Comparing Individual-Specific Benefit Estimates for Public Goods: Finite Versus Continuous Mixing in Logit Models

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Summary

Multi-attribute stated preference data, derived through choice experiments, is used to investigate the consequence of a finite number of preference groups in a sample of Yorkshire Water residential customers on the conditional distributions of willingness to pay in the sample. The research focuses on 'public good' values, and retrieves the implicit customer specific welfare measures conditional on a sequence of four observed choices. We assess and contrast the sample evidence for the presence of a finite number of 2, 3, 4 and 5 latent preference groups (classes), and contrast these with the presence of a continuous distribution of parameter estimates using mixed logit models. The main focus is the conditional valuations in the form of marginal values for the consequence of waste water handling and treatment, namely: river water quality, area flooding by sewage, presence of odour and flies, and other water related amenities.

Keywords: Choice experiments, Mixed logit, Latent classes, Individual-specific estimates, Non-market valuation

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Introduction

As well as the provision of water as a private good for residential and business customers, water companies are responsible for management actions that affect the provision of public goods. This is well recognised and for this, as well as social policy reasons, the market operations of such companies are publicly regulated. Water customers pay a flat rate for water provision, either on property value or measured consumption. In the process of water provision the management of water companies has discretion on how to achieve targets of water delivery and waste water disposal to satisfy demand, subject to legal minimum standards. In doing so they also jointly provide certain levels of 'public goods', such as bathing water quality, water quality in rivers, risk of flood in case of piping malfunctions etc.

The supply of water delivery targets is compatible with a large variety of combinations of different levels of related public goods. Optimal supply level will depend of on consumer preferences and willingness to pay for alternative levels of joint supply of the private/public good package. Such preferences cannot be derived from market transactions because customers cannot shop around for different levels of provisions of the public goods associated with water supply. An alternative way to investigate these preferences is via statements of choice.

Stated preference studies have recently established themselves as an important method to guide public good provision in joint production processes. In the recent periodic price review in the UK, which will set the water tariff for 2004-09, a leading UK water company, Yorkshire Water, employed this approach to guide their management decisions in accordance with the preferences of the customers they serve. In this chapter we present the results of a portion of a much larger study. In that study a series of choice experiments was administered to a representative sample of Yorkshire Water residential customers. We focus on two of these choice experiments that address issues of preferences for the quality of 'public good' aspects of waste water disposal and treatment.

The first choice-experiment illustrated here (WW1) deals with the way customers trade-off money with the percentage of area protected from sewage flooding (AF), the percent of river length capable of supporting healthy fisheries and other aquatic life in the long term (RQ), and the number of businesses/households exposed to bad odour and flies (OF). The second experiment reported in this chapter (WW2) looks at how customers trade-off money with the number of areas with waste water discharges designed to allow recreational activities on rivers (AM), and the standard of sewage works and disinfection designed to exceed government standards for bathing water (BB).

In this paper we depart from the conventional way of analyzing multinomial discrete choice responses via multinomial logit model and mixed logit models. The major focus of the analysis is an alternative characterization of preference heterogeneity via finite mixing (Provencher, et al. 2002) or latent class analysis (Boxall and Adamovicz, 2002). This approach, perhaps less elegant and flexible than the continuous mixing allowed by mixed logit, is shown to have some appeal on the basis of ease of interpretation of the utility functions of each preference group, ease of computation, and interpretation of the results obtained. The main feature is that, instead of a continuous of taste intensities for each attribute of choice, it provides the preference structure for each of a small number – two to five – groups in the sample. The probability of membership to each group is endogenous, although the number of groups is exogenously imposed, albeit statistically tested for.

On the basis of such preference estimates, we exploit the panel nature of the dataset to retrieve the distribution of part-worths (marginal willingness-to-pay values) for the individual in the sample, conditional on the individual sequence of observed choices in the choice experiment. This also departs from customary approaches in which the willingness to pay estimates are normally expressed as measures of central tendency of an a-priori distribution, such as mean or median value estimates with their computed standard errors. Instead, we compare and contrast the conditional kernel-smoothed distributions of these values estimated for each individual for as series of finite mixing models and for the mixed logit with normally distributed utility parameters.

In both samples we find statistical evidence in favour of the existence of four distinct preference groups. We argue that in some cases an immediate interpretation of the differences between groups is possible. While most preference structures in the groups are consistent with theoretical expectations in terms of signs, groups representing small fractions of the sample tend to show low significance of parameter estimates. Finally, the graphical representation of the distributions, of individual estimates of willingness-to-pay values for the attributes, show that while the 2 and 3 group latent class models (LCM) portray bi-modal WTP distributions, the 4 -group latent class specification implies WTP distributions very similar to those produced by the normally-distributed mixed logit.

The remainder of the paper is organised as follows. Section 2 first provides a background to the representation of taste heterogeneity in finite and continuous preference mixture logit models; and then briefly discusses the subject of heterogeneity in logit-based random utility modelling. Section 3 documents the data sources; whilst section 4 addresses the econometric issues. The results are presented and discussed in section 5, and section 6 draws some conclusions.

Heterogeneity in random utility-based multinomial logit models

Taste heterogeneity and mixed logit

The last decade has seen much attention paid to the development of alternative forms of modelling heterogeneity of preferences in discrete multinomial choice models based on random utility (Train 2003). It is a fact of life that preferences dictating decision rules vary across both individuals and choices made by the same individual. Taste heterogeneity, as captured by mixed logit models (or random parameter logit) is often quite instructive in this context, and it virtually allows the researcher to approximate any preference structure (McFadden and Train 2000). The notion that parameters of the utility function can vary according to continuous parametric distributions has greatly expanded the number of modelling assumptions available to researchers. Even the few limitations originally imposed by the relative restrictive set of empirically tractable taste distributions has recently been overcome by more flexible forms that allow for censoring and bounding (Train and Sonnier 2003; Hensher and Greene 2003). The underlying hypothesis in this modelling approach is a continuity of preferences over some range of parameter values.

Variance heterogeneity and heteroskedastic logit

Even if preferences are fairly stable, decision contexts and respondent knowledge or cognitive ability may vary, thereby introducing sources of heterogeneity in observed choice. One example of this source is the effect of choice-complexity and respondent familiarity with the choice task on the scale parameter of the unobserved component of utility, as illustrated empirically by deShazo and Fermo (2002). However, for those more inclined to think in terms of heteroskedasticity as the presence of co-variates affecting the error variance, instead of the scale parameter one can make the error variance a function of co-variates (e.g. Scarpa, Ruto et al. 2003). Either approach models heterogeneity affecting the spread of the noise or unobserved component (error) of utility in logit models. These models are normally called heteroskedastic logit, not to be confused with the Heteroskedastic Extreme Value model originally proposed by Bhat (1995). In this category of models a different scale parameter is fitted to each alternative in the set. One interesting recent example of heteroskedastic logit in the context of meta-design is the paper by Caussade et al. 2003, in which factors affecting the design of the choice-experiments are shown to have a systematic effect on the variance of the error term, along with individual-specific covariates.

Observed and unobserved taste heterogeneity

From the researcher's perspective we find it quite useful to think of heterogeneity as observed and unobserved. When some individual-specific variables that the researcher can observe can be linked to systematic differences in choice behaviour, for example by creating interaction terms between attributes or alternatives with such individual-specific variables, then preference heterogeneity across individuals can be captured (Pollack and Wales 1992).

On the other hand, when differences in taste for attributes are known to exist, but the available individual-specific variables cannot adequately capture this variability, then a generic form of heterogeneity of taste can be simply accommodated by mixed logit models, assuming that some attributes have taste parameters distributed according to some distributive law.

Of course, a single dataset can still display an amount of unobserved heterogeneity of taste, when unobserved heterogeneity is accounted for (Scarpa et al. 2001), and hybrid models accounting for individual specific effects on the unobserved component of taste heterogeneity can be estimated. For example, by making the mean of a normally distributed parameter dependent upon some individual-specific variable [Nlogit v.3 allows for such a model, but the default application constrains standard deviations to be the same].

Continuous versus finite taste heterogeneity

Mixed logit models assume heterogeneity to be continuous over the interval spanned by the assumed distribution for the varying taste parameters. For example, if no theoretical reason exists to limit the domain of a parameter value, one can assume a normal distribution. In that case the range of parameter values spans the real line and the values of the estimated mean and variance will dictate the probability with which these values are found in each segment of the line. A correlation structure can also be estimated. For example, if more than one parameter is normally distributed and there are reasons to believe that they are not independent then the correlation structure can be estimated (Train, 1998). The structure of correlation can be informative for joint probability inference and segmentation of taste groups (Scarpa, Spalatro and Canavari 2003, Scarpa and Del Giudice 2004).

However, the computational cost of estimating mixed logit with continuous distributions is high, especially when parameters need to be bounded in their domain for theoretical reasons (Train and Sonnier 2003). Furthermore, some research questions are best answered through the identification of defined preference groups, with homogenous preferences within the group. For example, from the perspective of a water company that wishes to optimize its management plan according to the preferences of its customers, the identification of such preference groups can be informative in allocating services accordingly.

This poses the practical query of identifying the size, number and preference structure of these distinct preference groups. This approach is sometime referred to as finite mixing (Provencher et al. 2002) or latent class modelling (Swait 1994). Although the latent class finite / mixing approach is well established theoretically (Heckman and Singer 1984) and in the econometric application of count models (Cameron and Trivedi 1998, section 4.8), despite its relative merits it does not seem to be very popular in multinomial discrete choice models.

Recent applications include three travel cost revealed preference studies in recreational site choice (Provencher et al. 2002; Shonkwiler and Shaw 2003; Scarpa and Thiene 2004). Provencher et al. 2002 assume group membership to be conditional on individual characteristics and a serially correlated error structure across the sequence of one individual's choices. They conclude that there is evidence of time dependence across choices and that finite mixing (as they called it) is a convenient and intuitive alternative to mixed logit, especially in terms of computational cost. They find evidence for three separate preference groups.

Shonkwiler and Shaw 2003, also assume group membership to be conditional on individual characteristics, and observe how the two-group models they estimate display different marginal utility of income. They suggest that this could be an elegant yet uncomplicated way to allow for non-linear preferences for money. This has implications in the valuation of attributes, which differ across groups. They also, like us in this paper, identify the potential use of posterior probabilities, although they do not seem to use them in the derivation of their welfare estimates.

Scarpa and Thiene (2004) investigate destination choices of rock-climbers in the North Eastern Alps and assume group membership to be semi-parametric. They find evidence of four preference groups and derive individual-specific welfare measures for various attributes and illustrate how to investigate the distribution of benefit and losses from a given policy in the sample.

Recent stated preference applications using latent class models (LCM) include Hensher and Greene (2003), in which the authors use a dataset on choice of road types in New Zealand and systematically contrast the merits of mixed logit with those of latent class modelling. Comparisons are carried out in terms of choice elasticities, distributions of predicted choice probabilities and changes in absolute choice shares. Based on the results from this data-set they conclude that no unambiguous recommendation can be made as to the superiority of any of the two approaches, although they find strong statistical support for the LCM approach with three preference groups.

Boxall and Adamovicz (2002), conduct a lucid investigation using factor analysis to determine the motivational determinants of trips to wilderness, and build individual specific factor loadings that are then used as determinants in the group membership equation. Their analysis supports the existence of four group preferences and a much richer interpretation than a conventional multinomial logit model. They do not contrast this approach with continuous taste heterogeneity models, such as mixed logit.

Scarpa, Drucker et al. 2003, use LCM analysis as an accessory to a more conventional conditional heterogeneity multinomial logit analysis of the choice of piglet breeds, in an effort to value an indigenous pig breed in Yucatan. They find evidence for two distinct preference groups, using membership equations including various individual specific variables.

As both theoretical and empirical evidence on the usefulness of finite mixed logit models is mounting we observe that little attention has been devoted to one of its most promising features to inform decision makers. This is the identification of conditional distributions of attribute valuations. Although conditional probabilities can be computed even with one single choice per individual, the more numerous the panel, the sharper is the estimation of individual posterior statistics. Such a feature is of particular interest in the context of motivating the collection of panel data on consumer’s choice.

Choice experiment data

In spring and summer 2002, as a part of a large-scale investigation into the preference structure of its customers, Yorkshire Water conducted a set of choice experiments. The aim was to characterize the preference for fifteen different attributes related to water provision, called here service factors (SFs). As a result of focus-group activities and discussion with the management, these SFs were separated into five groups, giving rise to five separate choice experiments. The first three were mostly concerned with SFs of a private good nature, and are ignored here. In this study we are concerned with the two choice experiments that addressed attributes of the service that can be commonly interpreted as ‘public goods’.

The first choice experiment, defined here as WW1, looked at four attributes: area flooding by sewage (AF); river quality (RQ); nuisance from odour and flies (OF); and cost of service (change in water bill payment). There were eight levels of payment expressed as increases or decreases on the current bill, while all other attributes were expressed at four levels. The design chosen was an orthogonal main effect factorial with a total of 32 profiles, which were split in sequences of four choices for each respondent.

The second choice experiment looked at three attributes: water amenities for recreation (AM); quality of bathing water (BB), and cost of service. There were seven levels of payment expressed as increases or decreases on the current bill, while all other attributes were expressed at three levels. The orthogonal main effect factorial of choice gave a total of 27 cards, which were also split in sequences of four choices for each respondent.

The survey instrument was tested in a pilot study and further refined as a consequence. It was finally administered face-to-face by personnel experienced in stated-preference questionnaires through a computer-assisted survey. A representative sample of 767 Yorkshire Water residential customers completed the sequence of choices in the first choice experiment for a total of 3,068 choices (sample WW1), and a representative sample of 777 residential customers completed the sequence for the second choice experiment with a total of 3,108 choices (sample WW2).

A full report on the study and the tested validity of the chosen experimental design are available to the interested reader (Scarpa and Willis 2002, Willis and Scarpa 2002).

Econometric issues

The derivation of the latent class logit model is based on a membership equation, and on a choice alternative equation, both of which turn out to have a convenient logit formulation when two independent Gumbel-distributed error components are used.

The membership equation explains the probabilistic assignment into a number of K groups, where K is exogenously defined and outside the space of estimable parameters. The choice probability equation explains the mechanics of probabilistic choice across alternatives based on a conventional random utility framework. For the sake of brevity, and to avoid unduly repetition, we refer the reader to cited works for the details of the formal derivation. In this study, we have adopted the approach documented in Hensher and Greene (2003), which is conveniently applicable using Nlogit version 3.

In brief, our specification does not use any socio-economic covariate in the membership probability specification, which assumes therefore a semi-parametric format for the membership probabilities. The utility function for each of the three alternatives in each choice context is simply specified as a function of the attribute values.

The main focus of this study is to compare estimates of marginal WTP for attributes conditional on the sequence of observed choices from a balanced panel. We run this comparison across different group-sized latent class models (2, 3 and 4 LCM), and with the mixed logit specification with all attributes but cost distributed normal and zero off-diagonal covariance (MXL). The emphasis on conditional WTP estimate is justified on the basis of the interest that a water company can have in identifying groups with specific public-good preferences and WTP amongst its customers, so as to better address and target management plans. In what follow we describe in some detail the derivation of the individual WTP values from the LCM and MXL models.

Derivation of conditional WTP estimates from LCM models

Consider a population with *c* preference-groups (or classes) and a sequence of four observed choices per *t* individual over *J* alternatives, including the status-quo. Given a sequence of four choices by the same individual and conditional on belonging to a given preference group or class *c*, say for example class *A*, the joint logit probability of a sequence is:

1) $$P_{jt} \mid A = \prod_{t=1}^{4} \frac{\exp(\boldsymbol{\beta}_A{}'\mathbf{x}_t)}{\sum_{J(t)} \exp(\boldsymbol{\beta}_A{}'\mathbf{x}_{j(t)})}$$

With the individual probabilities of membership to a group *c* defined as Q_{tc} one can derive the unconditional probability taking the expectation over all the *c* classes:

2) $$P_{jt} = \sum_{c=1}^{C} Q_{tc} \prod_{t=1}^{4} \frac{\exp(\boldsymbol{\beta}_c{}'\mathbf{x}_t)}{\sum_{J(t)} \exp(\boldsymbol{\beta}_c{}'\mathbf{x}_{j(t)})},$$

where in this study the *C*= 2, 3, 4 and 5.

A conditional estimate of the individual-specific class probability can be obtained given the observed sequence of four choices and using Bayes' formula:

3) $$Q_{tc}^{*} = P_{jtc} \mid y_t,\ \mathbf{x}_t = \frac{Q_{tc} \prod_{t=1}^{4} \frac{\exp(\boldsymbol{\beta}_c{}'\mathbf{x}_t)}{\sum_{J(t)} \exp(\boldsymbol{\beta}_c{}'\mathbf{x}_{j(t)})}}{\sum_{c=1}^{C} Q_{tc} \prod_{t=1}^{4} \frac{\exp(\boldsymbol{\beta}_c{}'\mathbf{x}_t)}{\sum_{J(t)} \exp(\boldsymbol{\beta}_c{}'\mathbf{x}_{j(t)})}},$$

where y_t and $\mathbf{x}_t$ are respectively the observed choices and the attributes of the alternatives in the choice set.

Given this set of individual-specific probabilities of membership in each preference-group *c*, one can derive individual-specific conditional estimates of the marginal WTP as:

4) $$W\hat{T}P_t = \sum_{c=1}^{C} Q_{tc}^{*} \left(-\tfrac{\beta_c}{\gamma_c}\right),$$

where $\hat{\gamma}_c$ is the marginal utility of money.

Notice that Nlogit v. 3 allows you to store the values for the posterior individual parameter $\hat{\beta}_t = \sum_{c=1}^{C} Q_{tc}^{*} \beta_c$ by using the subcommand ";parameters" in the vector "beta_i". However, setting

5) $$W\hat{T}P_t = \frac{\sum_{c=1}^{C} Q_{tc}^{*} \beta_c}{\sum_{c=1}^{C} Q_{tc}^{*} (-\gamma_c)} = \frac{\hat{\beta}_t}{-\hat{\gamma}_t}$$

is obviously incorrect. So, this part was computed in Gauss.[1]

Derivation of conditional WTP estimates from MXL models

Train (2003, Ch. 11) discusses the derivation of posterior means for normally distributed parameters of taste, conditional on observed choices in mixed logit models.

In our mixed logit specification the marginal utility of income γ is fixed, so the distribution of estimates for the individual specific WTP for each attribute is given by the mean of the individual parameter distribution $\bar{\beta}_t$ divided by $-\gamma$, which is assumed to be fixed.

In general, $\bar{\beta}_t$ is to be found by taking the expectation of the parameter over the parameter distribution conditional on observed choices and parameter estimates:

6) $$\bar{\beta}_t = \int \beta \cdot h(\beta \mid y_t, x_t, \theta) d\beta$$

By Bayes' rule:

7) $$h(\beta \mid y_t, x_t, \theta) = \frac{P(y_t \mid \mathbf{x}_t, \beta) g(\beta \mid \theta)}{P(y_t \mid \mathbf{x}_t, \theta)} = \frac{P(y_t \mid \mathbf{x}_t, \beta) g(\beta \mid \theta)}{\int P(y_t \mid \mathbf{x}_t, \beta) g(\beta \mid \theta)}$$

where $g(\beta \mid \theta)$ is the assumed distribution of the parameter in the entire population (in our case assumed to be normal, so $\theta = \{\mu, \sigma^2\}$). So:

8) $$\bar{\beta}_t = \int \beta \cdot h(\beta \mid y_t, x_t, \theta) d\beta = \frac{\int \beta P(y_t \mid x_t, \beta) g(\beta \mid \theta) d\beta}{\int P(y_t \mid x_t, \beta) g(\beta \mid \theta) d\beta}$$

Because of the non-closed form of these expressions, in practice one uses simulation methods. Posterior simulated estimates of $\bar{\beta}_t$ can be obtained in Nlogit v.3 for each individual by using the subcommand ";parameters" in the "RPL" estimation routine and are automatically stored in the matrix "beta_i". The one used here were obtained using 100 Halton draws (Train, 2000).

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[1] We understand from personal communication from Bill Greene, the author of Nlogit and LimDep, that future versions of Nlogit will include a routine to compute these values.

Number of groups with different preferences

The number of groups with different preferences is not part of the maximization process from which the parameter estimates are derived. In other words it is outside the space of the estimable parameters. The conventional specification tests used for maximum likelihood estimates (likelihood ratio, Lagrange Multipliers and Wald tests) are not valid in this context because they do not satisfy the regularity conditions for a limiting chi-square distribution under the null.

Resampling from the empirical distribution is feasible but very impractical because of the computational complexity it involves. As a guidance some authors have used the Akaike information criterion: $AIC = -2 \times \ln L - P$, where $\ln L$ is the log-likelihood of the model at convergence, and P is the number of estimated parameters in the model. Others have suggested the Bayesian Information Criterion: $BIC = -\ln L + (P/2) \times \ln(N)$, where N is the number of respondents. Boxall and Adamovicz (2002) also used the Akaike Likelihood Ratio index, which we omit here, since the other two methods provide concordant conclusions. However, these criteria also fail some of the regularity conditions under the null for a valid test under the null (Leroux, 1992). The AIC is reported to over-estimate the number of groups, while the BIC does not do this, asymptotically, although in small sample sizes it tends to favour too few groups (McLachlan and Peel 2000).

Results and discussion

For the sake of space we omit the presentation of all the model estimates. The testing for the number of preference-groups is reported in Table 1 and it is consistent with the hypothesis that there are four distinct groups of preferences in the sample in each of the two choice-experiments. We hence only present the LCM estimate for 4 classes along with the more ‘conventional’ mixed logit model with normally distributed parameters. Such estimates are presented in Tables 2 and 3.

The descriptive statistics of the distribution of conditional WTP estimates are reported in Tables 4 and 5. However, these distributions are best illustrated graphically by means of normal kernel densities in Figures 1-5, discussed below.

Preference groups for WW1

Three attributes were investigated in this experiment. The attributes could either be improved by YW management from the status quo condition at an additional cost to customers; or they could be decreased at the advantage of a lower water bill for customers.

One attribute (RQ) was defined as “the percent of river length capable of supporting healthy fisheries and other aquatic life in the long term” and has the character of a pure public good. The other two were (AF) defined as “percent of areas protected from sewage escape in gardens, roads, paths and open areas" and (OF) "number of households & businesses affected by odour & high numbers of flies from sewage treatment works". Attributes AF and OF concern goods whose benefits are probably perceived by most respondents as accruing to other members of the collective, and were therefore special types of mixed public goods. For OF the expected sign for the taste parameter is negative for people who value improvement, as fewer houses affected means better quality.

The latent class analysis is consistent with the presence of four groups of preferences in the sample. The highest probability (57.33%) belongs to preference Group A, followed by preference Group B with 21.68%. Preference Group C and D have 17.67 and 3.32 percent respectively.

Estimates for the taste parameters for attributes are all significantly different from zero at conventional levels only in Group A, the group with largest probability. This group shows WTP estimates slightly larger but not dissimilar from those obtained by the conventional MNL model, except for the OF attribute for which this group seem to have a marginal valuation of £1.22, rather than £0.93.

Group B and C have relatively high significance but they do not reach conventional significance levels. Group B has valuations practically identical to Group A, while the valuations in Group C are smaller by at least a factor of 10 for AF and RQ, and less than half those for OF. This result is consistent with the existence of a small segment of customers (17.7%) with low values for these public goods. Group D has the smallest probability and its parameter estimates show lowest precision, so this group is ignored in the discussion.

Distribution of conditional WTP estimates for Area Flooding

As can be seen the plot of the kernel estimates in Figure 1 shows the conditional WTP for each LCM model and for the MXL one. The 2-group LCM (dashed line) displays a bi-modal distribution implying the existence of 2 groups, one with large and another with smaller WTPs. The 3-group LCM (dotted line) is also bi-modal, but one modal value is negative, contrary to what one would expect, and altogether the distribution implies a much larger spread, with 0.41% of the respondents displaying negative WTPs for this attribute. The MXL estimates (continuous line) and the 4-group LCM (dashed/dotted line) display similar one-peaked modal values, although the latter shows 4.56% of respondents with negative values.

Distribution of conditional WTP estimates for River Quality

Figure 2 reports similar plots but for the conditional distributions of WTP for River Quality. Again, the dashed line of the 2-group LCM displays a bi-modal distribution implying the existence of 2 groups, one with large WTPs and another with WTPs centred round zero. The dotted line for the 3-group LCM also implies a WTP distribution centred round zero with a much larger spread and 41% of individuals displaying negative WTPs. The estimates from MXL and from the 4-group LCM display similar one-peaked modal values, and both seem more consistent with a-priori expectations as they have much smaller portions of the densities with negative values.

Distribution of conditional WTP estimates for Odour and Flies

Figure 3 shows the plots of kernels smoothing for the WTP for the number of households exposed to nuisance from Odour and Flies. WTP is negative because of the way the variable was coded, as improvements are represented by a lower number of households, hence a decrease in this value increases utility. The pattern observed for the 5 distributions is very similar to the one for Area Flooding, although it is developed along the negative orthant. Again MXL estimates are closest to 4-group LCM ones.

Altogether, in this sample the conditional WTP predictions from the LCM analysis results show that the selection procedure for the number of groups identifies a group composition of four preference groups. Such a model is producing conditional WTP distributions consistent with economic theory and not very dissimilar from those obtained by the mixed logit model with normally distributed parameters for the non-monetary attributes.

Preference groups for WW2

This choice experiment investigated preferences for the ability to use inland waters for recreation (AM), and for improvements in the quality of bathing beaches (BB) above the current mandatory standard. In the choice experiment only improvements from the status quo were investigated. So, there was no option to reduce the level of provision and gain a reduction in the water bill in this case. The latent class estimation identified four distinct preference groups, three have large probabilities (Group A 35.05%, Group B 28.41% and Group C 29.38%), while the fourth (Group D) has only 7.15%.

When values for AM are estimated using the conventional logit model (MNL) one obtains £0.41 per each additional area with waste water discharges managed so as to allow recreational activities on rivers. In the LCM results, however, it can be seen that in Group A the average valuation is 50% higher than the MNL, while in group B is ten times higher and in group C nearly ten times smaller, although it does not reach the conventional levels of statistical significance. The valuation for Group D, instead is not statistically different from zero.

The MNL values for bathing water quality (BB) for each consecutive 50% improvement on the current standard is very low: £0.08. LCM analysis reveals that customers in the largest Group A have a valuation of similar magnitude to that obtained by MNL. However, the valuation by Group B is ten times higher at £0.83, while Group C has a valuation less than half the MNL estimate. Again, the valuation for the smallest group (only 7.2%) cannot be discussed due to lack of significance of the parameter estimates.

The fact that Group B has a valuation for these attributes of water management ten times higher than the MNL is consistent with a high concern for amenity-related public good provision amongst a fraction of the Yorkshire

Water residential customers. This group has a probability of 28.41%, nearly 1/3 of the sample. On the other hand, a similarly sized fraction (29.4%) represented by Group C, seem to value these goods much less, and such a result is consistent with a polarization of tastes, perhaps linked to diversity in use values from recreation.

Distribution of conditional WTP estimates for water quality of bathing beaches

Figure 4 shows the kernel smoothing plots of individual WTP for water quality of bathing beaches. As in all the other cases the dashed and dotted lines of respectively the 2-group and 4-group LCM show a bi-modal distribution. The former with a much large taller peak, while the latter with two similar sized ones. Altogether they predict small variation in WTP values.

The dashed/dotted line for the 4-group LCM WTP distributions and the continuous line for the mixed logit show a completely different picture. They both represent a much spread out distribution, with great variability. In particular, the 4-group LCM shows a bi-modal distribution with a large fraction of respondents spread around £0.8 per each extra area "with waste water discharges designed to allow recreational activities on rivers". This group of customers might be keen recreationists, or people who care strongly for the quality of water that the water company can provide in bathing beaches.

Distribution of conditional WTP estimates for Water Amenities

A similar pattern is observed in Figure 5 for the plots for WTP for water amenities. The distributions of predicted conditional WTPs for 2 and 3 group LCM show a bimodal and narrowly spread pattern, while those for the mixed logit and 4-group LCM show a much more spread out distribution, only the latter, however, shows high densities of conspicuous values. This result would seem to indicate that care must be paid in selecting the adequate model when the purpose is the analysis of conditional WTP distributions. The choice of model can disguise some patterns that might be of interest to water managers, such as clear taste segmentation into separate preference-groups, rather than a continuum of taste intensities.

In this case the statistical evidence from the log-likelihood values obtained in the analysis would seem to lend some support to the hypothesis that a finite group of 4 sets of preferences exists in the sample. The mixed logit assumption rests on the belief that taste attributes have a specific continuous distribution, in our case the normal. There is no test that can be performed to compare LCM with MXL, and hence the choice of heterogeneity specification ultimately rests with the researcher and her beliefs. In our empirical case the log-likelihood values are once in favour of the 4-group LCM, in the WW1 sample, and once in favour of the MXL, in the WW2 sample. The LCM approach, however, may be desirable in some respects: it does not require distributional assumptions, the estimates are relatively easier to compute (no simulation methods are needed), and it is consistent with the existence of well-defined segments in the market for the public good. Finally, at least with respect to the conditional distribution of WTP values, LCM estimation seems to produce a richness of information similar to the mixed logit estimation.

Conclusions

This chapter explores alternative ways of modelling heterogeneity of tastes for attributes of a composite public good via choice experiments. It contrasts two advanced modelling techniques, the use of the mixed logit random parameter model with the use of latent class models, to explain water company customer choice; and to derive welfare estimates of changes in the levels of provision of a number of ‘public goods’ jointly produced as a function, in part, of changes to waste water treatment.

The mixed logit approach requires the analyst to specify a-priori a parameter distribution in the population (normal, log-normal, uniform, etc.), which is assumed to characterise the heterogeneity of preferences for that attribute. The choice of distribution from which to report WTP estimates is then determined by whatever mixed logit model is perceived to have the best ‘goodness-of-fit’ statistics and theoretical consistency.

Latent class modelling (or finite mixing) does not require any assumptions about the mixing variable: in a sense LCMs ‘let the data speak’. LCMs provide further insights into the data by identifying groups of customers who have high or low preferences for particular ‘public goods’; and the share of water company customers that these potential purchasers represent. Such form of segmented information is potentially very useful to company managers for a wide range of purposes. The LCM analysis could be readily extended to assess the significance that socio-economic characteristics of customers, such as income or ethnicity, as well as attribute or SF levels have on choice.

There is no unambiguous test of the superiority of one approach (mixed logit or LCM) over the other. However, the LCM approach may offer insights into the heterogeneity of consumer preferences that are not readily identifiable through a traditional mixed logit random parameter model, especially when there are reasons to believe that these are clustered around certain values.

Finally, we focussed on estimates of welfare conditional on observed choice, in the form of the distribution of marginal willingness to pay values, rather than focussing on more conventional estimates of central tendency based on a-priori statistics. Conditional distributions are obviously more informative than single values, and they should be pursued when possible. We would also argue that conditional estimates display richer information because they are informed by the observed sequence of choices. Water companies intending to adequately characterize the preferences of their customer base should endeavour to collect panel data from representative samples. This paper shows that even with as few as four choices conditional distributions can be usefully derived and studied. Other literature illustrating similar results in this field includes Hensher and Greene (2003), Scarpa and Thiene (2004) and Greene et al. (forthcoming).

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Choice experiment ww1			N = 767	
LCM groups	Parameters	Log-lik.	AIC	BIC
1	4	-2213.78	4429.55	2227.06
2	9	-2092.13	4188.26	2122.02
3	14	-2063.60	4133.20	2110.10
4	19	-2027.00	4062.00	2090.10
5	24	-2020.26	4050.52	2099.97

Choice experiment ww2			N = 777	
LCM groups	Parameters	Log-lik.	AIC	BIC
1	3	-2776.10	5554.21	2786.09
2	7	-2484.98	4973.96	2508.27
3	11	-2431.74	4869.47	2468.34
4	15	-2372.22	4752.43	2422.13
5	20	-2372.22	4754.43	2438.77

Table 1. Tests for group numbers in latent class models

N=767, choices= 3,068	4-Groups LCM lnL = -2027, Adj.R^2=0.397				MXL ln Sim.L = -2164, Adj.R^2=0.357	
	Group A	Group B	Group C	Group D	Mean	St.Dev.
Area Flooding (AF)	0.012 (12.21)	0.950 (1.58)	0.451 (1.32)	0.710 (1.13)	0.017 (10.67)	0.015 (4.36)
River Quality (RQ)	0.062 (20.12)	6.192 (1.10)	1.311 (1.53)	2.730 (1.03)	0.114 (17.80)	0.081 (10.43)
Odour and Flies (OF)	-0.103 (-19.94)	-9.487 (-1.63)	-11.094 (-1.60)	-2.600 (-1.02)	-0.179 (-14.12)	0.099 (6.64)
Cost	-0.084 (-17.13)	-7.128 (-1.65)	-27.674 (-1.54)	2.267 (1.03)	-0.161 (-20.22)	n.a.
Group Probability	0.573 (24.68)	0.217 (9.98)	0.177 (9.04)	0.033 (3.88)		

Table 2. Model estimates for sample WW1, asymptotic *z*-values in parenthesis

N=777, choices= 3,108	4-Groups LCM lnL = -2,752, Adj.R^2=0.304				MXL ln Sim.L = -2,328, Adj.R^2=0.317	
	Group A	Group B	Group C	Group D	Mean	St.Dev.
Water Amenities (AM)	0.451 (6.75)	0.166 (15.70)	0.010 (1.38)	-10.005 (0.00)	0.160 (11.15)	0.038 (15.54)
Bathing Beaches (BB)	0.056 (6.82)	0.033 (23.50)	0.007 (7.73)	-0.211 (-4.23)	0.028 (14.11)	0.081 (13.13)
Cost	-0.704 (-7.29)	-0.039 (-3.415)	-0.216 (-17.93)	1.777 (3.50)	-0.305 (-20.56)	n.a.
Group Probability	0.350 (10.97)	0.284 (9.52)	0.294 (11.65)	0.072 (7.41)		

Table 3. Model estimates for sample WW2, asymptotic *z*-values in parenthesis

	LCM-2	LCM-3	LCM-4	MXL
Area flooding with sewage				
Mean	0.1260	0.0356	0.1035	0.1036
St.Dev.	0.0488	0.0990	0.0531	0.0327
Median	0.1687	0.1225	0.1103	0.1038
Kurtosis	-1.7127	-1.7550	25.3722	0.8207
Water quality in rivers				
Mean	0.5999	0.1964	0.5970	0.7085
St.Dev.	0.1878	0.4153	0.2489	0.2845
Median	0.7642	0.5608	0.5760	0.7771
Kurtosis	-1.7127	-1.7550	18.3691	0.3625
Nuisance from odour and flies				
Mean	-0.9864	-0.8187	-1.0404	-1.1104
St.Dev.	0.3393	0.4165	0.2954	0.2515
Median	-1.2832	-1.1842	-1.0287	-1.1734
Kurtosis	-1.7127	-1.7550	15.6647	4.7375

Table 4. Statistics of the conditional distributions of WTP in the sample WW1

	LCM-2	LCM-3	LCM-4	MXL
Water amenities				
Mean	0.4316	0.5705	2.4119	0.5155
St.Dev.	0.4772	0.2140	1.7605	0.5815
Median	0.6764	0.5895	1.7713	0.5741
Kurtosis	1.1024	-1.5857	-1.1759	-0.4934
Water quality in bathing beaches				
Mean	0.0787	0.1062	0.3560	0.0945
St.Dev.	0.0637	0.0482	0.2857	0.0961
Median	0.1114	0.1105	0.2323	0.1059
Kurtosis	1.1024	-1.5857	-1.2139	-0.6479

Table 5. Statistics of the conditional distributions of WTP in the sample WW2

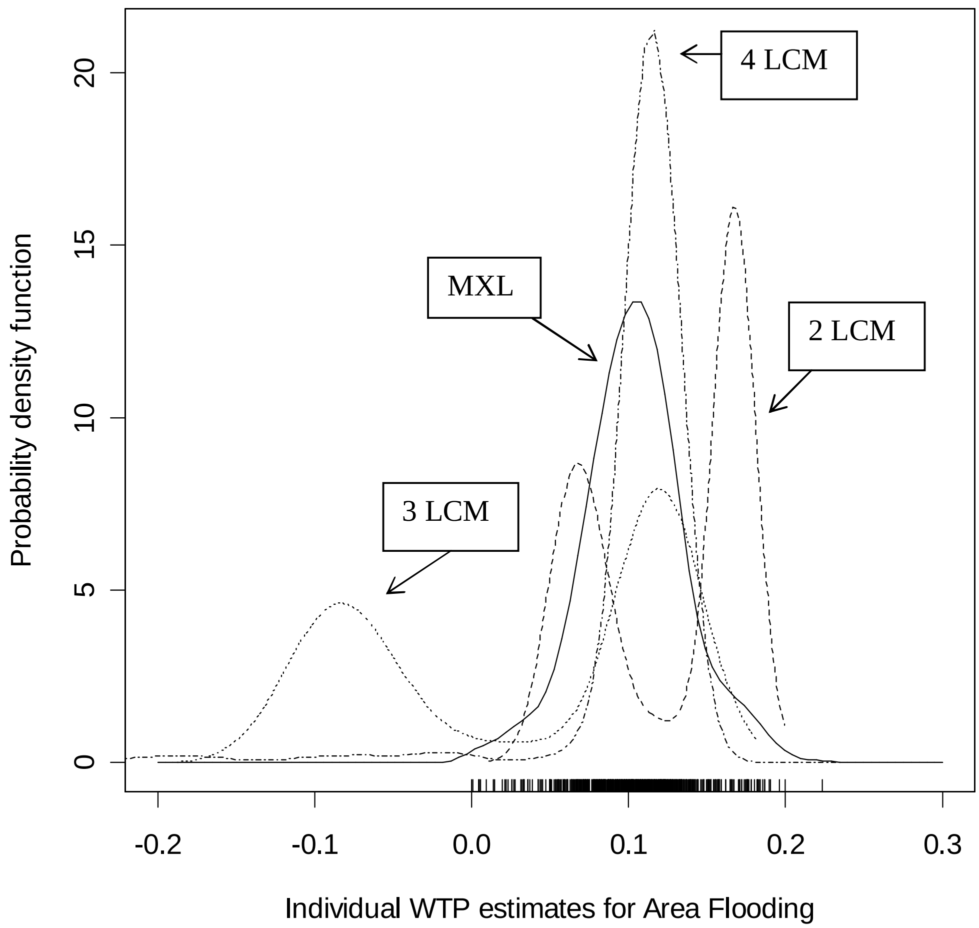

4 LCM
MXL
2 LCM
3 LCM
Probability density function
0
5
10
15
20
-0.2
-0.1
0.0
0.1
0.2
0.3
Individual WTP estimates for Area Flooding

Figure 1

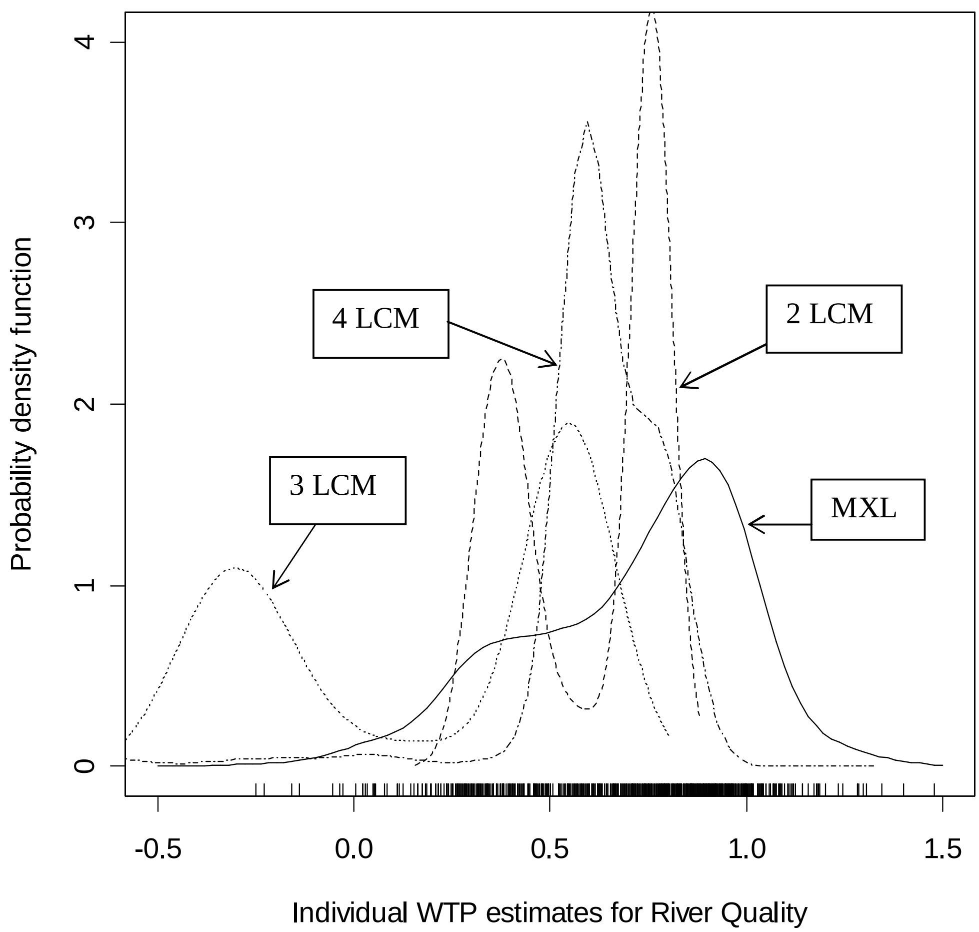
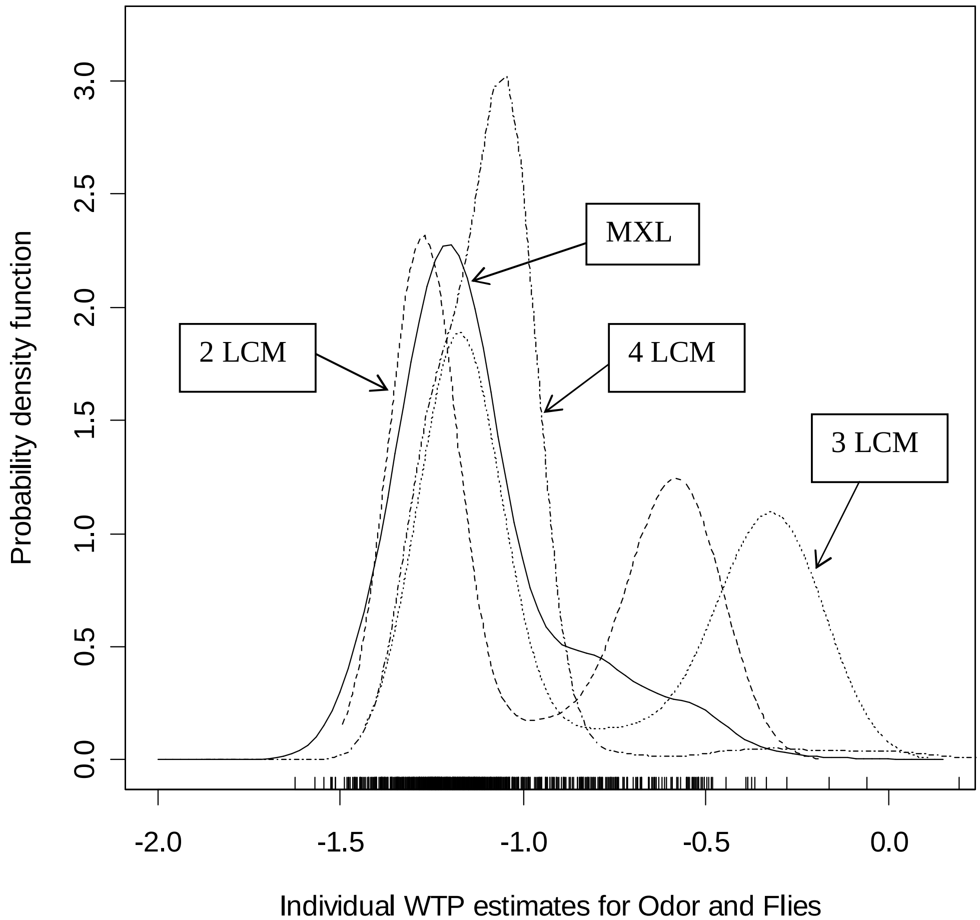
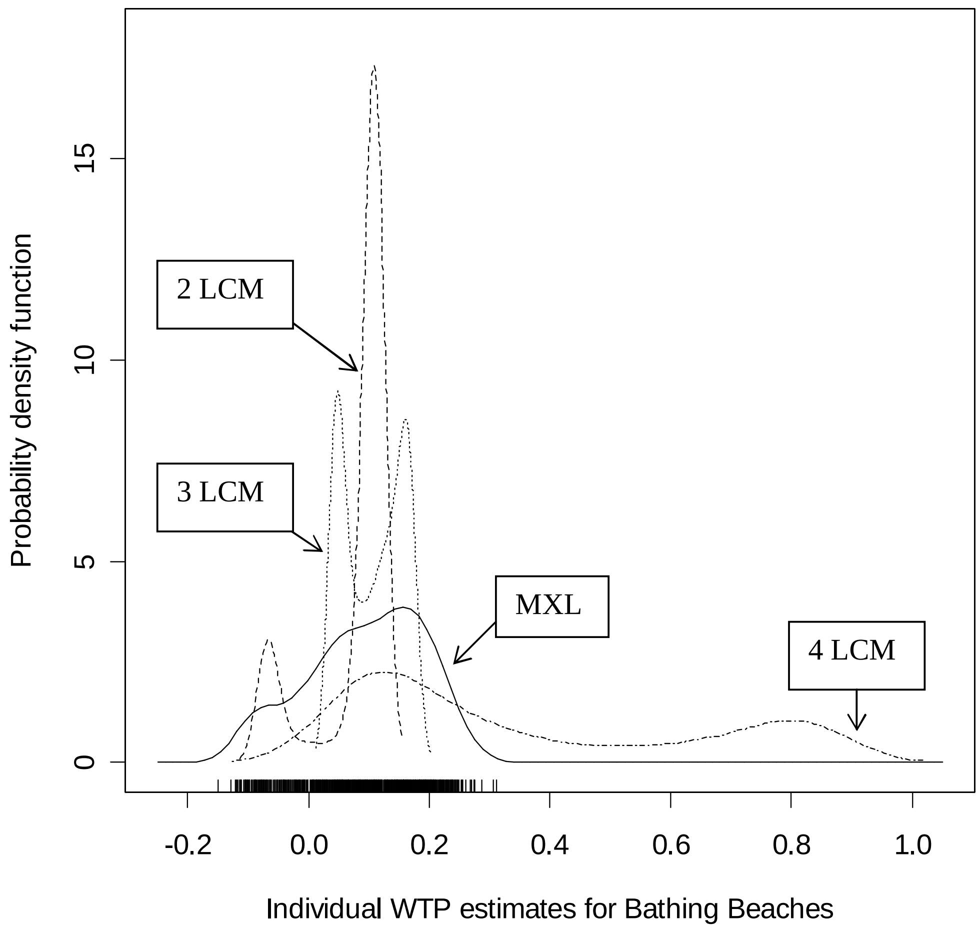

Probability density function
4
3
2
1
0
4 LCM
2 LCM
3 LCM
MXL
-0.5
0.0
0.5
1.0
1.5
Individual WTP estimates for River Quality

Figure 2



3.0
2.5
2.0
1.5
1.0
0.5
0.0
Probability density function
MXL
2 LCM
4 LCM
3 LCM
-2.0
-1.5
-1.0
-0.5
0.0
Individual WTP estimates for Odor and Flies

Figure 3


2 LCM
3 LCM
MXL
4 LCM
Probability density function
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5
10
15
-0.2
0.0
0.2
0.4
0.6
0.8
1.0
Individual WTP estimates for Bathing Beaches

Figure 4

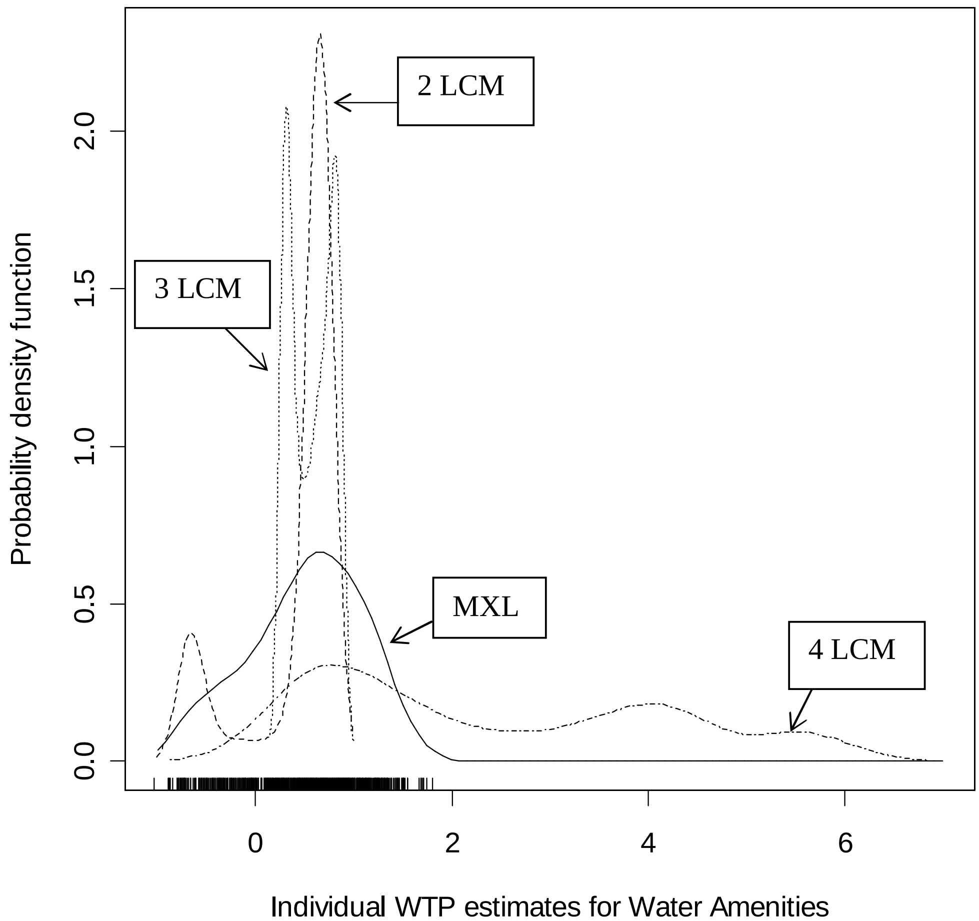
2 LCM
3 LCM
MXL
4 LCM
0.0
0.5
1.0
1.5
2.0
Probability density function
0
2
4
6
Individual WTP estimates for Water Amenities

Figure 5

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(lix) This paper was presented at the ENGIME Workshop on “Mapping Diversity”, Leuven, May 16-17, 2002

(lx) This paper was presented at the EuroConference on “Auctions and Market Design: Theory, Evidence and Applications”, organised by the Fondazione Eni Enrico Mattei, Milan, September 26-28, 2002

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(lxii) This paper was presented at the ENGIME Workshop on “Communication across Cultures in Multicultural Cities”, The Hague, November 7-8, 2002

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PRA	*Privatisation, Regulation, Antitrust* (Editor: Bernardo Bortolotti)
ETA	*Economic Theory and Applications* (Editor: Carlo Carraro)
CTN	*Coalition Theory Network*