

Bateman, Ian; Georgiou, Stavros; Lake, Iain

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The aggregation of environmental benefit values: A spatially sensitive valuation function approach

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Environmental Benefit Values:
A Spatially Sensitive Valuation
Function Approach**

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¹Ian Bateman, ¹Stavros Georgiou, ²Iain Lake

**¹Centre for Social and Economic Research on the Global Environment (CSERGE),
School of Environmental Sciences, University of East Anglia, Norwich, NR4 7TJ**

**²Centre for Environmental Risk, School of Environmental Sciences,
University of East Anglia, Norwich, NR4 7TJ**

Author contact details:

**Ian J. Bateman: Email – i.bateman@uea.ac.uk
Tel. +44 (0) 1603 593125**

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Abstract

The report reviews the literature regarding the aggregation of benefit value estimates for environmental resources. The report is prompted by the UK Environment Agency 'political jurisdiction' approach to aggregation of values for a single site as used in their study for the River Kennet tribunal. Two case studies are presented through which an alternative approach to aggregation is developed that 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 functions highlight the fact that resource values are expected to decline with increasing distance of households from the resource. The case studies show that the 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. The report concludes with some limitations of the approach used as well as recommendations for future work in this area.

EXECUTIVE SUMMARY

Cost benefit analysis requires the aggregation of individuals' benefits in order to compare with the total costs of a project or policy. 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. This will depend on both the benefits per person and the population of beneficiaries. It is thus necessary to identify the extent of the market and how this varies with changes in the good. This report builds upon earlier work by Smith (1993), Loomis (2000) and others to argue that the extent of the market may well be more important in determining aggregate values than any changes related to the precision of the estimates of per-person values.

The issue of defining the extent of the market for a public good essentially concerns the question of how broadly should individuals' marginal benefit schedules be vertically summed. Whether this should be confined to those living in the close vicinity of the good, or extended across the region, country or even further afield, has implications for the appropriate level of government financing and provision. This issue becomes further complicated when considering the distinction between user and non-user values.

In considering the extent of the market it is useful to distinguish between the *political jurisdiction* concerning the level of government at which decisions are made, and the *economic jurisdiction* incorporating all those who benefit from a decision. From an economic cost-benefit point of view, efficiency in resource allocation requires that the accounting stance taken should be such that it captures all Pareto-relevant impacts. Furthermore, whilst fiscal equivalence requires that political and economic jurisdictions coincide, it seems virtually inevitable that such equivalence will be the rare exception rather than the rule. Simple logic suggests that, where some resource site generates any element of use value, the density of such users will be higher near to that site. Furthermore, as users typically hold higher values than non-users then it is expected that average values will decay with increasing distance from that site. As such, the resultant economic jurisdiction is unlikely to coincide with any political jurisdiction. Although there is an extensive literature examining variability in estimates of mean WTP it has been suggested that such variability will have far less impact on estimates of total WTP than will changes in the extent of the market arising from the use of different approaches to aggregation.

The highest profile UK application of a political jurisdiction approach to aggregation occurred when the Environment Agency (EA) refused a water company application abstract water to from the River Kennet in southern England. The EA approach followed recommendations from FWR (1996) to use water company operations boundaries as the relevant area for aggregation. Total benefit value was then calculated by multiplying the population within this jurisdiction by a sample mean WTP estimate transferred from a contingent valuation (CV) study of the River Darrent. Aside from concerns regarding differences in the river types, commentators criticised the use of a sample mean taken from one area and applied without adjustment to an entirely different area which not only had differing geographic size but also contained a much larger population with very different socioeconomic characteristics. These academic reservations were reflected in judicial review through which the EA ruling was overturned after an appeal in which the plaintiff attacked both the valuation and aggregation procedure employed.

In order to make a defensible estimate of aggregate WTP for a political jurisdiction the analyst needs to ensure that the base information used has either been gathered from a representative sample of the population within that jurisdiction, or has been adjusted to make it representative. Any other sample will be inadequate if a simple mean WTP is to be used for aggregation purposes. Furthermore, even

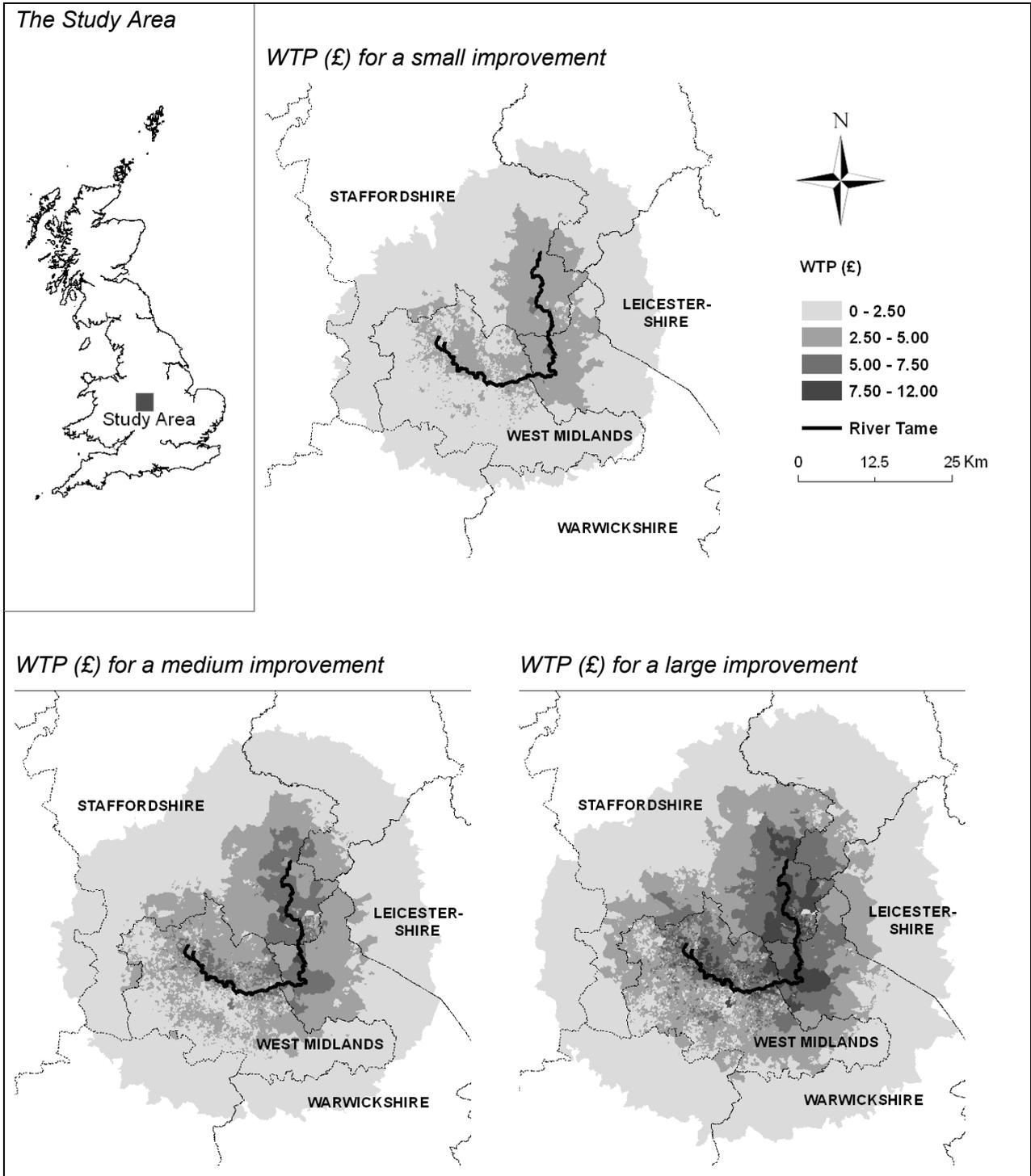
then, the political jurisdiction will almost inevitably fail to coincide with the economic jurisdiction. This report argues that a superior approach to aggregation is to use WTP responses to generate a *spatially sensitive valuation function* which incorporates both the distance decay relationship outlined above to define the limits of the economic jurisdiction and allows for variability in the socioeconomic characteristics of the encompassed population.

This approach is illustrated using a case study in which estimates of aggregate WTP are generated using data taken from a face-to-face CV survey of WTP for water quality improvements to the River Tame. A GIS is used to calculate distances from each respondent's home address to the River Tame. This is combined with survey data detailing each individual's socioeconomic and demographic characteristics. This information made up the individual level data from which value functions can be estimated. However, there is an issue here of the representativeness of any sample. Given self selection issues samples are liable to be a somewhat skewed section of society. The solution employed in this report is to incorporate additional census data (extracting data for the local census 'output areas' from which respondents originated), thereby adjusting the estimates generated from the sample for population characteristics.

The estimated value function can now be used to calculate the level of WTP for different areas progressing away from the study site. Given the significant distance decay relationship estimated, it is clear that at some point values will decline to zero. This defines the economic jurisdiction within which there are positive WTP values. As would be expected, the size of the jurisdiction depends on the scope of the improvement being considered, with larger improvements having a wider jurisdiction than smaller improvements in water quality.

One of the advantages of a GIS-based methodology is the ability of the software to readily generate graphic representations of findings. After removing those areas that are beyond the boundaries of the economic jurisdiction estimated for the specific distance decay function being considered (i.e. those with negative WTP values), choropleth maps can be produced for each of the improvements. These are illustrated in Figure A and show how the size of the economic jurisdiction varies according to the improvement scenario considered, as well as how WTP varies in each output area census unit according to both its proximity to the River Tame and its socioeconomic characteristics.

Figure A: Maps of estimated mean WTP (per household, per annum) of Census output areas for various water quality improvements



This analysis can now be used to provide spatially sensitive estimates of aggregate benefits for the economic jurisdiction and these can be compared with the standard approach to estimating aggregate benefits for a politically defined jurisdiction (such as the one adopted by the UK Environment Agency in the River Kennet enquiry). Under the latter approach the aggregation population is defined as simply those households that live within the relevant local water company area. Following the EA approach aggregate benefit estimates are calculated by simply multiplying this population by the sample mean WTP. Resulting estimates are reported as the first column of results within the table A. So as to allow comparison between aggregation errors (the extent of the market) and errors due to uncertainty regarding mean WTP, a confidence interval around these estimates is also reported based upon the 95%CI for the sample mean. The second column of results adopts the same approach to aggregation with the one refinement that the aggregation is now applied across the economic jurisdiction as defined by the spatially sensitive valuation function. The population within the economic jurisdiction is substantially smaller than that of the political jurisdiction suggesting immediately that the latter is liable to lead to overestimation of aggregate benefits as it includes households for which WTP is at best zero (and arguably negative). Furthermore, as the scope of the good declines so the population within the economic jurisdiction becomes even smaller. This will progressively lead to greater error arising from reliance upon the EA political jurisdiction approach. Indeed the political jurisdiction method leads to estimates which are just over double that for the economic jurisdiction for the large improvement and more than two and a half times too high for the small improvement. These errors dwarf those due to uncertainty in the estimate of mean WTP which range from 17% for the large improvement to 20% for the small improvement.

Table A: Aggregate benefits estimates based on sample mean and valuation function approaches

Quality change		Aggregation using sample mean WTP		Aggregation using WTP estimated from function
		Political Jurisdiction ¹	Economic Jurisdiction ²	Economic Jurisdiction ²
Large improvement	Number of households	3,494,438	1,647,777	1,647,777
	Sample mean WTP (£23.48)	£82,049,404	£38,689,804	£5,040,526
	95% CI for sample mean WTP (£19.46-£27.49)	(£68,001,763-£96,062,101)	(£32,065,740-£45,297,390)	
Medium improvement	Number of households	3,494,438	1,486,415	1,486,415
	Sample mean WTP (£15.65)	£54,687,955	£23,262,395	£3,350,233
	95% CI for sample mean WTP (£12.86-£18.44)	(£44,938,473-£64,437,437)	(£19,115,297-£27,409,493)	
Small improvement	Number of households	3,494,438	1,336,736	1,336,736
	Sample mean WTP (£9.88)	£34,525,047	£13,206,952	£1,997,502
	95% CI for sample mean WTP (£7.95-£11.81)	(£27,780,782-£41,269,313)	(£10,627,051-£15,786,852)	

1. Political Jurisdiction = local Water Utility Company area (Severn Trent and South Staffordshire Water Company Ltd.)

2. Area for which mean WTP > 0

While the change from political to economic jurisdiction substantially alters aggregation estimates, the final column of results shows that, at least in this case, an even greatest source of error arises from reliance upon sample means within the aggregation process. WTP values decline significantly across space such that, unless samples are fully representative of the underlying population, mean values can be poor indicators of value for that population. Given that, ahead of any valuation survey, the extent of the economic jurisdiction is unlikely to be known, ensuring sample representativeness of this *a-priori* uncertain area can be a difficult if not impossible matter to assess. Application of the valuation function allows us to estimate how household WTP varies across the economic jurisdiction, here calculating values for each census output area, taking into account its distance from the site and those area characteristics included within the model (other variables being held at their mean values). Resulting values, shown in the final column of Table A are, the report contends, superior to those given elsewhere in the table as they are both based upon the economic jurisdiction and best capture the variability of values across that area. Comparison with other estimates is revealing. In particular when compared with the political jurisdiction and sample mean aggregation approach used in the EA River Kennet study it can be seen that the latter are more than 16 times too high.

Whilst this report believes that the approach proposed represents a useful direction for future research which has the potential to substantially improve methodology in this area, a number of significant limitations are noted that require attention in future applications.

First, it is vital that stated preference surveys collect data on non-response and the spatial distribution of non-respondents. A Second issue concerns the need to gather data to allow an inspection of the effect that changes in site quality are likely to have upon the number of visitors to a site. Third, the models reported in this report use a combination of individual and area level data. However, unless one can be sure of the representativeness of the sample or can adequately reweight sample responses appropriately then these models are open to criticism. A final issue concerns substitution effects arising from quality change at multiple sites. Policies such as the EU Water Framework Directive envisage widespread improvements in river and lake quality. In such cases, research suggests rapidly diminishing marginal WTP for additional sites once an initial level of recreational or non-use provision is made. Given this, an obvious goal for future research will be to quantify and model these effects.

PROLOGUE

“Once upon a time a group of eminent rabbit chefs were asked to prepare the finest bowl of Horse and Rabbit Stew for the King’s Birthday. For days they toiled and argued about how the rabbit should be prepared. Should it be roasted first or simply boiled, or perhaps jugged or marinated in a fine wine sauce. Finally they agreed on the right way to prepare a rabbit and as the birthday dawned they prepared the finest rabbit ever tasted for the stew. Sadly all their efforts were completely overwhelmed by the subsequent addition of the horse.” (With thanks to Colin Green for the Tale of Horse and Rabbit Stew).

1. INTRODUCTION

Cost benefit analysis requires the aggregation of individuals’ benefits in order to compare with the total costs of a project or policy. Because the methods for measuring non-market benefit values are based on micro level analysis of individual behaviour, there is a problem in knowing how changes in a resource will affect aggregate use. Aggregate benefits will depend on both the benefits per person/household and the population of beneficiaries. It is thus necessary to translate per-unit values of an asset to the value of the resource by defining the ‘geographical extent of the market’ (Smith, 1993). For non-market resources defining the boundaries of the market requires knowledge about the population of beneficiaries (who has *standing* about the change) and how their values vary according to changes in the resource and with their individual characteristics (Smith, 1993). Defining the extent of the market will thus not be straightforward and as suggested by the tale of the horse and rabbit stew, may well be more important in determining the value of non-market resources than any changes related to refining the estimates of per-unit values. This report builds upon the earlier work by Smith (1993), Loomis (2000) and others to argue that differences in measures of individual values are the haggled-over ‘rabbits in the stew’ whereas the aggregation process regarding the extent of the market is the ‘horse’ that dominates the overall outcome.

The issue of defining the geographical extent of the market for a public good essentially concerns the question of how broadly should individuals’ marginal benefit schedules be vertically summed. Whether this extends to those living in the close vicinity of the public good, the country in which it is located, or to the entire world, has implications for the appropriate level of government financing and provision. This issue becomes further complicated when considering how to define the extent of the market related to non-use values.

As discussed by Loomis (2000), in considering the geographical extent of the market it is useful to distinguish between the *political jurisdiction* concerning the level of government at which decisions are made, and the *economic jurisdiction* incorporating all those who benefit from a decision. From an economic cost-benefit point of view, the notion of *accounting stance* (or who has *standing*) defines the relevant political jurisdiction for including benefits and costs. Now in order to achieve efficiency in resource allocation, it is necessary that the accounting stance should be such that it captures all Pareto-relevant impacts. Where political and economic jurisdictions coincide there is said to be *fiscal equivalence* (Olsen, 1969; Cornes and Sandler, 1996). However, it seems virtually inevitable that such equivalence will be the rare exception rather than the rule. Simple logic suggests that, where some resource site generates any element of use value, the density of such users will be higher near to that site. Furthermore, as users typically hold higher values than non-users then one would expect average values to decay with increasing distance from that site. It seems highly implausible that the resultant economic jurisdiction will coincide with any political jurisdiction. The divergence between political and economic jurisdictions in terms of economic efficiency can be found by comparing aggregate benefits

across the extent of the market under each jurisdiction¹. As noted above, any variability in the extent of the market under each jurisdiction may have a far greater impact on estimates of total WTP than any variability in estimates of per unit values of WTP. An example is provided by Smith (1993) concerning the estimation of natural resource damages, in which the differences in plaintiff's and defendant's estimates of per unit values were small but total damage assessment differences were huge as a result of each parties assumptions regarding the appropriate geographical extent of the market.

Although the problem of aggregation has been a focus of economic analysis over the past century, the debate has attracted prominent media attention following the increased use of benefit estimation studies in legal proceedings. In the US such studies have been used in cases regarding natural resource damage assessments (see Kopp and Smith, 1989 and 1993) whilst in the UK they form part of the UK Environment Agency (EA) approach to investment appraisal. The highest profile UK application of a political jurisdiction approach to aggregation occurred when the EA refused a water company application for a license to abstract water from the River Kennet in southern England in 1998 (ENDS, 1998; Moran, 1999). The EA approach followed recommendations from FWR (1996) to use water company operations boundaries as the relevant area for aggregation. Total benefit value was then calculated by multiplying the population within this jurisdiction by a sample mean WTP estimate transferred from a contingent valuation (CV) study of the River Darrent (Willis and Garrod, 1995). The problem for the assessment was that it was hampered by guidelines to which it had to conform and which led to the production of values that were difficult to substantiate. In particular, and as Moran (1999) states, "The limits on the valuing population in the Kennet case failed to address important bounds for natural resource damage assessment (NOAA, 1994; Dunford et al., 1995). These require knowledge of the resource and associated damages arising to a resource about which a respondent had prior resource". More specifically, Bateman et al., (2000) view the problem as one in which the relevant population was defined in an arbitrary manner, and that no allowance was made for the expected decay in unit values with increasing distance away from the site. Whilst these problems do not undermine the role of valuation in economic assessments of natural resources, the problem of how to appropriately aggregate remains, especially for non non-use values.

In defining the geographical extent of the market, a number of alternatives have been suggested for estimating the population of beneficiaries (FWR, 1996; RPA, 1998; Moran, 1999; Hanley et al., 2003):

1. Gravity model predictions - a common procedure, particularly in the recreation arena is to make use of simple gravity models in order to predict participation rates (and hence define the relevant population). However, such models are criticised on the grounds that variability in the availability of substitute sites and in socioeconomic characteristics by region may lead to misleading predictions of visitation (see Hanley et al., 2003; Gaterell et al., 1999; Brainard et al., 1999)
2. Specific Distance Boundary Rule – Aggregation is based on the population who live within a specific distance boundary of the resource in question. Such a rule has been suggested by the EA in the UK (RPA, 1998) based on 60 km boundary distance that was proposed on the basis of a partial review of studies looking at the decline in knowledge or valuation with distance. The universal application of such an arbitrary cut-off point could lead to significant over or underestimation of values depending on the actual observed distance decay relationship that exists for any resource and hence the population included (see later for more on distance decay).

¹ Another measure of the divergence of political and economic jurisdiction can be made in terms of the distance covered by each (Loomis, 2000).

3. Regulatory authority/Commercial Company Area Boundary – this is based on the regulatory/commercial structure of the sector/industry in which the change is occurring and follows the recommendation from FWR (1996) for assessing the benefits of water quality improvements in the UK. Here, a network of commercial utility companies are responsible for providing water and sewerage services across the UK, whilst regulation is undertaken by the UK Environment Agency. As such, the relevant population can be defined by the boundary of the relevant utility company in whose jurisdiction the change under consideration is occurring. This approach was used by the EA in the Axford case. Although not having any basis in terms of those who might benefit from any change being considered, it does have an equity motivation since the decision regarding the change is restricted to those who will ultimately have to pay for it. Alternatively, the population could be defined by the boundary of the regulatory authority responsible for the resource, e.g. in the UK the local EA area boundary. Nevertheless, as for the previous rule, the population covered will vary arbitrarily depending on the area covered by the regulatory body/company.

5. Site of Special Scientific Interest (SSSI)/Environmental Sensitive Area (ESA) Designation – This approach is based on the idea that designated status implies national importance and as such the relevant population boundary extends to the whole of the population of a country. However, such status does not guarantee that the national population will indeed hold value for the site. There may in fact be substitute sites and/or knowledge regarding the site may be limited.

6. Distance decay – If the extent of the market is defined in economic jurisdiction terms then it includes all those who benefit from a decision. As such its spatial range extends to the point at which WTP for the change under consideration equals zero (WTP is the economic measure of benefits). Hanley et al., (2003) suggest that for certain types of public good use value, it seems reasonable to expect spatial discounting, whereby WTP values decline with distance from the resource under consideration. The manner in which WTP decays with increasing distance defines a distance decay relationship which can be used to identify the relevant population and provides an empirical limit for the economic jurisdiction. Spatial discounting has been observed in on other areas of social science, with distance decay functions being originally used to express the way that distance (or travel cost) has an effect on usage of a resource (e.g. Hansen, 1959; Fotheringham, 1981). They stem from the so called ‘first law of geography: everything is related to everything else, but near things are more related than distant things’ (Tobler (1970). Brazee and Southgate (1993) express concern that traditional approaches to economic valuation lack a geographical dimension and fail to appreciate such spatial variation.

If distance is a statistically significant (negatively related) determinant of value, then the distance at which WTP falls to zero can be estimated (and defines the boundary of the relevant population, as discussed earlier). However if distance is not explicitly considered then it cannot be used to define the boundary and is implicitly assumed to have a constant effect across any jurisdiction used (and zero effect beyond). Given the variety of public goods, the spatial range over which to define the geographical extent of the market will be an empirical question. It is thus important to test the hypothesis that benefit values do indeed have a negative relationship with distance and to empirically estimate the boundary point at which WTP values fall to zero. The effects of substitute sites and knowledge are likely to influence the nature of any distance decay relationship found. Furthermore, whether a distance decay relationship exists at all and for non-use values is still debated and will be examined in more detail in a later section.

In addition to the definition of the geographical extent of the market, aggregate benefit estimates will, as already mentioned, be affected by any changes that arise from refining the estimates of the per unit values of WTP that are applied to beneficiaries. Although some writers suggest that the former effect

is probably more important than the latter, only limited empirical evidence exists on this issue (see Kopp and Smith (1989)). Estimates of per unit values of WTP will clearly vary according to theoretical and empirical arguments regarding the validity of the methods used to derive them. Leaving this issue aside, extrapolation of sample estimates of WTP to a population requires consideration of which measure of central tendency is most appropriate for aggregating across the population, as well as theoretical and methodological concerns regarding the correct approach for estimating the measure of central tendency.

Typically, a valuation study will estimate the mean or median as the measure of central tendency used to aggregate values across a population. In choosing one measure over the other an implicit assumption about the relevant population is made. The use of the median is akin to a (super-)majority voting decision where the relevant population of voters consists of everyone affected by the proposed change. In the case where the voting constituency is confined to those who will ultimately foot the bill for the cost of the change, such a decision rule may reflect an equity criterion based on those with a legitimate financial stake (Moran, 1999). Nevertheless, such a rule can only be reconciled with a social choice model if it can be assumed that nobody beyond the bill payers has a value for the change. The mean, on the other hand, reflects the welfare change that is experienced on average. It gives a measure of societal value that satisfies the Kaldor-Hicks potential compensation criterion, unlike the median. This distinction between the societal value and voting population underlies the earlier discussion related to political and economic jurisdictions. In essence, the difference between mean and median is between a rule where everyone has a notional say in the decision (mean) and one where the decision is based on some percentage of the population (Moran, 1999).

Freedman (1985) finds a consensus of opinion in favour of using the median as a measure of central tendency within a stratum of a sample while using the mean to combine the stratum. Hanemann (1989) argues for the use of the median for both elements, basing his argument on a rejection of the Kaldor Hicks potential compensation criterion.

Extrapolation will lead to bias if there is a divergence between the socioeconomic and spatial characteristics of the sample and the actual population (Morrison, 2000). In this case, either the measure of central tendency will have to be adjusted to allow for differences in characteristics or assumptions made about the preferences of non-respondents. Adjustment of the measure of central tendency can be done by substituting population averages in regression equations, using weighted regression analysis or weighted averaging. Non-respondents fall into two types – item non-response and unit non-response. The former is where a questionnaire is returned incomplete, whilst the latter is where the questionnaire is not returned or someone refuses to be interviewed. If non-responses are not random then they may lead to sample selection bias, such that sample characteristics diverge from the population. A number of ways exist to deal with non-respondents including (Morrison, 2000): assuming the willingness to pay of non-respondents is zero; extrapolation using the relationship between respondents' preferences and the time of response; use of sample selection models; and classifying non-respondents according whether they are likely to have similar preferences to respondents in the sample.

Further issues regarding the measure of central tendency concern its apparent sensitivity to outliers and the distributional assumptions used to model WTP estimates. Such problems have been extensively examined in the contingent valuation literature and can lead to significant differences in the values of central tendency found (see Hanemann and Kanninen, 1997; Kerr, 1996; Ready and Hu, 1995). Nevertheless whether the impact of such differences on aggregation outweighs concerns over the geographic extent of the market remains insufficiently investigated. This report seeks to shed some light on the issue.

The following section proposes an innovative and superior approach to aggregation that uses WTP responses and GIS techniques to generate a *spatially sensitive valuation function* which incorporates both the distance decay relationship outlined above to define the limits of the economic jurisdiction and allows for variability in the socioeconomic characteristics of the encompassed population. Section 3 reviews existing research on the question of how benefit values for environmental improvements decay with increasing distance from the site of the improvement (distance decay) and on the issue of aggregation of benefits to yield total values. Section 4 summaries an early case study that undertakes the rudiments of our proposed approach. This is followed in section 5 by a new case study looking at the willingness to pay value of different intensities of river water improvements. Our spatially sensitive valuation function approach is here used to generate estimates of aggregate WTP and contrast this with measures based upon both the use of a political jurisdiction and the reliance upon sample means. The impact of using different aggregation approaches is then contrasted with the variability induced by uncertainty in the estimate of mean WTP to examine Smith's contention that such variability will be overwhelmed by aggregation impacts. Finally section 7 provides some concluding comments and gives some pointers towards ways that this methodology might usefully be extended.

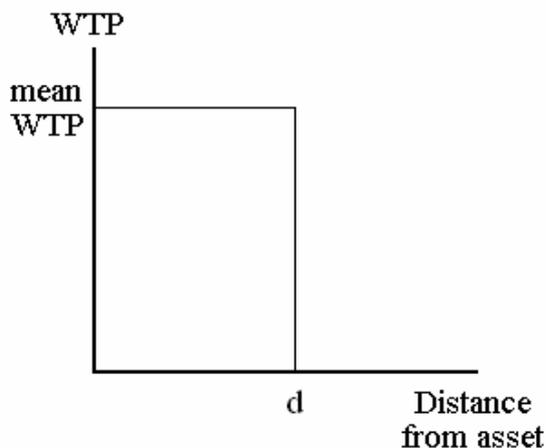
2. A SPATIALLY SENSITIVE VALUATION FUNCTION APPROACH - USING GIS TO ASSESS DISTANCE DECAY AND AGGREGATE TRANSFERRED BENEFIT ESTIMATES

The proposed spatial methodology approach for undertaking benefits aggregation is able to overcome a number of the problems and concerns associated with existing approaches, such as that used by the UK Environment Agency in the Axford Enquiry. In particular, the proposed approach allows for the following elements to be incorporated into the analysis:

- The possible variation of WTP across socio-economic and spatial characteristics
- the appropriate definition of the geographic extent of the market or population of beneficiaries
- Given the definition of the population of beneficiaries, how their distribution varies across space

Typically, current approaches to the aggregation of benefits, such as the one used by the Environment Agency, take (an often arbitrarily determined) political jurisdiction to represent the extent of the market. Given such a jurisdiction, the approach then assumes that the WTP applied to the corresponding population of beneficiaries is given by some measure of the central tendency of WTP (the mean). As summarised in figure 1, this measure of WTP is typically invariant across space up to the distance defined by the jurisdiction, d , and zero thereafter. Furthermore, it ignores the distribution of population across space. In the situation where the mean WTP is truly the mean for the distance d , then this would give the appropriate WTP value to apply across the variation in space. Invariably this is not the case, especially if the mean is transferred in from another study as was the case in the Axford enquiry. As such this severely restricts the application of this methodology.

Figure 1: WTP applied to the population of beneficiaries under the EA approach



Our proposed approach makes use of a GIS that allows the relaxation of the restrictive and unrealistic assumptions regarding spatial homogeneity in WTP and population, but which also allows the geographic extent of the market to be correctly identified.

First, it is necessary to consider the factors determining WTP for any given household in a survey sample. Usually these factors include socio-economic characteristics and the availability of substitutes. However, as discussed in the introductory section, there may also be spatial variation such that we have the following key determinants:

$$WTP = f(\text{distance, socio-economics, substitutes})$$

This is the point at which our proposed approach makes use of the Geographical Information System (GIS). Such systems have been widely used in a variety of environmental applications and in recent years have been increasingly used in applied research in environmental and resource economics (Bockstael, 1996). One particular use has been in accessibility modelling in order to estimate distance decay parameters (Skov-Petersen, 2001). In this respect the following advantages of using GIS have been suggested: the fact that it provides an easy assessment of accessibility options, as represented by a digital road network; data can be handled in a generally more flexible way; GIS enables cartographic presentation of results (Skov-Petersen, 2001). As such, our approach uses the GIS to calculate the distance from a WTP survey respondent's household to the site/asset being considered, thus enabling the effect of distance on WTP for the survey sample to be revealed. This is done by using multiple regression techniques to estimate a so-called distance-decay function, which shows the effect on WTP of distance, as well as any other socioeconomic characteristics included as explanatory factors. This distance-decay function thus allows for spatial and socioeconomic heterogeneity of WTP amongst the survey sample. In addition to looking at WTP effects, the GIS can make use of Census data to assess how population varies with distance. Figure 2 shows a stylised example of how the WTP and Population – Distance relationships might appear in terms of the pure distance effect, whilst figure 3 shows an example that incorporates both distance and socioeconomics.

Figure 2: Pure distance effect

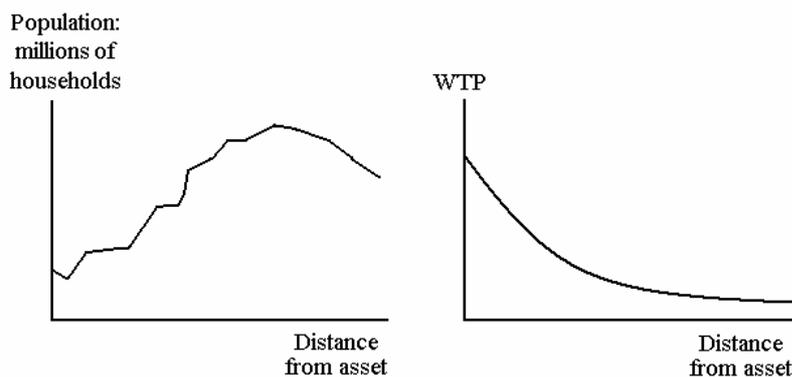
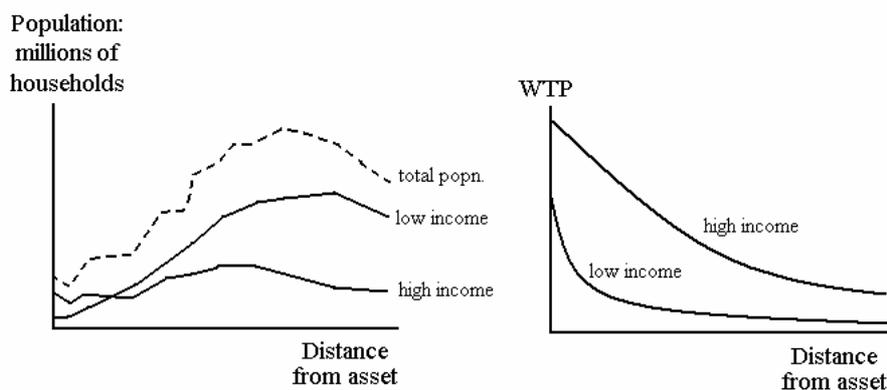


Figure 3: Distance and socio-economics effect



Since the GIS also allows us to model how population varies with distance then by combining this information with the spatially (and socioeconomically) sensitive WTP values obtained from the distance-decay function for the survey sample it is possible to estimate the total WTP across the

population of interest². Before considering how exactly this is done, it is still necessary to examine how the geographic extent of the market is defined in terms of the population of beneficiaries.

As outlined in the introduction, the distance-decay function can be used to define the geographic extent of the market. This is done in terms of an economic jurisdiction that includes all individuals receiving the good's benefits. Since the distance-decay function shows how benefits decline with distance, then the empirical distance boundary at which WTP for the change under consideration equals zero defines the economic jurisdiction and extent of the market. Whilst this economic jurisdiction is the correct accounting stance from the point of view of Pareto-relevant spillovers, alternative (and arbitrary) jurisdictions can be defined and used for comparisons, etc.

We can now combine the spatially (and socioeconomically) sensitive distance decay function WTP values with the relevant population of beneficiaries within the economic (or alternative) jurisdiction. There are a number of ways in which this can be done, which differ in how they model the distribution of the household to which the WTP values are applied. Before considering our GIS based approach to modelling that distribution, we consider two previously used approaches.

First, and as illustrated later in the first case study (section 4), concentric distance bands around the site/asset of interest can be defined and the total population within each distance band estimated. The distance decay function is then used to estimate the spatially sensitive WTP value that is applied to the population in each distance band. This approach is still based on aggregating across a cylindrical welfare space (as under the EA aggregation approach), but divides that space into concentric distance bands of cylinders. These bands allow for some spatial sensitivity of WTP and population between them. However, it is clear that the (arbitrarily defined) radius of each band will influence the WTP estimate and size of the population that is found within each.

A slightly more sophisticated approach, which is based on defining the welfare space for aggregation as conical rather than cylindrical, is described in Hanley et al., (2003). Aggregated benefits allowing for spatial sensitivity of WTP values is given by the following WTP 'conical volume' over the relevant range of beneficiaries:

$$V = \left(\int_{r=0}^R f(r) dr \right)^2 \pi k$$

where $f(r)$ is the empirical distance decay function, R is the radius of the jurisdiction used to define the population of beneficiaries, and k is the population density. Clearly a problem for aggregation here is in determining the appropriate value of population density, k , that should be applied.

Turning now to our proposed approach, this is able to avoid the problems associated with the two previous approaches. This is because whilst it incorporates a GIS that uses Census data to assess exactly how population varies empirically with distance, it does this on the basis of an innovative cell structure that uses geographic census units to map out where any household in the population lives. These individual census units can be quite small in area, covering not more than 100 households. Using these census unit cells allows a higher degree of spatial heterogeneity to be captured regarding the distance of households to the asset/site of interest. A further advantage of using these census units is that in addition to the information on distance, the census data also contains socioeconomic data for each individual unit. By linking the households in the survey sample to their census unit it is thus possible to provide, in addition to the individual characteristics of that household, census level

² As such the welfare space over which aggregation takes place is no longer cylindrical (as given by the usual approach to aggregation described at the beginning of this section), but instead allows for a space that decays the WTP value and/or the number of valuers with distance.

characteristics related to their residential location. These additional socioeconomic characteristics can be included in the distance decay regression equations to provide extra explanatory power. As such they allow for both spatial and socioeconomic heterogeneity of the WTP values estimated for any census unit cell. The socioeconomic heterogeneity is however only at the level of the census unit characteristics included in the distance decay function³.

The population in each cell contained within any jurisdiction (economically or otherwise defined) of interest is multiplied by the spatially (and socioeconomically) sensitive value of WTP for that specific cell (found by applying the cell specific distance and socioeconomic characteristics to the distance decay function) to give the total WTP of the population in that cell⁴. An economic value map can thus be drawn showing the spatial (and socioeconomic) distribution of WTP across all the cells in a jurisdiction. Aggregating across all the cells in the jurisdiction gives the total benefits for that jurisdiction and the appropriate measure for use in cost-benefit analysis. The approach is illustrated in our second case study in section 5.

2.1 Use Versus Non-use Values and Distance Decay

An important issue regarding the distance decay element of the proposed approach is whether or not distance decay applies to both non-use values as well as use values. This is because non-use values may in principle be held by anyone and hence increase the problems associated with defining the geographical extent of the market used in aggregation.

For the sake of simplicity we can identify two types of individual; users of a resource, and non-users. Users will hold use and option-use values and may well hold non-use values. Non users may hold option and non-use values or have negligible (or even negative) WTP. It seems reasonable to assume that, *ceteris paribus*, users will typically hold higher WTP values than non-users.

Should we expect that the values held by those who are presently users of the resource will decline as distance from that resource increases? There are a number of issues here. It is clearly true that, as distance and travel time increase so the costs of accessing a site also rise. Also it may well be that the availability of substitutes increases with distance, lowering their opportunity cost. But these are cost side issues and do not dictate a reduction in benefits. The WTP of someone who travels halfway round the globe to visit the Grand Canyon is quite likely to be higher than the average resident of nearby Phoenix. Now this lack of relation need not always hold. For example, Parsons (1991) commentary upon the travel cost (TC) method, notes that some of those with high use values for recreational resources will internalise some costs by choosing to live in locations near to those resources, (a tendency which will downwardly bias unadjusted estimates of consumer surplus in TC studies). However, this will be less of a problem for resources which have been degraded for long periods of time, as in the present case of the River Tame. Therefore, it is not *a-priori* clear that the WTP of those who are already users will necessarily exhibit a strong distance decay (although rising costs mean that their net benefits do decay with increasing distance).

³ It should be noted that the socioeconomic heterogeneity is only for the census unit level variables included in the distance decay function since the individual level characteristics for the sample are not available when aggregating to the population. The Census data only contains the census unit level characteristics. As such sample mean values are used for the coefficients about which there is no census unit level data when applying the distance decay functions to the population. This approach is essentially similar to the substituting of population averages in regression equations, as discussed in the introduction to the report.

⁴ At any cell, the characteristics of the cell in terms of the distance from the site/asset as well as the census level socioeconomic characteristics of the population in the cell are used in the distance decay function to determine the total economic value in that cell for the change under consideration.

Turning to consider those who are at present non-users of a resource, again it is not clear that values should decay across space. After adjusting for income etc., why should non-use values for preserving the Amazon rainforest be higher in the USA than in more remote Europe? Empirically there is some (limited) evidence that there may be a cultural or 'ownership' dimension to non-use values with, those who live closer (or even in the same country) as a resource expressing relatively higher non-use values for that resource (Bateman *et al.*, 2005). However, the theoretical basis for this association is unclear.

What is clear is that, as distance from a resource increases and opportunity costs rise, so we should expect two trends to appear:

1. The number of users will decline.
2. The proportion of users to non-users will also decline.

Given that users will generally hold higher values than non-users these trends will result in a distance decay in mean WTP per household values. This will be compounded by both the Parsons effect and any empirical reduction in non-user values across space.

Summarising the above, while there is no a-priori reason why the average values of either users or non-users should decline with increasing distance, what we will see is an increase in the proportion of households with low or zero values across space. This will result in a decay of mean WTP per household as distance from the resource increases.

An empirical problem in observing such distance decay is that of self-selection bias. Put simply, those with positive values for a resource are more likely to opt-in to a survey sample, upwardly biasing resultant WTP values. Even the best survey methods are unlikely to fully address this problem. However, one approach is to invest more time into assessing the distribution of non-respondents (those who refuse to complete a survey). In a study examining WTP for a nationally important resource, Bateman and Langford (1997) address this issue by conducting a stratified mail survey across Great Britain. In analysing response patterns the authors found that alongside strong socio-economic and use-experience dimensions, not only did the WTP of the sample decline significantly with increasing distance but also the rate of non-response rose. This latter finding suggests self-selection in the sample, with low and zero value individuals increasingly being under-represented as distance from the resource increases. Therefore, we should expect both that sample mean WTP underestimates the population mean and that any observed distance decay in the sample understates the true rate at which values in the population decline with increasing distance from a resource.

Provided that non-response rates are known then a simple lower bound approach is to assume that all non-respondents have zero WTP (as per Bishop & Boyle, 1985). We report examples of this approach in Bateman *et al.* (2000, 2002). Unfortunately, although tallies of non-response were noted in the present study some 53% of those approached with the River Tame study refused to be surveyed. This is a significantly lower rate of refusal than in many mail surveys such as that reported in Bateman and Langford (1997). A survey error meant that their geographical distribution was not recorded (an issue to be addressed in future research). Therefore, we cannot adequately incorporate this factor in our present study and recognise that our aggregation sums may consequently be somewhat inflated. However, information describing whether respondents are either users or non-users allows us to examine whether the trends identified above (increasing distance to the resource leading to both reductions in the prevalence of users and consequent falls in the proportion of users to non-users) are indeed present in our data. We consider this issue further in our subsequent case study analysis.

3. PREVIOUS RESEARCH ON DISTANCE DECAY AND AGGREGATION

There have been a number of CVM studies that have considered distance decay effects on WTP values and the impact on aggregate benefit estimates of using distance decay valuation functions to define the geographical extent of the market⁵. One of the earliest studies was undertaken by Sutherland and Walsh (1985) who considered the effect of distance on preservation (or non-use) values relating to water quality degradation due to coal mining activity in the Flathead River, Montana. The regression analysis, which was based on data from a regional CVM survey, was based on two models of the distance-decay hypothesis. First, a single equation model was applied in which distance directly influences willingness to pay. Although several functional forms were applied and negative distance coefficients were obtained, these were not consistently significant. As a result the authors estimated a two equation structural willingness to pay model where distance influences visits (equation 1) and visits influence willingness to pay (equation 2). The results suggest that there is a significant relationship between preservation values and distance, but that this appears to be a function of whether the household visited the study area (and as a consequence acquire an appreciation for water quality as a result of the knowledge gained by visitation). Total value was estimated by aggregating across households where WTP declines with distance (according to discrete distance zones), with the geographical extent of the market extending to all households having positive WTP values. Comparing the total value for the population of Montana with total value for all households within the distance decay defined boundary (in this particular study WTP approached zero at about 640 miles from the study area) indicates a six fold difference in total value (the total based on state jurisdiction being 1/6 of the distance decay defined boundary).

Following on from the Sutherland and Walsh (1985) study, Pate and Loomis (1997) look at the effect of distance on WTP for three proposed programs to protect and expand wetlands and reduce wildlife contamination in the San Joaquin Valley, California. Once again, the authors estimated distance decay valuation functions for each of the programs and then used these functions to estimate aggregate benefits. It was found that willingness to pay does not always show a statistically significant negative relationship⁶. Nevertheless the aggregation exercise undertaken in the cases where there was significant distance decay, found that restricting benefits to just the political jurisdiction in which the site is located would understate benefits by at least \$300 million. The aggregation exercise used discrete (zonal) distance weighted WTP values and multiplied these by the relevant population in each zone. It should be noted that the study did not use the distance decay valuation functions to define the extent of the market, but rather compared the single state political jurisdiction to a multi-state political jurisdiction.

Loomis (2000) extends this work to examine the correspondence between aggregations based on political jurisdictions compared with economic jurisdictions. In addition to using data from two of the three valuation programs in the Pate and Loomis (1997) study, three additional valuation study datasets were used to test whether public good benefits fall with distance and consequently to provide empirical (economic jurisdiction) limits for defining the geographical extent of the market. The first of these additional datasets was from a nationwide CVM survey of WTP for river restoration and associated increases in four species of fish. The second dataset was also from a nationwide CVM survey, but was concerned with the protection of a threatened species of bird, the Mexican spotted owl. The final dataset, again from a nationwide CVM survey, examined WTP values for a program to protect the California spotted owl's habitat from catastrophic fire. Using each of these survey datasets the authors estimate WTP equations that examine the relationship between an individual's WTP and a

⁵ The effect of distance on benefit values more generally is the basis of studies looking at the recreational use value of environmental quality that make use of the travel cost method (Freeman, 1993).

⁶ We examine reasons why this might be so in the analysis in section 5 (see non-use v use analysis).

variety of explanatory variables, including the distance that the individual lives from the resource being protected. In the case of every study, it was found that the coefficient on respondent's distance from the resource in question was negative and, in all but one case, statistically significant at the 5% level (and significant at the 10% level in the final case). The coefficients from each of the regression equations were then used to calculate the benefits per household for various distance increments from the resource for each study in turn. Benefits per household were still found to be positive even at a distance of 1000 miles from each of the resources. Total benefits were then calculated by multiplying the benefit per household by the population living at each distance increment from the resource. Total benefits based on this distance weighted WTP estimation procedure were calculated for commonly employed state or regional accounting stances as well as for the entire US. Comparing the percentage of national public benefits reflected in the state/regional accounting stance, it is found that even in the case where the resource being protected is in the most populous state in the US (California), the political jurisdiction accounts for less than 20% of the economic benefits to the US, whilst for some of the resources located in small population states this figure falls to just 5%.

Another study which uses a distance decay valuation function to define the geographical extent of the market is Hanley et al (2001). The study estimates WTP for protecting heather moorland and rough grazing habitats from being changed to forest or improved pasture. Based on the distance from the site at which WTP was predicted to go to zero (using the distance decay valuation function), the population within that distance was found from census data and used to estimate aggregate WTP to protect the existing landscape. However, although the distance decay valuation functions were used to define the extent of the market they were not used to produce distance weighted WTP estimates. Rather the aggregation procedure merely applied the same mean WTP estimate to the relevant population.

Bateman et al (2000) in a study looking at non-use values for the avoidance of further degradation associated with acidity affecting remote mountain lakes find that there is a "significant and substantial decay in values" as they cross national borders. The effect takes the form of a discontinuous step function rather than the more usual (continuous) distance decay functions of the other studies discussed here. No attempt was made to produce aggregate values.

The study by Hanley et al (2003) examines the effect of distance on both use and non-use values related to improving low-flow condition for single and multiple rivers in the Thames Region of the UK. Based on a series of Tobit distance decay valuation functions, the authors find that there are highly significant distance decay effects for improvements to a single river (the River Mimram) for both users and non-users. However, no significant effects were found when improvements to all rivers in Thames Region were considered. Based on the finding that distance is a significant determinant of WTP, the authors re-estimate the distance decay function using a double log functional form specification in order to provide a simpler model with which to perform an aggregation exercise. With regards to the aggregation exercise, despite estimating the distance decay valuation functions the authors arbitrarily define the "beneficiary area" (geographical extent of the market) as covering a radius of 100km from the resource. However, they do incorporate a somewhat more sophisticated aggregation procedure than previous studies that enables them to derive a WTP 'volume' over the region of beneficiaries. The procedure integrates the distance decay valuation function over the beneficiary area radius (0-100km) along with a uniform population density to derive aggregate benefits that allow for distance decay effects (distance weighted WTP) across the population. This aggregation procedure is repeated for all rivers in the Thames region using the single site values applied to each river and the benefits compared with a similar procedure using the all-Thames rivers improvement scenario values (for which no distance decay was found). The aggregation based on the single site values was found to be around 4 times higher than that based on the all-Thames scenario. The authors did not undertake any estimation for and comparison with a politically defined aggregation area.

Outside of the UK and US, Mouranaka (2004) undertakes a CVM study that seeks to evaluate forest management practices that reduce the risks of Japanese Cedar pollinosis. The authors used a multizonal contingent market with concentric belts from respondents' residences in order to investigate the issue of distance decay. WTP functions were modelled for each concentric zonal market using Tobit estimation. The results indicate that there is a clear distance decay trend. Although aggregate benefits are estimated across the local prefecture no comparison is made with alternative methods of aggregation.

One study that found no distance decay existed at all for non-use values is by Imber, Stevenson and Wilks (1991). This study found that WTP to preserve the Kakadu Conservation Zone from mining was higher amongst people throughout Australia than amongst people in the Northern Territory who were closer to the site. It is thought that other factors apart from distance, such as effects on employment and environmental preferences in general could explain the result (Morrison, 2000).

3.1 Distance Decay, Use and Non-use Values

In addition to considering how total values might decay with distance, a number of studies have also looked at the question of distance decay amongst the separate categories of use and non-use values. The study by Sutherland and Walsh (1985) found a negative relationship between distance and non-use value of water quality. The authors argue that the visit-distance relationship found in travel cost relationships supports the hypothesis that non-use values decline with distance. This is because a person who has visited the site and is impressed with its environmental qualities is more likely to be willing to pay for the option of visiting it in the future, as well as to preserve the site for its own sake and for his heirs. In other words visiting the site (and where visits can be explained by a travel cost model) results in information acquirement, which is critical to the establishment of non-use values. In this respect distance is one indicator of the costs of obtaining information. Although the results of the study suggest that visiting the area is the main mechanism by which information is obtained, the results are inconclusive. As such the authors recommend future studies should focus on information availability as a determinant of non-use value and particularly on distance and visits as sources of information. Such studies would thus be able to consider whether knowledge was indeed correlated with distance and visits. Pate and Loomis (1997) consider this issue and find that there is a high degree of multicollinearity between distance and knowledge. As distance from the site increases, knowledge decreases. The authors thus used distance as a proxy for knowledge in order to alleviate the multicollinearity problem. They argue that this also made sense from a procedural sense since distance is something observable and concrete, whereas knowledge is not.

Interestingly, Pate and Loomis (1997) find support for the result found in Sutherland and Walsh (1985) that WTP fell off at a less dramatic rate with distance under the option value category of non-use compared to the existence and bequest categories of value. Pate and Loomis (1997) find that distance has an effect on willingness to pay for wetlands and contamination control, but not for a river and salmon improvement program. They argue firstly that the WTP values for the river and salmon program are mostly use value driven. Second, whilst use and option are not equivalent, option value is closer to use value than are the other categories of non-use. As such, they maintain that if the value of salmon improvements consists mainly of use values then their results are consistent with the Sutherland and Walsh (1985) findings.

Hanley et al., (2003) report that some authors have argued that there is no reason to expect non-use values to be subject to a distance decay effect. The reason is that unlike the case for use values, there is no relationship between benefits, use, costs of access and distance. However, the authors suggest that a sense of 'ownership' or spatial identity may be important for some environmental assets. In this way someone may have stronger non-use values for Scottish wildlife sites if they are Scottish than for

an English wildlife sites, and hence a distance decay – non-use relationship is feasible. The Hanley et al., (2003) study finds that although a significant distance decay effect for non-users is established, the relationship is stronger for users than for non-users.

Table 1 summarises a number of the previous studies that have been undertaken on the issue of distance decay of users and non-users values.

Table 1: Summary of Distance decay studies

Study	Good	Distance Decay Present	
		All responses	Present non-users only
Sutherland & Walsh (1985)	Preserving water quality	✓	✗
Imber et al., (1991)	Preserving Kakadu Conservation Zone	n/r	✗
Loomis (2000)	Preserving endangered species	✓	n/r
Bateman et al (2000)	Preserve wetlands	✓	✗
Bateman et al (2005a)	Preserve remote mountain lakes	✓	✗
Pate & Loomis (1997)	Increasing the area of wetlands	✓	n/r
Pate & Loomis (1997)	Increasing bird numbers	✓	n/r
Hanley et al (2003)	Improving river flows	✓	✓
Mouranaka (2004)	Improving forests	✓	n/r
Present study	Improving a river	✓	✓

n/r = not reported

✓ = significant distance decay

✗ = no significant distance decay

Given this previous work on the issue of distance decay, use, non-use and aggregation, we now illustrate our proposed spatially sensitive valuation function approach using two case studies. In each case, a comparison is made with some alternative approaches to aggregation. The first case study makes use of a partial application of the approach, and although the results have been fully reported elsewhere (Bateman et al, 2000), it is briefly summarised here in order to illustrate the development and progression of the complete approach.

4. CASE STUDY I: SPATIALLY SENSITIVE VALUATION FUNCTION APPROACH APPLIED TO PRESERVING A NATIONAL PARK WETLAND IN THE UK

The first case study is based on data taken from a postal contingent valuation survey of households across Great Britain designed to estimate respondents willingness to pay for schemes designed to preserve the Norfolk Broads from the threat of saline flooding (see Bateman and Langford, 1997; Bateman et al., 2000 for details). The values elicited were for a sample of present non-users and hence may include motivations related to option values as well as pure non-use. The distinction between users and non-users of a resource is examined further in the second case study. Just over one thousand questionnaires were sent to households across Great Britain and a GIS was used to calculate distance from each address to the Norfolk Broads. Following two reminders a sample of 310 completed questionnaires was collected. This relatively modest return rate was expected given that surveys were equally distributed throughout the country, rather than being concentrated around the resource site. This permitted us to examine the determinants of response rates in an unbiased manner. The GIS was used in conjunction with census data to extract socioeconomic profiles for all areas. This information was combined with the distance estimates to permit the estimation of a survey response function. The main findings relevant for aggregation purposes were as follows: Visits to the Broads declines significantly with distance; the decision to reply to the survey was found to be inversely related to the respondents distance from the Broads but positively related to the socioeconomic status of the local area of the address to which the questionnaires were sent; the payment principle of incurring extra taxes to pay for flood defences was also found to be negatively related to distance from the Broads and positively related to respondent income; finally, based on an open ended elicitation format and inclusion of payment principle refusals (as zero's), a whole-sample mean WTP was estimated at £23.29. Valuation function analysis indicated that individuals' WTP bids were negatively related to distance from the Broads and positively related to income.

Aggregation was conducted in two ways. The first is based on the standard 'political jurisdiction' approach adopted by the UK Environment Agency (EA) in the benefits assessment for the Axford enquiry. Under this approach the whole sample mean WTP of present non-users (£23.29) is multiplied by the population of Great Britain on the assumption that the Broads has National Park equivalence status (c.f. SSSI/ESA designation aggregation approach earlier). The second approach uses a series of valuation functions that relate individuals' WTP amounts to distance, income and other variables (other variables were also included and set to their mean values). The valuation function is then used to estimate the WTP per representative household for each county in the UK, taking into account the distance of each county from the Broads and the average annual regional household income in each county. It is not however used to define the geographical extent of the market as proposed in the full GIS-distance decay approach. Rather, this was defined as the national population (using the county by county aggregate populations), taking into account survey non-response rates for each county. Aggregation was thus carried out on a county by county basis with information on distance being taken from the Bartholomew's digital map of Great Britain and regional income data being taken from official sources (ONS, 1997, 1998). To test sensitivity to these data, the distance decay valuation functions were also used for comparative purposes to provide aggregations based on a set of analyst defined distance zones and national income levels rather than the counties and regional income data (approach 2i). A further sensitivity analysis was undertaken upon all three of the aggregation approaches outlined above by truncation of the survey data to remove the upper and lower 2.5% of WTP responses so as to allow for WTP uncertainty and outlier effects.

The results from the various approaches are shown in table 2. This shows that the aggregate benefits vary considerably across the procedures used. It can be seen that for the untruncated sample the standard 'political jurisdiction' approach (1) gives aggregate benefits estimates that are around 6 times higher than that provided by either of the national population – value function based aggregations (2i

and ii). Interestingly the two value function approaches provide fairly stable estimates with respect to the geographic scale of data used in the aggregations. The results for the truncated estimates indicate that the political jurisdiction aggregations are more subject to the effects of truncation of outlier WTP values than the value function based aggregations. Whilst the political jurisdiction values are much higher in this case than the value function aggregations, given that the political boundary has no theoretically correct limit, its redefinition could in fact reduce rather than inflate aggregate values.

Table 2: The present non-user's benefits of preserving the present condition of Broadland aggregated across Great Britain using various procedures (£ million/annum)

Aggregation approach	Untruncated	Truncated
(1) Aggregation using sample mean WTP and national population (EA/Axford 'political jurisdiction' approach)	159.7	98.4
(2) Aggregation using partial GIS/valuation function based approach:		
i. using distance zone and national income	27.3	25.3
ii. using county distance and regional income	25.4	24.0

5. CASE STUDY II: SPATIALLY SENSITIVE VALUATION FUNCTION APPROACH APPLIED TO URBAN RIVER WATER QUALITY IMPROVEMENTS

The second case study extends the GIS based spatially sensitive valuation function approach to aggregation developed in our prior analysis. Data is taken from a face to face contingent valuation survey of WTP for water quality improvements to the River Tame (situated in the Midlands area of the UK). The data set has been used by the UK Environment Agency in order to provide environmental benefit estimate measures for the assessment of Asset Management Plans (AMP) of the Water Utility Companies as part of OFWATS's (the UK Water regulatory authority) Periodic Pricing Review (1994). This previous use of the benefit measures did not consider the issue of distance decay and aggregation. We report the characteristics of the study in detail in order to provide the full context for the findings reported.

As mentioned above, the case study used for this exercise concerned improvements to water quality in the River Tame passing through the City of Birmingham, UK. The river rises on the west of the city, flows eastward through the city and turns north till it meets with other elements of the Trent catchment. It is therefore a relatively minor asset compared to the National Park of the previous application. Furthermore its urban course means that it has suffered long term degradation and is now classed as one of the UK's most polluted rivers with fish stocks virtually non-existent and plant growth, insects, bird and animal life all severely limited. However, the river does have ecological and recreational potential and passes through residential areas, playing fields and a country park. A full description of the physical and human geography of the river is found in Annex 1.

The survey questionnaire used to elicit the CV opened by asking respondents for details regarding their residency in Birmingham, together with their patterns of use of the River Tame (how often they visit the river; for what purpose etc.). The survey then proceeded to ask a number of attitudinal questions employing Likert scales to assess respondents' perceptions of the importance of environmental issues relative to other social issues. Respondents were then asked for their perceptions of the water quality in the river before being provided with some detailed information regarding past and present state of the water quality in the River Tame.

Three nested levels of river quality improvement were used in the valuation exercise, namely a small (S), medium (M) and large (L) improvement. These were described textually detailing the impact of each improvement upon three attributes of water quality: fishing; plants and wildlife; and boating and swimming. Respondents were told that these three improvements were alternatives to each other, of which only one would be implemented, and therefore should be evaluated relative to a common baseline of the current situation, which was also described. It was made clear to respondents that values for all three improvements would be elicited, and this was then undertaken using a direct open-ended question asking the respondent to state their maximum WTP for the good in question. The specified payment vehicle was an annual increase in council tax paid by respondents. The final section of the questionnaire elicited information concerning the socio-economic and demographic characteristics of the respondents.

5.1 Descriptive Sample Statistics

A sample of 675 useable observations was gathered through face-to-face interviews conducted during August and September 1999 at respondents' places of residence in the Birmingham area⁷. Table 3

⁷ Although the sample was not specifically designed to capture a representative sample of the population of Birmingham households, it was randomised by the random selection of streets throughout the Birmingham area within which households were approached. Some 53% of those households approached refused to be surveyed. However a survey error led to the geographical distribution of refusals not being recorded (an issue to be addressed in future research).

provides some general characteristics of this sample with full information supplied by Georgiou *et al.* (2000). Note that the majority of the sample (54%) had not visited the River Tame whereas a minority (11%) visited every week. We consider the implications of this on certain aspects of the study in a late section.

Table 3: General Characteristics of Respondents

Characteristic	
Sample size	675
Mean Income (£) and % don't know/refused	19023 (50.0)
Age (mean)	48.4
Sex (% of men)	45.9
Employment (% employed)*	51.1

* full or part-time

We now consider the distance decay valuation function analysis used to derive the per-household WTP estimates and the geographical extent of the market used in the aggregation exercise as discussed in section 3. Simple descriptive statistics for the WTP values are described later in the aggregation analysis.

5.2 Distance Decay Valuation Function Analysis

Given the nature of the WTP response variable, the valuation function analysis is modelled using a generalised least squares random effects approach (Greene, 1990) in order to allow for possible intra-respondent correlation between WTP responses given for the three water quality improvements. Since the responses are also censored at zero (negative WTP amounts are not permitted), the WTP amounts were transformed to their natural logarithm form, thus preventing negative WTP amounts from being predicted in the first place (in order not to lose any zero bidders in the transformation process, a value of one is added to all WTP amounts prior to taking natural logarithms)⁸. Although Tobit analysis is often advocated for dealing with censored distributions, it is only applicable in those cases where the latent variable can, in principle, take negative values and the observed zero values are a consequence of censoring and non-observability. It is not clear that this is actually the case when considering open-ended WTP data (Randall et al, 2001). Nevertheless, maximum likelihood random effects Tobit specifications were also estimated in order to examine the performance of alternative specifications. It should be noted that the following analyses are all based on the sample of respondents excluding protest responses⁹ and for whom there were no missing observations¹⁰ (hence the reduced number of observations from the full sample found in the analyses that follow).

Therefore, we cannot adequately incorporate this factor in our present study and recognise that sample self-selection bias means that our aggregation sums may consequently be somewhat inflated. However, the methodology developed here and comparisons across aggregation modes is not dependent upon such refusals data.

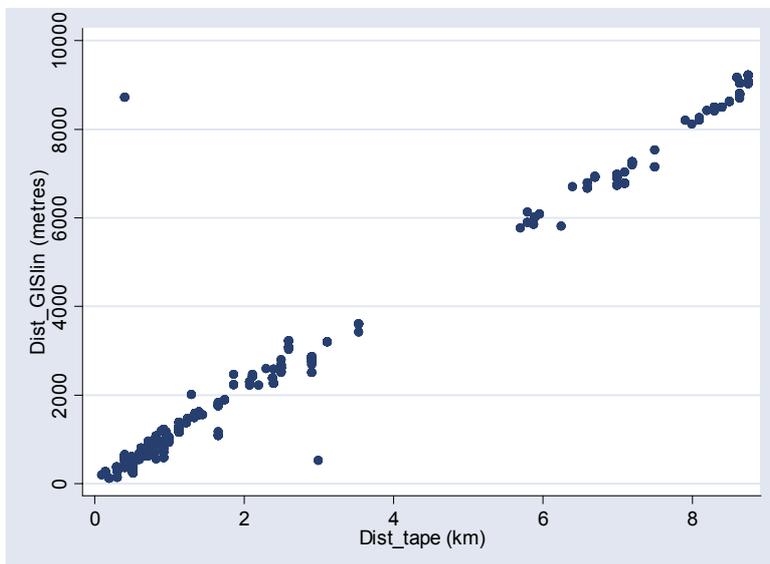
⁸ The logarithmic form also makes theoretical sense in that it captures the possibility of diminishing marginal effects, such that distance changes that are relatively close to the site have a more dramatic impact on WTP than those further away.

⁹ These are defined as zero WTP responses that are given in protest against some aspect of the contingent commodity, even though they actually value the improvement under consideration. Such responses are excluded since the factors determining protests may be quite different from those underlying the variation in WTP values of the good itself. It is this latter variation that the valuation function analysis seeks to explain.

¹⁰ As noted earlier non-response can lead to sample selection bias such that the characteristics of the sample and the actual population diverge. Morrison (2000) undertakes a full investigation of the impact of such non-response bias on aggregation.

The explanatory factors used in the distance decay valuation function analysis included dummy variables for two of the three (Large & Medium) water quality improvements (the omitted 'Small' one being used as the base case). Three different 'distance' variables were considered as potential measures to examine distance decay. The first was a measure made by hand from a paper map of the straight line distance from the respondents' homes to the river Tame (Dist_tape). The second distance variable was a GIS generated estimate of the distance from the respondents' home to the nearest section of the river Tame via the nearest access route/road (Dist_GISacc). The final distance variable was again a GIS generated estimate of the straight line distance from the respondent's home to the nearest section of the river Tame (Dist_GISlin). Figure 4 shows that the 'tape measured' and GIS generated estimates of straight line distance closely correspond (two outliers were found probably reflecting some measurement or recording error). A variety of other potential explanatory variables were investigated as reported in table 4.

Figure 4: Scatterplot of 'paper map' versus GIS generated measure of straight line distance from respondents home to River Tame



A variety of model specifications are considered in the distance decay valuation-function analysis (table 5 and table 6). As previously mentioned, a GLS random effects modelling approach using the log-transformed WTP amounts can be used, as well as maximum likelihood random effects Tobit modelling of the untransformed WTP amounts. Given the use of the dummy variables to represent the large and medium water quality improvements, the valuation function analysis uses the WTP responses for the smallest good to represent the base case. For each specification a group of three regression models are shown, each model using one of the three different 'distance' variables. It should be noted that

and hence we do not consider this further here. As already mentioned, the methodology developed here and comparisons across aggregation modes is not dependent upon such non-response data.

Table 4: Variables used in the distance-decay valuation function analysis

Variable Name	Description
wtp	Willingness to pay (continuous)
lnwtp	Natural log of willingness to pay (continuous)
Large	Large environmental improvement (dummy: 1=large)
Medium	Medium environmental improvement (dummy: 1=medium)
Dist_tape	Distance from respondents home to River Tame (km) – tape measured estimate
Dist_GISacc	Distance from respondents home to River Tame access point (m) – GIS using postcode
Dist_GISlin	Distance from respondents home to River Tame as crow flies (m) – GIS using postcode
Env	How interested is respondent in env. Issues (1-not interested at all; 5- very interested)
Know	Did respondent already know info about water quality in River Tame (dummy: 1=yes)
Retire	Is respondent retired (dummy: 1=yes)
Age	Respondent age (continuous)

Table 5: Distance Decay Regression Models - GLS random effects modelling approach specifications

Variable	(1)	(2)	(3)	(4)	(5)	(6)
	Lnwtp	lnwtp	lnwtp	lnwtp	lnwtp	lnwtp
Large	0.631 (15.15)**	0.625 (14.70)**	0.625 (14.70)**	0.629 (15.15)**	0.623 (14.69)**	0.623 (14.69)**
Medium	0.333 (8.00)**	0.331 (7.78)**	0.331 (7.78)**	0.332 (7.99)**	0.330 (7.78)**	0.330 (7.78)**
Env	0.292 (3.78)**	0.295 (3.78)**	0.295 (3.78)**	0.239 (3.18)**	0.242 (3.19)**	0.243 (3.19)**
Know	0.449 (3.00)**	0.454 (2.98)**	0.454 (2.98)**	0.410 (2.75)**	0.413 (2.73)**	0.414 (2.74)**
Age	-0.017 (3.88)**	-0.017 (3.89)**	-0.017 (3.88)**			
Retire				-0.618 (3.45)**	-0.648 (3.58)**	-0.646 (3.57)**
Dist_tape	-0.046 (1.79)			-0.049 (1.89)		
Dist_GISacc		-0.00005 (1.94)			-0.00005 (2.03)*	
Dist_GISlin			-0.00005 (2.06)*			-0.00005 (2.15)*
Constant	0.856 (2.64)**	0.869 (2.64)**	0.865 (2.63)**	0.419 (1.37)	0.432 (1.39)	0.428 (1.38)
Observations	1203	1176	1176	1206	1179	1179
Number of sn	401	392	392	402	393	393

Absolute value of z statistics in parentheses

* significant at 5%; ** significant at 1%

All the model specifications find that the two scope dummies, 'Large' and 'Medium', which act as intercept shifters upon the distance decay of values, indicate not only the expected higher values for

larger improvements, but also (given the logarithmic form of this function) a somewhat more rapid decline for the latter¹¹ although values for larger schemes always remain above those which they nest. A variety of other variables are found to be significant determinants of the WTP responses for each of the model specifications. In addition to the various distance variables, which are discussed separately below, WTP was, according to the different specifications, found to be significantly related to, respondents' prior knowledge regarding water quality problems, respondents' interest in environmental issues, the age of the respondent and whether the respondent was retired or not. Those who had prior knowledge (and thereby, arguably, higher concern) regarding the water quality problems affecting the River Tame were found to have increasing WTP, whilst respondents' interest in environmental issues was also positively related to WTP, whereas the negative sign on the coefficient estimated for the age variable indicates that WTP decreases with increasing age. This was also the case when retirement was used rather than the age variable (GLS specifications only).

Table 6: Distance Decay Regression Models – Maximum likelihood random effects Tobit modelling approach specifications

Variable	(1)	(2)	(3)
	Wtp	wtp	wtp
Large	21.320 (13.64)**	23.166 (14.29)**	21.719 (13.63)**
Medium	9.445 (5.96)**	10.380 (6.33)**	9.660 (5.98)**
Env	8.793 (13.53)**	3.188 (6.98)**	8.759 (5.00)**
Retire	-31.828 (7.99)**	-5.322 (1.77)	-33.774 (9.45)**
Dist_tape	-3.402 (7.10)**		
Dist_GISacc		-0.00007 (0.20)	
Dist_GISlin			-0.0034 (7.62)**
Constant	-22.217 (.)	-33.238 (.)	-20.908 (2.43)*
Observations	1206	1179	1179
Number of sn	402	393	393

Absolute value of z statistics in parentheses

* significant at 5%; ** significant at 1%

With respect to the distance decay issue, each specification includes a separate model for each of the three distance variables. As can be seen, each of the distance variables have the expected negative sign indicating that WTP does indeed exhibit distance decay, and are on the whole significant depending on the specific distance variable that is used. The main exception is in the random effects Tobit specification where there are also problems of convergence in some of the models.

¹¹ More rapid rates of change were investigated by adding two terms for the interaction between distance and the two scope variables. However, in this case both were found to be clearly statistically insignificant and so are omitted from the final model reported above.

Hausman tests were performed for each of the different distance variable models under each specification to see whether the coefficients estimated under each model are the same¹². For each set of models tested it is found that the hypothesis that the coefficients are the same cannot be rejected (i.e. they produce similar models).

5.3 Including Socioeconomic Variables Associated with Individuals' Residential Areas

Whilst the above regressions are all based on models that use individual specific characteristics, we were able to include additional socioeconomic information for each respondent in the data set based on the geographic (residential) census unit (output area) in which they live¹³. This was possible as a result of being able to link through a Geographical Information System the address of each respondent with official census information. From each questionnaire the postcode of the respondent was cross referenced with the UK postcode look up directory in order to identify the census unit (output area) within which each respondent's house was located. Once this has been identified a variety of census data was extracted for each output area including the employment status of the population (e.g. percentage unemployment), the qualification status (e.g. percentage with a university degree) and the percentage of car ownership.

Whilst a large number of such variables were extracted and investigated, only a few were actually used in the final analysis (many were found to be highly correlated to one another) The additional variables (to those already discussed in the earlier regression models) used are shown in table 7.

These additional census unit variables were then used along with the individual specific characteristics to produce the regression models shown in table 8 and 9. Once again a variety of specifications are shown based on the two previous modelling approaches. As can be seen, the use of the additional variables improved the performance of the various models. It was found that all of the additional variables had a negative relationship with the WTP responses, and all were highly significant, though once again there were some problems of convergence in the random effects Tobit regressions models. The use of the additional variables also had the effect of improving the significance level of all of the different distance variables.

Table 7: additional socioeconomic variables based on geographic (residential) census unit

Variable Name	Description
Self-Emp	Percentage of people aged 16-74 self employed
Unemp	Percentage of people aged 16-74 unemployed
Student	Percentage of people aged 16-74 full time student

¹² The Hausman test is used to test whether the coefficients estimated under each model are the same. LR test is not possible to use since the models are GLS random effects estimator models. Hausman is only able to compare coefficients estimated by both techniques. If p value is < 0.05 (i.e. significant) then we can reject hypothesis that coefficients are the same. For all specifications of the GLS random effects models

¹³ Given the problems noted earlier regarding the representativeness of the sample as a consequence of sample self selection, the incorporation of wider census data is one way of reducing such problems.

Table 8: Distance Decay Regression Models - GLS random effects modelling approach specifications with additional census unit variables

Variable	(1)	(2)	(3)	(4)	(5)	(6)
	lnwtp	lnwtp	lnwtp	lnwtp	lnwtp	lnwtp
Large	0.625 (14.70)**	0.625 (14.70)**	0.625 (14.70)**	0.623 (14.70)**	0.623 (14.69)**	0.623 (14.69)**
Medium	0.331 (7.78)**	0.331 (7.78)**	0.331 (7.78)**	0.330 (7.78)**	0.330 (7.78)**	0.330 (7.78)**
Env	0.268 (3.46)**	0.270 (3.48)**	0.269 (3.48)**	0.219 (2.89)**	0.219 (2.90)**	0.219 (2.90)**
Know	0.392 (2.58)**	0.392 (2.58)**	0.392 (2.59)**	0.356 (2.36)*	0.356 (2.36)*	0.356 (2.36)*
Age	-0.017 (3.83)**	-0.017 (3.88)**	-0.017 (3.87)**			
Retire				-0.598 (3.32)**	-0.601 (3.35)**	-0.604 (3.36)**
Unemp	-0.108 (3.32)**	-0.109 (3.36)**	-0.109 (3.37)**	-0.099 (3.03)**	-0.100 (3.06)**	-0.100 (3.06)**
Dist_tape	-0.074 (2.77)**			-0.075 (2.78)**		
Dist_GISacc		-0.00007 (2.88)**			-0.00007 (2.97)**	
Dist_GISlin			-0.00007 (2.97)**			-0.00007 (2.87)**
Constant	1.471 (3.93)**	1.501 (4.00)**	1.490 (3.99)**	0.986 (2.74)**	1.001 (2.79)**	1.010 (2.80)**
Observations	1176	1176	1176	1179	1179	1179
Number of sn	392	392	392	393	393	393

Absolute value of z statistics in parentheses

* significant at 5%; ** significant at 1%

Table 9: Distance Decay Regression Models – Maximum likelihood random effects Tobit modelling approach specifications with additional census unit variables

Variable	(1)	(2)	(3)
	wtp	wtp	wtp
Large	21.923 (13.90)**	22.050 (13.79)**	21.829 (13.65)**
Medium	9.785 (6.14)**	9.813 (6.07)**	9.716 (6.00)**
Env	8.195 (4.96)**	11.506 (6.73)**	9.886 (4.88)**
Student	-2.959 (3.73)**	-5.342 (3.08)**	-4.605 (4.92)**
Self-Emp	-3.084 (7.25)**	-2.116 (2.19)*	-1.171 (.)
Unemp	-8.666 (14.32)**	-7.548 (10.03)**	-7.221 (7.86)**

Retire	-29.136 (8.77)**	-24.045 (4.71)**	-10.750 (.)
Dist_tape	-1.544 (3.23)**		
Dist_GISacc		-0.002 (2.56)*	
Dist_GISlin			-0.004 (5.12)**
Constant	30.781 (3.15)**	12.039 (1.09)	12.735 (1.07)
Observations	1179	1179	1179
Number of sn	393	393	393

Absolute value of z statistics in parentheses

* significant at 5%; ** significant at 1%

5.4 Distance decay functions for Use and Non-Use Values

The preceding analysis considers the distance decay issue in the context of the total value of river water quality improvements in the river Tame. Although the valuation study did not distinguish between use and non-use values, respondents were nevertheless categorised according to whether they were visitors or non-visitors to the site. The categorisation into these two user groups enables us to some extent to consider the question of how non-use values may be related to distance (and consequently to the issue of the extent of the market). As discussed in section 2 the nature of the distance decay relationship for non-use values is more of an open question and may have much greater significance than for use values since the geographical extent of the market of non-users may extend over a much wider area¹⁴. We therefore also investigated the relationships regarding use values, non-use values, knowledge, visitation and distance from the site.

As already mentioned, the categorisation into use and non-use is not pure in the sense that the respondents to the survey were only able to be identified as current visitors and current non-visitors. Clearly visitors might be expected to express both use and non-use motivations in their WTP responses. However, since non-visitors are not making any current use of the site (and hence will not have any current use value), they will be solely expressing non-use motivations¹⁵.

Firstly with respect to the issue identified by Sutherland and Walsh (1985) regarding information availability as a determinant of non-use value, we considered the extent to which distance and visits are sources of information as suggested by the authors. Table 10 looks at the explanatory factors underlying whether respondents' had previous knowledge about the environment state of the river Tame or not (Know) and whether they visited the river or not (Visit). The regression models are all based on a binary dependent variable and hence logistic regression is used to model the

¹⁴ The effect of distance on use values has been extensively investigated since it provides the theoretical basis of studies utilising the travel cost method (Freeman, 1993).

¹⁵ It is assumed that non-use values incorporate option, existence and bequest demands as suggested by Krutilla (1967). Depending on the type of environmental change being considered, the non-use motivations may incorporate a greater or lesser element related to future use (or option) value. An environmental improvement (gain) in a resource is more likely to lead to some current non-visitors potentially wanting to use the resource in the future (such that option value will be a greater element of non-use value). However, such option values are likely to be less important in the case when the environmental change being considered is the avoidance of an environmental deterioration (loss) from the current level.

relationships. Regression equations 1-3 suggest that the probability of a respondent having knowledge about the state of the river is significantly and positively related to whether a respondent had previously visited the site (Visit), whether the respondent was a man, the age of the respondent (Age), but unrelated to the distance that the respondent lives away from the river (Distance). Regression equations 4-6 suggests that distance is in fact indirectly related to knowledge through the fact that it is significantly and inversely related to visitation. These results suggest that whilst visitation is indeed the main mechanism by which information about a site is obtained, distance also plays a role through the determination of visitation.

Table 10: Logistic regression models of Knowledge and Visitation regarding the river Tame

Variable	(1)	(2)	(3)	(4)	(5)	(6)
	Know	Know	Know	Visit	Visit	Visit
Visit	0.683 (4.17)**	0.722 (4.27)**				
Male	0.480 (2.94)**	0.491 (2.99)**	0.528 (3.27)**			
Age	0.022 (4.66)**	0.021 (4.50)**	0.023 (5.01)**	0.012 (2.63)**	0.016 (3.54)**	
Distance		0.029 (0.94)	-0.003 (0.10)	-0.200 (6.00)**	-0.196 (5.97)**	-0.183 (5.72)**
Know				0.748 (4.46)**		
Constant	-1.509 (5.94)**	-1.577 (5.96)**	-1.281 (5.14)**	-0.683 (2.79)**	-0.486 (2.06)*	0.269 (2.53)**
Observations	660	660	660	660	660	662
LR chi2	56.19	57.08	38.62	68.64	48.44	36.59
(Prob > chi2)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Pseudo R-squared	0.06	0.06	0.04	0.08	0.05	0.04

Absolute value of z statistics in parentheses

* significant at 5%; ** significant at 1%

Whether or not these relationships between knowledge, visitation and distance means that non-use values decline with distance is considered in the following analysis.

Table 11 repeats the distance decay valuation function analysis using split samples for visitors and non-visitors. A number of different specifications are considered. The first two models (1 and 2) include individual characteristics only, whilst models 3 and 4 include both individual and census level characteristics. The final two models (5 and 6) only include census level characteristics. In each case the linear GIS distance variable (Dist_GISlin) is used as the distance variable (similar results are found for the other distance variables). The table shows that, as expected, the distance variable coefficients are all negative. However only the distance variables in the regression models for the non- visitors split samples are significant. Amongst the visitors split sample models distance did not appear to play a role in determining WTP values. As was discussed in section 2, it is not *a-priori* clear that the WTP of those who are already visitors will necessarily exhibit a strong distance decay. Clearly this appears to be borne out in our empirical findings. Furthermore, and as was also discussed in section 2, figures 5 and 6 shown that there is a very clear declining trend regarding the number of users and their proportion relative to non-users as distance increases.

Table 11: Distance decay relationships for visitors and non-visitors WTP

Variable	(1) non visitors	(2) visitors	(3) non visitors	(4) visitors	(5) non visitors	(6) visitors
	lnwtp	lnwtp	lnwtp	lnwtp	lnwtp	lnwtp
Large	0.676 (11.42)**	0.556 (9.25)**	0.676 (11.42)**	0.556 (9.25)**	0.676 (11.42)**	0.556 (9.25)**
Medium	0.329 (5.56)**	0.331 (5.50)**	0.329 (5.56)**	0.331 (5.50)**	0.329 (5.56)**	0.331 (5.50)**
Dist_GISlin	-0.00005 (1.93)*	-0.00002 (0.47)	-0.00008 (2.56)*	-0.00004 (0.90)	-0.00008 (2.60)**	-0.00005 (1.21)
ENV	0.340 (3.45)**	0.053 (0.44)	0.298 (3.00)**	0.053 (0.45)		
Unemp			-0.100 (2.28)*	-0.097 (1.98)*	-0.146 (3.25)**	-0.107 (2.20)*
Know	0.541 (2.63)**	0.151 (0.65)	0.503 (2.46)*	0.071 (0.31)		
Retire	-0.653 (2.60)**	-0.647 (2.47)*	-0.613 (2.45)*	-0.604 (2.32)*		
Constant	-0.048 (0.12)	1.372 (2.68)**	0.583 (1.22)	1.860 (3.30)**	2.021 (7.87)**	2.035 (7.55)**
Observations	660	519	660	519	660	519
Number of sn	220	173	220	173	220	173
sigma_u	1.42	1.44	1.41	1.42	1.47	1.43
sigma_e	0.62	0.56	0.62	0.56	0.62	0.56
Rho	0.84	0.87	0.84	0.87	0.85	0.87
wald chi2	161.78	93.59	167.58	97.64	143.76	92.09
r-squared	0.14	0.06	0.16	0.08	0.08	0.05

Absolute value of z statistics in parentheses

* significant at 5%; ** significant at 1%

Figure 5: Frequency Distribution of visitors and non-visitors

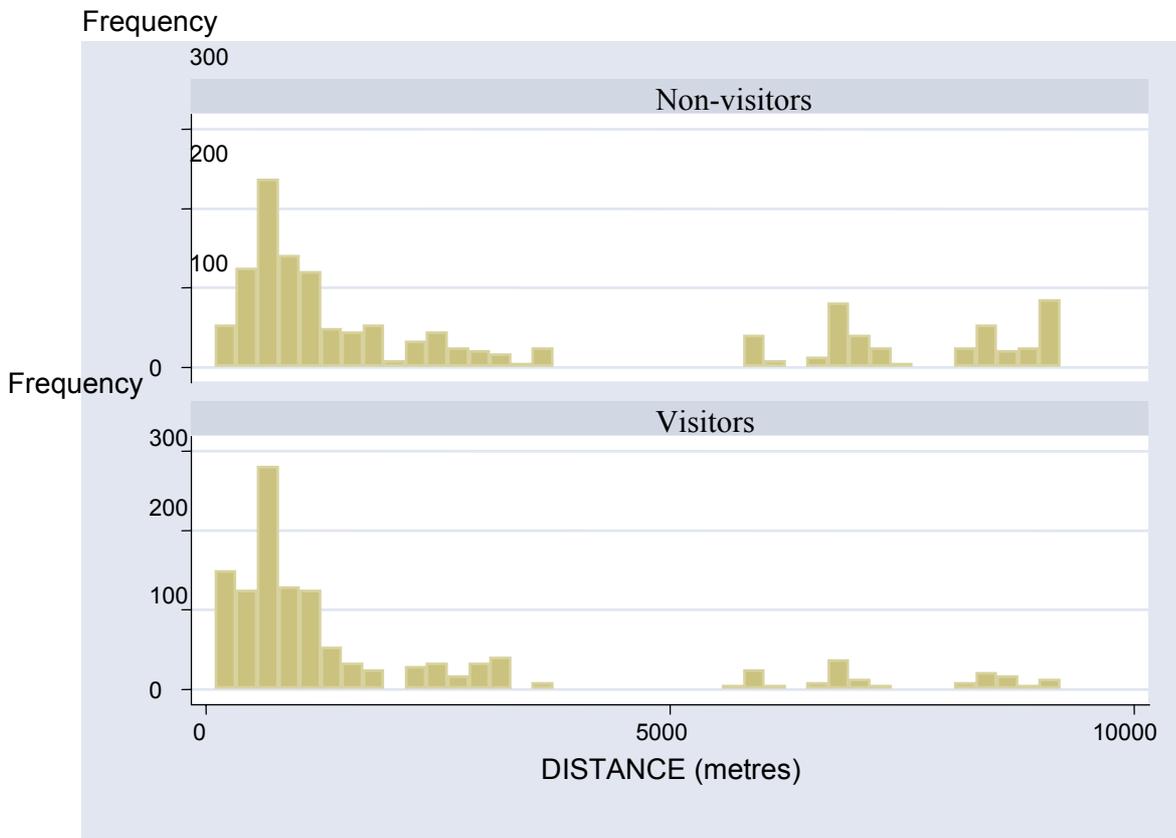
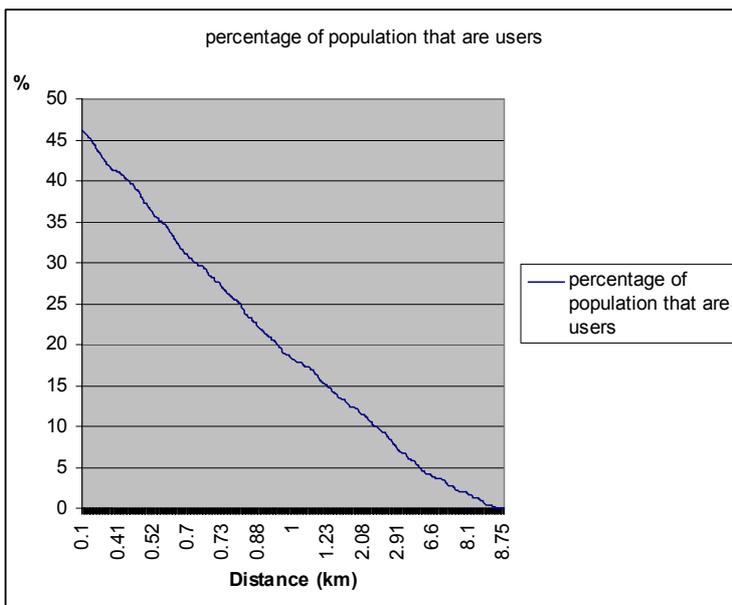


Figure 6: Number of visitors as a percentage of total sample



5.5 Analysis to Define Economic Jurisdictions for Aggregation

Given any distance decay valuation function, it is possible to define the spatial range (geographical extent of the market) over which WTP for the improvements in water quality are positive i.e. the economic jurisdiction. As discussed earlier in the report the economic jurisdiction should include all those who benefit from the improvement, and in terms of distance extends to the point at which WTP for the improvement equals zero (beyond the boundaries of the economic jurisdiction, WTP is non-positive). Given the variety of distance decay valuation function specifications that were estimated earlier, there are a number of economic jurisdictions that are possible depending on which model is used. We therefore select a number of the simpler specifications in order to illustrate the approach, though any one of the models could be used. For this reason, as well as the problems of convergence in the modelling, the Tobit specifications are not included in any further analysis. Furthermore we also drop the analyses based on the less precise 'tape measured' estimate of distance and concentrate only on the models using the two GIS based measures of distance. Three types of specifications are thus considered (table 12). The first two are based on the GLS random effects models that included individual level characteristics only (specification 1 and 2) and individual plus census level characteristics (specification 3 and 4). The final type which is included for comparative purposes is again based on GLS random effects modelling but incorporates only the census level characteristics of each respondent whilst including none of their individual characteristics (specification 5 and 6). In each case, the distance decay valuation function is used to calculate the maximum distance at which WTP for the improvement becomes zero. This is done by re-arranging the distance decay function and solving for the distance at which WTP = zero (and holding the non-distance variables at their sample mean values – see table 13). Given that there are three levels of river water quality improvement – Large, Medium and Small, the maximum distance defining the economic jurisdiction is different in each case, as shown in the final three rows of table 12¹⁶. As would be expected we see that the limit for the Medium improvement is wider than that for the Small improvement, while limits for the Large improvement are greater than either of the nested schemes. However, it is interesting to note that the limit for even the largest scheme, at less than 30 km, is very much smaller than the economic jurisdiction observed in our previous case study concerning a National Park and reflects the smaller scale of benefits under consideration in the present application.

Based on these functions, it is also possible to show a graphical representation of the variation in WTP as distance increases for each water quality improvement considered. An example is shown in figure 7 for model specification 3 of the distance decay functions given in table 12. The distance decay functions can also be represented as benefits gradients which show the percentage of at site benefits (defined as the WTP for someone living zero distance from the river) for respondents living at the other distances from the river. Again an example based on specification 3 of the distance decay functions is shown in figure 8. The benefits gradient figure shows, for any given distance decay function, how benefit values for any specific improvement decay over the entire spatial range of the economic jurisdiction defined by that function. As expected, figures 7 and 8 shows that the distance decay curves and the spatial range of the economic jurisdiction vary with the size of the water quality improvement considered.

One of the advantages of a GIS based methodology is the ability of the software to readily generate graphical representations of findings. As such we were able to produce maps showing the estimated mean WTP per household, per annum in each census unit (output area) contained within the economic jurisdiction estimated for any specific distance decay function under each water quality improvement scenario. In order to estimate the WTP in each census unit area, census information and

¹⁶ Annex 2 contains distance decay functions that use continuous measures of water quality rather than the discrete levels of water quality improvements found in the present analysis. This allows for more marginal changes in water quality to be considered (but makes no difference to the aggregation analysis that we undertake).

proximity to the River Tame were obtained for all output areas in England and Wales. This was completed in an identical fashion to that described for the questionnaire data. The data for each output area were applied to the specific distance decay function of interest (using sample mean values for the other explanatory variables) in order to provide an estimate of mean WTP per household per annum in that census area. Once the WTP for each output area under each improvement scenario was calculated, these data were joined to the boundaries of the output areas with the GIS. After removing the output areas that were beyond the boundaries of the economic jurisdiction estimated for the specific distance decay function being considered (i.e. those with negative WTP values), choropleth maps were produced of the results. These are illustrated in figure 9 using as an example one of the distance decay functions (specification 3 from table 12). The maps illustrate how the size of the economic jurisdiction varies according to the improvement scenario considered, as well as how, for each scenario, WTP varies in each census unit according to its proximity to the River Tame and the socioeconomic characteristics found there. This latter facet of the results is amply illustrated by the contrast in values either side of the upper reaches of the Tame (its west to east reach). Here higher values are predicted for the more affluent north bank, with lower values estimated for the poorer central city area on the south bank.

Table 12: Final distance decay valuation function models used to define Economic Jurisdiction

Explanatory variables	Specification type 1 – Individual characteristics only		Specification type 2 – Individual and census level characteristics		Specification type 3 – Census level characteristics only	
	(1) lnwtp	(2) lnwtp	(3) lnwtp	(4) lnwtp	(5) lnwtp	(6) lnwtp
Large	0.623 (14.69)**	0.623 (14.69)**	0.623 (14.69)**	0.623 (14.69)**	0.623 (14.69)**	0.623 (14.69)**
Medium	0.330 (7.78)**	0.330 (7.78)**	0.330 (7.78)**	0.330 (7.78)**	0.330 (7.78)**	0.330 (7.78)**
Env	0.243 (3.19)**	0.242 (3.19)**	0.219 (2.90)**	0.219 (2.90)**		
Know	0.414 (2.74)**	0.413 (2.73)**	0.356 (2.36)*	0.356 (2.36)*		
Retire	-0.646 (3.57)**	-0.648 (3.58)**	-0.601 (3.35)**	-0.604 (3.36)**		
Dist_GISlin	-0.000054 (2.15)*		-0.0000771 (2.97)**		-0.000085 (3.20)**	
Dist_GISacc		-0.0000523 (2.03)*		-0.0000767 (2.87)**		-0.0000847 (3.11)**
Unemp			-0.100 (3.06)**	-0.100 (3.06)**	-0.127 (3.87)**	-0.127 (3.86)**
Constant	0.428 (1.38)	0.432 (1.39)	1.001 (2.79)**	1.010 (2.80)**	2.044 (11.01)**	2.055 (10.83)**
Observations	1179	1179	1179	1179	1179	1179
Number of groups	393	393	393	393	393	393
sigma_u	1.43	1.43	1.41	1.41	1.45	1.45
sigma_e	0.60	0.60	0.60	0.60	0.60	0.60
Rho	0.85	0.85	0.85	0.85	0.86	0.86
wald chi2	250.92	250.41	261.06	260.48	235.86	235.27
prob>chi2	0.000	0.000	0.000	0.000	0.000	0.000
r-squared	0.10	0.10	0.12	0.12	0.07	0.07

Max Distance - L	38.43km	39.73km	27.75km	28.01km	25.43km	25.64km
Max Distance - M	32.99km	34.11km	23.94km	24.18km	21.98km	22.18km
Max Distance - S	26.88km	27.80km	19.66km	19.90km	18.09km	18.28km

Absolute value of z statistics in parentheses
 * significant at 5%; ** significant at 1%

Table 13: Summary statistics for variables included in Table 12 Distance decay functions

Variable	No. of Observations	Mean	Std. Dev.	Min	Max
Inwtp	1179	1.61959	1.620593	0	5.968708
Large	1179	0.3333333	0.4716046	0	1
Medium	1179	0.3333333	0.4716046	0	1
Env	1179	3.933842	0.9943984	1	5
Know	1179	0.5139949	0.5000162	0	1
Retire	1179	0.221374	0.4153479	0	1
Dist_GISacc	1179	2908.558	2899.525	244.831	9242.384
Dist_GISlin	1179	2775.401	2963.088	106.489	9211.766
Unemp	1179	3.98532	2.392932	0	11.16505

Figure 7: WTP – distance decay function (specification 3 in table 12)

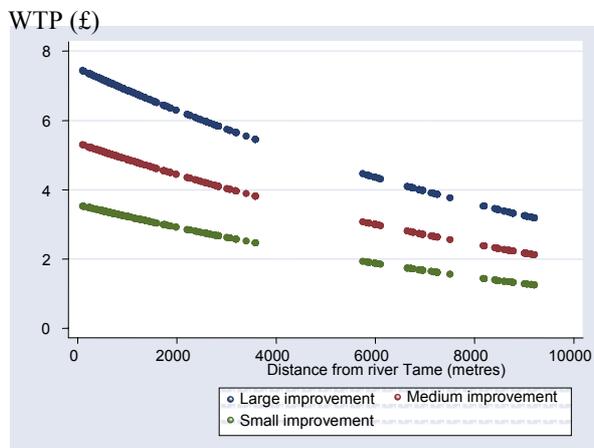


Figure 8: Benefits Gradient for distance decay function (specification 3 in table 12)

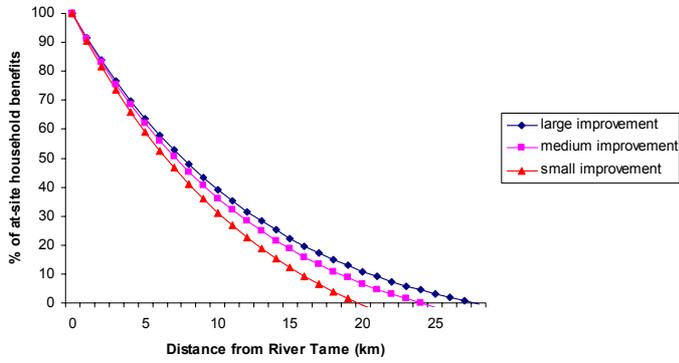
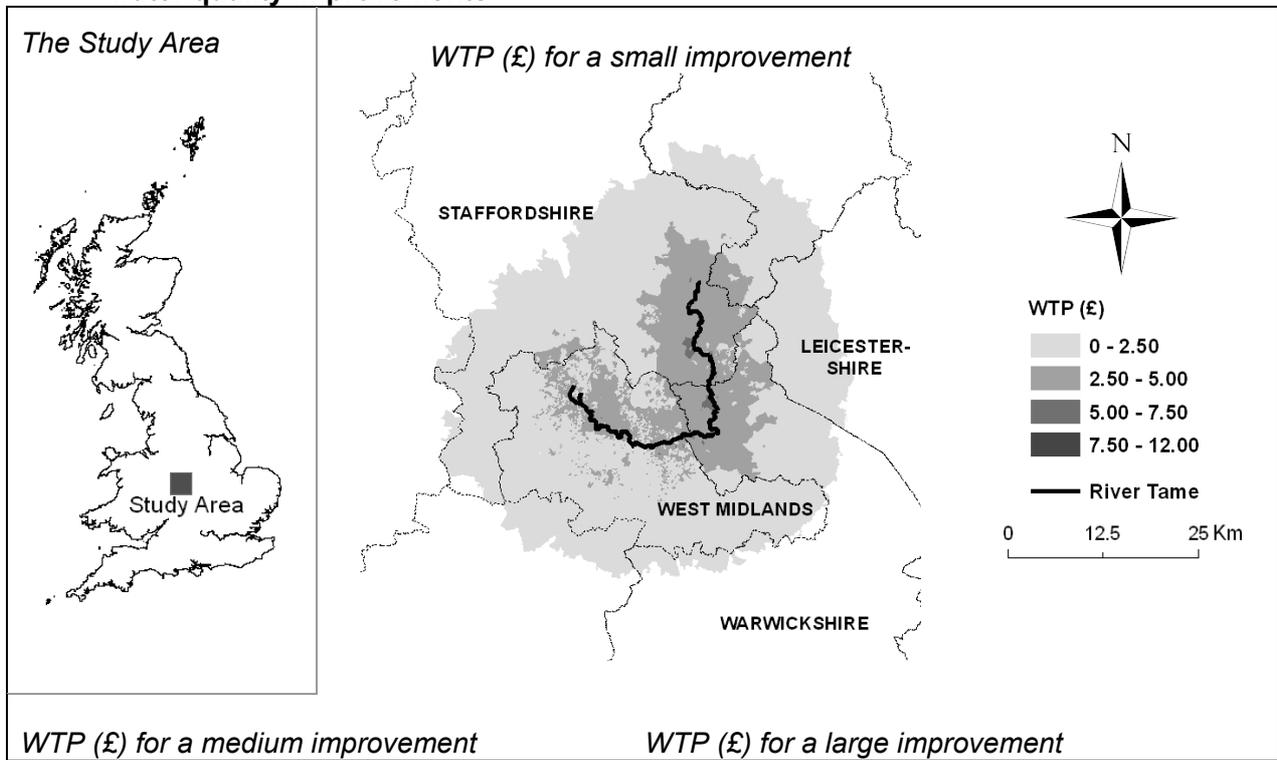
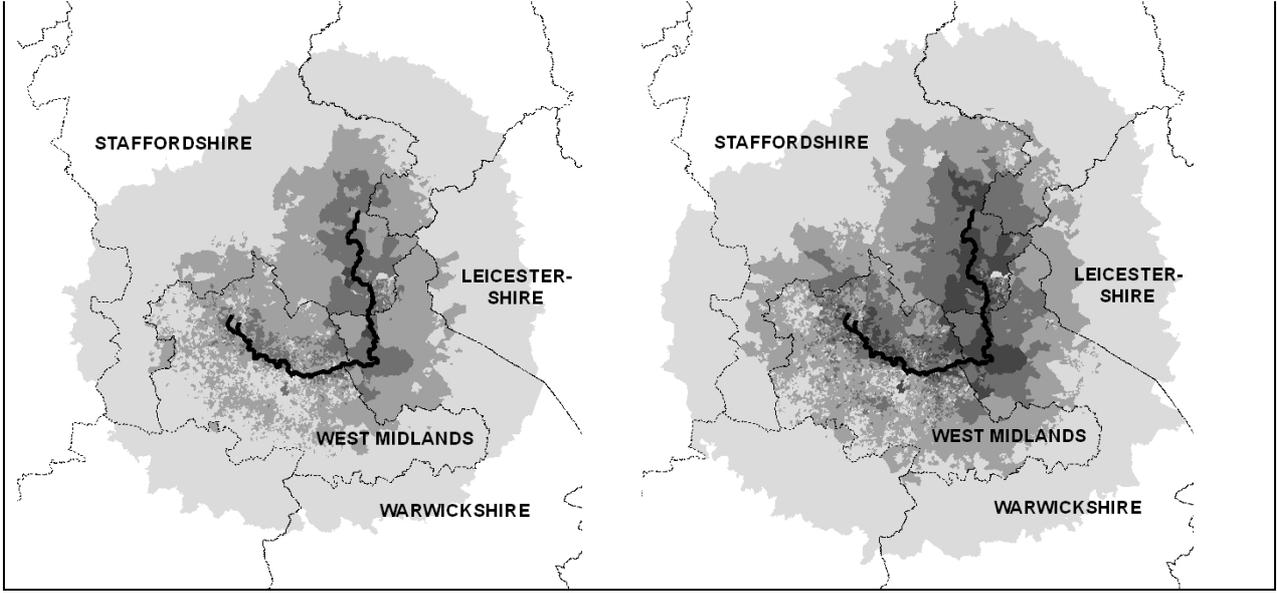


Figure 9: Maps of estimated mean WTP (per household, per annum) of Census areas for various water quality improvements





5.6 Aggregation of Benefits

We can now use the above analysis to provide a spatially sensitive estimate of aggregate benefits for the economic jurisdiction and compare these with the standard approach to estimating aggregate benefits for a politically defined jurisdiction (such as the one adopted by the UK Environment Agency in the Axford enquiry). It is first necessary to identify the population of households that are included for aggregation within each type of jurisdiction. We consider how this was done for each jurisdiction in turn:

a) Economic Jurisdiction:

As discussed in the previous subsection, the distance decay functions can be used to derive the maximum distances from the river Tame that define economic jurisdictions for each improvement level. These are shown in Table 14 for the three different types of distance decay function specifications shown in table 12 earlier. For brevity, the analysis is only undertaken on the functions that used the Dist_GISlin variable to measure distance from the river Tame. The table shows each distance decay function formula as was applied to calculate the WTP in each census unit area (including variable sample mean values where relevant), along with the maximum distance that defines the economic jurisdiction (shown in italics). Finally, in order to identify the number of households within the economic jurisdiction it is necessary to identify which census unit areas are contained within the boundary of the relevant economic jurisdiction's maximum distance. This was done on the basis of the previously extracted GIS data on proximity to the River Tame obtained for all census unit areas in England and Wales. Once the census unit areas within the particular economic jurisdiction were thus identified, the number of households in each unit was aggregated using the data from the census database to provide the total number of households within each economic jurisdiction. These are shown in bold in the table. As expected, the aggregate number of households falls as the spatial range of the jurisdiction decreases and the size of the improvement scenario decreases.

Table 14: Distance decay functions, Distances and household populations used to define economic jurisdiction benefits

		Economic jurisdiction 1: based on distance decay function specification 1 (Individ)	Economic jurisdiction 2: based on distance decay function specification 2 (Individ&Area)	Economic jurisdiction 3: based on distance decay function specification 3 (Area)
Large improve-ment	Distance decay valuation function	$\begin{aligned} \text{Ln (WTP+1)} = & (0.4279538+ \\ & (0.6234586*1) + \\ & (0.2425039*3.933843) \\ & + \\ & (0.4137753*0.5139949 \\ &)+ \\ & (- \\ & 0.6457285*0.221374) \\ & + \\ & (-0.000054*Distance)) \end{aligned}$	$\begin{aligned} \text{Ln (WTP+1)} = & (1.000733+ \\ & (0.6234586*1)+(0.219 \\ & 375*3.933843)+ \\ & (0.3560594*0.5139949 \\ &)+ \\ & (- \\ & 0.6013551*0.221374) \\ & + \\ & (-0.099794*econ4)+ (- \\ & 0.0000771*Distance)) \end{aligned}$	$\begin{aligned} \text{Ln (WTP+1)} = & (2.044495+ \\ & (0.6234586*1)+ \\ & (-0.1271792*econ4)+ \\ & (-0.000085*Distance)) \end{aligned}$
	<i>Max Distance from river that defines jurisdiction (km)</i>	38.43 km	27.75 km	25.43 km
	No. of households within jurisdiction	2,123,800	1,647,777	1,546,544
Medium improve-ment	Distance decay valuation function	$\begin{aligned} \text{Ln (WTP+1)} = & (0.4279538+ \\ & (0.3299763*1)+(0.242 \\ & 5039*3.933843)+ \\ & (0.4137753*0.5139949 \\ &)+ \\ & (- \\ & 0.6457285*0.221374) \\ & + \\ & (-0.000054*Distance)) \end{aligned}$	$\begin{aligned} \text{Ln (WTP+1)} = & (1.000733+ \\ & (0.3299763*1)+(0.219 \\ & 375*3.933843)+ \\ & (0.3560594*0.5139949 \\ &)+ \\ & (- \\ & 0.6013551*0.221374) \\ & + \\ & (-0.099794*econ4)+ (- \\ & 0.0000771*Distance)) \end{aligned}$	$\begin{aligned} \text{Ln (WTP+1)} = & (2.044495+ \\ & (0.3299763*1)+ \\ & (-0.1271792*econ4)+ \\ & (-0.000085*Distance)) \end{aligned}$
	<i>Max Distance from river that defines jurisdiction (km)</i>	32.99 km	23.94 km	21.98 km
	No. of households within jurisdiction	1,849,502	1,486,415	1,408,224
Small improve-ment	Distance decay valuation function	$\begin{aligned} \text{Ln (WTP+1)} = & (0.4279538+ \\ & (0.2425039*3.933843) \\ & + \\ & (0.4137753*0.5139949 \\ &)+ \end{aligned}$	$\begin{aligned} \text{Ln (WTP+1)} = & (1.000733+ \\ & (0.219375*3.933843)+ \\ & (0.3560594*0.5139949 \\ &)+ \end{aligned}$	$\begin{aligned} \text{Ln (WTP+1)} = & (2.044495+ \\ & (-0.1271792*econ4)+ \\ & (-0.000085*Distance)) \end{aligned}$

)+ (- 0.6457285*0.221374) + (-0.000054*Distance))	(- 0.6013551*0.221374) + (-0.099794*econ4)+ (- 0.0000771*Distance))	
<i>Max Distance from river that defines jurisdiction (km)</i>	26.88 km	19.66 km	18.09 km
No. of households within jurisdiction	1,614,896	1,336,736	1,289,523

b) Political Jurisdiction:

For the political jurisdiction, two different definitions were used to define the aggregation population. The first was the UK Environment Agency Region (Midlands Region) which contains the River Tame (political jurisdiction 1) and the second was the Water Utility Company (Severn Trent Water incl. South Staffordshire) whose area the River Tame is in (political jurisdiction 2). This latter definition equates to that used by the Environment Agency in the Axford enquiry. A map of the UK showing all the Environment Agency Regions and Water Utility Companies, including the above two political jurisdictions is shown in figure 10.

Once again, using the census database, it was possible to identify which census unit areas were contained within the boundaries of the two political jurisdictions and to aggregate the number of households in each unit in order to provide the total number of households within each political jurisdiction. Table 15 shows the maximum spatial range covered by each political jurisdiction area, along with the population of households in each case.

Figure 10: Map of the UK showing (1) Environment Agency Regions and (2) Water Utility Companies



(1)



(2)

Table 15: Area and household populations used to aggregate political jurisdiction benefits

	Political Jurisdiction 1 Environment Agency region - (Midlands)	Political Jurisdiction 2 Water Utility Companies – (Severn Trent incl. South Staffs)
Max distance covered by area	112.6km	124.8km
Population of households covered by area	3,545,593	3,494,438

The final stage of the analysis is to aggregate the WTP values across the different types of jurisdictions and associated number of households. Given the different political and economic jurisdictions and associated households that have been defined above, it is possible to undertake a number of benefits aggregations according to the per household WTP value applied as discussed in section 3. We consider the following two cases:

1. Aggregation based on unit mean values of WTP – this applies the sample mean (or trimmed mean) household WTP across all of the households within the jurisdiction being considered. Simple descriptive statistics for household WTP of the sample of respondents used in the analysis used to define the jurisdictions is given in table 16. Table 17 applies the mean (and trimmed mean) WTP estimates to the total number of households within each type of jurisdiction and improvement scenario in order to estimate aggregate benefits. It should be recalled (from table 14) that whilst the number of households does not vary across improvement scenarios within each politically based jurisdiction, this is not the case for the economic jurisdictions, where the number varies both across jurisdiction and improvement scenario. It can be seen that aggregate benefits vary considerably according to the jurisdiction used to aggregate (and also across improvement scenarios). The two political jurisdictions give very similar estimates, whilst there is somewhat more variation across the different economic jurisdictions. Nevertheless the main difference is between the two sets of political and economic jurisdictions. It should be noted that the approach used to produce the aggregation figures for political jurisdiction 2 is identical to the approach taken by the Environment Agency in the Axford Enquiry.

Table 16: Descriptive Statistics for household WTP of sample used in aggregation analysis

Improvement	No. of Obs.	Mean	5% Trimmed Mean	Median	95% confidence interval	Std. dev
Large	393	£23.48	£19.87	£10	19.46-27.49	40.49547
Medium	393	£15.65	£13.06	£5	12.86-18.44	28.14396
Small	393	£9.88	£7.97	£1	7.95-11.81	19.44941

Table 17: Aggregate benefits based on 'unit mean' values of WTP applied across jurisdictions

	'Unit mean' WTP value used in aggregation	Aggregate Benefits = WTP value * no. households ¹				
		Political Jurisdiction 1 (EA)	Political Jurisdiction 2 (WUC)	Economic Jurisdiction 1 (Individ)	Economic Jurisdiction 2 (Individ&Area)	Economic Jurisdiction 3 (Area)
Large improvement	Mean = £23.48	£83,250,524	£82,049,404	£49,866,824	£38,689,804	£36,312,853
	<i>5% trimmed mean = £19.87</i>	£70,450,933	£69,434,483	£42,199,906	£32,741,329	£30,729,829
	<i>(95% confidence interval =</i>	(£68,997,240	(£68,001,763	(£41,329,148	(£32,065,740	(£30,095,746
	<i>£19.46-27.49)</i>	£97,468,352)	£96,062,101)	£58,383,262)	£45,297,390)	£42,514,495)
Medium improvement	Mean = £15.65	£55,488,530	£54,687,955	£28,944,706	£23,262,395	£22,038,706
	<i>5% trimmed mean = £13.06</i>	£46,305,445	£45,637,360	£24,154,496	£19,412,580	£18,391,405
	<i>(95% confidence interval =</i>	(£45,596,326	(£44,938,473	(£23,784,596	(£19,115,297	(£18,109,761
	<i>£12.86-18.44)</i>	£65,380,735)	£64,437,437)	£34,104,817)	£27,409,493)	£25,967,651)
Small improvement	Mean = £9.88	£35,030,459	£34,525,047	£15,955,172	£13,206,952	£12,740,487
	<i>5% trimmed mean = £7.97</i>	£28,258,376	£27,850,671	£12,870,721	£10,653,786	£10,277,498
	<i>(95% confidence interval =</i>	(£28,187,464	(£27,780,782	(£12,838,423	(£10,627,051	(£10,251,708
	<i>£7.95-11.81)</i>	£41,873,453)	£41,269,313)	£19,071,922)	£15,786,852)	£15,229,267)

Political Jurisdiction 1 =local Environment Agency area (Midlands Region)

Political Jurisdiction 2 = local Water Utility Company area (Severn Trent and South Staffordshire)

¹ See table 14 and 15 for number of households in each case. For economic jurisdictions the number of households varies across improvement scenarios

2. Aggregation based on spatially sensitive valuation function approach – This uses the distance decay functions both to define the (economic) jurisdictions as above, but also to adjust the WTP values that are applied to households within the boundary of the jurisdiction. The distance decay function is used to calculate the estimated mean WTP (per household, per annum) of each improvement scenario for each census unit area in the jurisdiction (as discussed earlier and shown in figure 10). This mean value is then multiplied by the number of households within the specific census

unit (again as discussed earlier) to give the total WTP for all households within that census unit area. Aggregating across all census unit areas in the jurisdiction gives the aggregate benefits across the entire jurisdiction. It is not possible to apply the adjusted WTP estimates to census unit areas that lie outside of the economic jurisdiction (since the distance decay functions estimate negative WTP) and hence the approach is not (sensibly) applicable to aggregating across a politically defined jurisdiction when that political jurisdiction encompasses the economic jurisdiction within its boundary¹⁷. This is the case in the present study and hence Table 18 only provides aggregate benefit estimates for each of the economic jurisdictions produced by the different specifications of distance decay functions. As can be seen, the aggregate benefits vary as expected across improvement scenarios and are relatively stable across the different distance decay function specifications used to produce each economic jurisdiction.

Table 18: Aggregate benefits based on ‘spatially sensitive’ aggregation function: WTP for each output area in economic jurisdictions derived from distance decay valuation function used to define economic jurisdictions

	Aggregate benefits (Spatially sensitive aggregation function approach)		
	Economic Jurisdiction 1 (Individ)	Economic Jurisdiction 2 (Individ&Area)	Economic Jurisdiction 3 (Area)
Large improvement	£6,235,847	£5,040,526	£4,819,012
Medium improvement	£4,146,515	£3,350,233	£3,200,581
Small improvement	£2,498,740	£1,997,502	£1,903,508

¹⁷ In this case, the politically defined jurisdiction will give aggregate benefits that are identical to the economic jurisdiction (or strictly speaking, lower aggregate benefits since census unit areas outside of the economic jurisdiction but within the political jurisdiction will have negative WTP estimates applied to the households in them).

6. COMPARISON OF AGGREGATION APPROACHES

The aggregate benefit estimates produced by the two approaches discussed above are compared in Tables 19, 20 and 21. Table 19 compares the aggregate benefit estimates within jurisdictions for the different unit mean values of WTP applied. Two particular comparisons are made. The first based on comparing aggregations using the upper and lower 95% confidence interval of mean WTP as the unit value applied to households. The second is based on comparing aggregations using the sample mean and the 5% trimmed mean WTP as the unit value applied to households. It can be seen that the change in unit mean value of WTP applied does not make a great deal of difference to the overall aggregate benefits within any of the jurisdictions used.

Table 20 compares the two aggregation approaches across corresponding jurisdictions. Hence only the economic jurisdiction aggregations are compared (since no political jurisdiction aggregation was feasible under the 'spatially sensitive' approach). The table calculates the proportion of aggregate benefits estimated using the 'spatially sensitive' aggregate function approach that are reflected in the aggregate benefits estimated using the 'unit mean' approach. Across the various improvement scenarios and different economic jurisdictions, the 'unit mean' approach produced aggregate benefits that are between 6 and 8 times greater than the 'spatially sensitive' aggregation function approach.

Table 21 again compares across the two approaches, but now compares across political and economic jurisdictions. Specifically it compares the aggregate benefits using unit mean values of WTP and a political jurisdiction with aggregate benefits using spatially sensitive WTP values and an economic jurisdiction. These were chosen to illustrate the possible scale of error that may arise based on the choice of a typical aggregation procedure used (unit mean value and political jurisdiction) compared to the proposed approach (spatially sensitive valuation function). It can be seen that the typical aggregation procedure used by for example the UK Environment Agency can produce benefit estimates that are 17-18 times greater than the spatially sensitive valuation function approach.

Given these results, there would appear to be a lack of fiscal equivalence between jurisdictions. Using an approach based on the more typical procedure used by some agencies to make decisions regarding public goods may result in serious errors regarding their benefits. The factors that will determine whether the benefits are under or overestimated include: how the jurisdictions are defined; whether unit mean or spatially sensitive WTP values are used and, if used, the specific distance decay functions applied.

Table 19: Comparison of aggregate benefits across variations in unit mean values of WTP within jurisdictions

	Political Jurisdiction 1 (EA)	Political Jurisdiction 2 (WUC)	Economic Jurisdiction 1 (Individ)	Economic Jurisdiction 2 (Individ&Area)	Economic Jurisdiction 3 (Area)
Large improvement	aggregate benefits using 'upper 95% CI of mean' WTP as proportion of aggregate benefits using 'lower 95% CI of mean' WTP	1.41	1.41	1.41	1.41
	(Aggregate benefits using 'sample mean' WTP as proportion of aggregate benefits using '5% trimmed mean' WTP)	(1.18)	(1.18)	(1.18)	(1.18)
Medium improvement	aggregate benefits using 'upper 95% CI of mean' WTP as proportion of aggregate benefits using 'lower 95% CI of mean' WTP	1.43	1.43	1.43	1.43
	(Aggregate benefits using 'sample mean' WTP as proportion of aggregate benefits using '5% trimmed mean' WTP)	(1.20)	(1.20)	(1.20)	(1.20)
Small improvement	aggregate benefits using 'upper 95% CI of mean' WTP as proportion of aggregate benefits using 'lower 95% CI of mean' WTP	1.49	1.49	1.49	1.49
	(Aggregate benefits using 'sample mean' WTP as proportion of aggregate benefits using '5% trimmed mean' WTP)	(1.24)	(1.24)	(1.24)	(1.24)

Table 20: Comparison of aggregate benefits between unit mean values of WTP and spatially sensitive WTP values within jurisdictions

		Economic Jurisdiction 1 (Individ)	Economic Jurisdiction 2 (Individ&Area)	Economic Jurisdiction 3 (Area)
Large improvement	aggregate benefits using 'sample mean' WTP as proportion of aggregate benefits using spatially sensitive WTP	8.00	7.68	7.54
	(aggregate benefits using '5% trimmed mean' WTP as proportion of aggregate benefits using spatially sensitive WTP)	(6.77)	(6.50)	(6.38)
Medium improvement	aggregate benefits using 'sample mean' WTP as proportion of aggregate benefits using spatially sensitive WTP	6.98	6.94	6.89
	(aggregate benefits using '5% trimmed mean' WTP as proportion of aggregate benefits using spatially sensitive WTP)	(5.83)	(5.79)	(5.75)
Small improvement	aggregate benefits using 'sample mean' WTP as proportion of aggregate benefits using spatially sensitive WTP	6.39	6.61	6.69
	(aggregate benefits using '5% trimmed mean' WTP as proportion of aggregate benefits using spatially sensitive WTP)	(5.15)	(5.33)	(5.40)

Table 21: Comparison of aggregate benefits between unit mean values of WTP and spatially sensitive WTP values across jurisdictions

Large improvement	Aggregate benefits for political jurisdiction 1 using sample mean WTP as proportion of aggregate benefits for economic jurisdiction 3 using distance decay valuation function WTP	17.28
	(Aggregate benefits for political jurisdiction 1 using 5% trimmed mean as proportion of aggregate benefits for economic jurisdiction 3 using distance decay valuation function WTP)	(14.62)
Medium improvement	Aggregate benefits for political jurisdiction 1 using sample mean WTP as proportion of aggregate benefits for economic jurisdiction 3 using distance decay valuation function WTP	17.34
	(Aggregate benefits for political jurisdiction 1 using 5% trimmed mean as proportion of aggregate benefits for economic jurisdiction 3 using distance decay valuation function WTP)	(14.47)
Small improvement	Aggregate benefits for political jurisdiction 1 using sample mean WTP as proportion of aggregate benefits for economic jurisdiction 3 using distance decay valuation function WTP	18.40
	(Aggregate benefits for political jurisdiction 1 using 5% trimmed mean as proportion of aggregate benefits for economic jurisdiction 3 using distance decay valuation function WTP)	(14.85)

7. CONCLUSION

This report has considered some of the difficulties related to the aggregation of the benefits of public goods for use in cost-benefit analysis. Whilst much valuation work has focussed on the refinement of estimates of WTP and the appropriate measure of central tendency for use in aggregating population benefits, little attention has been given to the question of defining the extent of the market. In particular, the problem of defining the population of beneficiaries, or who has *standing*, has been an issue of significant public policy attention as a result of legal proceedings in the US and UK that have questioned the basis of existing institutional approaches to aggregation. This issue also goes to the heart of the debate about the appropriate level of government financing and provision (fiscal federalism).

This report has examined a number of issues regarding both the definition of the extent of the market and the appropriate value of WTP that is used for aggregation. An innovative approach is proposed that provides an empirically straightforward procedure for aggregation that relies upon the estimation and application of spatially and socioeconomically sensitive valuation functions. The approach is based on the spatial analytic power of a GIS and its integration with census and similar databases. Two case studies are used to illustrate this spatially sensitive valuation function approach. The analysis confirms the findings of Smith (1993) and Loomis (2000) that the choice of whether to aggregate across a politically defined or economic jurisdiction can have a very substantial impact upon estimates of aggregate value. Similarly it has been shown that the use of simple approaches such as aggregation via simple means can severely bias such estimates and is very likely to occur given that the analyst is very unlikely to have prior knowledge of the correct extent of the market over which to aggregate. As an alternative to such over-simplified the spatially sensitive valuation function approach explicitly incorporates expected distance decay in values to both define the limits of the economic jurisdiction and investigate how values vary within that area.

This approach developed in this report represents a useful direction for future research which has the potential to substantially improve methodology in this area. However, it is recognised that there are a number of significant limitations in the present case studies that require attention in future applications.

First, as demonstrated in the contrast between the first and second case study, it is vital that stated preference surveys collect data on non-response and the spatial distribution of such non-respondents. Surveys are inherently liable to self-selection bias with higher value individuals being over represented in any sample. The first case study addresses this issue by identifying the location of non-respondents and observing a strong spatial dimension to their distribution. This is then used with lower bound assumptions to substantially adjust aggregate value estimates.

A second issue concerns the need to gather data to allow an inspection of the effect that changes in site quality may have upon the number of visitors to a site. This effect is the driving force behind the significant distance decay within the non-users values discussed in the second case study. Within stated preference studies this could be addressed through direct questioning of respondents regarding the expectations of future visit demand once site quality has been improved. However, this seems liable to error both because people may well be poor judges of future visit rates and because of possible strategic behaviour if respondents see this as a provision rather than valuation exercise. An alternative and potentially preferable approach to this problem is to adopt revealed rather than stated preference methods. This allows inspection of the quality/visitation relationship through visitation data derived from multiple sites across which both quality and visitation varies.

This raises a further issue concerning appropriate models for valuation functions. The models reported in this paper use a combination of individual and area level data. Unless it is possible to be sure about

the representativeness of the sample (which for the reasons set out above seems unlikely) or can re-weight sample responses appropriately (as discussed by Morrison, 2000), then simpler combinations of different data types are open to criticism. Future work might look at possible way to combine conventional RUM travel cost methods with the mixed individual/group (output area) demand modelling approaches recently pioneered for differentiated marketed goods (Petrin, 2002; Berry et al., 2004).

A final issue concerns substitution effects arising from quality change at multiple sites. Policies such as the EU Water Framework Directive envisage widespread improvements in river and lake quality. In such cases the predictions of single site studies such as those presented in this paper may be very poor guides to the impact of such widespread changes. Research suggests rapidly diminishing marginal WTP for additional sites once an initial level of recreational or non-use provision is made (Bateman et al., 2005). Given this, an obvious goal for future research will be to quantify and model such effects, bearing in mind the complicating issue of path-dependency; that the order in which any set of site improvements is enacted is liable to have a dramatic impact on the value of any given improvement.

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Annex 1

Physical and Human Geography of River Tame Catchment

The Tame river basin is an example of a catchment with widely varying land use, river use, river modification and ecology. It represents an example of a degraded urban river. The main River Tame runs through heavily urbanised areas of Birmingham and has been subject to many pressures and modifications. Increased peak runoff due to urbanisation, combined with floodplain development has led to a channel that is heavily engineered for much of its length. Some of the tributaries in the Tame catchment are less modified, and are good examples of degraded rivers with potential for rehabilitation. This has resulted in rivers with varying levels of modification and ecology.

General Remarks About the River Tame

The Trent catchment in central England (Figure A1-1 and A1-2) extends from south west of Birmingham to Scunthorpe in the north east, where the River Trent enters the Humber estuary. The Tame catchment (Figure 2) is a major tributary of the River Trent. Its catchment includes most of Birmingham, Tamworth and Hinkley. Significant tributaries of the River Tame include the Cole, Blythe and Anker. Urbanisation in the catchment has decreased infiltration capacity leading to higher flood peaks, which rise and fall rapidly, requiring flood defences to protect property. The river regime is also altered by the sewer network which bypasses the river system. The urban runoff is polluted, which combined with poor habitats has led to poor ecological conditions. Pollution (depleted dissolved oxygen, raised ammonia, metals and sediments) is particularly evident following rainfall after dry weather. There has been a continual upgrading of sewage treatment facilities in the catchment. Water resources are imported from outside the catchment, notably from Wales. The less urbanised eastern and southern parts of the catchment contrast with the heavy urbanisation in the west of the catchment area.

The River Tame catchment covers an area of 1490km² at its outlet with the Trent, with a Main River length of 285km. It is the major river system of the West Midlands conurbation. The highest point is Brecon Hill at 270m above ordnance Datum (AOD) falling to 50m AOD at Chetwynd Bridge. The main Tame is formed from the confluence of the Oldbury arm, Wolverhampton arm and Ford Brook at Bescot (mean flow 2.5 m³s⁻¹, Q10 4.0 m³s⁻¹). Further tributaries include the Hockley Brook and rivers Cole and Blythe, and lower down the Black/Bourne Brook and River Anker. The River Tame rises at approximately 150m AOD on the Lower and Middle Carboniferous Coal Measures between Dudley and Wolverhampton. It flows in a south-easterly direction through West Bromwich and on until it is joined by the River Rea, in the northern area of Birmingham. The River Rea rises to the south of Birmingham and runs northeast in a constructed channel to join the Tame. The Tame then flows in an easterly direction towards but not reaching Nuneaton. Between Birmingham and Nuneaton it is joined by the Rivers Cole and Blythe. The Cole and Blythe rise close to each other south of Solihull but then diverge. The Cole flows through the south of Birmingham, whilst the Blythe flows almost entirely outside the urbanised area. The two rivers then join each other just before flowing into the River Tame about 10km south of Tamworth. From this confluence, the Tame flows in a northerly direction through Tamworth, where it is joined by the River Anker. The River Anker rises southeast of Nuneaton on Triassic Mercia Mudstones. It flows northwest through mainly agricultural land although it receives drainage from Nuneaton and Hinckley. The River Sence, which flows into the Anker between Tamworth and Nuneaton drains a predominantly rural area. Having been joined by the Anker, the Tame then flows in a northerly direction to the catchment boundary.

Mean annual rainfall across the catchment is 740mm of which 450mm constitutes runoff.

Socio-Economic Geography and Human Activities in the Catchment

Land use in the catchment is divided between agricultural (55%), urban (41%) woodland and rough grass (4%). Approximately two thirds of the agricultural land is arable (36%) and the remainder grassland (14%) with small amounts of fallow (5%). The agricultural areas lie in the central and western parts of the catchment, whilst urban area is predominant in the west. The urban areas (collectively known as the West Midlands conurbation), are of particular significance, supporting a population of 1.7m and centred in the following cities/towns: Birmingham - England's second city (pop. 665,000), Sandwell (261,000), Walsall (259,500), Wolverhampton (83,000), Nuneaton (76,500), Tamworth (69,000), Dudley (59,000), Hinckley (44,500) and Lichfield (28,500). A major part of the upper catchment is more than 50% urbanised, an extremely high figure. The catchment forms the focus for several major motorways, with the M6 motorway running adjacent to, and in some cases over the river. There are also major interchanges: M5/M6, M6/A38(M) and M42/M6 very close to the river. Birmingham is also a focus for the national rail network and has a major international airport. Historically, mineral extraction has played a major part in shaping the development of the upper Tame catchment. Resources included coal, iron (Fe) and copper (Cu). This led to a consequent development of associated industries such as steel production. In the 20th century, heavy industry has gradually declined, although there are still some major works such as Albright and Wilson's chemical plant (Oldbury), the IMI copper refinery (Walsall) and the MG/Rover car works (Longbridge). In the early 21st century, the principal industries in the area are engineering, metal finishing and vehicle manufacture.

Figure A1-1: Trent Catchment
(The Tame catchment is shaded yellow)

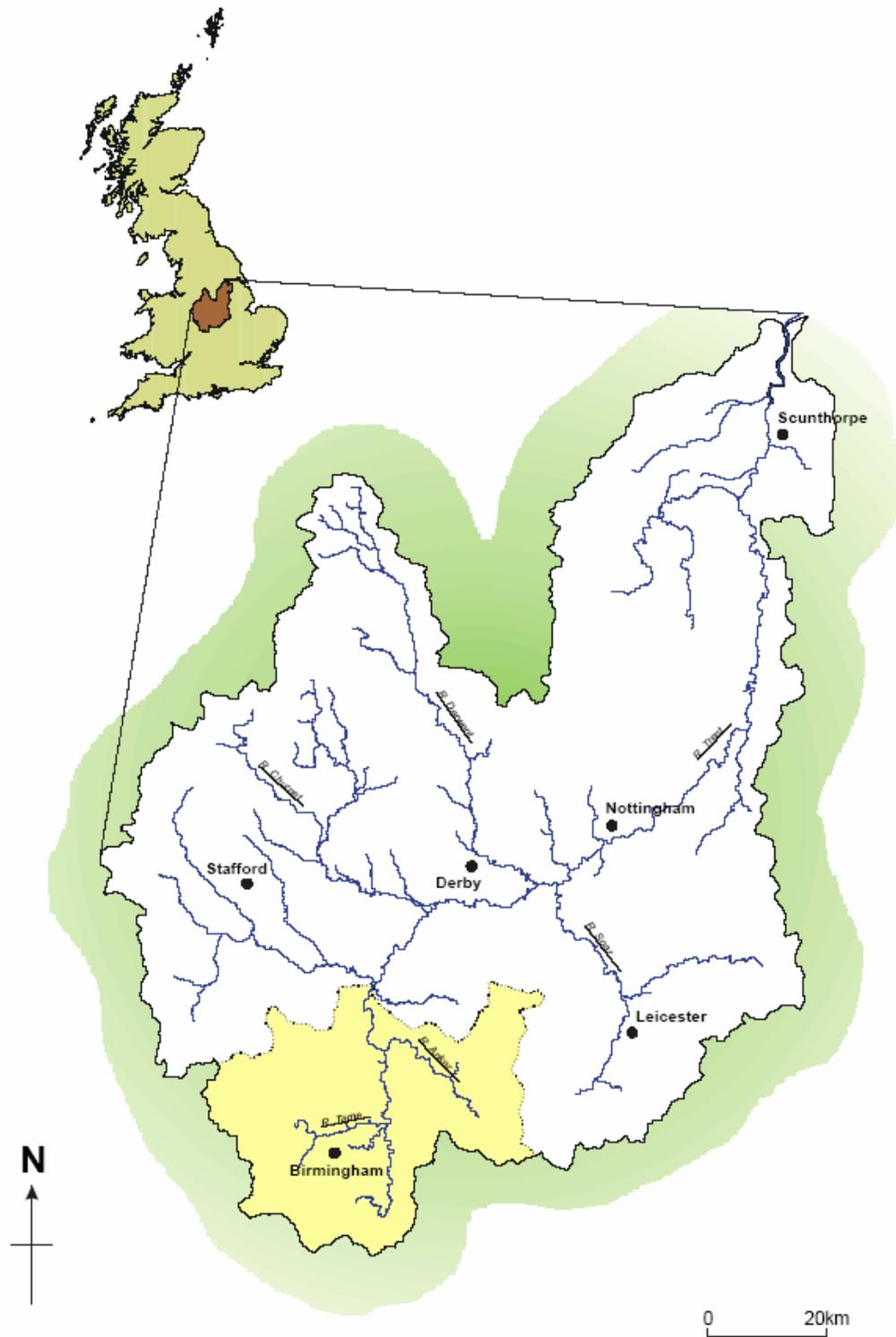
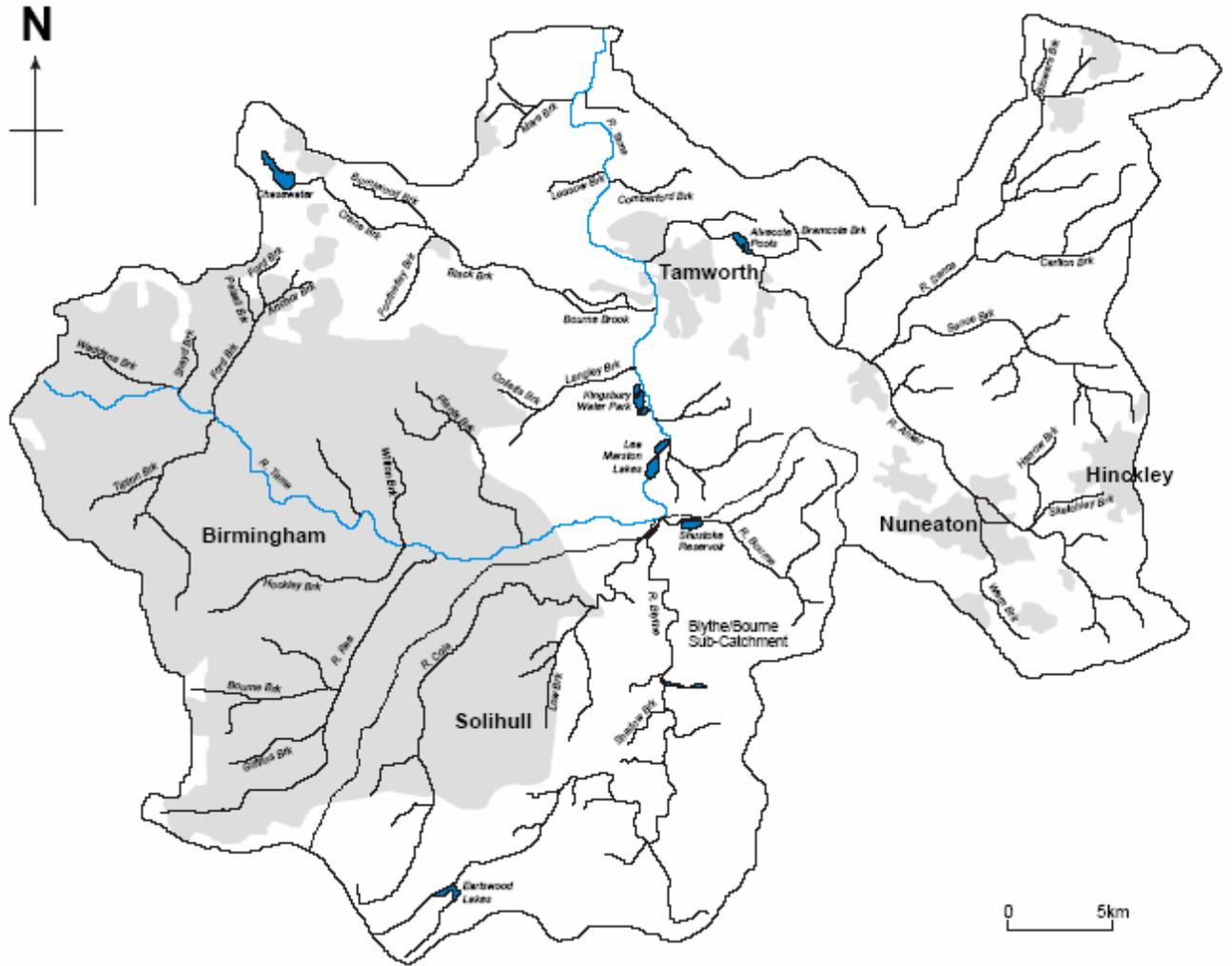


Figure A1-2: River Tame Catchment Including the tributaries of the Anker, Blythe, Cole, Rea and Black/Bourne Brook.



Annex 2

WTP and Water Quality Measure Functions

In order to provide continuous water quality measures for use in the distance decay regression equations, use is made of the UK Environment Agency's River Ecosystem Classification scheme. This describes rivers according to their suitability for fish in terms of these continuous measures (see tables A2-1 and A2-2 below for details). Given that the discrete water quality improvement levels (Large; Medium; Small) considered in the Tame study are also characterised by their suitability for fish it has thus been possible to match up the continuous measures of water quality used in the river ecosystem classification scheme (Dissolved Oxygen; BOD; Total Ammonia) to the discrete water quality improvement levels.

Table A2-1: Characteristics of Discrete Water Quality Levels used in River Tame Study

Water Quality Level	Characteristics of Water Quality Level		
	Fishing	Plants & Wildlife	Boating & Swimming
Large Improvement in Quality (Level L)	Trout and Salmon return Good game fishing possible	Increase in plants and wildlife Possible for Otters to survive	Water good enough for boating and swimming
Medium Improvement in Quality (Level M)	Some game fish species return (e.g. perch) Good enough for fishing	Increase in number and types of insects Greater numbers of birds and wildlife	Suitable for boating, but not swimming
Small Improvement in Quality (Level S)	A few fish species return (e.g. Roach)	More plants would grow, waterfowl can use river	Suitable for boating, but not swimming
Current Situation (Level C)	Fish stocks virtually non-existent	Plant growth, insects, birds and animal life limited	Unsuitable for boating and swimming

Table A2-2: River Ecosystem Classification: Water Quality Criteria

Class	Dissolved Oxygen % Saturation	BOD (ATU) Mg/litre	Total Ammonia mg N/litre
RE1	80	2.5	0.25
RE2	70	4.0	0.6
RE3	60	6.0	1.3
RE4	50	8.0	2.5
RE5	20	15.0	9.0

Class RE 1: Water of very good quality (suitable for all fish species)

Class RE 2: Water of good quality (suitable for all fish species)

Class RE 3: Water of fair quality (suitable for high coarse fish populations)

Class RE 4: Water of fair quality (suitable for coarse fish populations)

Class RE 5: Water of poor quality (which is likely to limit coarse fish populations)

Unclassified: Water of bad quality (In which fish are unlikely to be present)

Table A2-3 Gives the corresponding discrete water quality improvement levels used in the River Tame and continuous measures of water quality. Table A2-4 gives the variable name of these continuous measures of water quality as used in the regression equations that model the distance decay valuation functions for WTP.

Table A2-3: Water Quality Improvements and Water Quality Indices

Water Quality Level	Dissolved Oxygen (% saturation)	BOD (mg/litre)	Total Ammonia (mg N/litre)	
Large Improvement – L	80	2.5	0.25	
Medium Improvement – M	65	5	0.95	
Small Improvement – S	50	8	2.5	
Current Situation – C	20	15	9	

Table A2-4: Water Quality Measure Variables used in Distance Decay regressions

Variable Name	Water Quality Measure
IndWQdo	Natural log of increase in Dissolved Oxygen level (% saturation)
IndWQbod	Natural log of decrease in Biological Oxygen Demand (mg/ltr)
IndWQta	Natural log of decrease in Total Ammonia (mg N/ltr)

Table A2-5 shows the distance decay valuation functions that were modelled using the continuous water quality measures. A variety of specifications were considered based on the general types of specifications considered in the main body of this report and for the linear GIS based distance variable. All the models give the same results as the equivalent specifications for the models based on discrete water quality changes that are described in the main report (apart obviously from the coefficients on water quality). Although these results do not make any difference as far as any aggregation exercise is concerned, one advantage of using the continuous water quality measures is that the coefficient on water quality in double log functional form format gives an elasticity. So in equation 6 for example (WTP+1) increases by 1.988% for each 1% reduction in total ammonia over the range 9 – 0.25 mg N/ltr of total ammonia. (alternatively WTP increases by $1.988 * ((WTP+1)/WTP)$ % for each 1% reduction in total ammonia, again over the range 9 – 0.25 mg N/ltr of total ammonia. (note: the coefficient on water quality is no longer a constant elasticity on the original WTP scale).

Figure A2-1 gives a diagrammatic representation of how WTP varies with the reduction in the level of total ammonia across the range of values spanning the River Ecosystem Classification Classes used by the UK Environment Agency.

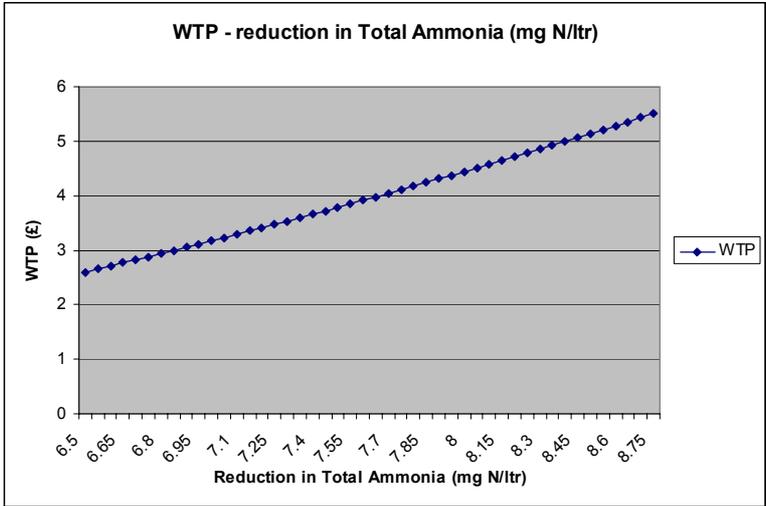
Table A2-5: WTP Functions using Water Quality measures

	Individual characteristics only			Individual and area level characteristics			Area level characteristics only		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	lnwtp	lnwtp	lnwtp	lnwtp	lnwtp	lnwtp	lnwtp	lnwtp	lnwtp
IndWQdo	0.894 (14.67)**			0.894 (14.67)**			0.894 (14.67)**		
IndWQbod		1.061 (14.62)**			1.061 (14.62)**			1.061 (14.62)**	
IndWQta			1.988 (14.29)**			1.988 (14.29)**			1.988 (14.29)**
Dist_GISlin	-0.000054 (2.15)*	-0.000054 (2.15)*	-0.000054 (2.15)*	-0.0000771 (2.97)**	-0.0000771 (2.97)**	-0.0000771 (2.97)**	-0.000085 (3.20)**	-0.000085 (3.20)**	-0.000085 (3.20)**
Env	0.243 (3.19)**	0.243 (3.19)**	0.243 (3.19)**	0.219 (2.90)**	0.219 (2.90)**	0.219 (2.90)**			
Know	0.414 (2.74)**	0.414 (2.74)**	0.414 (2.74)**	0.356 (2.36)*	0.356 (2.36)*	0.356 (2.36)*			
Retire	-0.646 (3.57)**	-0.646 (3.57)**	-0.646 (3.57)**	-0.601 (3.35)**	-0.601 (3.35)**	-0.601 (3.35)**			
Unemp				-0.100 (3.06)**	-0.100 (3.06)**	-0.100 (3.06)**	-0.127 (3.87)**	-0.127 (3.87)**	-0.127 (3.87)**
Constant	-2.622 (6.82)**	-1.651 (4.73)**	-3.313 (7.91)**	-2.049 (4.82)**	-1.078 (2.74)**	-2.741 (6.00)**	-1.005 (3.42)**	-0.034 (0.14)	-1.697 (5.01)**
Observations	1179	1179	1179	1179	1179	1179	1179	1179	1179
Number of sn	393	393	393	393	393	393	393	393	393
sigma_u	1.43	1.43	1.43	1.41	1.41	1.41	1.45	1.45	1.45
sigma_e	0.59	0.60	0.60	0.59	0.60	0.60	0.59	0.60	0.60
Rho	0.85	0.85	0.85	0.85	0.85	0.85	0.86	0.86	0.85
Wald chi2	250.07	248.54	238.84	260.21	258.68	248.99	235.01	233.48	223.78
r-squared	0.10	0.10	0.10	0.12	0.12	0.12	0.07	0.07	0.07

Absolute value of z statistics in parentheses

* significant at 5%; ** significant at 1%

Figure A2-1: WTP as a function of the reduction in total ammonia based on the coefficients from equation 6 in table A5 (sample means used for other coefficients included in the model).



Note: Reduction in Total Ammonia covers range spanning River Ecosystem Classification Classes used by the Environment Agency