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Integrating spatial econometric information and optimisation models to improve Agri-Environmental payment design: A resource allocation model for Emilia-Romagna (Italy)

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Abstract

The efficiency and cost-effectiveness of the European Agri-Environmental Measures (AEMs) depends on policy design variables, spatial targeting and participant selection process. This paper develops an optimisation model jointly aimed at optimal AEMs targeting and payment setting. The model tests the potential integration of spatial information into optimisation models simulating spatially differentiated payment mechanism for AEMs in Emilia-Romagna (Italy). The results highlight a significant cost saving with differentiated payments. Spatial information modelled as a proxy of the willingness to accept the payment supports the fine-tuning of the model. The study highlights the importance of using the information on spatial differentiation in optimisation tools searching for optimal incentive-compatible targeting.

Keywords: European agri-environmental measures, agri-environmental payments, differentiated payments, spatial targeting, optimisation tool, mathematical programming.

JEL: Q18; Q58

1. Introduction

The European Union (EU) agri-Environmental payments (AEPs) can be viewed as an example of payments for ecosystem services (PES) (Engel et al., 2008; Claassen et al., 2008; Dobbs and Pretty, 2008; Baylis et al., 2008). These policy instruments aim to support farmers in the production of environmental goods by providing payments conditioned to the adoption of environment-related agricultural practices (Engel et al., 2008). Since the Common Agricultural Policy (CAP) reform in 1992, the EU has increased its payments to encourage sustainable resource use and to develop environmentally friendly farming practices that resulted in the so-called “greening” of the CAP (Garrod, 2009). Moreover, this major shift in EU policy has emphasized the

importance of sustainable and integrated rural development that is largely based on agri-environmental schemes (AES), as long as positive development pathways are (also) generated by environmental goods and landscape services (Defrancesco et al., 2008).

These measures, currently regulated by Council Regulation (EC) 1305/2013, are implemented through voluntary schemes, in which farmers commit themselves for a specific time period to adopt agricultural management practices that aim to reduce environmental risks or help to maintain cultivated landscapes (Uthes et al., 2010). The incentive to participate is provided by a fixed payment that is justified by the additional costs and/or loss of income (plus transaction costs) related to the scheme (DG Agriculture and Rural Development, 2005). In line with economic theory and observed practice, farmers tend to apply to these measures on the basis of the difference between compliance costs and the payments (Raggi et al., 2015). Assuming profit maximisation behaviour by farmers, in order to incentivize participation to AES, the payments must be set high enough to cover compliance costs. However, to maximise effectiveness they should also prevent, to the extent possible, unneeded information rents. The difference between payments and compliance costs, when positive, generates an economic surplus for the farmers and consequently a deadweight loss for the programs (i.e. social cost).

One potential way to improve the efficiency and cost-effectiveness of AEMs is to focus on "cost targeting". According with recent literature of participation in AES the production function and compliance costs are heterogeneously distributed across farmers due to spatial differences (Schmidtner et al., 2012). Thus, one can assume to set the level of payments on the basis of the marginal cost of those applicants that face lower compliance costs and taking into account the most easy-to-measure spatial information connected to different cost structures, such as farmers' location and structural characteristics (Raggi et al., 2015). The opportunity to develop such payments is largely driven by information availability about farmers' compliance costs, which at the least should include a more detailed account of the cost variability in the spatial dimension. In spite of information limitations, this is not completely unrealistic if measures are targeted to specific areas (e.g. location in mountain or plains) (Viaggi et al. 2008; Raggi et al., 2015).

Similarly to public regulators, also optimisation models are affected by limitations in contributing to a better payment design, because of the lack of appropriate and readily usable information about the actual cost differentiation and factors affecting the farmers' willingness to participate.

In addition, the assumption that farmers are profit-maximizing agents restricts the focus of these approaches on the solely economic indicators, while more complex phenomena, i.e. a wider range of determinants of participation, such as distance, location, agglomeration and neighbourhood effects, are instead considered by ex-post analyses of participation in AES through econometric models (Midmore et al., 2001; Padel, 2001; Pietola and Oude Lansink, 2001; Kerselaers et al., 2007, Defrancesco et al. 2008). A developing branch of such literature (i.e. spatial econometrics) recognises that participation is affected by agglomeration effects due to spatial dependence and downstream effects such as spillovers (Raggi et al., 2015). Schmidtner et al. (2012) recognize that agglomeration effects resulting from the presence of local markets and institutions can facilitate the acquisition of information and the implementation of agri-

environmental commitments by reducing transaction costs. However, to the best of our knowledge, there are no examples in the AES literature about the use of spatial data in programming models for optimal policy design. Thus, it is not surprising if one of the main problems encountered in spatial models regards the lack of explanatory variables related to policy design at a meaningful aggregation level, which could provide the fundamental link between optimisation models and ex-ante analysis.

The objective of this paper is to develop and test a simulation model of a differentiated payment mechanism that focuses on incentive compatibility and cost targeting. The model is a bi-period recursive resource allocation model that integrates data from spatial analysis and secondary data on farmers' structural characteristics and compliance costs. It aims to simulate the potential contribution of spatially differentiated compensation payments to optimal targeting of agri-environmental measures at the regional level.

While in the efficiency and resource allocation analyses (Zafeiriou et al., 2016) there has been an extensive use of Deterministic Frontier Analysis (DFA), Stochastic Frontier Analysis (SFA) and Data Envelopment Analysis (DEA) that applied mathematical programming model to observational data (Seiford and Thrall, 1990), this paper that provides a measure of cost-effectiveness related to a differentiated payment mechanism, is not based on the above-mentioned methodologies. On the one hand, the parametric approaches require to define a priori explanation of a cost or production function, while our methodology uses a parameter estimated through spatial analysis in order to develop a measure of the participation cost that is related to different target areas (i.e. we use the spatial information to estimate a participation cost function rather than define a priori formulation of it). On the other hand, we do not measure the efficiency of similar decision-making units through linear programming techniques (i.e. DEA approaches) but assuming the heterogeneity in participation costs we aim to provide an optimization strategy to develop differentiated payment mechanism based on cost-targeting and in line with some assumptions of optimisation models in AES literature (Moxey et al., 1999; Wätzold and Dreschler, 2005). Thus, we developed an empirical cost function that takes into account the heterogeneity of costs according to different target areas, which we used in our model to overcome the information asymmetry and calculate for a given budget, the optimal payments for each type of area or target. The participation parameters have been developed through spatial econometrics in order to capture its ability to account specifically for spatial dependency due to spillover effects (Raggi et al., 2015).

Against this background, since there are no similar examples in the AES literature, this paper can be taken as a primer for future development in the direction of an improved integration of farmers' explanatory variables of participation and the spatial dimension of compliance costs in ex-ante modelling.

The paper is organised as follows: section 2 describes the background of payment setting, targeting and spatial issues related to participation in AEMs. Section 3 describes the methodology, followed in section 4 by the results of the simulation model and in section 5 by a discussion. Concluding remarks are provided in section 6.

2. Key issues related to payment and targeting design in agri-environmental programs

Despite the increasing importance of AEMs, the debate about the design of more cost-effective and efficient payments, is still subject to a good deal of debate; specifically, with regard to the following deemed inefficiencies (Engel et al., 2008): a) limited information about measures; b) high administrative burden; c) absence or lack of monitoring of farmers' commitments; d) lack of information about actual compliance costs; and e) poor spatial targeting.

The first two points are related to the difficulties for farmers to access and properly use the funds. The third point concerns the lack of control and monitoring by the public agency, which may give rise to problems of moral hazard (Latacz-Lohman and Schillizzi, 2005; Ohl et al., 2008).

The fourth point regards the problem of farmers' information rent (Moxey et al., 1999; Latacz-Lohman and Schillizzi, 2005). The presence of information asymmetries on farmers' production technologies and compliance costs does not allow the public administration to set a proper payment level, resulting in a miscalculation of payments. When the payment is high enough, the difference between payment and cost generates a rent for all those farmers that have to cover lower compliance costs. At the opposite, when the payment is below the compliance cost, the farmers with higher compliance costs will decide against participating in the programme.

Finally, Uthes et al. (2010) and Coisnon et al. (2014) identify poor spatial targeting as a major cause of the deemed low effectiveness and efficiency of AEMs. The absence or weakness of spatial targeting can be the result of the lack of information on the main local needs and environmental vulnerabilities. In some cases, it results in the failure to take into account of areas where the value of environmental benefits is higher. In other circumstances the absence of targeting reflects cases of payments directed to practices that would have been adopted anyway, hence generating a wasteful use of public resources. Finally, the lack of targeting may hinder its potential contribution to cost reduction, as targeting could support an attempt to balance concentration in high environmental and low-cost areas to pursue a cost-effective application of the measures.

To increase the spatial targeting of AEMs the government needs to set and identify zoning and target provisions in policy/measure design such as selection criteria, priority mechanisms (Bartolini et al., 2013) and differentiated payments. However, this process entails higher transaction costs and leads to significant administrative costs, as compared to the lower targeting efforts (Vatn, 2010). Adding to the complexity of this decision making, there are many factors that have a role in the choice of a particular targeting approach, such as administration costs, budget availability, and spatial variability in terms of benefits and costs. Wünsher et al. (2006) remind us that the limit for each reasonable improvement is given by the amount of transaction costs required by additional data needs and changes in administrative procedures.

The literature on targeting issues includes a set of various priority or eligibility criteria that can be applied to the measures (i.e. presence of significant environmental vulnerabilities in the areas, population density in the municipalities). Uthes et al. (2012) distinguish different targeting mechanisms, which range from relatively simple approaches based on cost or benefit and eligibility criteria, to more complex and

selective targeting mechanisms based on zoning policies or scoring systems.

Since the purpose is to encourage farmer participation in the RDP, the identification of the target areas should be accompanied by the provision of an adequate system of incentives. Wätzold and Dreschler (2005) discuss the opportunity to design spatially heterogeneous compensation payments for biodiversity-enhancing land-use measures. They found that the cost-effectiveness of uniform payments may be lower than differentiated payments, depending on the assumption on the cost heterogeneity (i.e. the cost clearly differs because of variations in soil quality, opportunity costs for land, distance from markets), the choice of a proper benefit function and the correlation between them.

Other works have studied the issue of the spatial differentiation of environmental policy instruments by analysing efficiency losses of spatially uniform regulations (see e.g. Kolstad, 1987; Babcock et al., 1997; Ferraro, 2003; Johst et al., 2002). These studies, focusing conservation measures, try to incorporate ecological and economic knowledge into the evaluation of conservation instruments through an estimation of a biodiversity benefit function. Their findings seem to confirm the opinion of efficiency losses with uniform payment policies and the need for alternative payment mechanisms that consider the joint distribution of costs and benefits. Yet it is very difficult for the administration to know the different compliance costs and it would be administratively burdensome to attempt to determine such costs. For this reason, the actual payments are designed on the basis of average compliance costs as uniform between different areas and targets. Even in this case, however, the regulator does not necessarily know the correct average. Finally, a branch of the economic literature on AES has analysed the efficiency of flat rate compensation schemes based on average costs compared with the possibility of introducing other mechanisms, including self-selection contracts (Wu and Babcock, 1996; Moxey et al., 1999; White, 2001), and auction (Stoneham et al., 2003; Latacz-Lohmann and Schilizzi, 2005; Schilizzi and Latacz-Lohmann, 2007; Glebe, 2008; Connor et al., 2008).

3. Methodology

The methodology used in this paper is designed to test the integration of information from the spatial analysis of participation in AES into a bi-period recursive mathematical programming model at the regional level. As we previously introduced, the integration of the two methods does not rely on classic approaches such as DFA or DEA, but build on a resource allocation model based on cost targeting in line with optimisation literature in AES. The objective is to optimize participation in environment-related measures by offering differentiated payments subject to participation or incentive rationality (IR) and resource or budget constraints (BC). According to Nicita and Scoppa (2005) the explicit consideration of information asymmetries between the parties involved in the agri-environment contract refers to the approach of information economics, in which authors like William Vickrey, George Akerlof, Michael Spence and Joseph Stiglitz, have created the foundations since the 90s. In our approach, the problem of information asymmetry is modelled through an incentive compatible contract (Wu and Babcock, 1996; Moxey et al., 1999; White, 2001) with a cost-target approach to ensure that farmers will find it optimal to choose

the appropriate contract for their type. Bartolini et al. (2005) found that targeting can be able to solve present problem in AEMs if is accompanied with contract diversification in terms of both constraint and payment, Canton et al. (2008) suggests that spatial targeting may improve the regulator ability to keep ex-ante information and therefore simplify the trade-off between allocative efficiency and information rents.

Through the use of spatial information, we develop a cost function that account for a different cost of participation per area allowing to calculate differentiate payments under the public budget constraints. Thus, the spatial analysis allows us to develop a parameter of willingness to accept (WTA) a payment for participation in AES close to the different farmers' compliance cost per area and we include this parameter in the optimisation model as a component of the compliance cost function.

In order to understand the type of problems that can be encountered in this exercise, the type of information produced by econometric analyses of participation and the type of information used in economic models to account for incentives to participate are examined. When explaining participation, an econometric model (Anselin, 1988) would usually yield a result similar to the following equation:

$$y = f(X, P) \quad (1)$$

where y expresses the participation rate, X represents the vector of area and farmer characteristics and P is a vector of policy parameters (e.g. average payment, eligibility rules, etc.). Simplifying the number of policy parameters to the payment only (p), the (1) above becomes:

$$y = f(X, p) \quad (2)$$

In contrast, in economic models of participation, it is usually assumed that participation is determined by the maximisation of profit, given by the difference between the payment offered and compliance (participation) costs, i.e., assuming a flat rate payment:

$$\Pi = py - \theta(y, X) \quad (3)$$

where Π expresses the profit of the participating farmers and θ represents the marginal compliance participation cost. Which yields first order conditions with respect to y :

$$p - \theta_y(y, X) = 0 \quad (4)$$

Both (2) and (4) provide a way to determine y . In principle, they can be related to each other, for example if we assume the existence of an inverse function of $y(g)$ such that:

$$p = g[f(X, p)] = g(y, X) \quad (5)$$

Using (3) and (4) it is possible to derive a proxy of participation cost function, which accordingly it becomes:

$$p = \theta_y(y, X) = g(y, X) \quad (6)$$

While this operation is theoretically feasible, with empirical exercises there are several difficulties in comparing (2) and (3). First, equation (5) assumes that all components contributing to decision-making (e.g. personal attitudes connected to age, education and other farmers' characteristics) can be translated into the willingness to accept the payments and are comparable with the payment. While this is acceptable conceptually, in practice several elements do not translate into actual participation costs, which means that the outcome of equation (4) would not be comparable with participation costs from "accounting" data, or similar.

Second, most econometric models would not explain 100% of the variability of y . In fact, R^2 are usually rather low, which means that, if the estimate coefficients are used for simulation, they can only provide a partial view of the expected results.

Third, and likely most important, the policy variable related to payment is not usually available as a determinant in econometric models, either because it is uniform in an area or because it is so complex that it is almost impossible to determine what payment is actually being offered to each individual farmer (this is also our case).

Finally, when a payment is included in an econometric model, it is not necessarily true that the information would be usable in an economically meaningful way. For example, assuming that a linear specification is used (Raggi et al. 2015):

$$y = \sum_k \beta_k x_k + \alpha p \quad (7)$$

When the payment is equal to zero, then participation becomes $y = \sum_k \beta_k x_k$, which means that participation can be explained only by the farmers' characteristics, but is inconsistent with the assumptions behind (3).

The case under analysis is one of those for which (5) is not applicable as such, as the effect of the payment level was not estimated in the econometric model. In order to overcome this limitation, we opted for an approximation in which, by declaring $\beta_k x_k$ as r_k , the equality between payment and marginal cost has been approximated through:

$$p = \theta_y(y, X) = g(y, X) = (1 - \sum_k r_k) C(y) \quad (8)$$

Equation (8) provides further development of the equation (5) in a formulation consistent with (3). It includes the derived econometric parameter of farmers' willingness to accept the payments $(1 - \sum_k r_k)$ based on the estimation of participation function $\sum_k r_k$ and a component $C(y)$ of marginal compliance costs which is exogenously taken from the relevant literature. In this formulation, a low willingness to accept the payment is determined by a high level of participation in the measure, which results from a low level of participation costs. Vice versa, a low level of participation is assumed to point toward high participation costs and determines the high level of payments required by farmers to participate. This solution derives from the assumption

that the willingness to accept the payments operates as a linear parameter, influencing the slope and height of the average marginal cost function.

In line with previous studies on the design of incentives to AES (Wu and Babcock, 1996; White, 2001) the resource allocation model used in this paper is based on the maximisation of participation rate per areas to an AEM under participation and resource constraints. As we previously introduced the maximisation of the participation is constrained by the classical IR constraint (Bolton and Dewatripont, 2004) given by the comparison between the payment level offered to farmers for participating in the measure and the compliance costs and by the budget constraint.

According with Regulation (EC) 1698/2005 and 1305/2013 the focus is on area-related measures of the previous Rural Development Program of Emilia-Romagna (E-R) such as sub-measure 214.1 (integrated production), currently regulated by measure 10, 11 and 12 concerning agri-environmental and climate payments.

The model uses a bi-period and recursive logic, which foresees to carry out the optimisation problem in two periods. The optimisation carried out for period 2 uses input data from the output of the same optimisation problem at period 1. This solution is primarily adopted to account for the spill-over effects, which are mimicked in the model through the spatial econometric parameter. While the real timing of this effect, which induces participation based on spatial distance/location, is not always clear (i.e. econometric models often treat it as simultaneous), the two-period strategy is used to include these interactions, while maintaining a rather simple model by assuming that the spill-over effects only occur between the first and the second period. In this way, one can expect a reduction in participation costs in the neighbourhood areas due to a positive neighbourhood effect between municipalities as a result of the participation rate in period 1.

This logic is also being consistent with the temporal development of the RDP programming tasks, where the decisions for a new programme on AEMs are taken at the end of the planning period before the opening of the new RDP call and decisions concerning the participation of farmers depend on actual participation in the previous period. In this way, the method can express (temporally and spatially) a dynamic picture of the participation rate.

Furthermore, the analysis was conducted through two versions of the model. Model 1 does not contain any spatial information in the econometric-derived costs coefficient. Model 2, which includes spatial information, is based on the rho coefficient of a spatial lag model. Moreover, since Model 1 does not contain the spatial portion, the analysis for this model was conducted only for the first period, while the analysis for Model 2 covered both periods.

The objective function of the models assumes a simplified hypothesis with regard to the Public Administration objective, which is the maximisation of participation, measured by the degree of uptake ($Y = \sum y$), without consideration, for example, of the value of different environmental services produced by different farmers.

As a result of the hypotheses above, Model 1 takes the following structure, given a fixed value of the available budget for period 1 (B) and maximising the total area under contract ($Y1$):

Max

$$Y^1 = \sum_{i=1}^I y_i^1 \quad (9)$$

Subject to:

$$\sum_{i=1}^I \phi_i^1 y_i^1 \leq B \quad (10)$$

$$\phi_i^1 - \theta_i^1 \geq 0 \quad (11)$$

$$\theta_i^1 = [1 - \sum_{k=1}^K r_{k,i}^1 (X_{k,i}, \beta_k)] C(y_i^1) \quad (12)$$

$$y_i^1 \leq S_i \quad (13)$$

$$y_i^1 \geq 0, \phi_i^1 \geq 0, \theta_i^1 \geq 0 \quad (14)$$

Where:

Superscripts 1 indicates that the variables refer to period 1 and $i = 1, 2, \dots, I$ denotes the various municipalities. The (9) is the objective function (i.e. y rate of participation in the area i). In line with the traditional formulations (Bolton and Dewatripont, 2004) the (10) expresses the linear budget constraints where ϕ_i^1 is the parameter of the marginal payment per area i (Euro/ha). While we adopted a linear specification for (10) as payment per hectare, in line with most of the above-mentioned classic literature and the current RDP practice, in other economic reasoning several authors suggest how to address the problem of non-linearity in optimisation problems with continuous variables (examples are given by Glover, 1975; Zafeiriou and Sariannidis, 2011; Petridis, 2015;).

The (11) represents the classic IR constraint in which the $\theta(y_i^1)$ is the marginal cost function (Euro/ha). The (12) introduce the marginal cost function which is composed by the product between the distribution function of the average regional participation costs $C(y_i^1)$ and a parameter of the willingness to accept the payments for the AEM based on the estimation of participation $\sum_{k=1}^K r_{k,i}^1$, as discussed above. This component is estimated, for Model 1, through a standard linear regression model using the formulation in Breustedt and Habermann, 2011. With the assumption that there is no spatial dependence, it takes the following form:

$$r_{k,i} = X_{k,i} \beta_k + \varepsilon \quad (15)$$

with

$$\varepsilon \sim N(0, \sigma^2 I) \quad (16)$$

where I denotes the identity matrix (an $n \times n$ matrix with 1 on the diagonal and zeros everywhere else) and $N(0, \sigma^2 I)$ indicates that the errors are distributed normally with a constant variance and that the cross products of the error covariance matrix are 0.

In equation (12) and (15) $k = 1, 2, \dots, K$ denotes the variables representing farm characteristics and features included in the econometric model from which the coefficients are derived. Furthermore, $r_{k,i}$ expresses the estimated participation in measure 214.1 in terms of the percentage of participating farms per municipality i and $X_{k,i}$ denotes the vector of variables representing farm characteristics related to farm

location, such as socio-economic (i.e. age, UAA, education level, etc.) and institutional factors (i.e. LFA, regional priorities, etc.). Moreover, the $\beta_1, \beta_2, \dots, \beta_k$ are the estimated coefficients of the regression model for measure 214.1 of Raggi et al. (2015). For more details on the specific econometric analysis and of the statistical significance of the analysed coefficients that was carried out for measure 214.1 in E-R, we refer to Viaggi et al. (2012) and Raggi et al. (2015).

The (13) represent the classic area constraint with S_i that is the total UAA (ha) per municipalities i .

At the end of the optimisation process for period 1 of Model 1, it is assumed to find different levels of participation among municipalities according to the different participation costs. Moreover, it is supposed on the basis of the IR constraint, that the model assigns a payment value corresponding exactly to the value of the marginal cost.

The optimisation problem for Model 2 takes the following structure; given a fixed value of the available budget (B) for period 1 and period 2, it is assumed that the public administration will maximise the area under contract Y^2 :

Max

$$Y^2 = \sum_{i=1}^I y_i^2 \quad (17)$$

Subject to:

$$\sum_{i=1}^I \phi_i^2 y_i^2 \leq B \quad (18)$$

$$\phi_i^2 - \theta_i^2 \geq 0 \quad (19)$$

$$\theta_{i,period 1}^2 = C(y_i^2)[1 - \sum_{k=1}^K r_{k,i}^2(\rho, W_1 r_{k,i}, X_{k,i}, \beta_k)] \quad (20)$$

$$\theta_{i,period 2}^2 = (1 - \check{y}_i^2)C(y_i^2)[1 - \sum_{k=1}^K r_{k,i}^2(\rho, W_1 r_{k,i}, X_{k,i}, \beta_k)] \quad (21)$$

$$y_i^2 \leq S_i^2 \quad (22)$$

$$y_i^2 \geq 0, \phi_i^2 \geq 0, \theta_i^2 \geq 0 \quad (23)$$

Where:

Superscripts 2 indicates that the variables refer to period 2. Model 2 is similar to Model 1, except that in (20) and (21) the parameter of the willingness to accept the payments is now estimated through a spatial lag model (Breustedt and Habermann, 2011), which takes the following form:

$$r_{k,i} = \rho W_1 r_{k,i} + X_{k,i} \beta_k + \varepsilon \quad (24)$$

with

$$\varepsilon \sim N(0, \sigma^2 I) \quad (25)$$

In (24), under the assumptions that $\rho=0$, there is no spatial dependence (assumed in Model 1), while with $\rho \neq 0$ the equations return a spatial lag model. W is the spatial weights matrix as in Raggi et al. (2015). As a result, in Model 2 it assumed to find different levels of participation at the end of the first optimisation process compared to

Model 1, due to the presence of the spatial component.

Another difference, comparing the two models, concerns the equation (21), which computes the marginal cost function for the second period. In this equation, the marginal cost function is multiplied by a linear parameter $(1 - \check{y}_i^2)$, where $\check{y}_i^2$ represents the optimal participation area obtained from the optimisation of Model 2 in period 1.

The new linear parameter $(1 - \check{y}_i^2)$ operates as an ex-post policy parameter in order to replace exogenously the spatial effects (Anselin, 1988; Schmidtner et al., 2012) explained above: it reduces the participation costs in those municipalities where period 1 had a higher rate of participation. Consequently, the participation at the end of period 2 in these municipalities will be higher than the others due to the differences in participation costs across areas.

4. Case study and results

The methodology described in the previous section has been applied to a simulation exercise for the sub-measure 214.1 (integrated production) of the RDP of E-R 2007-2013.

E-R has a heterogeneous territory located in the highly productive, densely populated and industrialised Po Valley (north-eastern Italy). With a total area of more than 2.2 million hectares, in the southern part is composed mostly by hills and mountains, whilst in the northern part is formed by plains. In 2007, the utilised agricultural area (UAA) was nearly 1.1 million hectares with an average of 12.8 ha per farm, and a total of approximately 82,000 farms. The UAA is about 47.6 percent of the entire area of the region, and the E-R has the highest percentage of utilised agricultural area of all of the Italian regions, even higher than the national average (42.3 per cent), and is among the top European regions. The total UAA considered in the analysis is 1.1 million hectares, which is divided into 649,047.53 ha for plains, 218,617.47 ha for hills and 244,332.52 ha for mountains, according to the Regional Landscape Territorial Plan which identifies the "plain", "hill" and "mountain" areas. The mountainous area is characterised by extensive agriculture (grasslands), the plains are dominated by intensive agriculture and arable crops and the hilly area is specialised in vineyards and orchards. Moreover, the plain area is highly urbanised, while at opposite the mountains are marginalised and are experiencing land abandonment. Biodiversity in the plain area is very low and there are risks related to water quality. In the mountainous area, there are mainly risks of water erosion. Since these zones are an expression of specific agri-environmental sensitivities, the past RDP programme focused in order to develop the entire strategy provided in Axis 2 on measure 214 and the relative sub-measures. In addition, the Region has fixed a territorial priority for Less Favourable Areas (LFA) that follows the application of EU directives (NATURA 2000, WFD, the Nitrates Directive etc.) and the regional territorial planning, which applies a scoring system to select those farmers to be funded under the scheme (for more detail on the prioritisation process see Raggi et al., 2015).

Measure 214 (defined in the current RDP under measure 10, 11 and 12) is organised into several sub-measures (operation) that target different environmental objectives and areas of E-R. The measure covers a substantial part of the RDP budget: in 2010, the share of public resources was about 30 per cent of the entire RDP, with total budgetary

resources of approximately 295,962,544 (Euro) (Regione Emilia-Romagna, 2010). Taking note of the financial resources used in the RDP E-R 2007-2013 for measure 214 from the E-R interim evaluation report (2010), in the analysis we opted to choose a budget in the magnitude of this amount of resources in order to simulate the programming period 2007-2013. More in detail, we selected a budget that range from 0 to 288,000,000 (Euro) assuming that this budget level covers the entire programme period, including any carry-over in the following years. This budget level allows to perform a broad sensitivity analysis.

The analysis was conducted at the municipality level (i.e. taking into account the 341 municipalities of ER as the units of analysis) and results were then aggregated to the target areas of plains, hills and mountains to take into account the regional interest for this type of zoning.

As we mentioned above, the data concerning the regional UAA, the UAA at the municipality level and the spatial analysis results for participation in measure 214.1 are taken from Viaggi et al. (2012) and Raggi et al. (2015).

Raggi et al. (2015) demonstrate how the distribution of participation (percentage of participating farms per municipality) is differentiated among the plain area and in the hilly-mountainous area; the results are different when considering either the whole measure or single specific sub-measures. More in detail, for the whole measure 214, the uptake in 2010, excluding farmers that continue to participate from the previous program, was about the 49 per cent of UAA for the plain area, 14 per cent of UAA for the hill area and 25 per cent of UAA for mountains. Moreover, the distribution of participation in the whole measure 214 also differs across municipalities with some spatial agglomeration that partially follows the regional zoning system, as well as the targeting areas identified in the measure design (see Raggi et al., 2015). In this spatial characterisation, sub-measure 1 (integrated production) is mainly located in the plain areas of E-R which are characterised by significant fruit production (eastern part of the region).

Data for the distribution function of average regional participation costs $C(y_i)$ (Euro/ha) are elaborated from FADN data 2010 and 2011 of E-R with the computation strategy described in Viaggi et al. (2008) and Vergamini et al. (2016). The function is based on the same calculation used for the estimation of compliance costs for the Integrated Production measure in the justification of payments for the RDP Emilia-Romagna 2007-2013. The formulation used for the period 1 is:

$$C(y_i) = 1415.2y_i^3 - 1670y_i^2 + 701.9y_i \quad (26)$$

According to the classic properties of a cost function in economics, we calculated a monotonically increasing third degree function. Whilst the cost function in Viaggi et al. (2008) was applied to the cumulative UAA of the entire region, in this paper, we opted to parameterize the function in a range of 0 to 1 in order to be applied to the different target area of each municipality. This operation was undertaken in order to adapt and homogenise the function to the different levels of the analysis. In line with this choice, we obtained an average regional distribution function of participation costs that allows us to approximate the compliance cost of participating in measure 214.1 for each

municipality.

The results of the optimisation carried out with GAMS (the indices/sets, the main variables and parameters are those described in the methodology section above) for period 1 are summarised in Tables 1 and 2. The results of Model 1 are reported in Table 1 and Table 2 provides data from the optimisation of Model 2 (for the additional statistical information regarding the econometric analysis we refer to Viaggi et al., 2012; Raggi et al., 2015).

Tab. 1. - Results of Participation Model 1 (Period 1)

Budget (Euro)	Marginal cost (Euro/ha)			Average Marginal payment (Euro/ha)	Plain (ha)	Hill (ha)	Mountain (ha)	DU total (ha)	DU/UAA (%)
	Plain	Hill	Mountain						
0	0	0	0	0	0	0	0	0	0
8,000,000.00	239.04	226.10	225.78	230.31	31,572.12	1,085.63	918.41	33,576.18	3.0
24,000,000.00	395.82	354.87	354.05	368.24	57,800.12	1,715.66	1,447.64	60,963.44	5.4
96,000,000.00	685.14	504.17	502.47	563.93	136,793.00	2,457.36	2,067.00	141,317.38	12.7
184,000,000.00	801.34	479.89	478.35	586.53	227,040.94	2,335.91	1,965.86	231,342.72	20.8
288,000,000.00	871.17	636.51	633.73	713.80	326,398.02	3,125.19	2,621.16	332,144.39	29.8

Source: own elaboration

In Table 1, following the sensitivity analysis carried out for the budget parameter, an increase in this parameter reflects a growth in the degree of uptake. Moreover, the share of UAA in the different zones is growing, but at different ratios depending on marginal costs. In addition, considering the sensitivity analysis conducted on the budget parameter, with regard to the maximum budget (i.e. the amount of public resources for the whole programming period), the results show that the plain area has the highest share of areas under commitment (approximately 98 per cent) while the hill and the mountain areas divide the remaining 2 per cent.

Though not strictly comparable, it is possible to get a sense of the reliability and potential for interpretation of the results in Table 1 from a comparison with the predictions included in the ex-ante evaluation report of RDP Emilia-Romagna (Regione Emilia-Romagna, 2007). The report shows that, with a budget of 8,000,000 Euro, there is an average flat rate payment for measure 214.1 of 164 Euro/ha and an expected commitment area of 49,246 (ha) whilst, with regard to Model 1, the average payment for the reference level of a budget of 8,000,000 Euro is 230 Euro and the involved area is 33,500 (ha). This sheds light on the fact that the model actually considers higher participation costs that determine higher payments and results in a lower share of participating hectares compared to reality.

Table 2 highlights the concentration of participation in the plain area that has the main share of the total uptake (ha) for each budget level (approximately 80 per cent of the area subject to commitments with the maximum budget). However, both the hill and mountain areas increase proportionally more than the plains, in terms of area under commitment, from 2 per cent together with Model 1 to about 10 per cent each in Model 2.

Tab. 2. - Results of Participation Model 2 (Period 1)

Budget (Euro)									
	Marginal cost (Euro/ha)			Average Marginal payment (Euro/ha)	Plain (ha)	Hill (ha)	Mountain (ha)	DU total (ha)	DU/UAA (%)
	Plain	Hill	Mountain						
0	0	0	0	0	0	0	0	0	0
8,000,000.00	474.4	467.8	467.9	470.0	12,927.7	1,872.4	2,117.3	16,917.5	1.5
24,000,000.00	810.8	789.9	790.0	796.9	22,936.7	3,208.2	3,628.8	29,773.8	2.6
96,000,000.00	1,567.0	1,469.9	1,470.6	1,502.5	48,923.3	6,168.8	6,982.4	62,074.6	5.5
184,000,000.00	2,104.7	1,895.0	1,896.2	1,965.3	71,811.31	8,127.6	9,204.3	89,143.2	8.0
288,000,000.00	2,550.4	2,183.2	2,184.9	2,306.2	95,552.34	9,509.3	10,773.5	115,835.2	10.4

Source: own elaboration

The optimisation process in the second period was carried out only for Model 2, as mentioned above, with the same data input as the first period (recursive method) and a linear ex-post policy parameter ($1 - \hat{y}_i^1$) is added to the cost function, which operates as a component of cost reduction proportional to the participation surface area. The results from this second optimisation process (period 2) are summarised in Table 3.

Tab. 3. - Results of Participation Model 2 (Period 2)

Budget (Euro)									
	Marginal cost (Euro/ha)			Average Marginal payment (Euro/ha)	Plain (ha)	Hill (ha)	Mountain (ha)	DU total (ha)	DU/UAA (%)
	Plain	Hill	Mountain						
0	0	0	0	0	0	0	0	0	0
8,000,000.00	443.1	435.8	435.8	438.2	14,230.1	1,822.6	2,062.3	18,115.1	1.6
24,000,000.00	756.3	732.8	732.9	740.7	25,311.4	3,108.3	3,518.1	31,937.9	2.8
96,000,000.00	1,454.5	1,345.7	1,346.3	1,382.2	54,383.8	5,885.7	6,666.2	66,935.9	5.5
184,000,000.00	1,943.0	1,708.2	1,709.2	1,786.8	80,407.2	7,616.0	8,630.0	96,653.3	8.6
288,000,000.00	2,337.8	1,928.7	1,930.2	2,065.6	107,863.6	8,704.4	9,866.4	126,434.4	11.3

Source: own elaboration

The results highlight differences in the participation rate, marginal costs and payments between the two optimisation periods (1 and 2). As expected, the share of participating UAA significantly increases in the plain area where, at the end of the first period, there was already a high concentration of participants. The share of total participating UAA also increases by a few percentage points compared to the first period, while in the hill and mountain areas it decreases slightly. The increase in participation in the plain area overcompensates for the reduction in the hill and mountain areas and leads to an increase in the share of total area under commitment. Considering the low budget level in the plain area, the share of participating UAA increases from the first period by about 10 per cent and with the highest budget level the increase from the first period is about 12 per cent. Instead, the decrease in the hill and mountain areas ranges around 2-3 per cent.

Moreover, the marginal participation cost decreases in each area, from 8 per cent in

the plain and 11 per cent in both the hill and mountain areas. Furthermore, in the surrounding areas (hill and mountain) the reduction in participation costs seems to confirm this hypothesis.

Table 4 reports a comparison between the participating areas, the relative marginal participation costs and a measure of the deadweight loss (surplus) between the two periods (for Model 2).

Tab. 4. - Results of Participation Model 2 (Period 1-2)

Budget: 24,000,000.00 Euro							
TARGET ZONE	Period	Participation (ha)	Marginal cost (Euro/ha)	Total Payment	Total Cost	Surplus	Surplus/Budget (%)
PLAIN	1	22,936.7	810.8	18,598,713.4	9,570,386.8	9,028,326.6	37.6
	2	25,311.4	756.3	19,143,345.4	9,880,768.2	9,262,577.2	38.5
HILL	1	3,208.2	789.9	2,534,194.0	1,282,086.0	1,252,108.0	5.2
	2	3,108.3	732.8	2,277,887.5	1,151,990.73	1,125,896.8	4.6
MOUNTAIN	1	3,628.8	790.0	2,867,092.4	1,450,712.2	1,416,380.2	5.9
	2	3,518.1	732.9	2,578,767.0	1,304,344.5	1,274,422.4	5.3

Source: own elaboration

Parts of these results have been discussed in the comments regarding the results of table 3. Especially noteworthy is the surplus measure, representing in each area the difference between the total payment and total cost, which slightly increases in the plain area due to an increase in participating UAA and decreases in the other areas, likely due to the decrease in marginal costs on the one hand and the decrease in participation on the other. Considering the ratio between the surplus for each area and the public expenditure, the results show that the lowland area surplus absorbs about 38 per cent of the public budget, while the surpluses of the hill and mountain areas absorb only about 5 per cent respectively. This is due to the increased amount of UAA that is committed in the plain area instead of the hill and mountain areas, which means that the targeting mechanism works. Providing a higher payment in areas where participation costs are higher, because more traditional and intensive farming is practiced, participation can be increased but at a higher cost for the scheme. To confirm this, the ratio between participants and public expenditure is ten times higher in the plains than in the hills and mountains. However, the increase in cost for lowlands is offset by a reduction in the information rents of farmers in the other areas. With the same budget based on the different cost structures per area, this means to increase the overall participation rate to the scheme.

5. Discussion

This paper provides an exploratory attempt at using spatial analysis data within an optimal targeting resource allocation model for AES. The model shows the possibility of improving the targeting of AEMs by modelling farmers' economic behaviour by virtue of their participation in scheme 214.1 and offers an alternative approach to the design of payment mechanisms, based on differentiated payments (by target areas) instead of a flat rate payment. The results from the optimisation problem confirm the

hypothesis of heterogeneity in cost and payment functions that could depend on location, type and farmers' structural characteristics, as has been assumed by Wätzold and Drechsler, 2005; Schmidtner, 2012. Moreover, the analysis confirms the findings of Wätzold and Drechsler, 2005 and Viaggi et al. (2008) with regard to the efficiency losses for AEMs associated with the uniform payment mechanism. In this way, considering both the costs and payments spatially heterogeneous and setting the payments equal to the marginal costs of different areas, we can reduce the information asymmetries the relative farmers' rents and the deadweight loss for the measure, leading to a more efficient allocation of funds for the regional administration.

The modelling choice used in this paper, while reflecting a number of plausible assumptions, remains somewhat simplified and could be improved in further research. The main weakness of the approach rests in the fact that the econometric information was particularly poor with respect to the effect of policy design parameters (in particular payments), due to the limited range of payment observations and of the scale of the analysis (i.e. municipality level). Furthermore, in our model the prioritisation process that has been applied by the regional administration in the management of the measures has not yet been modelled. For this reason, a participation cost function, the ideal input one would expect for this type of model, was not available. Hence, in this paper we used an approximate coefficient, derived from spatial econometrics, to correct an exogenously derived cost function. Moreover, a meaningful empirical functional form for compliance costs in the area was not "well behaving" in terms of the sought after economic properties for a cost function, which yielded difficulties in managing the model from a numerical point of view. The model can be improved on several other grounds, particularly considering the complexity of factors that affect participation and the difficulties in modelling hidden transaction costs. However, the results confirm the relevance of a policy design related to connected payments, or in the case of the E-R, to explicit policy priorities (targeting and zoning system). The study highlights the importance of using the information on spatial differentiation to understand the determinants of farmers' participation in AE schemes and the relevance of considering this differentiation in optimisation tools searching for optimal incentive-compatible targeting.

6. Concluding remarks

This paper focused on the use of spatial econometric information within mathematical programming methods to test the feasibility of using the data from spatial analyses to support the design of AE policies, in particular concerning spatial targeting and payment differentiation.

Based on the importance of spatial differentiation to explain the determinants of farmers' participation in AE schemes, the paper highlights the relevance of considering such differentiation in optimisation tools searching for optimal incentive-compatible targeting. It should be stressed that further improvements are possible in the efficiency of AEMs. Such improvements would require the consistent development of implementation data collection, data analysis and ex-ante policy design and evaluation.

Moreover, the results raise the problem of the balance between the objective of efficiency in public expenditure, and therefore in the reduction of surpluses, and the objective of effectiveness, understood as the achievement of the highest level of

participation. Unfortunately, in order to assess both of these goals, a measure of the benefits of measure 214.1 is required. Regrettably, this was not available for this paper and is hence one of the possible areas for further development of this study.

The discussion also demonstrated the weaknesses of this approach in the current form. Despite its limitations, due mainly to issues of data availability, the analysis showed the potential for contributing to the design process of an alternative incentive scheme based on different farmers' compliance costs through space instead of the classical flat rate payments. Future research could seek to improve on the integration between the spatial approach and optimisation methods to explain the determinants of farmers' participation in AE schemes.

Accordingly, it could be possible to identify better policy design options for the definition of appropriate Rural Development Measures and the greater involvement of farmers, hence a better delivery of environmental goods.

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ⁱ The share of AEMs in the Rural Development budget of the Common Agriculture Policy is more than half, thus demonstrating the importance of this kind of measure in EU policy (Uthes et al., 2010). Moreover, average data published by the EU for the period 2000-2003 show that in Italy the national agri-environment spending for 2000-2003 is more than 60% of the rural development budget.

ⁱⁱ The reference study is Deliverable 5.2 of the SPARD EU FP7 (SPARD: Spatial Analysis of Rural Development Measures - Providing a tool for better policy targeting) (<http://project2.zalf.de/spard/>).