Transferring the benefits of water quality enhancements in small catchments.

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Abstract

The Water Framework Directive (WFD) sets targets of "Good Ecological Status" for water bodies across the EU. Environmental regulatory authorities must undertake economic analysis of all waterbodies as part of the process of drawing up catchment management plans. In this paper, we test the transferability of benefit estimates across the kinds of smaller catchments where original benefits estimation is unlikely to be undertaken on grounds of costs. This is done in a context where agricultural-source nonpoint pollution and irrigation water abstraction are the main threats to ecological status.

Jel codes: Q25, Q51.

1. Introduction

The Water Framework Directive's target is to improve surface and ground water quality to a "Good Ecological Status" across Europe. The directive requires that river basins are considered as a whole in integrated river basin management plans and that economic costs and benefits be considered in these management plans (Hanley and Black, 2005). Part of the motivation for this consideration of benefits and costs is to identify cases where improvements to Good Ecological Status (GES) come at what the Directive describes at "disproportionate cost". This has led regulatory bodies in member states to seek cost-effective ways of estimating cost/benefit ratios for the very large number of water bodies covered by the Directive (WATECO, 2004). For many catchments, benefits transfer will be crucial to estimating benefit/cost ratios. In this study we investigate the use of Choice Experiments in such a benefits transfer system. In Scotland, a major water quality issue is non-point or diffuse pollution, in particular from agricultural leaching, whilst low flow episodes due to excessive abstraction from rivers by farmers has also been implicated in river quality problems in Easterm Scotland (SEPA, 1999; Darcy et al, 2000). We thus analyse individuals' willingness to pay for improvements in the ecological status of two, small catchments, through stricter controls on irrigation and on diffuse-source (non-point) pollution.

2. Case Study

The case studies chosen were two small catchments located in Eastern Scotland, the Motray & Brothock. We selected catchments with difficulties in meeting Good Ecological Status on account of the twin problems of high nitrate levels and low summer flows. Low summer flows in both cases are primarily due to surface water abstraction by farmers for irrigating potato crops. High nitrate levels (ie in excess of 11.3 mg/l) are mainly due to fertiliser and manure applications by farmers.

3. Benefits Transfer

Benefit transfer (BT) can be defined as the use of existing valuation information for one or more goods or services to estimate the value of a similar good or service. There are several methodologies which, in principle, can be used when carrying out a BT study. Undoubtedly, the most used has been contingent valuation (see, for example, Ready et al, 2004; Rozan, 2004). However, Morrison et al. (2002) have argued that the Choice Experiment (CE) method has greater potential for benefit transfer since it has the advantage over contingent valuation that it is easier to control for differences in improvements in environmental quality as well as differences in socio-demographics when transferring value estimates, due to the attribute-based approach which CE takes. Rather few BT studies have been carried out, though, using choice experiments (e.g. Morrison et al; Bueren and Bennett; Morgas and Riera). All the studies that tested CE for BT reported above employed either conditional logit (CL) or nested logit model specifications. These specifications assume a homogeneous structure of preferences among respondents. However, there might be advantages to employing an approach which allows for heterogeneity in preferences for benefit transfer purposes. The random parameter logit (RPL) model allows for such variation in preferences across individuals (Train), and is what we use here.

4 Choice experiment design

The Choice Experiment (CE) technique is a stated preference methodology which is now widely used in environmental economics, which aims to elicit individual's preferences from goods usually not traded in markets (such as environmental assets) by constructing hypothetical markets. The random parameter logit (RPL) model (Train 1998), is a generalisation of the standard conditional logit model most often used in CE. The underlying utility function of individual n for the generic alternative j, $U_{jn,}$ is described by:

$$U_{jn} = A_j + \sum_k \beta_{jk} X_{jkn} + \sum_m \gamma_m S_{mn} + \sum_k \eta_{kn} X_{jkn} + \varepsilon_{jn} \quad (1)$$

where A_j is an alternative specific constant,, X_{jkn} is the k^{th} attribute value of the alternative j; b_{jk} is the coefficient associated to the k^{th} attribute, S_{mn}, is the m^{th} socio-economic characteristic of individual n, γ_m is the coefficient associated with the m individual socio-economic characteristic, η_{kn} is a vector of K deviation parameters which represents the individual's tastes relative to the average (β) and ε_{jn} is an unobserved random term that is independent of the other terms in the equation, and which is identically and independently Gumbel distributed. The coefficient vector β_{jk} varies among the population with density $f(\beta|\theta)$, where θ is a vector of the true parameters of the taste distribution. The probability that respondent *n* choose alternative *i* is given by:

$$P_{ni}(\theta) = \int L_{ni}(\beta) f(\beta|\theta) d(\beta) \quad (2)$$

where L_{ni} (β) is the logit probability evaluated at parameters β. In order to estimate the model it is necessary to make an assumption over how the β coefficients are distributed over the population. Here we assume that preferences for all attributes follow a normal distribution except price which is constrained to be fixed (Chen and Cosslett, 1998).

Standard RPL models assume that attributes are uncorrelated so that the r^{th} draw of β_{nk} is taken using a diagonal variance-covariance matrix. This assumption is somewhat difficult to defend in the case of environmental attributes whose attribute levels are likely to be correlated. For instance it is logical to expect that people who like a “slight improvement” in ecological condition will also like a “big improvement” in ecological condition. Because of this, in addition to the standard RPL model, we estimate a RPL model that allows for correlation among attributes. The model specification is more complex, since it requires the addition of the six covariance parameters which are allowed to differ from zero as shown in equation 3.

$$\Gamma_\beta = \begin{bmatrix} \sigma^2_{job} & & & \\ \sigma^2_{job,\ flow} & \sigma^2_{flow} & & \\ \sigma^2_{job,\ ecol1} & \sigma^2_{flow,\ ecol1} & \sigma^2_{ecol1} & \\ \sigma^2_{job,\ ecol2} & \sigma^2_{flow,\ ecol2} & \sigma^2_{ecol1,\ ecol2} & \sigma^2_{ecol2} \end{bmatrix} \tag{3}$$

The estimation of the RPL model with correlated coefficients follows exactly the same steps as the standard RPL model, with the difference that the draws of the β_{nk} are made from a distribution $f(\beta|\theta)$ whose variance-covariance matrix is as per equation 3, instead of being diagonal.

Choice Scenarios

In order to estimate the benefits of improving water quality in the case study catchments it was necessary to identify the current situation, potential improvements to this situation, and the attributes which could be used to describe these. Attributes considered mainly related to river flora and fauna, but also included bad smells from the river if a eutrophic state were reached. Policy options related to measures taken with respect to abstraction of water by farmers in each catchment for irrigation, and controls over fertilizer applications and manure management.

Background information on threats to local water quality and options available to improve the situation was included in the survey instrument. A series of 4 choice cards was then presented to individuals. Each choice card asked respondents to choose between the status quo (implying "inevitable" worsening if no action were taken) with no impact on jobs or the costs faced by households, and two alternative policy scenarios. These policy scenarios were expressed in terms of combinations of ecological improvement (described as slight improvement or big improvement), flow rate (months of low flow), employment (local agricultural jobs lost or gained) and the cost. The payment vehicle for any policy action to improve water quality over this baseline was increases in local water rates as part of household's council tax bill.

A mail survey was used to collect responses, with addresses being selected on a random basis from registers of voters living in each catchment. The response rate was around 30% in both catchments.

5. Results

Table 1 presents the estimates of the RPL models for the two water bodies and of a pooled model obtained by stacking the two databases. For both the Motray and Brothock models all of the choice attributes enter with the expected sign and are statistically significant. A decrease in the number of low flow days and an increase in the ecological quality of the river both increase utility. A "big" improvement in river ecology is valued more than a "slight" improvement. Protecting local jobs in the agricultural sector also seems to generate positive utility for respondents, even though very few people are actually employed in this sector. The two models show a very similar pattern in terms of preference heterogeneity, as can be seen from an examination of the standard deviation terms. Indeed, respondents' preferences are heterogeneous in all the attributes considered except river flow conditions.

A comparison of preference estimates between the two rivers needs to allow for the fact that the model parameters are confounded with a scale parameter which is inversely proportional to the variance of the random term. We thus perform a grid search technique as proposed by Swait and Louviere (1993) using the pooled, stacked data sets by rescaling the Brothock dataset. The estimated variance-scale ratio is 0.95, which implies that the Brothock sample has somewhat lower response variability than the Motray sample. The likelihood ratio test statistic for a comparison of the choice model parameters is -2*[-479.5 - (-225.8 + -252.0)]= 3.4. The critical chi-square value is 16.91 at the 5 per cent significance level (9 degrees of freedom); hence the hypothesis of parameters equality cannot be rejected. A further step is to test for differences in the random component variance by assuming that the variance-scale ratio is the same across datasets. The likelihood statistic in this case is -2*[-481.6 – (-479.5)]= 4.2 which is greater than the tabulated chi-square value with 1 degree of freedom. Thus, we reject the hypothesis of equal random component variance while retaining the hypothesis of equal utility parameters.

The approach used so far considers attributes to be independent of each other. As noted above, this assumption is somewhat difficult to support in the case of environmental attributes since environmental processes are often highly correlated, whilst preferences may also be correlated across attributes. Table 2 shows the coefficients of RPL models estimated by allowing free correlation between attributes.

Turning to the model coefficients in Table 2, it is possible to observe that the signs of the coefficients do not change when correlation is permitted. If we compare the

RPL models with and without correlation, using a likelihood ratio test, it can be seen that the Motray water models do not differ (LR= 10.22 χ^2_6=12.59) whilst the Brothock model does. Nevertheless, for BT purposes it is more important to check if the implicit prices and welfare measures are transferable and if and how the model specification can affect the transferability of these measures.

Table 3 shows the implicit prices for each attribute for the Motray, Brothock and for the pooled models. As can be seen, the implicit price estimates indicate that a "big improvement" in river ecology is the most valued improvement, since household willingness to pay is between £24 and £28 over the base case of "worsening" ecological conditions. A reduction in the number of low flow instances is valued at £2.70-£3.87 per household per month reduction in low flows.

Several tests were carried out to compare implicit prices across samples and model specification. The method outlined by Poe et al. (1994) is used to test for differences. Comparing first the Brothock and Motray waters implicit prices (test H_{01}) for the model with independent attributes it is possible to see that the implicit prices for improvements in river flow and for a "big improvement" in ecological conditions differ. This also happens in the model with correlated attributes. However, there are no significant differences between the two catchments for willingness to pay for incremental improvements in local farm jobs, or for an improvement in river ecology from "worsening" to "slight improvement". The pooled model can be thought of as the potential basis for a benefits transfer system, since it combines information from both catchments. If we compare the implicit prices of the pooled model with the ones of the Brothock ($H_0$2) or Motray waters ($H_0$3) it is possible to observe that one of the four implicit prices is different in the first case and three of the four are different in the second case. The model that allows for correlation shows a higher similarity between the implicit prices of the pooled model to the ones of the single sample models, as three of the four implicit prices do not differ statistically.

Table 4 examines welfare estimates for a number of policy scenarios, all designed to improve river quality towards Good Ecological Status. Compensating surplus estimates are calculated using the standard Hanemann utility difference expression. Using the "no correlation" version of the choice model, Table 4 shows that households are, on average, willing to pay £56 (Motray) [95% confidence interval £45.86-£67.93] and £62 (Brothock) [95% confidence interval £44.06 - £83.93] for the improvements over the baseline described in Scenario 1. Values for Scenarios 2 and 3 are £67 and £97 per household per year for Motray, and £72 and £103 for Brothock. We thus see that the same improvement is slightly more highly valued in the Brothock than in the Motray, although the difference is not statistically significant at the 95% level, using the Poe et al (1994) test. In other words, a benefit transfer exercise that used data from the Motray to predict the benefits of an improvement in water quality in the Brothock would not produce statistically significant errors. This is an encouraging finding from an environmental regulator's perspective. Using the model that allows for correlation shows a similar pattern, save that the compensating surpluses estimates are much greater in the Brothock sample. This was expected given the higher willingness to pay for all attributes in the Brothock water. The Poe et al. (1994) test reveals that the compensating surpluses are now statistically different at the 95% level, but not at the 90% level.

6. Conclusions

The Water Framework Directive requires good ecological status be achieved in all water bodies, unless regulators can show that the costs of achieving this improvement are “disproportional” to benefits. Our analysis focussed on two small catchments in the East of Scotland, whose quality was predominantly impacted upon through fertiliser runoff and irrigation water abstraction for agriculture. We have argued that original valuation studies commissioned as part of implementing the WFD are likely to be unusual due to time and budgetary considerations, and will most likely be restricted to large, controversial cases. Analysis of the viability of benefits transfer showed that transfer of the valuation of the analysed policies between sites was possible, particularly for the transfer of welfare estimates of the benefits of different policy options. Values associated with improvement in the Brothock catchment tended to be higher than those for the Motray catchment, but not always significantly so. As the Brothock had an initially worse condition in terms of ecology and low flows, and since improvements were studied relative to this starting point, this result is consistent with standard economic theory given diminishing marginal utility in environmental quality.

Table 1: Random Parameter Logit results (independent attributes)

	Motray (n=348)		Brothock (n=344)		Pooled (n= 692)	
	Coeff.	Std errors	Coeff.	Std errors	Coeff.	Std errors
Mean effects:						
Local Farm Jobs	0.594*	0.113	0.414*	0.082	0.511*	0.074
Flow	-0.653*	0.161	-0.307**	0.125	-0.420*	0.111
Ecology level 1	1.513*	0.344	1.199*	0.353	1.322*	0.244
Ecology level 2	4.052*	0.684	3.218*	0.598	3.626*	0.455
Tax	-0.169*	0.025	-0.114*	0.020	-0.140*	0.017
Standard deviation terms:						
Jobs	0.401*	0.129	0.239**	0.100	0.344*	0.083
Flow	0.231	0.286	0.033	0.276	0.395	0.283
Ecology 1	1.314*	0.355	1.498*	0.458	1.631*	0.297
Ecology 2	2.492*	0.512	2.480*	0.602	2.614*	0.429
Log Likelihood (pseedo-R2)	-225.78 (0.37)		-252.01 (0.31)		-481.61 (0.34)	

* Statistically significant at the 1% level; ** statistically significant at the 5% level.

Table 2: Random Parameter Logit results (correlated attributes)

	Motray (n=348)		Brothock (n=344)		Join (n= 692)	
	Coeff.	Std errors	Coeff.	Std errors	Coeff.	Std errors
Mean effects:						
Local Farm Jobs	0.581*	0.121	0.467*	0.115	0.528*	0.083
Flow	-0.813*	0.266	-0.406***	0.244	-0.543*	0.148
Ecology level 1	2.364**	0.945	2.219**	0.993	1.570*	0.355
Ecology level 2	5.143*	1.254	4.572*	1.215	3.982*	0.575
Tax	-0.217*	0.035	-0.127*	0.031	-0.155*	0.021
Standard deviation terms:						
Jobs	0.358**	0.144	0.308*	0.121	0.415*	0.095
Flow	0.772**	0.340	0.425	0.303	0.614*	0.204
Ecology 1	2.536*	0.742	2.146*	0.782	1.645*	0.329
Ecology 2	4.334*	0.792	2.522**	1.347	2.472*	0.560
Log Likelihood (pseedo-R2)	-220.67 (0.38)		-242.76 (0.34)		-467.00 (0.36)	

*Statistically significant at the 1% level; ** statistically significant at the 5% level;
*** statistically significant at the 10% level.

Table 3: Implicit prices and 95% confidence intervals

	Motray	Brothock	Pooled	Ho1 Mo-Br	Ho2 POOL-BRO	Ho3 POOL-MOT
Independent attributes model						
Local Farm Jobs	3.52 (2.38; 4.66)	3.63 (2.41; 4.98)	3.65 (2.81; 4.48)	0.13	0.46	0.23
River Flow Conditions	3.87 (2.52 ; 5.07)	2.70 (0.90 ; 4.21)	3.00 (1.74 ; 4.25)	0.00	0.09	0.00
Ecology slight improvement	8.97 (5.41; 12.38)	10.53 (4.57; 17.19)	9.45 (6.25; 12.93)	0.12	0.23	0.01
Ecology big improvement	24.03 (18.53; 31.08)	28.26 (19.65; 40.57)	25.91 (21.10; 31.74)	0.02	0.17	0.04
Correlated attributes model						
Jobs	2.67 (1.90; 3.42)	3.69 (2.64; 5.04)	3.40 (2.67; 4.13)	0.06	0.30	0.00
Flow	3.74 (1.57; 5.55)	3.20 (1.28; 5.30)	3.50 (1.92 ; 4.72)	0.35	0.41	0.20
Ecology slight improvement	10.88 (2.07; 19.29)	17.53 (1.88; 36.96)	10.11 (5.76; 14.39)	0.28	0.16	0.45
Ecology big improvement	23.67 (14.99 ; 31.47)	36.13 (21.89; 55.71)	25.65 (21.04; 31.07)	0.06	0.08	0.18
H04	0.34	0.11	.34			
H05	0.31	0.45	.31			
H06	0.40	0.32	.40			
H07	0.47	0.42	.47			

Table 4: Compensating surplus estimates for different changes in catchment management

		Mean WTP	95% ci	Mean WTP	95% ci	Mean WTP	95% ci
		Motray		*Brothock*		*Pooled*	
Scenario 1: add. Jobs=0, flow =3, ecology = slight improvement	Ind. coef.	56.8	45.8-67.9	62.0	44.0-83.9	58.1	48.6-68.4
	Corr coef.	58.3	33.8-79.1	85.0	*43.3-133.6*	*59.7*	*47.24-72.2*
Scenario 2: jobs = +2, flow = 2, ecology = slight improvement	Ind. coef.	67.7	55.3-80.5	72.0	53.6-93.3	68.4	57.9-79.5
	Corr coef.	67.4	42.1-88.4	95.6	52.8-144.6	70.0	56.5-83.1
Scenario 3: jobs = +5, flow = 1, ecology=big improvement	Ind. coef.	97.2	79.7-115.5	103.3	80.9-133.3	98.9	85.1-114.7
	Corr coef.	91.9	65.8-113.7	128.5	85.22-179.3	99.2	83.2-11.8
V_0 Base: jobs = -2, flow = 5, ecology = worsening							

Notes: “Ind. Coef.” means the welfare measures are calculated from the model which does not allow for correlation between attributes; “Corr. Coef.” means the welfare measures are calculated from the model which does allow for correlation.

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