Using Spatial Microsimulation techniques in the Aggregation of Environmental Benefit Values: An Application to Corncrake Conservation on Irish Farmland*

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Abstract

This paper considers the use of spatial microsimulation techniques in the growing area of Benefits Transfer. Benefits transfer involves the results of existing environmental valuation studies being applied to different policy contexts such as alternative populations or environmental sites. The spatial microsimulation model developed in this paper uses a combinational optimatisation technique called simulated annealing to match the Irish Census of Agriculture data to a Contingent Valuation Survey that contains information on Irish farmers' willingness to pay (WTP) to have the corncrake restored as a common sight in the Irish countryside. We then use this matched farm survey and Census information to produce small area population environmental benefit microdata estimates for the year 2005. These figures are then aggregated to get a total value figure for the farming community of Corncrake conservation in Ireland and compared to figures derived using more standard approaches to calculating aggregate environment benefit values.

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1. Introduction

Using statistical matching techniques within a microsimulation framework, economists can now create attribute rich datasets by matching across common variables in two or more datasets. Static spatial microsimulation then uses these "synthetic" datasets to analyse the relationships among regions and localities and to forecast the spatial implications of economic development and policy changes. The spatial microsimulation model developed in this paper uses a combinational optimization technique called simulated annealing to match the Irish Census of Agriculture data to data from a Contingent Valuation (CV) survey that contains information on Irish farmers' willingness to pay to have the corncrake restored as a common sight in the Irish countryside. The main contribution of this paper is in illustrating how microsimulation can be used to improve benefits transfer practice, for policy analysis. We are not aware of any previous studies which have used the method in this way.

The case study used in the paper considers changes in farm practices needed to conserve an endangered farmland bird, the Corncrake (*Crex crex*). National Farm Survey (NFS) and Census information is used to produce small area population environmental benefit micro data estimates for the year 2005. These figures are then aggregated to get a total value figure for the farming community of Corncrake conservation in Ireland and compared to figures derived using the more traditional approaches of calculating aggregate environment benefit values. Given the rich set of attribute data in our micro simulated farm population, we can also examine the heterogeneity in preferences for a biodiversity conservation project in the farm population across space. For example, this allows us to take into account the different types of farming activity that may dominate in particular parts of the country which may produce higher or lower estimates for the environmental value of a corncrake conservation project in that area compared to the rest of the country.

In the next section, we briefly discuss current threats to the Corncrake in Ireland. In section 3 we briefly review the topic of benefits transfer and outline previous applications involving the aggregation of environmental benefit values. Section 4 then describes the design of our WTP survey and discusses the datasets used in the microsimulation process. In section 5 we discuss the spatial microsimulation approach used to aggregate the environmental benefit values for corncrake conservation. This section also reviews the payment card Contingent Valuation methodology and the use of a Generalised Tobit interval modeling approach. The aggregated estimates from this approach are contrasted with those from our spatial microsimulation approach in section 6. All model results are presented in section 6. Finally, section 7 concludes with some recommendations for further research.

2. The Corncrake in Ireland

The corncrake is highly secretive bird which is rarely seen in the open, concealing itself effectively in long grass and herbaceous vegetation (Mayes and Stowe, 1989). In Ireland, the corncrake is associated with grass meadows and other areas of dense cover, such as nettle patches. Traditionally, flower-rich hay meadows would have been favoured by birds, and still are in the corncrake's remaining strongholds. Recently, corncrakes have suffered from a switch to more intensively managed grassland, which is often destined for cutting as silage too early in the season to allow the birds to breed successfully. Indeed, this is the main reason why the Corncrake is the only Irish breeding bird which is currently threatened with global extinction. It has been listed on the 2005 International Union for the Conservation of Nature (IUCN) Red List of Threatened Species (BirdLife International, 2005), due to population and range declines of more than 50% in the last 25 years.

There is conclusive evidence to show that declines in corncrake populations are primarily linked to changes in agricultural practice on their breeding grounds. (Green & Williams, 1994 and Green & Rayment, 1996). Corncrakes began to decline when traditional farming systems began to be replaced by modern agricultural methods. Increasingly sophisticated machinery meant that grass could be cut earlier in the year and more rapidly than ever before. Farmers also began to take several crops of grass per year. Earlier mowing dates have meant that corncrakes and other ground-nesting birds have been prevented from successfully hatching young in the meadows. Research has shown that, in order to maintain population levels, corncrakes need to hatch two broods of chicks per year (Copland and Donaghy 2001). As the peak hatching date for the second brood is in late July, corncrakes will decline rapidly in areas where most of the mowing takes place before early August.

Corncrakes were once common in Ireland. Conservative estimates put the population at the turn of the century in the tens of thousands. By the late 1960s, the population had declined to about 4,000 singing males. An All-Ireland census carried out in 1994 found that the population had dropped to just over 129 singing males (Bird Watch Ireland, 2000). As a result of concentrated conservation measures, however, numbers rose for the first time in 1995[1]. Numbers in 1999 and 2000 showed some stability with around 150 singing males recorded. Numbers have since remained stable and in 2005, the Irish corncrake population stood at 164 (NPWS, 2005). According to the All Ireland Action Plan (NPWS, 2005) the main targets are an increase in the corncrake population in the three core areas in the Republic of Ireland to 150 in Donegal, 50 in West Connacht and 60 in the Shannon Callows by 2010 and to re-establish breeding populations in other parts of its former range, in suitable areas in both Northern Ireland and the Republic of Ireland by 2015. Figure 1 shows where the corncrakes remaining breeding grounds can still be found in Ireland.

In order to achieve these conservation objectives it is vital that farmers in Ireland are willing to support corncrake conservation. Using the National Farm Survey, conducted by Teagasc each year, 1,177 nationally representative farmers were asked their willingness to pay (WTP) each year into a conservation fund to aid in the restoration of the corncrake and to bring the singing male population back up to a sustainable population of 900 birds. The estimates of the value to farmers of policy measures which restore the corncrake population in the Irish countryside are then transferred across a simulated population of all Irish farmers according to the statistical matching process of simulated annealing. To estimate the total value of this policy intervention across the entire farming population of Ireland we aggregate our WTP estimates across our simulated population of farmers. Finally, using GIS mapping techniques we compare our regional environmental benefit estimates to the landcover types in each small area jurisdiction to examine whether the benefit values associated with those areas that contain the habitats of the corncrake are higher than other habitat types where the corncrake is less likely to nest.

3. Benefit Transfer and the Aggregation of Environmental Benefit Values

Benefits transfer is a technique in which the results of existing studies on monetary environmental valuation are applied to different policy contexts such as alternative population cohorts or environmental sites. The topic is a growing yet controversial area within the environmental economics literature and in this paper we discuss how a spatial microsimulation methodology can be used in order to estimate the aggregate environmental value of a biodiversity conservation program in Ireland.

[1] With the support of the Irish Department of Environment, Heritage and Local Government, Bird Watch Ireland has operated an intensive Corncrake Conservation Project in Ireland since 1991.

Benefits transfer is commonly defined as the adaptation of value estimates generated at a study site to another site (the "policy site") for which such estimates are desired but no primary data for their generation are available (Rosenberger and Loomis, 2001). One of the most important reasons given in the literature for using previous study results in a new policy site is cost effectiveness (Boyle and Bergstrom, 1992). For certain policy and management decisions, governing bodies require inexpensive benefit estimates in a timely manner. Benefit transfer is a method that can achieve exactly that. Benefit transfer has been applied extensively in various natural resource policy contexts (Luken et al., 1992, Brisson and Pearce, 1995, Bateman et al., 2000 and Hanley et al. 2003). An in-depth review of benefit transfer studies by Bateman et al. (2000) indicated that there was no single clear and universally adopted methodology towards benefit transfer analysis up to that time, a conclusion echoed recently by Navrud and Ready (2006).

Aggregating environmental benefit values can be thought of part of the benefits transfer exercise, being the process whereby the mean values of WTP or welfare are converted to a total value figure for the population (Hanley et al., 2003). Bateman et al. (2006) point out that because the methods for measuring non-market benefit values are based on analyses of individual behaviour, there is a problem in knowing how changes in a resource will affect aggregate values, since aggregation will depend on both the benefits per person and the population of beneficiaries (the extent of the market). Indeed, Smith (1993), Loomis (2000) and Bateman (2006) argue that the extent of the market may be more important in determining aggregate values than any changes related to the precision of the estimates of per-person values.

A number of other issues in the literature regarding the aggregation of environmental value estimates can be resolved by using the spatial microsimulation method developed in this paper. At a very basic level, Loomis (1987) states that the problem of generalising results from a sample to the population is at the heart of sampling theory and is the cause of concern of survey researcher in relation to low response rates. By statistically matching our sample of farmers and their associated WTP values with associated farm characteristics obtained from a census we can generate a representative population with individual WTP values for the entire farming population. Our method also alleviates the problem highlighted by Morrison (2000) in relation to how representative the sample of respondents, in any public good valuation study, is of the actual socioeconomic and demographic characteristics of the population in question. Using the microsimulated modeling techniques employed in this paper and assuming a relatively representative sample size it should be possible to produce a synthetic micro-dataset that contains constraining characteristics statistically matching those of the actual population.

Another issue in relation to representativeness in the aggregation process is discussed by Bateman et al. (2006). In this case the importance of spatial representativeness in regard to the aggregation of environmental benefit values is highlighted. The authors present two case studies through which they develop an approach to aggregation which applies the spatial analytic capabilities of a geographical information system to combine geo-referenced physical, census and survey data to estimate a spatially sensitive valuation function. These case studies show that the common reliance upon political jurisdictions and the use of sample mean values within the aggregation process are liable to lead to significant errors in resultant values[2]. The authors explicitly address self-selection and incorporate distance decay relationships into defining the limits of the economic jurisdiction while allowing for variability in the socioeconomic characteristics of the encompassed population within the aggregation process. They then use this approach to generate estimates of aggregate WTP and contrast this with estimates based upon both the use of a political jurisdiction and reliance upon sample means.

The issue of spatial representativeness is something that is also relevant for our study. Different parts of Ireland are represented by different types of farmers. The western seaboard for example is predominately represented by relatively small extensively operated, dry-stock farmers while the south east of the country would be presented by larger, more intensive dairy and tillage farm holdings. In any aggregation process for this particular group it is vital that these spatial differences in farm size and type is taken into account especially if we wish to examine regional variations in the total benefit value of the corncrake conservation program under review. The method we use in this paper is not unlike that of Bateman et al. (2006) in that it is an approach which takes into account the variation in the socioeconomic circumstances of the relevant aggregation population and uses GIS techniques to combine geo-referenced census, physical and survey data. We also generate estimates of aggregate WTP and contrast this with estimates based upon the simple aggregation of sample means and the use of a benefit transfer function. Unlike Bateman et al (2006) however, we do not rely on the estimation

[2] Loomis (2000) refer to a political jurisdiction as an area concerning some administrative area while an economic jurisdiction incorporates all those who hold economic values regarding a project.

of a “spatially sensitive valuation function” but instead produce a synthetically representative population of farmers using spatial microsimulation techniques that contain individual values of WTP for each farmer in the country that are then simply aggregated up to estimate the total value to Irish farmers of a corncrake restoration program. How this spatial microsimulation process works will be discussed in section 4 but firstly we review the data used in the analysis and the format of the WTP questionnaire.

4. Data and WTP Survey Questions

In this section we briefly describe the data used in this paper and the format taken by the willingness to pay questions. *The National Farm Survey (NFS)* is collected as part of the Farm Accountancy Data Network of the European Union (FADN). The aim of this network is to gather accounting data from farms in all member states of the EU for the determination of incomes and business analysis of agricultural holdings (FADN, 2005). The method of classifying farms into farming systems used in the NFS is based on the EU FADN typology set out in the Commission Decision 78/463. The system titles refer to the dominant enterprise in each group based on Standard Gross Margins (SGMs). Within the NFS, the farm system variable is broken down into six different categories as follows: Dairying, Dairying and Other, Cattle rearing, Cattle Other, Mainly Sheep and Tillage Systems.

In the 2005 NFS additional questions were asked in terms of farmers’ willingness to pay towards the restoration of the corncrake into the Irish countryside. A pilot sample was used to inform general survey design and to gauge the likely range of farmers’ willingness to pay in order to inform the bid design of the main survey. In carrying out the main survey each interviewee was told about the current population of the corncrake and how its numbers have fallen over the last 20 years. The farmers were also informed that “Bird Watch Ireland has operated an intensive Corncrake Conservation Project in Ireland since 1991, with the support of the Department of Environment, Heritage and Local Government and the Royal Society for the Protection of Birds”. The farmers were then informed that “As the population of corncrakes increases and spreads across the country, their management and maintenance will impose additional costs on the funding bodies, local authorities and local landowners (restrictions in land use) compared to the status quo of no restoration program. This cost would have to be paid for by the general public so it is important to find out how much if anything YOU would be willing to pay to have the corncrake restored as a common sight in the Irish countryside".

The farmers interviewed were then asked if they were willing to pay something towards the restoration of the corncrake into the Irish countryside and the maintenance of a sustainable population of corncrakes into the future. The farmers were instructed to bear in mind their total annual budget, the amount they might allocate to wildlife conservation and finally how much of this they could afford to spend on this restoration program. Also, they were told to bear in mind that paying too much for this restoration program may mean that they could not afford other worthwhile wildlife conservation schemes. Respondents answering "No" to this question were then asked which of several statements best described why they were not willing to pay anything. Those who answered the question in the affirmative were then presented with a payment card showing the bid amounts of €10, €20, €30, €40, €50 and €60 and were asked: "of these bid amounts which would be the maximum you would be willing to pay (€) each year into a conservation fund to aid in the restoration of this bird and bring the singing male population back up to a sustainable population of 900 birds.

A total of 1117 surveys were carried out. The Payment Card Method (Cameron and James, 1987) was chosen given the data collection method being used. 15 separate recorders go out to collect the NFS on the individual farms. Given that the farmers are asked over 300 questions on these surveys it was necessary to chose a simple approach to the additional WTP questions on the survey to avoid question answering fatigue on the part of the respondents.

The other dataset used in this paper is the Census of Agriculture. The Census of Agriculture began in 1847 and was last conducted in June 2000. The Census in 2000 was the first full census to be conducted since 1991, thus keeping in line with the general practice of conducting a full census approximately every 10 years. The 2000 Census of Agriculture was conducted entirely by post. The objective of the Census was to identify every operational farm in the country and collect data on agricultural activities undertaken on them (CSO, 2000). The census classifies farms by physical size, economic size, economic type and geographical location, and contains information on people who have registered with the Dept of Agriculture to avail of agricultural subsidies, and to comply with the Departments agricultural regulations. It contains information on approximately 145,000 active farms (CSO, 2000). To enrich our knowledge of farmers' willingness to pay for wildlife conservation at a more regional level in Ireland and in order to estimate the aggregate environmental value of a biodiversity conservation program to Irish farmers, we combine the NFS and the Census to create an attribute rich synthetic farm dataset with information on the willingness to pay of every farmer in Ireland[3] and also the Electoral Division (ED) where they are located. The spatial microsimulation methodology used to do this is reviewed in the next section.

5. Methodology

Microsimulation models have been increasingly adopted to study the impacts of social and economic policies on individual units (Merz, 1991; Ballas et al., 2005) mainly for predicting the effects of changing public policies. However, microsimulation has not yet been applied to the valuation of public goods. Within the spatial microsimulation framework, the benefits from the implementation of a corncrake conservation policy can be analysed at the micro-level, at a regional level or aggregated to show the overall national value of the conservation program. It is the dependence on individual information from the micro-data at every stage of the analysis that distinguished microsimulation models from other sorts of economic, statistical and descriptive models (Mitton et al, 2000).

In the context of the research presented here we generated synthetic farm population microdata sets at the Electoral Division (ED) level for Ireland with the use of a Simulated Annealing (SA) based reweighting programme. SA is a generic probabilistic meta-algorithm for the global optimization problem, namely locating a good approximation to the global optimum of a given function in a large search space. The SA algorithm was implemented in Java, an object-oriented programming language, which has been accepted as the most suitable type of programming language for spatial microsimulation modelling (Ballas and Clarke, 2000; Jackson, 1994). The programme aims at implementing a combinatorial optimisation approach to generating spatially disaggregated population

[3] With regard to the matching of the Census and the NFS a problem encountered was that in the Census, for a small proportion of Electoral Divisions (EDs), some details were not made available due to confidentiality or non-response. Furthermore, it was found that the two variables, farm size and farm system, were rounded to the nearest decile in a further effort to increase the confidentiality of the census. To overcome this rounding up problem, a one-stage iteration method was applied. This one-stage iteration involved generating a new variable for the six farm size categories, that is, rounded up to the nearest one rather than ten. The iteration process was also carried out in the same manner for the farm system variable in the Census of Agriculture.

microdata sets at the small area level (in our case, EDs). Object-orientated modelling has, amongst other benefits, the added advantage of platform-independence[4].

The implementation of the microsimulation approach to estimate a spatially disaggregated microdata set for farming activity in Ireland involves selecting the combination of individuals from the microdata (the 2005 NFS) which best fits the known constraints in the selected small areas of the 2000 Census of Agriculture. There are 3 important parts to creating the microdata population. The first key part of the programme is the microdata filtering process. This process needs to go through the entire microdata base and check whether an individual farm in the NFS fits the column constraints of the census tables (for example, does the farm fit the column of tillage in the system constraint, could it be one of the 2 farms in the 20-30 hectare column in the Size constraint table, etc.). Through this process, we gain all the farms that fit each of the column constraint in all tables for each ED. The second key part is the simulated annealing process itself, which searches for the best combinations of individuals based on the result of the filtering process. The process is repeated with the aim of gradually improving fit between the observed farms in the census and the selected combination of individual from the NFS. The third and final key part in creating the microdata population is the merge process.

On completion of the simulated annealing process an output file is produced that contains the selection of farm codes of the representative farmers from the NFS for every ED that best fulfills the census of agriculture information on these EDs, i.e. the number of farmers by size category, system of farming and soil classification in each ED. The merge process then involves the merging of the WTP (and other variables) into the microsimulated farmer population dataset using the farm code variable that is common to both the NFS and the output file from the simulating annealing process. This final step completes the spatial microsimulation process, resulting in a large scale microdata set with information on every farmer in the country.

[4] Spatial microsimulation exploits the benefits of object-orientated programming both as a tool and a concept. Spatial microsimulation frameworks use a list-based approach to microdata representation: a household or an individual has a list of attributes that are stored as lists rather than as occupancy matrices (Williamson et al., 1998). From a computer programming perspective, the list-based approach uses the tools of object-orientated programming because the farms can be seen as objects with their attributes as associated instance variables. For a technical discussion of a java based framework similar to that used in the development of the microsimulation model in this paper see Kelly (2004).

The simulated annealing process selected a set of farms from the 1177 records of the NFS that best fits the Census small area constraints of Farm Size in hectares; Farm System and Soil Class. These constraints were chosen as they best explain variations in many other farm variables such as family farm income (FFI), investment decisions, age profile of farmers, etc. These constraint variables also vary considerably across Irish rural space. All three constraints have a significant effect on the other main variables that will be produced in the microsimulation process. For example variations in family farm income (FFI) can to a large extend be explained by differences in the size and system of farming. When we produce the microsimulated population the additional farm variables such as FFI and WTP for corncrake conservation are merged into the synthetic population using the farmcode which is common to both the NFS and the microsimulated population. By choosing size, system and soil type as the constraining variables in the simulating annealing process we ensure that the replicated farms in each ED are as representative as possible.

It could be argued that a higher number of variables used as constraints generally produces better synthetic micro-data. However, we have to bear in mind that the more constrained variables we add in, the more comparisons with the real data will be required which means more time will have to be spend to run the model. As Huang and Williamson (2001) point out, the quality of the synthetic microdata is also likely to be affected by the size of the sample used as a parent population and the constraints used to guide the individual selection. It has also been noted that the larger the sample size, the more possible combinations of individuals exist and the better the fit is likely to be. The constrained variables in this study are chosen as they are potential predictors of WTP for corncrake conservation.

The simulated annealing algorithm works by selecting an initial random sample of records until sufficient farms are represented. Each pair of tables (simulated versus actual data) is then compared to calculate the total absolute error between the two tables. A number of records in the set are then selected at random and replaced with ones chosen at random from the universe of records. The error is then recalculated and the change in error (Δe) is calculated. If Δe is less than zero then there has been an improvement and the changes are accepted. Simulated annealing also allows sub optimal changes to occur. If Δe is positive, $\exp(-\Delta e/T)$ is compared to a random number between 0 and 1. T is a control parameter, which by analogy with the original application is known as the system `temperature' irrespective of the objective function involved. If Δe is greater than the random numbers then the changes are accepted, otherwise the changes are rejected and reversed. In this implementation if Δe is zero the change is accepted to allow the exploration of a greater part of the solution space. If the new error is the best seen so far the set of farms used is stored. As the simulation progresses, the number of records selected at one time decreases. This process allows a faster rate of improvement in the error term. The static model also employs a restart method. When a restart occurs the simulated annealing process begins again with a new sample of records. The restart is used so that more farm combinations can be explored.

The static microsimulation model also employs a restart method which is applied if the model fails to find a satisfactory solution within the maximum permitted iterations. When a restart occurs, the simulated annealing process begins again with a new initial sample of farm records. The restart is used so that more farm combinations can be explored. The simulation is complete when the total relative error is less than a specified target. The procedure is summarised in Figure 2. As shown in Figure 2, the matching process described above works as an analogy of the physical process of annealing, as described by Metropolis et al (1953). The T value (or number of farms in the EDs to be swapped at each iteration) is a control parameter and is initially set high and then slowly lowered after a set of iterations has taken place. In practice, T is selected equal to half the total number of farms in the ED. This means for an ED containing 100 farms, 50 farms are swapped in the first iteration. As the error decreases, the number of farms per swap is reduced to 1. The number of iterations is inversely proportional to the 'temperature', so that as the number of farms per swap is reduced as the number of iterations is increased. . By analogy with this physical process, each step of the SA algorithm replaces the current solution by a random "nearby" solution, chosen with a probability that depends on the difference between the corresponding function values and on the global parameter T (called the temperature), that is gradually decreased during the process. The dependency is such that the current solution changes almost randomly when T is large, but increasingly "downhill" as T goes to zero. The allowance for "uphill" moves saves the method from becoming stuck at local minima.

The simulation is complete when the total relative error is less than a specified target. In our case, when the selection of farms from the NFS can reproduce the SAPs tables for the number of farms by size and system and soil type contained in the Census of Agriculture with less than 5% of a difference between the original SAPS tables and those generated from the NFS selection, that set of farms is stored as the set that best fits that particular ED. Once this point is reached the programme stores the set of farms for that ED and repeats the process to find the set of NFS farms that best fits the Census SAP tables for the next ED and so on. Matching the NFS and the SAPS data creates synthetic demographic, socio-economic and farm level variables, such as martial status, age, fertiliser usage, livestock units per farm, etc and most importantly from our research perspective WTP values *for each farmer in the population.* The simulating annealing process conduced for this research produces 145,000 individual farm records.

In terms of the aggregation of environmental benefit values spatial microsimulation can potentially offer three main advantages over more traditional methods such as meta-analysis or the simple aggregation of sample mean values. First, it allows data from various sources to be linked if datasets contain at least one attribute in common (for example the variable farm size in the NFS dataset and the Census of Agriculture dataset). In this manner, a public good valuation survey can be manipulated to produce estimates for WTP for every individual in a nationally representative synthetic population. Secondly, the models are flexible in terms of spatial scale that is data can be re-aggregated or disaggregated. For example, the environmental value estimates for the corncrake conservation project can be aggregated to counties (by ED), regions (by province) or the country as a whole. Finally, the models allow for updating and projecting as new census data becomes available.

The Payment Card Estimation Procedure

On completion of the microsimulation model it was important to be able to compare estimates of aggregate environmental value with other benefits transfer aggregation methods, such as simple mean WTP aggregation in the NFS sample and a value function approach. In what follows we briefly outline the generalised Tobit model that was used in this comparison as the value function approach. The elicitation format chosen in this study was the Payment Card Method (PCM) where each farmer was shown a payment card listing various euro amounts and asked to indicate the maximum amount they were willing to pay. Following Cameron and James (1987) the response is interpreted not as an exact statement of willingness to pay but rather as an indication that the WTP lies somewhere between the chosen value and the next larger value above it on the payment card. The price range used in this study was based on the responses to the pilot study (which utilised the open-ended elicitation format (see Haab and McConnell, 2002)) discussed in the previous section. It was assumed that the preferences of farmers could be explained using the standard random utility model of McFadden (1974). In this case the farmer chooses from the alternatives (the status quo versus a sustainable population of corncrakes) and picks the one that yields the highest utility level on any given choice occasion (Hanemann, 1984).

Following on from the payment card specification, the WTP responses were treated in a parametric model, where the WTP value chosen by each farmer was specified as: WTP = $\mu + \varepsilon.$ It is assumed that $\varepsilon \sim N(0, \sigma^2 I)$. This is a generalised Tobit model and is estimated via maximum likelihood procedures. Daniels and Rospabé (2005) provide a log-likelihood function adjusted to make provision for point, left-censored, right-censored (top income category with only a lower bound) and interval data. For farmers $j \in C$, we observe WTP_j, i.e. point data. Farmers $j \in L$ are left censored (unused in this setting, since the lowest group contains only zero values, which are counted as missing when logged). Farmers $j \in R$ are right censored; we know only that the unobserved WTP_j is greater than or equal to WTP_{Rj}. Finally farmers $j \in I$ are intervals; we know only that the unobserved WTP_j is in the interval $[WTP_{1j}, WTP_{2j}]$.The log likelihood is then given by:

$$
\begin{aligned}
\ln L = & -\frac{1}{2}\sum_{j \in C} w_j \left\{ \left(\frac{WTP_j - x\beta}{\sigma} \right) + \log 2\pi\sigma^2 \right\} \\
& + \sum_{j \in L} w_j \log \phi \left\{ \left(\frac{WTP_{Lj} - x\beta}{\sigma} \right) \right\} \\
& + \sum_{j \in R} w_j \log \left\{ 1 - \phi \left(\frac{WTP_{Rj} - x\beta}{\sigma} \right) \right\} \\
& + \sum_{j \in I} w_j \log \left\{ \phi \left(\frac{WTP_{2j} - x\beta}{\sigma} \right) - \phi \left(\frac{WTP_{1j} - x\beta}{\sigma} \right) \right.
\end{aligned}
$$

Where $\phi\,()$ is the standard cumulative normal and w_j is the weight of the jth farmer. In our study no weights are specified so w_j is set equal to 1.

6. Results

Results I: Validation of Microsimulation Model Results and some Summary Statistics

As Ballas et al. (2001) point out; one of the biggest drawbacks of microsimulation models is the difficulty in validating the model outputs. This is due to the fact that microsimulation models estimate distributions of variables which were previously unknown. However, one way of validating microsimulation model outputs is to re-aggregate estimated data sets to levels at which observed data sets exist and compare the estimated distributions with the observed.

The static model developed in this paper uses three different statistics to assess (internally) the models goodness-of-fit: total absolute error, relative error and z-scores (Kelly, 2004). Farms are added or removed in the simulation process based on the total absolute error of all the target tables. The simulation process is ended based on the total relative error of the target tables. The relative error result for each table is calculated by dividing the total deviations of the estimated table from the actual table by the sum of the cells in the actual table. The relative error is chi-squared distributed at the 95% level. Finally, as a further validation exercise Z-scores for cellular fit and Z^2 –scores for tabular fit are calculated and outputted along with the results.

The Z-score is based on the difference between the relative size of the category in the synthetic and actual populations, although an adjustment is made to the formula when dealing with zero counts. A Z-score can be summed and squared to provide a measure of tabular fir similar to a chi-squared statistic. If a cell's Z-score exceeds the critical value, the cell is deemed not to fit, while if a Z^2 –score exceeds the critical value, then the dataset is deemed not to fit (i.e. |Z|>1.96). The Z score calculation is given by:

$$Z = \frac{\dfrac{T_{ij} - O_{ij}}{\sum_{ij} O_{ij}} \pm \dfrac{1}{2 \times \sum_{ij} O_{ij}}}{\sqrt{\dfrac{\left(\dfrac{O_{ij}}{\sum_{ij} O_{ij}}\right)\left(1 - \dfrac{O_{ij}}{\sum_{ij} O_{ij}}\right)}{\sum_{ij} O_{ij}}}}$$

Where: T_{ij} is the estimated data, column i, row j.

O_{ij} is the census data, column i, row j.

$\sum_{ij} O_{ij}$ is the sum of all the elements in the table.

The $\frac{1}{2 \times \sum_{ij} O_{ij}}$ stochastic component is added or subtracted because in some large tables it is possible to have 0 values, and then we would have division by zero. One adds the stochastic component if T_{ij} < O_{ij} and subtracts it if $T_{ij} > O_{ij}$. Of course if the observed and the expected are the same then Z is 0. We use the above formula to calculate the Z score. It is easy to see from the sample of Z squared results presented in Table 1 which tables and which EDs fit the small area constraints the best.

Information on the relative error and the z-scores are outputted automatically in the static simulation. As shown in table 1, the first line in section 3 of the table shows the degrees of freedom and associated 95% critical value for the Z^2 –score. The degrees of freedom are the number of columns in the table that represent a farm system. As there are seven such columns, the associated degrees of freedom for specialist are 2.16. Taking ED 26 as an example, the z^2 –score of zero indicates that the estimated tables fit the actual tables. Also for this ED, the Z-score is zero across all cells, indicating that the estimated cells fit the actual cells from the Census perfectly. On the other hand in ED 24, cell 3 is 0.1641 as is cell 6. This is above zero but still does not exceed the critical value, i.e. these cells still fit the actual cells at the 95% confidence level and its Z^2 –score is also below the critical value (0.0538), thus indicating that the estimated table still fits the actual table.

Examining the actual and estimated *System* variables in Table 1 will verify this. The census and estimated tables for ED 24 to ED 31 for the variable specialist are shown in the first and second sections of Table 1 respectively. On examining the estimated and actual farm numbers per ED, the two tables do correspond for ED 24, as was indicated by our Z-scores. However, we can see by comparing the estimated and actual tables, that cell 5 for ED 24 tells us that there are 10 specialist beef farmers and 10 mixed grazing and livestock farmers in ED 24, while the information from the Census indicates that are 11 and 9 such farms respectively in ED 24. There are corresponding Z-score results produced by the model for each of the other three SAPS tables – farm numbers, farm size and soil code[5].

As well as these internal validation measures we can also validate the synthetic microdata estimates produced by the spatial microsimulation model by re-aggregating the model results up to the county and national level and then comparing the estimates against Irish Central Statistics Office (CSO) figures for average farm size at the county level and a cross-tabulation of farm size and system at the national level. This analysis at the national and county level of farm size and system is a further validation of our synthetic microdata and in turn it validates the z-score and z^2-score results discussed above. Table 2 demonstrates that the estimates for average farm size at the county level derived from the synthetic microdata are approximately the same as the average farm sizes from the Census of Agriculture. Only for county Dublin is there are a greater than 10% difference between the estimated and actual average farm size. This comparison further validates the z-scores and z^2 –scores taken from the Static Farm Level Spatial Microsimulation Model. A comparison between the synthetic microdata estimates and the actual Census of Agriculture results can also be carried out using a cross tabulation of farm size and system at the national level. Once again it was found that the majority of results were quite accurate. For example, the Microsimulation Model estimated that for farms between twenty and thirty hectares the Static Farm Level Spatial Microsimulation Model estimated that there were 25,230, while according to the Census there are 25,045. For farms between fifty and a hundred hectares the Static Farm Level Spatial Microsimulation Model estimated that there were 20,700 farms in this category, while the actual Census records 19,535[6].

Finally the comparison of variables in the NFS to those in the microsimulated farm population (but not used as constraints in the microsimulation modelling process) can also be used to validate our spatial microsimulation results. For example the average family farm income estimate from our model can be compared to the weighted NFS average income findings in 2005. According to the NFS, weighted average family farm income in 2005 was €22,456.92. This compares to €20,026.95 according to our Static Farm Level Spatial Microsimulation Model. Thus, as with our comparisons between the simulated microdata estimates and the CSO figures at county level, the national estimate

[5] To save space these results are not presented here but are available from the authors upon request.

[6] To save space the table showing the cross tabulation comparison of farm size and system at the national level between the synthetic microdata estimates and the actual Census of Agriculture results is not presented here but is available from the authors upon request.

from the Static Farm Level Spatial Microsimulation Model is a very close approximation of the actual NFS results at the national level. Table 3 presents a comparison of other summary statistics for both the NFS and our microsimulated population.

Results II: Regional and National Estimation of the Benefit of Corncrake Conservation

The main goal of the microsimulation exercise carried out in this paper was to be able to analysis the environmental value of the proposed corncrake conservation project at different levels of aggregation across space. As can be seen from figure 3 and table 4 this can be done at a number of different levels including ED, county, NUTS III regions and nationally. Of the 3440 EDs in the country 2850 contain farms; the average number of farms in each of these EDs being 53 (min 10, max 320). It is very evident from the map (figure 3) that farmers in EDs found in the west, south west and border areas of the country seem to be willing to pay higher amounts on average, into a conservation fund to have the corncrake restored into the Irish countryside. These WTP values were produced during the merging phase where the WTP values from the NFS were merged into the synthetic microsimulated population using the farm code variable that is common to both the NFS and the output file from the simulating annealing process.

As can be seen from Table 4 the areas of the country represented by the highest average WTP figures are once again predominately in the west of the country. Donegal, Mayo, Leitrim, Roscommon and Galway, which are all found on or close to the western seaboard of Ireland, display the highest average WTP values. The Dublin region is the only anomaly to this finding with an average WTP per farmer of 9.75. It should be noted however that County Dublin represents the lowest population of farmers for all counties in our synthetic population of farms with only 31 farms. The general finding of higher average WTP values in certain areas also holds true at the NUTS III level where once again the Border and Western regions display the highest WTP values.

This is a very interesting finding given that the remaining singing male population of corncrakes in Ireland is largely restricted to four areas, Co. Fermanagh (which is on the border on the Northern Ireland side) and three core areas in the Republic of Ireland, north Donegal, west Connacht, and the Shannon Callows (Mayes & Stowe, 1989 and Schäffer and Green, 2001). Records outside the three remaining core areas are sporadic, though 1 or 2 males have regularly been recorded on the Dingle peninsula in Co. Kerry and on Rathlin Island. By 2005, the Irish population stood at 162 in these core areas, with a further 2/3 in Northern Ireland and 2 others in the Republic of Ireland (NPWS, 2005). As can be seen in Figure 3 and table 4 the willingness to pay values in our microsimulated population of farmers are thus positively correlated spatially with areas where the corncrake can still be found.

There are 2 main reasons why the farmers (as demonstrated in figure 3 and table 4) in these areas may display higher WTP values that farmers in other parts of the country. Firstly, the rasping call of the corncrake is probably still a familiar night-time sound in theses areas and as such farmers in these areas may be willing to pay higher amounts to maintain the population at a sustainable level, relative to other areas in the country where the distinctive call of the corncrake may not have been heard by the current generation of farmers. Secondly, farming activity in these areas would be considered more extensive in nature than other more intensive run farming enterprises in the south and south east of the country. The dominance of the less intensive farm management systems of beef and sheep grazing in the border and west of the country has meant that herbicide and pesticide use, together with the associated biodiversity loss has been less than that of the more extensive systems of dairy and tillage to be found in the south and south east. It has been previously been pointed out by Bullock and Styles (2006) that in the South-East where cereals and sugar-beet have traditionally been cultivated, chemical applications and past removal of hedge-rows may have substantially reduced biodiversity. Therefore, it may be that the simulated farms in the higher WTP areas are willing to pay more simply because they would have less changes to make in how they run their farm operations than the more intensive farmers of the south and south east under any corncrake conservation programme.

We also wanted to use our microsimulated population to calculate the aggregate environmental value of a corncrake conservation programme to Irish farmers at a national level and alternative levels of regional aggregation. We contrast this value to the aggregate value for the same programme estimated by two alternative approaches. The two alternative approaches are aggregation using the CVM interval regression model outlined in section 3 (the value function approach) and the simple multiplication of the average value of WTP in the NFS sample by the number of farms in the country (the simple mean WTP aggregation approach). The parametric regression results of the value function approach (calculated using the 2005 NFS sample) are presented in Table 5. It can be seen from the results that WTP increased significantly with the age of the farm operator and with the size of the farm. It may be the case that older farmers remember the corncrake on their land in times past and are more willing to pay to see it being restored than those younger farmers who may never have seen or heard it.

The REPS farm variable indicates that farmer participating in the Rural Environment Protection scheme (REPS)[7] are willing to pay (significantly) higher amounts than those farmers not participating in the scheme. Given the environmental education component involved in the uptake of this scheme and the fact that farmers participating in an agri-environmental scheme are more likely to favour a biodiversity conservation programme this finding was not surprising. The Organic Nitrogen Production per hectare variable is an indicator of how intensive the farming enterprise is. As expected the farms with the higher rates of organic nitrogen per hectare are willing to pay less for a corncrake conservation programme. Once again we would speculate that the main reason for this is the fact that these represent the more intensive farm enterprises that would have to make significant changes in terms of how and when they cut silage and in how they manage permanent grassland under any successful corncrake conservation programme.

The value function approach produces a higher value for the average WTP per farm than the value generated from either the microsimulation model or the average value in the NFS sample[8]. As can be seen from table 6 the microsimulation model and the simple mean WTP aggregation approach produce an estimate of the total environmental value of a corncrake conservation programme that differs by only 2.6%. However, the estimate of the total environmental value of a corncrake conservation programme to Irish farmers as calculated using the value function approach and aggregated using the population weights in the NFS, results in a figure that is 16% higher than that produced by the NFS average value been multiplied by the total number of farms in the country and 18% higher than the figure generated using the results of our microsimulation model.

Finally, in relation to the aggregation of environmental values we also use the microsimulation results to produce an estimate of the total environmental value of the corncrake conservation programme at a county and NUTS III regional level. The results of this regional aggregation are displayed in figure 4 and once again it is very evident that total regional environmental values for our microsimulated population of farmers is positively correlated with where the corncrake can still be found (as displayed in figure 1).An attempt also can be made to estimate the regional value of the corncrake conservation

[7] The Rural Environment Protection Scheme (REPS) was introduced in Ireland under EU Council Regulation 2078/92 in order to encourage farmers to carry out their activities in a more extensive and environmentally friendly manner. Approximately 43,000 farmers were actively participating in the scheme in 2005.

[8] The average value in the NFS is calculated by the simple multiplication of the average value of WTP in the NFS sample by the number of farms recorded in the Census of Agriculture.

project by simply multiplying sample mean WTP by ED farm population figures. Once again however this method fails to take into account the substantial differences in the farm types across space. If we aggregate up the average WTP of our sample (€6.99) by the total number of farmers in each NUTSIII region we get a resulting estimate that is 7% higher than the aggregated benefit transfer estimate from the microsimulation model (€158,195 versus €147,964 respectively). By not recognizing the difference in farming activity across Irish rural space, through the use of the microsimulated population, we would be overestimating the regional aggregation of the welfare associated with the corncrake conservation programme. Studies that fail to take account of the regional heterogeneity in their study population may introduce biases in their attempts to estimate regional environmental aggregate benefit values.

The final aim of this analysis was to investigate whether the land cover type representing the main habitat of the corncrake was positively associated with the average WTP values per farm for corncrake conservation in each ED. Land use data represent an important baseline for environmental monitoring and policy initiatives (Frolking et al.,1999). We used a recent land cover classification for Ireland developed by Teagasc under the Forest Inventory Planning System and Irish Forest Soils (FIPS–IFS) project. The FIPS–IFS land-cover data set was developed using GIS and remote sensing, along with "ground truthing" field tests (Loftus et al. 2002). A report published by the United Nations Environment Programme on the development of indicators of biological diversity (UNEP 2000) lists GIS and remote sensing with ground truthing as suitable methodologies for measuring ecosystem quantity. The mapping unit employed in the FIPS–IFS land-cover data set was 1 hectare. The main classes in the FIPS–IFS land-cover data set include bog and heath, cut-bog, wet grassland, dry grassland, bare rock, rocky complex, mature forestry, immature forestry and scrub, built land, sand and water.

Using this land cover data set in conjunction with the spatial annalist tool in the software package ArcMap 9.1 we created a geo-referenced dataset containing the percentage of each land cover type in each of the 3450 EDs in Ireland. By combining this information with the average values for the farms in our microsimulated farm population we were then able to run a simple OLS regression where the dependent variable was the average WTP per farm per ED and the independent variables included a number of relevant land cover types percentages for each ED along with some average farm and farmer characteristic variables. The results of this analysis can be seen in table 7. Earlier versions of the model showed that many of the percentage land cover type per ED values were insignificant. Indeed in the final version of the model only the land cover types of dry grassland and build land showed up as significant explanatory variables.

The average age of the farmer and the average farm income in the ED and the level of REPS payments in an ED all had a significant and positive impact on the average willingness to pay per farmer per ED. In terms of land cover types only 2 turned out to have a significant impact on the average willingness to pay of a farmer in an ED. It can be seen from table 7 that EDs with a higher percentage of build upon land have a positive impact on the average WTP of a farmer in that ED. This may suggest that farmers close to built up areas are wishfully longing for a "pre-Celtic Tiger" time when urban populations had not yet started to encroach on the rural, predominately farming landscape. The most surprising and worrying finding from a corncrake conservation perspective in the results of table 7 is the fact that the second land cover type that turns out to be significant but of the wrong sign (in terms of corncrake conservation) is the dry grassland land type. The negative sign on the dry grassland coefficient suggests that the higher the percentage of dry grassland as a land cover type in an ED the lower the average WTP of a farmer in that ED will be. During the breeding season, corncrake nests are situated in areas of tall vegetation, usually in hay and silage fields, which provide continuous cover and a good food supply. The corncrake breeding season runs from May to August when hay and silage fields are the predominant form of "dry grassland" land cover in Ireland. The fact that there is a significantly negative association between this land cover type and the willingness to pay by farmers for corncrake conservation does not bode well for the restoration of the corncrake in more intensively farmed areas outside the four main zones mentioned earlier in the paper where the bird species is currently found.

7. Discussion and Conclusions

In this paper we outlined the development of a spatial microsimulation model that uses a combinational optimatisation technique called simulated annealing to match the Irish Census of Agriculture data to a National Farm Survey (NFS). The matched NFS and Census information was then used to produce small area population environmental benefit microdata estimates for the year 2005. These figures were then aggregated to get a total value figure for the farming community of

Corncrake conservation in Ireland and we were also able to aggregate the individual WTP figures at a more regional level across Ireland thus allowing us to assess the variability in preferences for a corncrake conservation project in different areas of the country.

There were two main findings from the microsimulation analysis in terms of corncrake conservation. Firstly, it is very evident from our microsimulation model results that farmers willingness to pay for the restoration of the corncrake is positively correlated with where the corncrake can still be found. We speculate that this reflects the fact that farmers in these areas are willing to pay higher amounts to maintain this statuesque situation compared to other farming areas in the country where the distinctive call of the corncrake may not have been heard by the current generation of farmers. Also, it may be that the simulated farms in the higher WTP areas of the border and western regions are willing to pay more simply because they would have less changes to make in how their run their farm operations under any corncrake conservation programme than the more intensive farmers in the south and south east of the country.

The second main finding of the study in terms of corncrake conservation was the fact that those areas of the country where grassland was the main land cover type were negatively (and significantly) associated with the willingness to pay of farmers for corncrake restoration in the Irish countryside.[9] This finding would seem to suggest that the Irish government's target of the re-establishment of breeding populations of the species in other parts of its former range by 2015 may be difficult to achieve. Research has shown that, in order to maintain population levels, corncrakes need to hatch two broods of chicks per year (BWI, 2000). As the grass harvest period in Ireland corresponds closely to the timing of breeding, nests are often destroyed and young killed during mowing. Also, since the peak hatching date for the second brood is in late July, corncrakes are unlikely to reappear in areas where most of the mowing takes place before early August. A sustainable population of corncrakes in the Irish countryside would require that farmers hold of on their second cut of silage or first cut of hay until late in the month of August. Given that our analysis has shown that farmers in areas with a higher percentage of grassland are less willing to pay for corncrake conservation, the probability of a sustainable corncrake population being maintained in these areas is unlikely without monetary

[9] The areas where the corncrake is still found is on small pockets of grassland and on remote islands in counties that are dominated by the land cover types of "rocky complex" and "bare rock" rather than grassland.

compensation being paid to farmers (through some sort of conservation scheme) to adjust the dates in which they mow their meadows.

In Ireland, a Corncrake Grant Scheme, run by National Parks and Wildlife Service (NPWS), has been in operation in the three core areas where the corncrake can still be found today (Co. Donegal, west Connacht and the Shannon Callows) since 1991 (see figure 1) . Three sites have also been designated as Special Protection Areas (SPAs) for the corncrake under the Birds Directive - the Shannon Callows and the Donegal Islands of Tory and Inishbofin. Also since June 2004 under the Rural Environment Protection Scheme a supplementary payment for the implementation of a corncrake friendly grassland management prescription is available to any farmer who signs up to the scheme in the Shannon Callows. While these steps should ensure the survival of the corncrake in these small pockets of the country the analysis presented in this paper would suggest that unless the schemes are extended to other areas where silage is harvested as a key feed source for wintered store cattle and dairy cows on more extensive farm enterprises, the Irish government's aim of the re-establishment of breeding populations of the species in other parts of its former range by 2015 may be a very unrealistic target.

In terms of the methodology used in the paper, we employed an approach that has not previously been considered for use in the aggregation of environmental benefit and transfer values. As discussed in section 3 there are numerous examples in the literature where the reliance upon sample means will fail to yield an accurate measure of aggregate WTP. As an alternative, we propose a new approach based upon the estimation of a spatial microsimulation model which takes into account the impact of variation in the socioeconomic characteristics of the relevant aggregation population and allows for the calculation of regional as well as total environmental benefit values. The comparison between aggregate estimates in table 6 demonstrated that the microsimulation modeling approach provides similar estimates of aggregate environmental value as the simple mean WTP aggregation approach but resulted in values which were 18% larger than those obtained using the value function approach. We would contend however that the microsimulation approach developed in this paper has the advantage of being able to be aggregated to different regional levels while taking into account the regional variation in the characteristic of the farms; an option that is not available when one is dealing with aggregation options for a sample of respondents to a survey, even if it is nationally representative.

We would speculate that there are 4 main benefits of using spatial microsimulation methods to create synthetic microdata for use in environmental transfer studies. Firstly, as demonstrated in this paper, it allows the creation of spatially disaggregated data containing WTP estimates from aggregated WTP surveys. Secondly, the many simulated characteristics of each individual or farm can be used for follow multivariate analysis, thereby providing a method of identifying and analysing specific policy questions at a regional level that may not be possible in a field survey alone. Also by using GIS spatial analyzing techniques, the microsimulation modelling approach allows the individual synthetic data to be combined with area data within contingent valuation models of demand in a manner which allows us to address a much wider range of policy issues. This usage was demonstrated in this paper by carrying out an OLS regression of the average willingness to pay of farmers per ED on different land cover types and other socio-demographic characteristics of farmers at the ED level. Without the combination of the simulate population and the accompanying spatial land cover information we would not have been able to examine this relationship. Thirdly, creating synthetic spatial microdata gives the researcher the potential to estimate the spatial impact of policy change on particular groups within the population. Although this was not done in this paper an avenue for further research is to examine how the WTP figures vary across the different farm systems and what this implies for the restoration of the corncrake in the Irish countryside.

The creation of the microsimulated population of farmers with their accompanying WTP values is not a technique that is unique to the datasets in this study but is an approach that should in theory be able to be replicated and used with large sample data sets in other CVM studies and indeed with revealed preference techniques such as the recreation travel cost method and the hedonic price valuation technique. In recreational travel cost studies it can be very difficult to calculate the aggregate value of a site as a recreational resource due to lack of information on the total population that might us that site on an annual basis (Hynes and Hanley, 2006). By using distance decay functions in a microsimulation framework this obstacle could be overcome.

For example, it would be possible to statistically match a large sample of individuals interviewed about the forest walking activity they undertake to census of population small area statistics to produce a national map of forest recreational walkers. The variables age, gender, marital status and occupation could perhaps be used as the constraints in the simulating annealing process. Given the fact that you have the EDs in which the synthetic population of forest walkers live, the travel cost to a number of forest sites could be calculated using the distance from the centroid point of the ED where a walker is located to the recreational site. By utilising the coefficients from a forest walking travel cost model in conjunction with the microsimulated population of forest walkers the aggregate value of the forest from a walking recreational viewpoint pay be calculated.

A second example of where the microsimulation modeling approach could be used is in calculating the aggregate WTP (according to user socioeconomic profiles at selected sites) for benefits of improved ecological status of rivers as a result of the implementation of the Water Framework Directive (WFD). This was done previously by Hanley et al. (2006) where the WTP for the benefits of improved ecological status of a number of rivers in Britain was estimated using a survey of the residents along the river banks and choice modeling techniques. By using the spatial socio-economic information in a microsimulation model of the general population, and adapting it to include spatial information on rivers and their ecological characteristics, the coefficient results in a choice experiment model could be used to build a Spatial Microsimulation Benefit Transfer System to estimate the economic value of improvements in the ecology of the entire inventory of a nations rivers.

In effect an estimate of the WTP of each person in every ward or parish where a river flows through could be calculated in the microsimulation model using the coefficient results for the river characteristics and socio economic characteristics of the original Hanley et al (2006) choice experiment model and aggregated to calculate the total monetary value a move to “good ecological status” for every river in Britain. This methodology would take into account the varying socio economic characteristics of the people living in each river catchment area and of course the varying characteristics between different rivers. The incorporation of estimates of economic benefits in river catchment management plans that is required under the WFD could be a very costly exercise for European nations if it had to be done on a river by river basis. However through the use of the spatial microsimulation modeling approach this cost could be significantly reduced.

One further area for further research in terms of using microsimulation techniques in public good valuation studies would be a “ground truthing” exercise to examine whether the WTP estimates in our microsimulated population are statistically equivalent to what one would find if the WTP questionnaire was to be conducted in each ED. To this end it would be worth while to pick a number of EDs around the country and survey the farmers in them to see how close the actual WTP values of the farmers in the chosen EDs are to the estimates for those farmers in the corresponding simulated ED populations. The one disadvantage of the technique employed in this paper, that needs to be kept in mind, is that validation of the results is difficult. Even though we presented a number of methods that attempt validation of the results the difficulty with validation of results is an obvious fact given that one of the objectives of creating synthetic microdata is to create data that does not currently exist for small geographic areas.

It is clear from all of the foregoing that Ireland faces enormous challenges in the years ahead in terms of halting the loss of the corncrake (and a number of other farm bird and animal species) from the Irish countryside. The reform of the European Common Agricultural Policy (CAP) in 2005 saw member states decoupling agricultural payments from production. The consequences of this for corncrake conservation are uncertain, but it is expected that cattle and sheep numbers on Irish farms will fall which in turn may lead to changes in mowing and grazing regimes, which ultimately may have a positive effect on the corncrake population. Apart from the loss in corncrake due to changing trends in agriculture over the last 20 years, the habitats of other species of Irish bird and animal are becoming increasingly fragmented and isolated within small pockets on individual farms. A continuation of these trends could cause further extensive biodiversity loss and according to a report by the Irish Environmental Protection Agency could lead to more than 80% loss of existing farm syrphid fauna (EPA, 2004). The microsimulation modelling technique developed in this paper may provide a useful tool in the future in accessing which alternative policy options will facilitate the restoration of the corncrake and other endangered species back into the Irish countryside.

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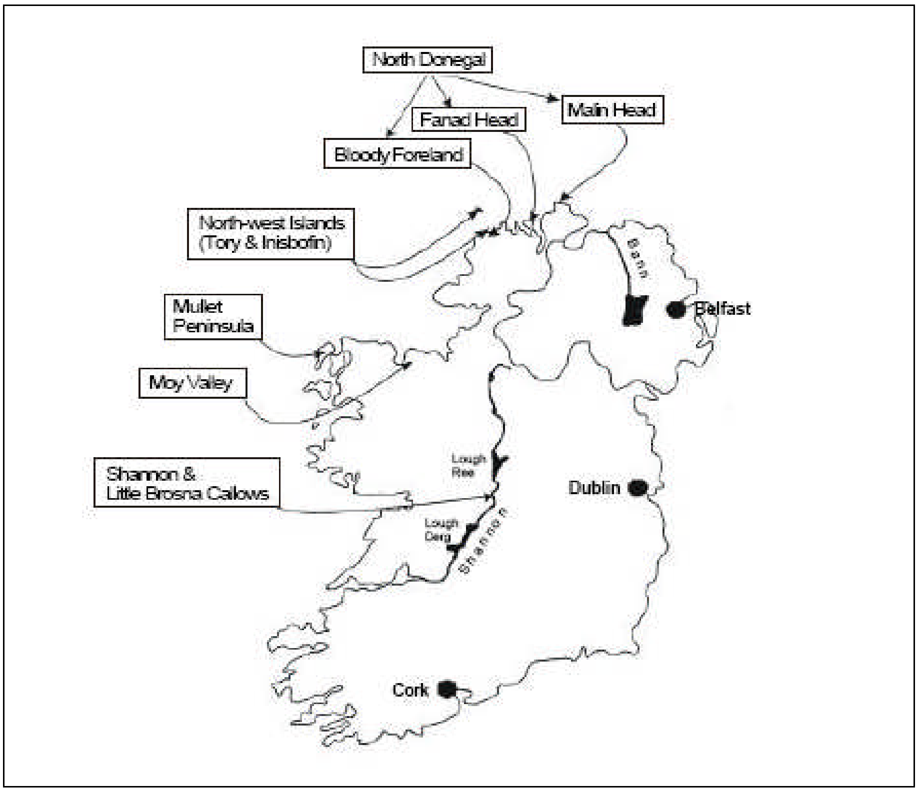
Figures and Tables

Figure 1. The Remaining Breeding Ground of the Corncrake in Ireland



Source: McDevitt and Casey (2004)

Figure 2. Static Farm Level Spatial Microsimulation Flowchart

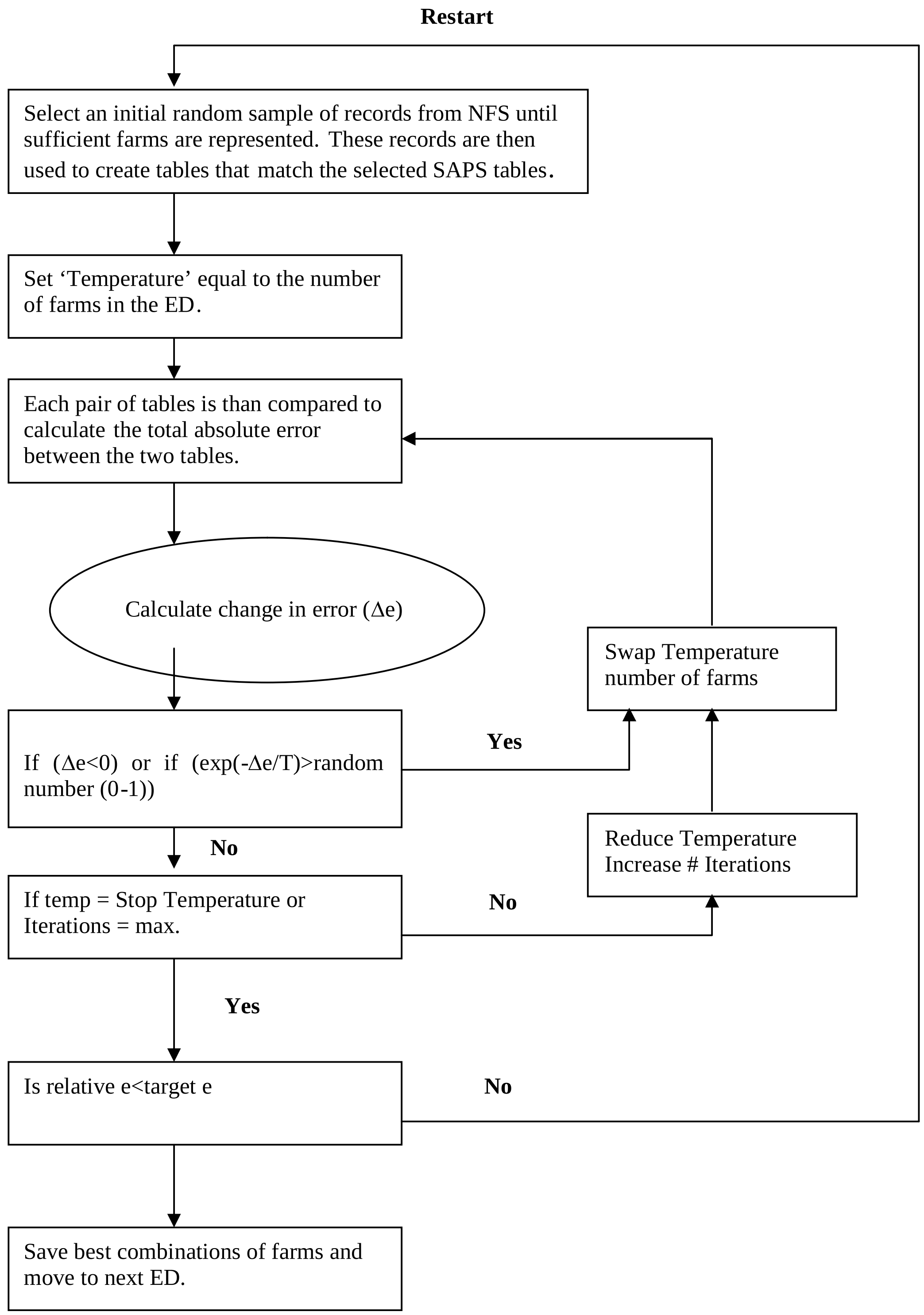


Figure 3. Average WTP for a Corncrake Conservation Programme per Farm per ED

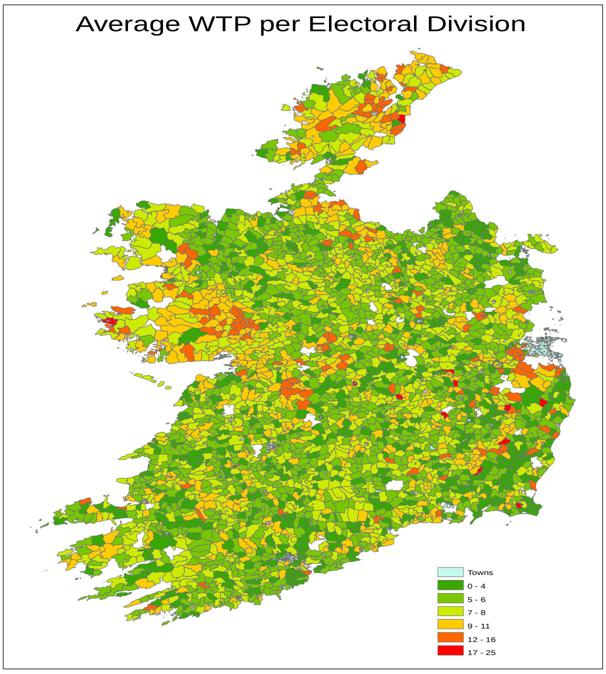


Figure 4. Total Environmental Value of a Corncrake Conservation Programme at Alternative levels of Spatial Aggregation

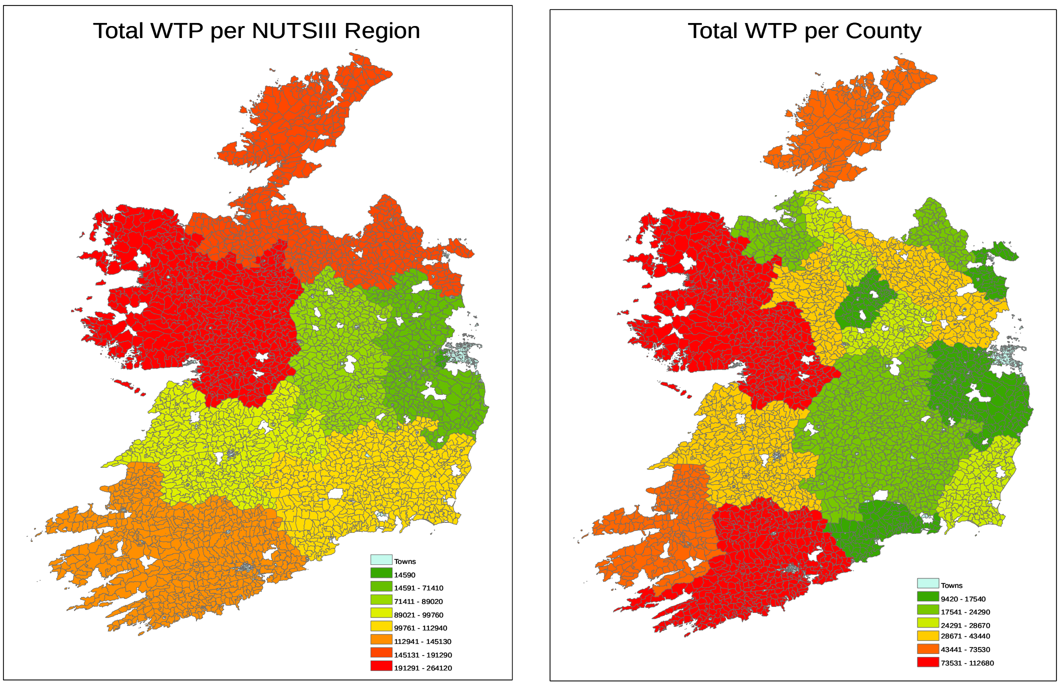


Table 1. Microsimulation Validation for a Sample of EDs

Farm System	Specialist Tillage	Specialist Dairying	Specialist Beef Production	Specialist sheep	Mixed grazing livestock	Mixed crops & livestock	Other	Total No. of Farms	Z^2 – score
1. Census Table									
DED: 24	10	0	10	20	20	10	0	70	
DED: 25	14	0	0	0	0	14	0	28	
DED: 26	10.33333	0	10.33333	0	0	10.33333	0	31	
DED: 27	0	0	9.666667	0	9.666667	9.666667	0	29	
DED: 28	10	0	10	0	10	0	0	30	
DED: 29	0	0	10.75	10.75	21.5	0	0	43	
DED: 30	11	0	0	0	11	0	0	22	
DED: 31	0	12.25	12.25	0	12.25	12.25	0	49	
2. Estimated Table									
DED: 24	10	0	11	20	20	9	0	70	
DED: 25	14	0	0	0	0	13	0	27	
DED: 26	11	0	10	0	0	10	0	31	
DED: 27	0	0	10	0	10	9	0	29	
DED: 28	10	0	10	0	10	0	0	30	
DED: 29	0	0	11	11	21	0	0	43	
DED: 30	11	0	0	0	11	0	0	22	
DED: 31	0	13	12	0	12	12	0	49	
3. Z-Scores	X Squared Critical Value:		2.16		Degrees of Freedom:		7		
DED: 24	0	0	0.1641	0	0	-0.1641	0		0.0538
DED: 25	0	0	0	0	0	-0.1543	0		0.0238
DED: 26	0	0	0	0	0	0	0		0
DED: 27	0	0	0	0	0	0	0		0
DED: 28	0	0	0	0	0	0	0		0
DED: 29	0	0	0	0	0	0	0		0
DED: 30	0	0	0	0	0	0	0		0
DED: 31	0	0	0	0	0	0	0		0

Table 2. Microsimulated Estimates of Average Farm Size at the County Level, compared to Actual Average Farm Size from CSO Statistics

County	Microsimulation Model	Census of Agriculture	% Error
Carlow	37.64	38.3	-1.73
Cavan	25.58	25.2	1.50
Clare	30.58	31.3	-2.30
Cork	35.88	37.5	-4.31
Donegal	25.34	26.2	-3.27
Dublin	61.71	42.2	46.22
Galway	23.45	24.6	-4.67
Kerry	31.34	32.7	-4.15
Kildare	40.65	41.8	-2.74
Kilkenny	41.91	42.6	-1.63
Laois	34.07	35.3	-3.49
Leitrim	23.19	24.6	-5.72
Limerick	33.56	32.6	2.94
Longford	26.67	26.9	-0.86
Louth	34.43	35.1	-1.91
Mayo	22.96	21.9	4.85
Meath	37.72	40.2	-6.16
Monaghan	23.72	21.8	8.83
Offaly	31.97	34.5	-7.34
Roscommon	24.67	24.8	-0.51
Sligo	24.47	24.5	-0.12
Tipperary North	36.81	38.8	-5.14
Tipperary South	38.62	40.7	-5.12
Waterford	40.84	44.6	-8.43
Wexford	38.10	40.1	-5.00
Wicklow	40.55	42.2	-3.91
Westmeath	33.16	34.9	-5.00

Table 3. Summary Statistics of the NFS and the Microsimulated Farm Population

	National Farm Survey Sample 1,177 Observations		Microsimulated Farm Population 145,057 Observations	
Variable	***Mean***	***Standard Deviation***	***Mean***	***Standard Deviation***
Rough grazing (acres)	8.87	39.07	3.91	20.64
Total crop and Pasture (acres)	83.17	71.22	72.53	61.13
Gross margin (€)	38980.89	40937.45	35039.79	37645.17
Farm income (€)	22456.92	24618.09	20026.95	22417.42
Grossoutput (€)	55465.31	59268.50	50421.83	54912.12
REPS payment (€)	2386.04	3393.09	1892.79	2959.51
Age (years)	53.95	12.71	54.34	12.83

Table 4. WTP Estimates for the Microsimulated Population of Farmers

County	Average WTP Per Farm	Total WTP per County	County	Average WTP Per Farm	Total WTP per County
Carlow	6.01	22150	Roscommon	6.81	43440
Cavan	6.60	34720	Sligo	5.43	22870
Clare	6.35	40410	Tipperary North	5.89	21770
Cork	6.18	94410	Tipperary South	6.20	23450
Donegal	8.71	73530	Waterford	6.40	17540
Dublin	9.75	14590	Wexford	5.69	25510
Galway	8.49	112680	Wicklow	7.18	16080
Kerry	6.23	50720	Westmeath	6.68	28670
Kildare	6.46	16710			
Kilkenny	6.48	24290	**NUTSIII Region**	Average WTP Per Farm	Total WTP per Region
Laois	6.76	22540			
Leitrim	7.75	27730	Border	6.99	19290
Limerick	6.25	37580	Dublin	9.75	14590
Longford	6.69	16930	MidEast	6.79	71410
Louth	5.93	9420	Midland	6.56	89020
Mayo	7.36	108000	MidWest	6.21	99760
Meath	6.80	38620	SouthEast	6.12	112940
Monaghan	5.38	23020	SouthWest	6.19	145130
Offaly	6.15	20880	West	7.69	264120

Table 5. CVM Interval Regression Results

Variable	Coefficient
Size of Farm (acres)	0.073
	*(2.41)**
Age of Farm Operator	0.084
	*(2.32)**
Organic Nitrogen Production per Hectare (kg)	-0.024
	*(2.03)**
REPS farm^	2.624
	*(2.84)***
Total crops and pasture (acreage)	-0.018
	-1.78
Constant	4.461
	1.79
Log likelihood	-3931
Likelihood Ratio χ squared test	18.89

Absolute value of z statistics in parentheses. * significant at 5%; ** significant at 1%. ^REPS farm indicates that the farmer participates in the Rural Environment Protection scheme (REPS)

Table 6. A comparison of the WTP estimates for the 3 alternative estimation methods

	Average WTP Per Farm	Total environmental value of a corncrake conservation programme
NFS Sample [a]	6.99	1,013,948
Microsimulation Model	6.79	988,260
Payment Card Interval Regression	8.10	1,174,962

a. In this case the average WTP per farm is calculated by adding the WTP values of each individual in the sample together and dividing by the total number in the sample. This mean figue is then multiplied by the total number of farms in the country to estimate the total environmental value of the corncrake conservation programme

Table 7. OLS Regression of Average WTP per ED for Corncrake Conservation

Coefficients	Average WTP per farm per ED
Family Farm Income	0.00002
	*(2.56)**
Size of farm (hectares)	-0.01
	-1.02
Age	0.15
	*(8.66)***
REPS Payment	0.01
	*(10.32)***
% Bog per ED	-3.09
	-1.56
% Wet grassland per ED	-0.38
	-0.64
% Dry grassland per ED	-1.24
	*(5.43)***
% Built land per ED	3.01
	*(4.88)***
% Sand per ED	-45.11
	-1.21
Constant	-0.82
	-0.82
Number of Eds	2850
R-squared	0.11
F(9, 2838) Statistic	32.53 (Prob>F = 0)