £95,000 under the payment for actions scheme. Further to this, the ecological gains in terms of lapwing abundance are greatest under the payment for modelled results scheme, with an increase of 131 lapwing compared to 100 under the hybrid scheme and 91 under the payment for results scheme. Indeed, lapwing abundances were found to be significantly higher (*mean* =0.05, *SD* = 0.46) on parcels restored under the payment for modelled results scheme compared to the payment for results scheme (*mean* = 0.03, *SD* = 0.32 (t(2570) = 1.67, p =<0.05)). Lapwing abundances were also found to be significantly higher (*mean* =0.05, *SD* = 0.46) on parcels restored under the payment for modelled results scheme compared to the hybrid scheme (*mean* = 0.04, *SD* = 0.36 (t(2570) = 1.35, p =<0.10)). These results suggest that for this case study region, the payment for modelled results policy offers clear ecological and economic benefits over the payment for actions policies. This is directly attributable to the variations in famers' opportunity costs for restoring agricultural land to low-intensity grassland and the spatial heterogeneity in predicted increases in lapwing abundance across the landscape. For our landscape, we find a significant, positive correlation between the opportunity cost and the predicted increase in lapwings, r (2569) = 0.54, p <0.001.

The benefits of the payment by modelled results policy are further enhanced when we consider the predicted gains in the non-target species. Recall that within our ecological modelling framework we can also predict the change in abundance of two further waders of ecological

importance, curlew and oystercatcher. We predicted that the greatest increase in curlew abundance would also be under the payment for modelled results scheme, with an increase of 77 compared to 60 under the hybrid scheme and 53 under the payment for actions scheme. Curlew abundances were found to be significantly higher (*mean* =0.03, *SD* = 0.28) on parcels restored under the payment for modelled results scheme compared to the payment for actions scheme (*mean* = 0.02, *SD* = 0.19 (t(2570) = 1.60, *p* =<0.05)). However, there were no significant differences between the predicted curlew abundances under the payments for modelled results (*mean* = 0.03, *SD* = 0.28) and hybrid scheme (*mean* = 0.02, *SD* = 0.21 (t(2570) = 1.20, *p* =<0.05)). The increase in oystercatcher numbers was consistent across the three alternative schemes, ranging from a gain of 28 under the payment for actions scheme to 32 under the payment for modelled results scheme.

We show that there are also large differences in where restoration occurs under the three schemes (Figure 6). Under payment for action, restoration occurs where the opportunity costs of changing land use are lowest. Under payment for modelled results, these opportunity costs are effectively weighted by the ecological model to reflect differences in the costs per predicted increase in the target species across space, which in itself depends on a large number of factors taken into account in the ecological model.

4   Discussion

Using an ecological-economic modelling framework, we simulated the landscape scale ecological and economic outcomes of three alternative AES policies for a case study region. We compared a payment for actions policy, a hybrid spatially weighted payment for actions policy and a payment by modelled results policy, all of which were designed to benefit the same environmental target, an increase in lapwing abundance. We show that for the same overall budgetary cost, the payment for modelled results schemes yields superior outcomes in terms of biodiversity indicators than either the payment for actions or the hybrid scheme. Fewer hectares of low intensity grassland are created under payment for modelled outcomes, but the gains in lapwing and curlew populations are greater, since the ecological

model enables the targeting of restoration actions where the biodiversity pay-off in terms of increases in lapwing is greater. However, there are also, as a result, large differences in where restoration occurs under the three schemes. Under payment for action, restoration occurs where the opportunity costs of changing land use are lowest. Under payment for modelled results, these opportunity costs are effectively weighted by the ecological model to reflect differences in the costs per predicted increase in the target species across space, which in itself depends on a large number of factors taken into account in the ecological model.

This set of results would seem to offer evidence in favour of the payment for modelled results suggestion put forward by Bartkowski et al (2021). Whilst we were unable to compare outcomes with actual ecological results (since the schemes we simulate are hypothetical), it would also seem likely that payment for modelled results will encourage higher levels of participation than payment for monitored, actual, results, since the latter transfers risks from the regulator to the farmer. If farmers are risk averse, then this will reduce participation, other things being equal.

Payment for modelled outcomes is an interesting suggestion since it retains some of the advantages of a payment for actual results policy, as argued by Bartkowski et al, whilst avoiding the problems of uncertainty for the farmer and monitoring costs for the regulator. However, payment for modelled outcomes means that one of the main advantages of the "pure" payment for results approach – that linking payments to actual environmental outcomes has the potential to harness farmers' self-interest in optimizing outcomes, thereby providing incentives for entrepreneurship in the provision of environmental goods and services – no longer holds. Farmers are instead constrained to the ecological production technology which is incorporated into the model used by advisors to generate expected ecological outcomes, rather than using their own mental models of, for example, the links between how they manage their land over time and bird populations. Moreover, we note that

in our model, farmers do not choose which "technology" to use to produce more lapwings since we constrain this to involve creation of low-intensity grassland only.

Payment for modelled results also does not get around the moral hazard problem of farmer's actions in implementing the contract being hidden/costly to observe, so the regulator still needs to monitor farmer actions which are contracted under the AES policy. This monitoring of actions is also needed, of course, under the standard payment for actions approach, unless some self-enforcing contract design is used. In contrast, under payment for measured or actual outcomes, the regulator does not need to worry about monitoring what actions the farmer takes, since we only care about these measured outcomes, not how they were generated.

Our hybrid approach involves spatially weighting payments for action, and thus realizing some of the gains possible under payment for modelled results (those due to more spatial targeting of restoration actions), without involving a major shift away from current policy design. The variables used to spatially weight payments (distance to urbanisation, presence of power lines) are those which come out as important in the ecological model given that our objective is a net gain in lapwings. Whether this way of spatially-weighting payments for our target outcome (lapwings) has beneficial off-market effects (in our case on curlews and oystercatchers) is likely to be context-specific. It depends on species complementarities (the sense in which an action taken to benefit species x also benefits species y), and the spatial correlation between agricultural rents and species distributions.

A crucial aspect of payment for modelled results is the accuracy of the ecological modelling used to produce predictions of expected outcomes from changes in land management. For our species abundance model, predictions are less reliable for land parcels in areas in our case study region where data are sparse, and for the few parcels that hold particularly high abundances of birds. Furthermore, our model does not take into account spatial or temporal dynamics. However, there is clearly a general issue here in terms of how good a model has to be before it is good enough to be used in a payment for modelled results policy.

Finally, a major challenge when designing results-based AES is the choice of the result indicator (Fleury et al., 2015). This problem attaches to payment for modelled results as well: which indicator that an ecological model is capable of producing will be chosen for use? One can imagine lobbying over the choice, if the nature of the indicator on which payments are based affects the expected payoffs of land managers. Here we use single species indicators, but more complex biodiversity indicators (such as DEFRA's Net Gain indicator in the UK) may find more favour amongst stakeholders. However, ecologists will want to be assured of the model's capability of producing accurate, stable-over-time and generalisable forecasts, since it is actual biodiversity or environmental quality outcomes that are ultimately relevant for society. This necessitates some expenditure on monitoring actual outcomes, and comparing these to the policy model's predictions (by "policy model" we mean the ecological model used to generate the predictions on which contracts are made). However, determining whether a set of measured outcomes is evidence that the policy model is wrong, and what is wrong with it, is no simple task.

5. Conclusions

This paper undertakes an empirical examination of the relative ecological and economic outcomes of three different designs of agri-environmental policy aimed at increasing the population of an endangered farmland bird, the lapwing. In particular, we are interested to examine the likely consequences of implementing the "payment for modelled results" idea recently suggested by Bartkowski et al (2021). For a given overall budget, ecological outcomes vary significantly between payment for modelled results and payment for actions, whether the latter is spatially-differentiated or not. We find that payment for modelled results leads to bigger increases in both the target species and off-target farmland waders, even though the area of habitat restored is lower. Economic outcomes also change. Farm surplus is higher under payment for modelled results, even though the numbers of farmers participating is lower.

Because these differences in outcomes relate to specific spatial relationships in observable variables (agricultural profits, land use and predicted bird numbers), our results have broad implications for AES design globally. However, we raise an important question in terms of "how good is good enough?" in terms of the ecological model used to predict the outcomes which form part of the contract design.

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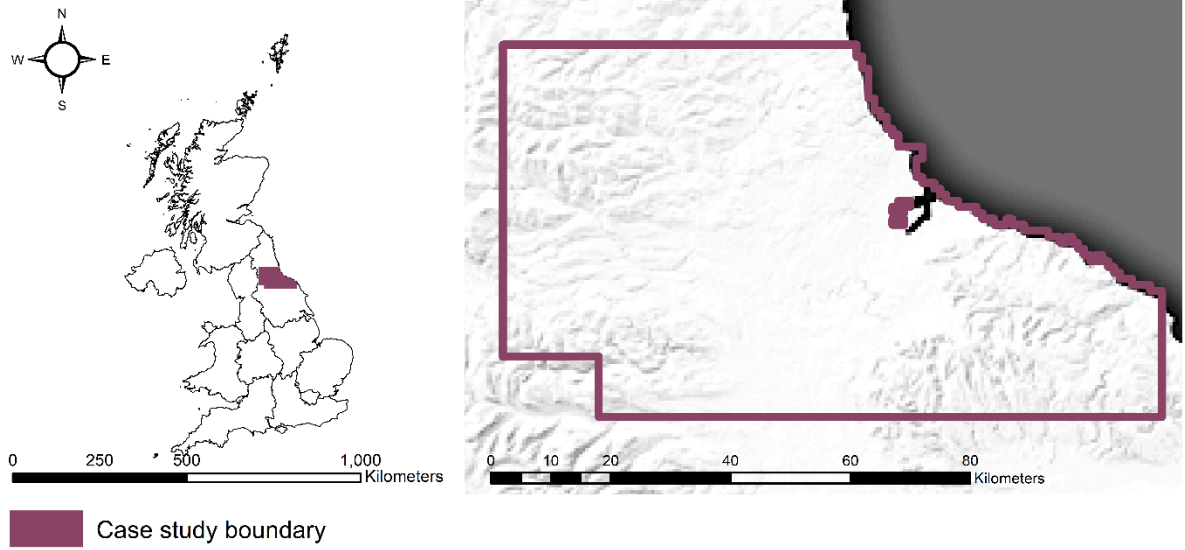
Figure 1: Case study region. Contains Ordnance Survey Data. © Crown copyright and database rights 2022 Ordnance Survey (100025252)
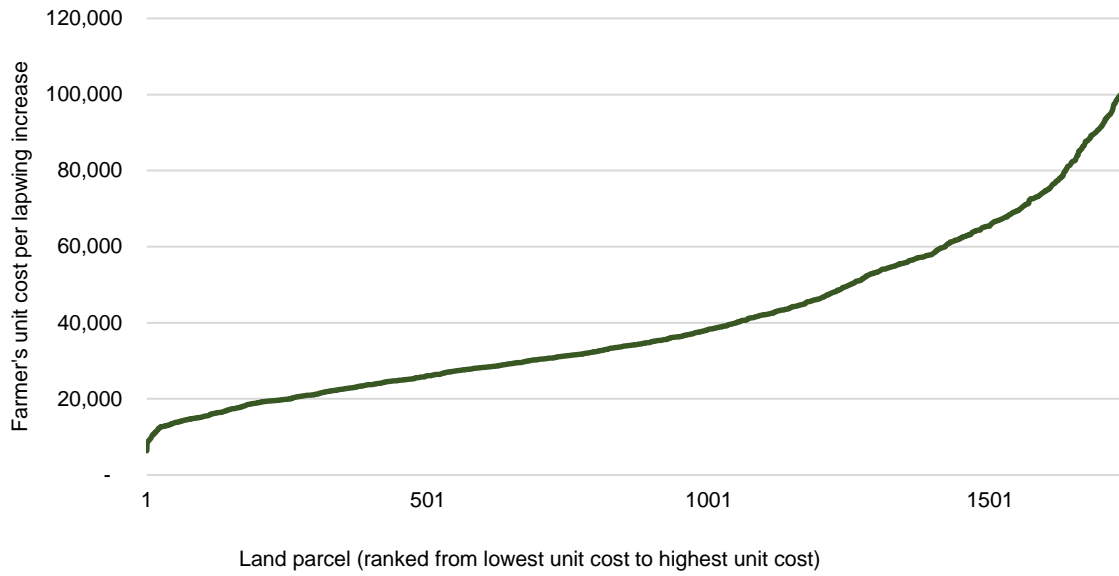
Figure 2: Farmers opportunity cost per modelled lapwing increase ranked from lowest to highest for all parcels that could restore agricultural land to low intensity grassland within the case study region. Note: 26 parcels had a unit cost of greater than 100,000. These are not included in this Figure.
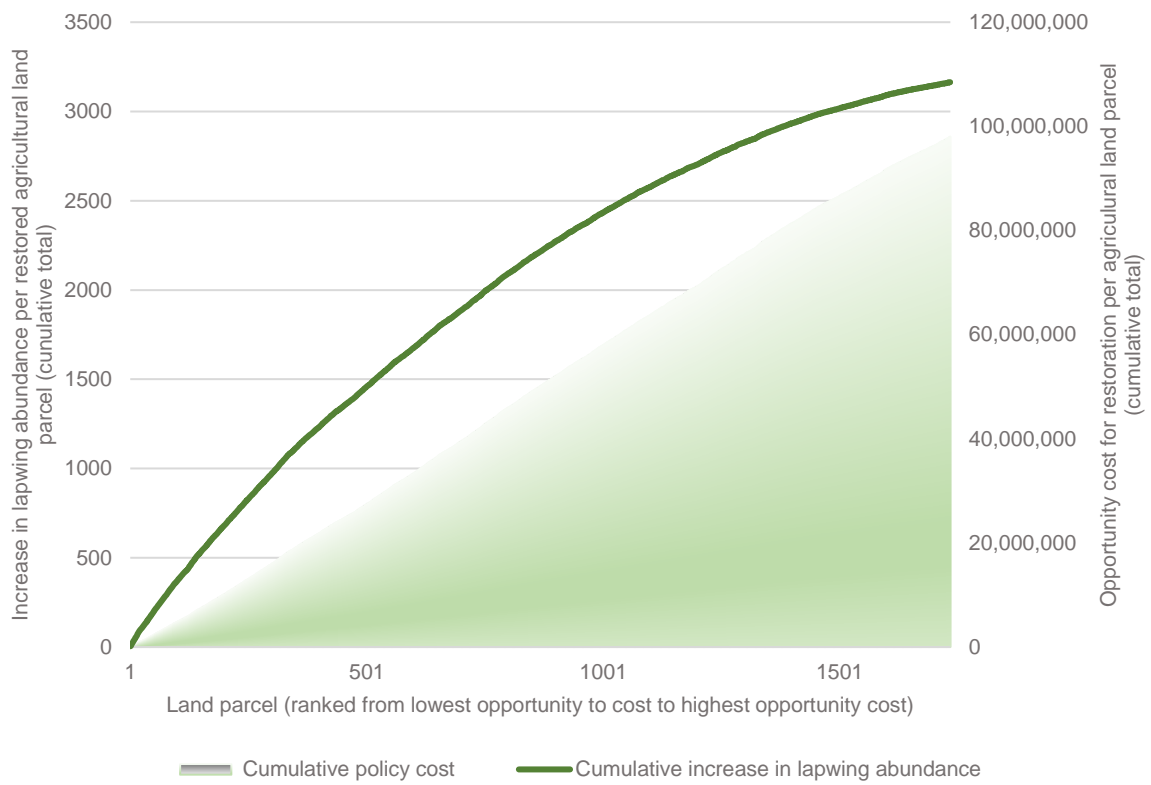
Figure 3: The cumulative policy cost for increases in modelled lapwing abundance across all agricultural land parcels that could be restored to low-intensity grassland across the case study region. Land parcels are ranked from the lowest opportunity cost to the highest opportunity cost of the farmer participating in the scheme
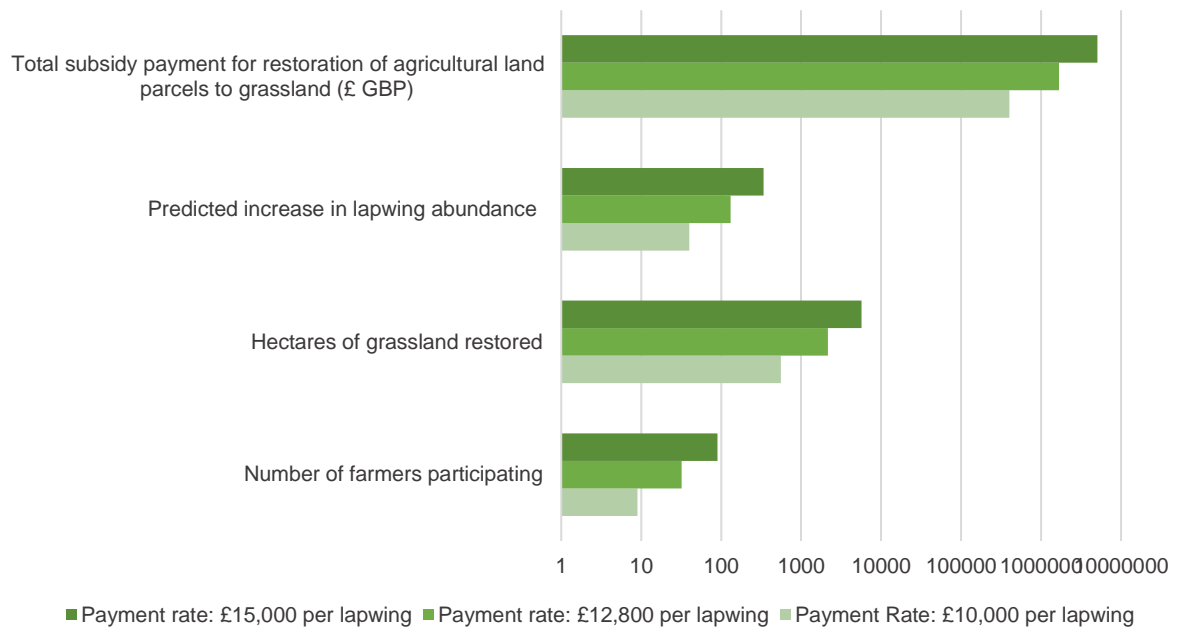
Figure 4: A comparison of the ecological and economic outcomes under three alternative payment rates for the payment for modelled results scheme
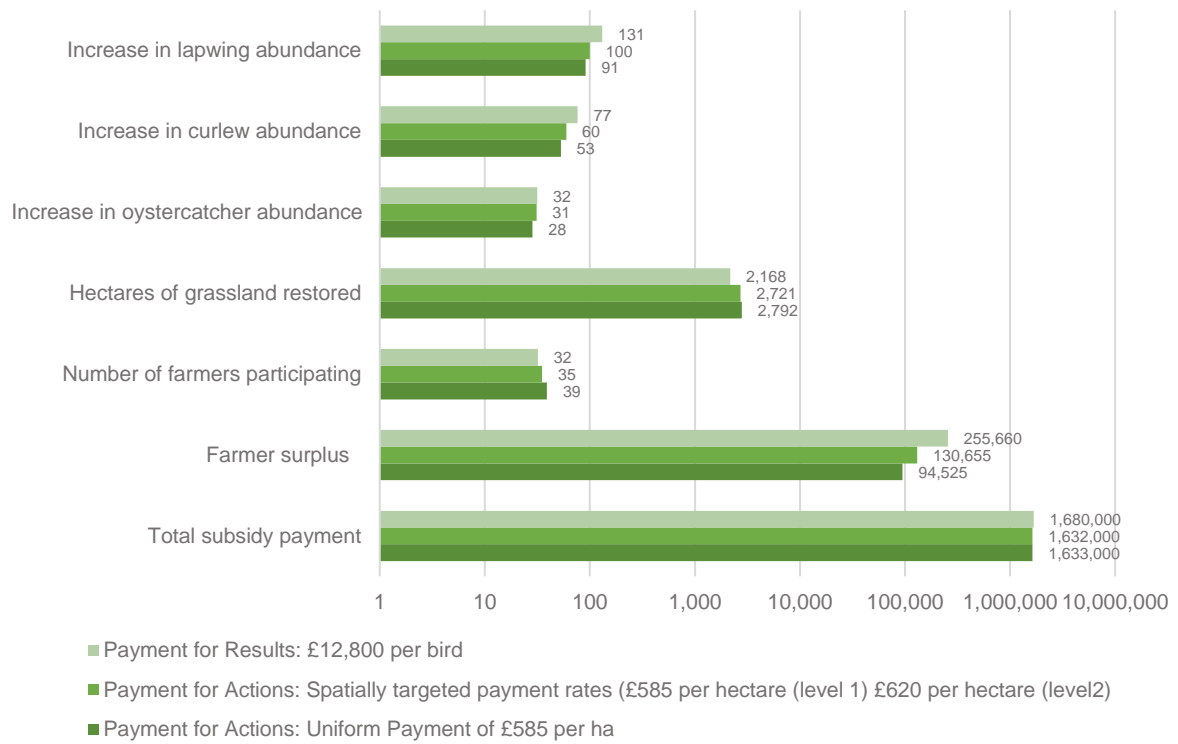
Figure 5: A comparison of the ecological and economic outcomes of the three alternative AES designs

Legend:

Farmers particpation in all three schemes

Payment for modelled results particpation

Hybrid policy particpation

Payment for actions particpation

Lapwing abundance under current land use

Less than 2 per 100 ha

Between 2 and 5 per 100 ha

Between 5 and 10 per 100 ha

Between 10 and 15 per 100 ha

More than 15 per 100 ha

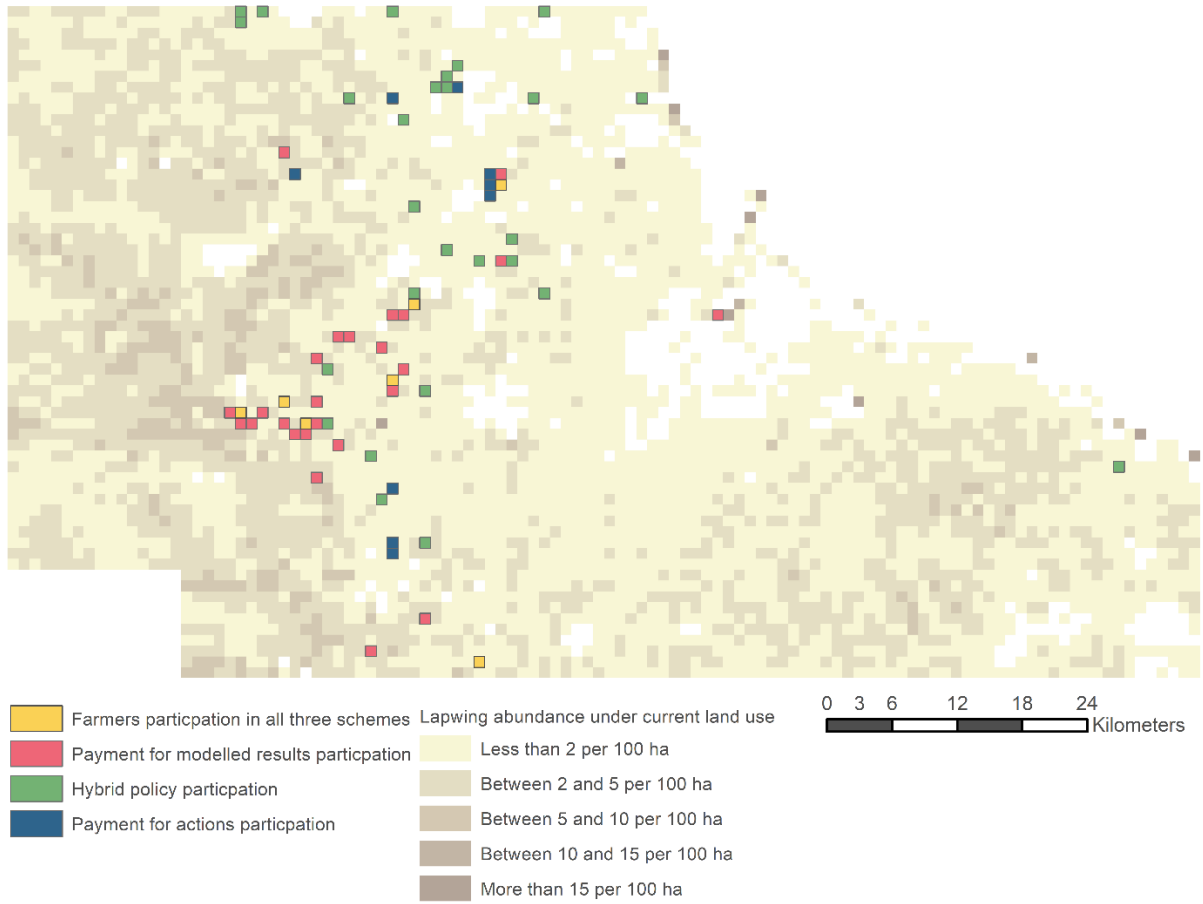0 3 6   12   18   24
Kilometers

Figure 6: A comparison of farmer participation under the payment for actions and the payment for results scheme across the case study landscape

Table 1: Change in grassland coverage and species abundance under the payment for actions scheme

	Total	Percentage Gain
No. land parcels restored to grassland	39	-
Hectares of grassland restored	2792	1.7%
Predicted increase in lapwing abundance	91	2.8%
Total subsidy payment for restoration of agricultural land parcels to grassland (£ GBP)	1,633,000	-

Table 2: Change in grassland coverage and species abundance under the hybrid spatially differentiated payments for action scheme

	Total	Percentage Gain
No. land parcels restored to grassland	37	-
Hectares of grassland restored	2721	1.6%
Predicted increase in lapwing abundance	100	3.0%
Total subsidy payment for restoration of agricultural land parcels to grassland (£ GBP)	1,631,907	-

Table 3: Change in grassland coverage and species abundance under the payment for modelled results scheme

	Total	Percentage Gain
No. land parcels restored to grassland	32	-
Hectares of grassland restored	2168	1.3%
Predicted increase in lapwing abundance	131	4.0%
Total subsidy payment for restoration of agricultural land parcels to grassland (£ GBP)	1,680,000	-