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The Value of achieving Good Environmental Status in the North East Atlantic using Contingent Valuation and Value Transfer

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Abstract

This paper uses a combination of the contingent valuation method (CVM) and value transfer (VT) to estimate the non-market benefit values associated with the achievement of good (marine) environmental status (GES) as specified in the EU Marine Strategy Framework Directive (MSFD) for Atlantic member states. The increased use of geographic information systems in VT means that many VT exercises now include spatial elements such as distance decay and population density. This paper explores the impact of distance decay on welfare estimates as well as the impact of the modifiable area unit problem when population density is included as an explanatory variable. These issues can have a large effect on a VT estimate. In this study the overall value for achieving GES for Atlantic member states varied between €2.37 billion and €3.64 billion. It was found that the different distance decay specifications changed values between -3% and 82% with a mean absolute difference of 25% and by adjusting the spatial scale in an effort to overcome the MAUP changed aggregate values between 13% and 25% with a mean of 17%.

Keywords: Marine Strategy Framework Directive (MSFD); Value transfer; Distance decay; modifiable area unit problem (MAUP); Interval regression; Contingent valuation method (CVM); population density

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1. Introduction

The EU Marine Strategy Framework Directive (MSFD) requires member states (MSs) to achieve GES by 2020 in their marine waters by enacting a marine strategy. This marine strategy will be composed of a programme of measures that will improve different aspects of the state of the marine waters as measured by 11 descriptors. Bertram and Rehdanz (2012) note that the MSFD requires that these measures should be cost-effective. MSs will have to assess the social and economic impacts of new measures which should include conducting cost-benefit analyses. MSs may delay or not achieve GES, if the cost of the measures needed are disproportionate. Additionally, the MSFD calls for a social and economic analysis as part of the initial assessment and consideration of social and economic impacts when setting environmental targets. While costs are thought to be easier to estimate for measures, many of the benefits generated by the MSFD will be non-market goods and services (Bertram and Rehdanz, 2012).

Non-use values attached to changes in the marine environment have been previously found to constitute a significant proportion of the total economic value of the benefits produced by changes to marine and coastal environments (Luisetti et al., 2010, McVittie and Moran, 2010). It is expected that the non-use values arising from the introduction of the MSFD will also form a considerable portion of its benefits (Bertram and Rehdanz, 2012). The contingent valuation method (CVM) has been widely used in the valuation of environmental goods and services or for changes to the environment (Darling 1973, Carson & Mitchell, 1989, Hanemann et al. 1991, Alberini et al. 2005, Bateman et al., 2006, Abdullah & Jeanty, 2011). The method was first used by Davis (1963), and has increased in popularity since a blue ribbon panel in the United States validated its use (Arrow et al. 1993). The CVM estimates values of a non-market good or service by presenting respondents with a hypothetical situation in a survey format. The name of the valuation method derives from the values being ‘contingent’ on the respondent’s willingness to pay (WTP) or willingness to accept (WTA) a change to the good or service being valued.

However, using primary valuation methods such as CVM can be costly and time-consuming. An alternative approach is value transfer (VT) also known as benefit transfer (BT) (Brouwer, 2000, Navrud and Ready, 2007, Johnston et al., 2015). A value transfer occurs when an estimated value, based on original studies (study sites), is transferred to a new application (policy site) (Boyle et al., 2010). This secondary valuation technique negates some of the problems with primary valuation as identified above; namely cost, time and complexity (Rosenberger and Loomis, 2003) but has the disadvantage of the VT practitioner not knowing how close to the actual value they have estimated, the difference known as the transfer error. As well as being time and cost efficient, VT's other advantage is that it can be applied on a scale that would be practicably unfeasible for primary research studies in terms of valuing large numbers of services across multiple ecosystems (Troy and Wilson, 2006, Brenner et al, 2010, Plummer, 2009, Hynes et al. 2013). This has been enabled by the recent combination of the VT method with GIS (Geographical Information Systems). The use of GIS in VT had been advocated by some (Lovett et al., 1997, Bateman et al., 2002, Boutwell, and Westra, 2013) as a way of improving VT and lowering transfer errors by including more socio-economic characteristics, allowing for spatial differences in preferences or allowing for substitute sites.

This paper explores two issues arising from using spatial methods with VT that can affect the resulting value estimates; the functional form of distance decay measure and the modifiable area unit problem (MAUP). Distance decay is a well-known concept within the non-market valuation literature (Sutherland and Walsh, 1985, Pate and Loomis, 1997, Loomis, 2000, Hanley et al., 2003, Bateman et al., 2005, Bateman et al. 2006, Kniivilä, 2006, Moore et al., 2011, Schaafsma et al., 2013, Jørgensen et al., 2013) and occurs where values tend to decline as one moves further from the site being valued. However, some studies also note that the spatial pattern may not be a monotonic continuous function such that values may be distributed heterogeneously (Campbell et al. 2009, Johnston and Ramachandran, 2014).

The MAUP is a well-known phenomenon in geography (Openshaw, and Taylor, 1979 Goodchild et al., 1993, Dark and Bram, 2007), in political science (Darmofal and Strickler, 2016) and to a lesser extent in the economics literature (Doll et al., 2006, Briant et al., 2010, Arbia and Petrarca, 2011). This is the first study to examine the impact of the MAUP on VT. The MAUP arises due to the use of modifiable areal units in quantitative analysis (Openshaw and Taylor, 1979). The arbitrary nature of how spatial data at individual level (or in the form of points) is aggregated and how the results of such analysis are influenced by both the shape and scale of the aggregation and the arbitrary spatial basis of the data used is known as the MAUP (Openshaw 1984).

The MAUP occurs through two effects; (1) the scale effect when aggregation of high resolution (i.e. a large number of small areas) data to a lower resolution (i.e. a smaller number of larger areas) and (2) the zoning effect where spatial units to which the higher-resolution data are aggregated are arbitrarily created by some decision-making process and represent only one of an almost infinite number of possible constituencies (Reynolds, 1999). This latter issue creates the gerrymandering problem in political science (Wong, 2009). The MAUP issue in this paper is explained in more detail in Section 3.

This paper adds to the marine valuation literature by using the CVM to estimate the value of the non-market ecosystem service benefits associated with the achievement of GES as specified in the EU MSFD and it is the first paper to highlight the MAUP in VT. A 'value function transfer approach' based on the CVM results of achieving

GES is employed to transfer values to five EU Atlantic MSs. The paper also explores the differences arising from how distance decay is specified in the VT function.

In what follows, section 2 provides a brief review of marine valuation studies, the description of the MSFD and its requirement for economic valuation and VT. Section 3 outlines the spatial issues addressed in this paper. Section 4 describes the CVM that is used to estimate the value of achieving GES in Irish marine waters and the VT methodology. Section 5 details the results and finally the discussion and conclusions are presented in Section 6.

2. The Marine Strategy Framework Directive and marine environmental valuation

The MSFD (2008/EC/56) requires that EU MSs achieve GES by 2020 in their coastal and marine waters. GES is measured using 11 descriptors. When all 11 descriptors are at good status then the marine region/ sub-region will have achieved GES. Achieving GES will be met by protecting, maintaining and preventing deterioration of the marine ecosystems and also by preventing polluting inputs being introduced into the marine environment. These targets are to be achieved by developing and implementing measures that will manage human activities to ensure a balance between sustainable use of the waters and conservation of marine biodiversity (Long, 2011).

The MSFD builds on previous EU legalisation in the environmental area such as the Water Framework Directive (WFD) (2000/60/EC). The MSFD complements the efforts of the WFD within coastal water bodies where the two Directives overlap by allowing for interaction of management plans. MSFD does not apply to transitional waters which are solely covered by the WFD. This process may not be seamless. Borja et al (2010) have identified some potential conflicts between the two directives due to issues of spatial application.

A number of commentators, including the EU Commission, have found deficiencies in the manner MSs developed marine strategies and the lack of co-ordination between MSs leading to lack of coherence in what GES is, even within the same regions/sub-regions and noting the lack of ambition in the programme of measures announced to-date (EC, 2014; Hanley et al., 2015; Oinonen et al., 2016a).. The deficiencies could be considered a fulfilment of the concerns highlighted by some (Long, 2011, Van Leeuwen, 2012) of the willingness of MS to implement the MSFD and improve the status of their marine waters. Most recently this has led to a revision in how GES is measured (EC, 2017).

Four main requirements have been identified within the MSFD by Bertram and Rehdanz (2012) that require valuation of the benefits generated by the MSFD. These are:

- An initial assessment of a Member States' marine waters, including economic and social analysis (ESA) of the use of those waters, and of the cost of degradation of the marine environment (Art.8.1(c) MSFD).
- Establishment of environmental targets and associated descriptors describing GES, including due consideration of social and economic concerns (Art.10.1 in connection with Annex IV, No. 9 MSFD).
- Identification and analysis of measures needed to be taken to achieve or maintain GES, ensuring cost-effectiveness of measures and assessing the social and economic impacts including cost-benefit analysis (Art.13.3 MSFD).
- Justification of exceptions to implement measures to reach GES based on disproportionate costs of measures taking account of the risks to the marine environment (Art.14.4 MSFD).

Estimating the value of coastal and marine ecosystem services is even more difficult than estimating the value of their terrestrial counterparts as the majority of coastal ecosystem services are not traded in established markets where they command a price (fish consumption and established marine energy sources being obvious exceptions) (Beaumont et al. 2007, McVittie & Moran, 2010). Also, for changes to the marine environment as envisaged by the MSFD, the impact on non-use values is expected to be much larger relative to use values (McVittie and Moran, 2010, Bertram and Rehdanz, 2012). This is due to a combination of a lower number of direct users for the ecosystem services and the smaller area over which these users operate (i.e. mainly restricted to the coastal zone). The CVM employed in this paper allows us to pick up both the use and non-use values associated with achieving good environmental status as described in the MSFD.

In a review of valuation studies related to coastal and marine environments in the Black Sea and Mediterranean, Remoundou et al. (2009) found that CVM was the most common valuation methodology used, being used in six of the thirteen studies reviewed. Nunes and van den Bergh, (2004) used a joint travel cost (TC) - CVM survey to estimate the value in preventing harmful algae blooms (HAB) for the Dutch coastline. Carson et al. (2003) used CVM to estimate the non-use value or passive value of an oil spill in Alaska and estimated a mean WTP of $79.20 based on a modified Weibull distribution. Elsewhere, Ressurreição et al. (2012) undertook a CVM with 1502 respondents in three sites (Azores islands (Portugal), the Isles of Scilly (UK) and in the Gulf of Gdansk region (Poland)) to estimate WTP for biodiversity. For a more detailed discussion of non-market valuation of coastal and marine environments the interested reader is directed to Torres and Hanley (2016) who undertook a comprehensive review of 196 papers on the subject. The authors note that aggregating a large number of studies is useful for those using value transfer (VT) in response to a growing political demand.

Value transfer (VT) is the second methodology used in this paper and is an alternative to the primary non-market valuation methods such as revealed (e.g. travel cost and hedonic valuation methods) and stated (e.g. CVM and CE) preference approaches. When analysed carefully, information from past studies published in the literature can form a meaningful basis for coastal zone management policy (Rosenberger and Loomis, 2000, Brouwer, 2000, Ledoux and Turner, 2002). As with CVM, the VT method has been widely applied in the environmental literature (Luken et al, 1992, Bateman et al., 1995, Brander et al. 2012 Johnston et al., 2015) and also to value marine and coastal environments or elements within these environments.

Brenner et al (2010) estimated the value of the non-market ecosystem services of the Catalan coastal area of Spain using GIS with VT. In the UK, Beaumont et al. (2008) used a mixture of market prices and VT to estimate values for 8 ecosystem services supported by marine biodiversity. Hynes et al (2013) used an international value transfer with a cultural adjustment to value the marine and coastal ecosystems of Galway Bay, a coastal inlet on the western coast of Ireland. Elsewhere, Ghermandi and Nunes, (2013) undertook VT using a GIS based meta-analysis to generate a global map of coastal recreation values. Brander et al. (2007) also undertook a meta-analysis of marine related recreation but only at coral reef sites.

There are various methods of transferring values between sites (Colombo & Hanley, 2008). The simplest and most commonly used is to use the unadjusted WTP estimates from one or more study sites and apply their average value to the policy site. This method is referred to as ‘unit value transfer’. An extension to the unit value transfer method is where the WTP values are adjusted for one or more factors (e.g. adjustments for differences in income between study and policy sites and for differences in price levels over time or between sites) before the values are transferred between the sites. The next step in complexity of value transfer is to use a value ‘function transfer’ method (Loomis, 1992). This is the approach adopted in this paper. This involves using the parameters from the original demand function from the study site (WTP^S) and using environmental and population characteristics from the policy site to generate the WTP for the policy site (WTP^P). In effect it is assumed that;

$$predicted\ WTP\ (\beta^S, X^P) = WTP^P \qquad (1)$$

Meta-analytic value function transfer is a more complex form of value function transfer that uses a value function estimated from multiple study results together with information on parameter values for the policy site, to estimate policy site values (Brander et al., 2012). The use of spatial micro-simulation techniques for VT is another form of value function transfer that has been suggested and used by Hynes et al. (2010).

However, VT has some disadvantages, the most significant being that the value transferred may not be similar to the actual value (which is unrevealed to the VT practitioner) at the study site. This difference between the transferred value and the actual real value is known as the 'VT error' (Kaul et al, 2013). This error has been found to be highly significant in a number of studies with values of up to 7496% being reported (Kaul et al, 2013). Transfer errors and the applicability of transferring certain values are of the greatest concern in the transfer valuation literature as these issues are the most important for providing confidence in the final valuation of the policy site (Colombo and Hanley, 2008).

The subject of VT is a maturing area, and with more studies and more understanding of the valuation of ecosystems, more confidence will be attained in the methodology. It has been acknowledged that the general view within the literature is that function transfers generally outperform unit transfers (Johnston and Rosenberger, 2010) although this is not always found to be true. Brouwer (2000) found that the unit-VT method had a lower range of transfer errors in half of the VT studies he reviewed. The inclusion of environmental attitudes which is often an unobserved preference may also help to increase the accuracy of benefit transfers (Brouwer and Spaninks 1999). Brouwer et al. (2015) noted that for international VT transferring multi-country values can also reduce VT errors.

Transfer errors are typically presented as the percentage difference between the value estimated for the policy site and the 'actual' value at the policy site. Following Bateman et al. (2000), the transfer error is calculated as:

$$Transfer\ Error = \left(\frac{Transferred\ Estimate - Policy\ Site\ Esimate}{Policy\ Site\ Esimate}\right) \times 100 \qquad (2)$$

An alternative method (equation 3) has been proposed by Chattopadhyay (2003) which would give the same transfer error between two study sites no matter the direction of transfer tested.

$$Transfer\ Error = \left(\frac{\frac{Transferred\ Estimate - Policy\ Site\ Esimate}{Transferred\ Estimate + Policy\ Site\ Esimate}}{2}\right) \times 100 \qquad (3)$$

While the reason for undertaking a VT exercise is that the 'Policy Site Estimate' is unknown, a number of studies have estimated the policy site value using primary valuation techniques and then undertaken VT and tested the difference between the two. Brouwer (2000) reviewed a number of VT exercises that reported transfer errors and found transfer errors varied between 1% and 475% but noted that most of them were in the range of 20%-50% which includes the median error reported by Kaul et al. (2013). Kaul et al. (2013) also noted the large variability in transfer errors finding transfer errors between 0 and 7496% with a median of 39% and a mean of 172% indicating some large outliers had skewed the distribution.

3. Spatial issues with value transfer – Distance decay and MAUP

One suggested method for reducing transfer errors is through the use of geographic information systems (GIS). Eade & Moran (1996) were one of the early adopters of GIS for VT and noted that it had great scope to take account of the spatial variation of respondent's characteristics in VT. Lovett et al. (1997) used GIS to improve a travel cost demand function for forest recreation by incorporating spatial variation in socio-economic characteristics and allowing for substitute sites. They noted that using GIS in improving VT is dependent on the amount of data available and the spatial scale that data is available at. Bateman et al. (2002) also noted that using GIS with VT can allow easier communication of results to policymakers and the general public.

Another important issue in using GIS with VT is defining the extent of the market at the policy site. Bateman et al. (2006) argued that the use of GIS coupled with the concept of distance decay may be a method of determining market size for public goods, especially for non-use values, coining the term "economic jurisdiction". Loomis (2000) and Bateman et al. (2006) argue that the extent of the market may be more important in determining aggregate values than any changes related to the precision of the estimates of per-person values. Norton et al. (2012) also highlight the importance of the choice of the relevant population and the extent of the market in the aggregation process.

Distance decay is one concept that has been used to determine the extent of the market for non-market goods (Bateman et al., 2006). There are many valid reasons for non-use values incorporating distance decay. The first is the altruistic element where respondents value a site for the reason of knowing that someone else might use it. Often people may have a higher WTP value if the site is near to themselves, their family and friends. This could be considered an application of Tobler's First law of geography – "All things are related, but near things are more related than far things" (Tobler, 1970). The same logic can be applied to the bequest element of non-use value in passing down an environment in good condition to the next generation which traditionally live close to their parents although this may be changing (Compton and Pollak, 2015). The final element of non-use value is option value where the person may opt to use the ecosystem service or good in the future and geography dictates that location may be a factor in this as discussed by Jørgensen et al. (2013).

Schaafsma (2010) found in a review that nearly 85% of studies that include a spatial element, found significant distance effects but noted that these were a very small proportion of stated preference studies in the sample. However, often these studies assume spatial homogeneity where spatial variation is not accounted for or model it as a single monotonic continuous function (Johnston et al., 2011) which may not be the case. The same author (Schaafsma, 2011) noted that users' preferences measuring in a CE are less responsive to distance decay compared to non-users, and that the non-users WTP declines at faster rate with the distance to the site relative to user's WTP. Johnston and Ramachandran (2014) examined more complex spatial patterns in stated

WTP using local indicators of spatial association (LISA) to identify WTP hotspots. The same paper also found population density, measured at zip code level in the USA (local scale), was found to affect WTP. Higher population density was associated with a higher probability of hot spots for some attributes and a lower probability of cold spots for other attributes. Other studies have also studied heterogeneous spatial patterns related to stated WTP (Campbell et al. 2008, 2009, Johnston et al., 2015).

The other spatial issue that has not been previously discussed in detail in the VT literature is the modifiable areal unit problem (MAUP). The MAUP, as identified by Openshaw and Taylor (1979), arises from the use of modifiable area units in quantitative analysis. These area units can take a variety of shapes or sizes. This causes complications with statistical analysis related to both scale and the method used to create the area units.

Two possible reasons are put forward which may explain the differences in preferences or values for the conservation of the (marine) environment between areas of low and high population density. The first of these is based on the concept of a spatial externality defined by Papageorgiou (1978) as the "manner one obtains two interacting surfaces unfolding over the landscape—a population surface and an externality surface". As agents get closer together (increased population density) this also increases the intensity of the externalities (congestion, pollution or noise). This experience of concentrated negative externalities may be one explanation of difference in attitudes or values related to population density.

The second possible reason may be that those living in higher density locations (e.g. urban dwellers) may be less likely to be affected by conservation measures and this may affect their WTP as they will not suffer any negative effects as compared to those living in lower density or rural areas where they or their neighbours may have their actions curtailed by conservation measures. This is argued by Lutz (1999) who suggest that rural residents may place a lower value on the intrinsic importance of wilderness than on its use for economic purposes.

The same argument is made by Berenguer et al. (2005) when they examined the differences in environmental concerns, attitudes, and actions between areas of high and low population density in Spain. The study found that urban dwellers were significantly more concerned about the environment than their rural counterparts. However, looking at specific concerns the study found more nuanced results with differences between the two groups being context specific. For example concern over shortage of water scored higher in the rural cohort while air pollution, exhaustion of natural resources and climatic change scored higher in the urban cohort. This finding may also echo others (McDermott, 1972, Bauer, 2004, Cronon, 1998), who describe a form of urban nostalgia for a wilderness which may have never existed but which they still value returning to a mythical status. It may be that population density differences in values and attitudes, which in turn affect WTP, are dependent on the role of various types of ecosystem services in each individual's or their communities/ neighbourhood's life.

While population density is not commonly included within demand functions for public goods, a binary form of population density in the form of a rural/urban split is often used. The EU uses the OECD methodology (OECD, 2009) and classifies Local Administrative Units (LAU2) [1] with a population density below 150 inhabitants per km² as rural. However other studies (Howley et al., 2012, Russell, 2014) often let respondents self-report if they live in an urban or rural area. Therefore it is often not clear how respondents in such studies are allocated between urban and rural in terms of population density.

A number of papers in economic valuation have noted that there does seem to be differences in WTP between areas of differing population density (Bergmann et al., 2008, Hensher et al., 2009). Ericsson et al. (2009) included human density in their WTP study on wolverine (*Gulo gulo*) conservation finding that the more urban the location, the higher the WTP. However, while it noted that population density has also been used in meta-analysis VT and found to be positively related to WTP (Ghermandi and Nunes, 2013, Wright and Eppink, 2016) this simply reflects that values tend to be higher when there are more beneficiaries. It does not suggest that WTP per person or household is higher in areas with higher population density in these studies.

The scale at which the population density affects the respondent is assumed in this study to work at a neighbourhood level. This echoes a number of previous studies on the link between human attitudes and their neighbourhood. Horton & Reynolds (1971) noted that "while environmental perception is almost certainly affected by group memberships of the individual, or by his position and role in networks of social interaction, and by his stage in the life cycle, it will also be affected by his geographical location". Gifford (2014), in a review of the environmental psychology literature, stated that "place attachment influences attitudes and behaviour beyond itself" citing work by Lewicka (2005) that increased civic activity is related to neighbourhood social ties. In a more recent study, Vemuri et al. (2011) found that perceived individual environmental satisfaction is related to neighbourhood level measure of life satisfaction.

Examining our neighbour measure for population density we used LAU2. Coulton et al. (2013) examined individual's perceptions of neighbourhood scale by asking them to outline on a map the boundary of their neighbourhood. They found the median

[1] The EU has a number of spatial levels that demographic and socioeconomic data is reported at. These are termed Nomenclature of Units for Territorial Statistics (NUTS). Different types of data are reported at various levels. The highest level with the coarsest level of spatial detail is the NUTS1 regions that often have the greatest level of socio-economic data. These are either large areas of MSs or the entire MS itself for smaller EU members. The levels then go down to NUTS2, NUTS3, LAU1 and LAU2. As the spatial scale of the NUTS region increases the amount of socio-economic data available for that area decreases. Therefore, there is a trade-off in what level is acceptable in terms of spatial detail and socio-economic or demographic detail.

resident map size was approximately 30% smaller than the median census tract at 0.35 mile^2 with map size at the 25th percentile of 0.10 mile^2 and the 75th percentile map size of 0.98 mile^2. Other studies had similar results, with Haney and Knowles (1978) reporting values of a median 0.0306 mile^2 for inner city residents to median 0.0753 mile^2 for outer city residents while Coulton et al. (2001) reported a mean neighbourhood size of 0.32 mile^2. These areas are smaller than the LAU2 scales which have a median value of 19 km^2 ranging from 0.045 km^2 to 162 km^2. As the LAU2 areas are the smallest units we have available for this analysis, they are the best proxy measure of the neighbourhood population density.

Population density is calculated by dividing the population within a LAU2 area by that LAU2 area. It is assumed that the population is distributed evenly throughout the area. However, most of the variables used for the VT exercise were only available at the higher NUTS3 level. This leads to the MAUP as identified by Goodchild et al. (1993[2]).

To further demonstrate this issue, the following is an example of a hypothetical value function transfer where only three factors affect WTP for a marine ecosystem service; namely income (modelled as a log function), distance to the sea (based on distance from centroid of region to sea) and population density (modelled as a log function).

$$WTP = -70 + 27\ln(income) - 0.25distance + 1.5\ln(population\ density) \qquad (4)$$

The region that the function is being transferred to is shown in figure 1 and comprises of a rectangular region (10 x 3 km) beside the sea and home to 45 residents of varying income. As shown in scenario A of figure 1, the function value transfer could treat the region as a whole, or as in the case of scenario B1 and B2 be divided into two parts or as in the case of scenario C1 and C2 three parts. This is an example of the MAUP scaling effect. How the partitioning is done, once the number of units to divide an area up into is decided, demonstrates the MAUP zoning effect as shown in the differences between B1 and B2 in the first instance and C1 and C2 in the second instance in figure 1. The varying mean WTP results (Table 1) of applying the same function value transfer to the same population in the same region only differing in how the region is split up shows how both the MAUP scaling and MAUP zoning effects arise and is another issue practitioners of VT should be careful of.

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[2] Imagine picking random people from a NUTS3 region and calculating the population density in their area. If the area is NUTS3, they all people from the same NUTS3 will have the same population density. However, imagine again picking random people from a NUTS3 region but this time their population density variable is based on the LAU2 region they are in. Then the odds of picking a person from a higher density area is higher due to its larger population. Therefore, the mean population density for a NUTS3 region based on LAU2 region as weighted by population will be higher. This spatial mismatch between data zones is the MAUP as the population density was calculated for Irish LAU2 in the survey data but the spatial unit for the VT exercise is the NUTS3 level.

Table 1. Population weighted variables for scenarios in Figure 1

Scenario	Population Weighted Variables			
	Income (€ ,000s)	Distance (km)	Population Density (persons km^{-2})	Mean WTP (€ person^{-1})
A	21.1	5	1.5	11.69
B1	21.11	6.05	1.76	11.37
B2	21.11	7.33	3.54	11.81
C1	21.11	6.33	2.34	11.18
C2	21.11	7.04	20.76	13

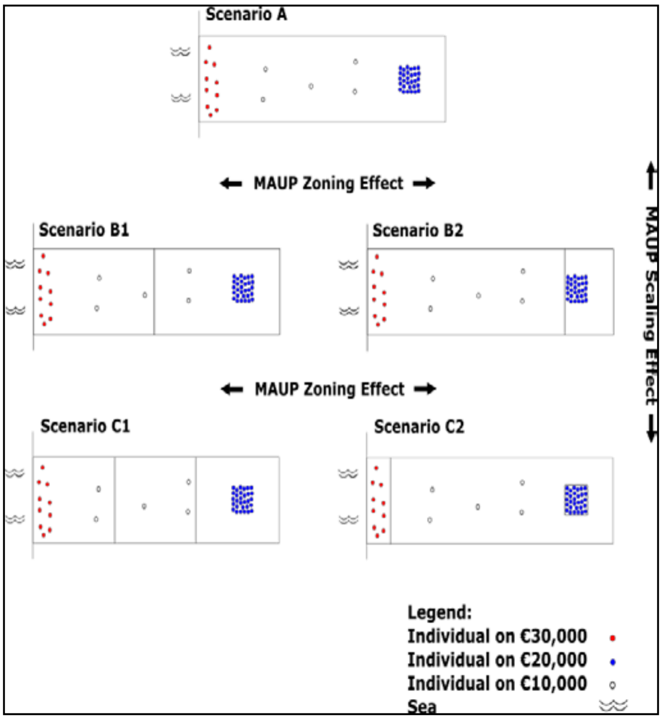


Figure 1. MAUP arising from hypothetical scenarios for VT to a hypothetical coastal NUTS 3 region

3. Methodology

A survey was undertaken with 812 respondents throughout the Republic of Ireland. The survey was conducted face-to-face and respondents were selected on a quota system based on gender, age and geography. The first section of the survey comprised of a number of questions related to use of the marine environment and attitudes to the marine environment. This was followed up with the CVM portion of the survey and some socio-demographic questions. The survey was conducted between September 2012 and November 2012. To ensure a representative sample of the Irish public aged

18 years and above, a quota controlled sampling procedure was followed to ensure that the survey was nationally representative for the population. This was based on age, gender and region of residence. Each respondent's LAU2 area of residence was recorded in the survey and the population density for that LAU2 was used for the respondent's population density.

The respondents were given information on the changes that implementing GES would involve in terms of the MSFD descriptors for marine biodiversity and healthy ecosystems; sustainable and healthy fisheries; pollution levels in the sea; non-native species and physical impacts on the seabed (description of the current state, expected change and potential threats). The respondents were told that:
If you choose the policy alternative, there will be an amount that you as an individual would have to pay annually for the next 10 years to help protect the Irish marine environment under this alternative. Payment is expected to be made through a ring fenced tax dedicated to protecting the marine environment either through your income tax or VAT. Please consider how much money is available in your budget considering all your other expenses before making your decision".

The respondent was then asked *" Based on all the information you have heard so far and again remembering your income and budget, what would be the most that you would be willing to contribute towards achieving good environmental status in the seas around Ireland? "* and the respondents were presented with a payment card with a series of 24 values ranging from €0 to €200.

The fact the respondent is asked to choose their maximum willingness to pay from the card the data generated through this method is treated as interval data. This means that although it is highly possible that the amount chosen by the respondent correspond directly to the amount on the payment card, (it was noted there were higher frequencies at euro note denominations) it is also possible that the amount chosen could also be between that amount and the next figure on the payment card. Additionally it is noted that there were a number of respondents that chose the '€200 or more' option meaning that these amounts are right censored. While the analysist could still employ OLS, using the midpoints of the intervals, Cameron and Hubbert (1989) suggest that interval regression model is a more appropriate model for this type of data as using OLS may lead to biased parameter estimates. This model has previously been used to estimate WTP for reducing air and noise pollution (O'Garra & Mourato, 2007), offsetting carbon emissions from passenger flights (Brouwer et al., 2008) and for biodiversity conservation (Hynes et al., 2010).

The interval regression used 558 of the 812 available survey observations. Some 254 respondents gave zero values for their WTP that were classed as protest responses if they choose one of the following options, "I object to paying taxes; The Government/ County Council/EU or other body should pay; I don't believe the improvements will actually take place; Those who pollute the seas and ocean should pay; I didn't know which option was best, so I stayed with the "No Change" option; Don't know". A total of 184 zero bids were retained as legitimate responses. Two models were estimated that differ only in terms of the definition of distance to the coast. In model 1 the distance is modelled linearly. In model 2 the distance decay is measured using a log function that assumes that the WTP values decay exponentially.

Table 2. Sources of data for the VT exercise

Variable	Geo. Level	Source
PPP Adjusted Income (€'000)	NUTS2	Eurostat (2011)
Married	NUTS3	CSO, INE (ES), INE (PT), INSEE, ONS (2011)
Children in the household	NUTS3	CSO, INE (ES), INE (PT), INSEE, ONS (2011)
Has third level education	NUTS2	Eurostat (2011)
Male	NUTS3	Eurostat (2011)
Age (years)	NUTS3	Eurostat (2011)
Distance from the coast	NUTS3	QGIS - Own calcs.
Rated ocean health as important or very important	Member State	Knowseas (2010-2011)
Log of population density (LAU2 level)	NUTS3	Eurostat (2011)
Agreed/strongly agreed with MPAs	Member State	Knowseas (2010-2011)
How competent is the government to manage and protect the marine waters	Member State	Knowseas (2010-2011)

Following the estimation of the two CVM WTP models, a VT exercise was undertaken where data based on the spatial unit of NUTS3 regions (See Table 2) was used. While the CV valuation exercise was restricted to Ireland, it was decided that VT would be used to estimate values for achieving GES across a number of Atlantic EU MSs.

It was decided that the NUTS3 level would be used as the spatial unit for the VT exercise due to the availability of the geographic variables of distance and population density to allow for heterogeneity within MSs; this was the finest scale that most data was readily available. Data was available from Eurostat or from its agglomeration of Census 2011 results from all MSs, CensusHub2 (ESS, 2016), or from individual MSs central statistics agencies (France - INSEE, Spain - INE, Portugal - INE, Republic of Ireland - CSO, England and Wales - ONS, Scotland - NRS, Northern Ireland - NISRA). All data used was based on the year 2011 as this was the census year that most of the data was available. Income was adjusted using purchasing power parity (PPP) figures from the Penn World Table (Feenstra et al., 2015). The income data was only available at the NUTS2 level, and the attitudinal variables from the KNOWSEAS Project (Potts et al., 2011) were only available at the MS level. Table 2 details the source of each variable used in the VT exercise. Table 3 outlines the descriptive statistics for the NUTS3 variables. A graphical summary of the methodology is shown in Figure 2.

Table 3. Descriptive statistics for all NUTS3 regions (5 MSs) used in the VT exercise.

VT Exercise NUTS3 Variables (n=332)	Mean	Standard Deviation
Income (€'000)	25.43	6.82
% Married	0.49	0.05
% people living with children in the house hold	0.32	0.07
% with third level education	0.25	0.07
% Male	0.49	0.01
Mean Age (>17years)	48.02	2.59
Distance from the NUTS3 centroid to the coast (km)	84.01	94.36
Population density (NUTS3 level) (persons km^{-2})	768	1838
% that rated ocean health as important or very important	0.47	0.13
% that agreed or strongly agreed with marine protected areas (MPAs)	0.75	0.07

To investigate the MAUP effect in relation to population density, two different scales were used to measure population density, the first was the NUTS 3 population density and the second was population weighted LAU2 population densities aggregated for each NUTS3 region. For both, population density was calculated at the NUTS3 level then log transformed. In the regression models 1 and 2, the log transformed population density was calculated based on NUTS3 regions. Models 3 and 4 use the same coefficients as models 1 and 2 respectively but population weighted LAU2 population densities aggregated for each NUTS3 region were used instead. Table 4 compares the different population density measures and their values for Irish NUTS3 regions for the interval regression and the VT exercises. The MAUP seems to be a bigger issue for rural areas compared to the large urban agglomeration of the Dublin NUTS3 region.

Figure 2. Flowchart of the steps undertaken during the valuation process.

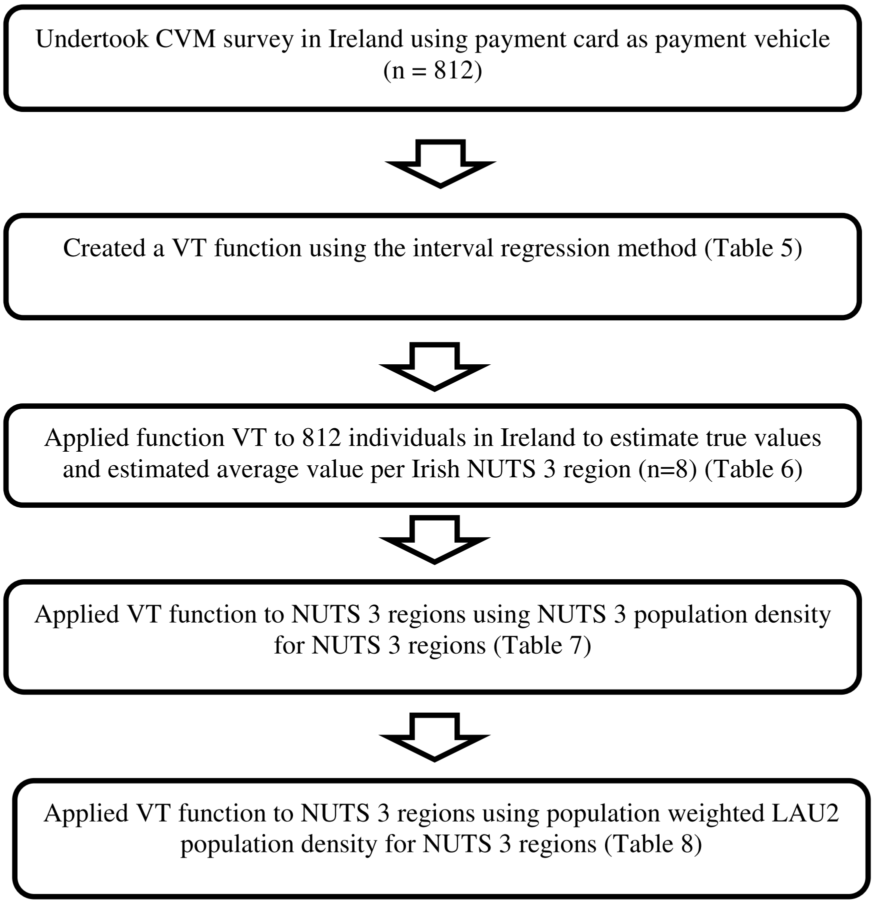


Table 4. Population weighted natural log of population density for Irish NUTS3 regions based on this survey, NUTS3 data and LAU2 data.

NUTS 3	Survey (n=812)	NUTS3 (Ireland) (n=8)	LAU 2 (Ireland) (n=3409)
Dublin	8.38	7.23	8.35
Mid-West	6.41	3.87	6.59
Mid-East	6.13	4.48	6.38
Border	6.34	3.76	6.01
South-East (IE)	7.02	3.98	6.47
South-West (IE)	7.05	4.00	6.92
West	5.66	3.48	6.20
Midland	6.23	3.78	5.92

4. Results

Table 5 presents the results of the interval regression models. WTP to achieve GES per annum over ten years is used as the dependent variable. Two models were estimated that differ only in terms of how distance to the coast was specified. In model 1 the distance is modelled linearly. In model 2 the distance is measured using a log function. Figure 3 shows how the values decline over distance between the models, *ceteris paribus*.

Table 5. Interval regression models for WTP for GES in Irish marine waters.

	Model 1- Linear Distance Decay	Model 2- Exponential Distance Decay
Ln Income (€1,000's)	-2.95 (10.60)	-5.61 (10.60)
Married	-8.73 (3.89)**	-8.43 (3.91)**
Children in the house hold	5.46 (3.43)	5.55 (3.45)
Has third level education	-5.90 (7.02)	-5.28 (7.05)
Third level education x ocean health	19.46 (7.60)***	19.83 (7.64)***
Male	7.15 (2.89) ***	6.95 (2.90)***
Age (years)	-1.18 (0.63)**	-1.14 (0.59)**
Age^2 (years)	0.01 (0.01)	0.01 (0.01)
Distance from the coast (km)	-0.25 (0.07) ***	
Ln of distance from the coast (ln (km))		-3.73 (1.38)***
Ln of population density (LAU2 level)	-18.89 (5.31)***	-19.43 (5.34)***
Ln pop. density x ln income	4.88 (1.56) ***	5.07 (1.57) ***
Ln of pop density x age	0.11 (0.04)***	0.11 (0.04)***
Rated ocean health as important	6.93 (4.13)*	7.16 (4.16)*
Agreed or strongly agreed with MPAs	6.17 (3.01)**	5.06 (2.99)*
Constant	57.96 (36.78)	68.74 (17.90)
Log Likelihood	-2117.02	-2120.04
AIC	4266.03	4272.07
BIC	4335.22	4341.26
n	558	558

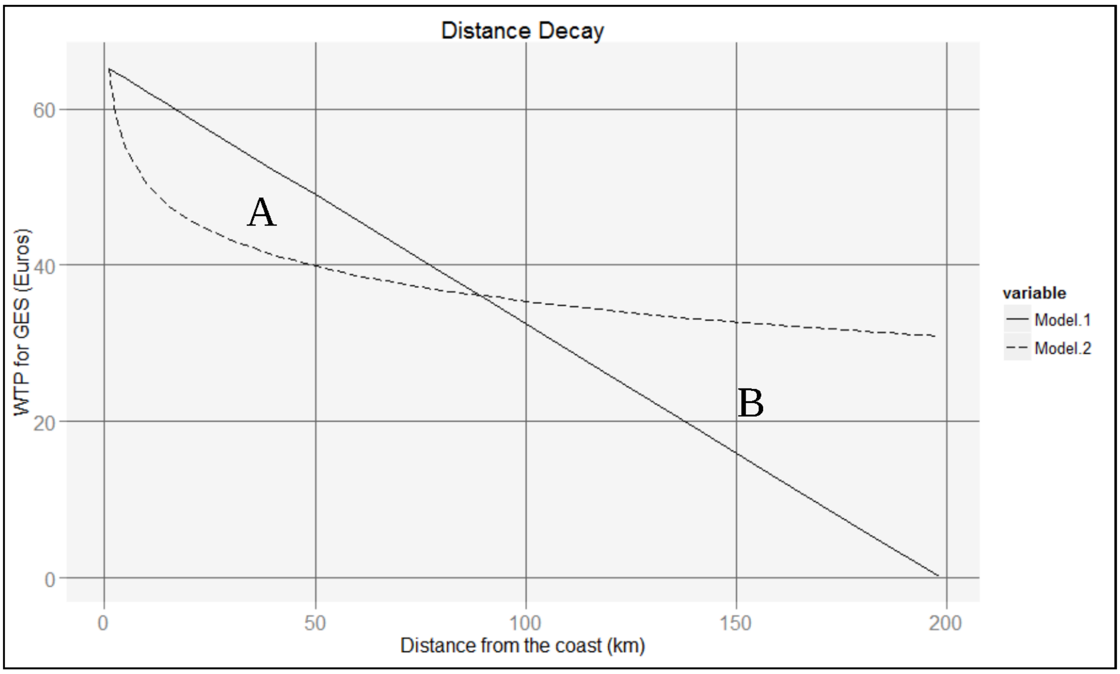
Standard errors in brackets; * indicates significant at 10%, ** indicates significant at 5%, *** indicates significant at 1%.

Most of the parameters are of the expected sign and the coefficients are very similar in both models (apart from the distance decay variable) [3]. WTP for GES increases with income interacted with the natural log of population density and is significant. The natural log of population density interacted with age is also positive and significant. However, the individual effect of population density is negative and significant. To further examine the marginal effect of population density including the

[3] The coefficient results from the interval regression model can be interpreted in the same manner as an OLS model (Mahieu et al., 2012).

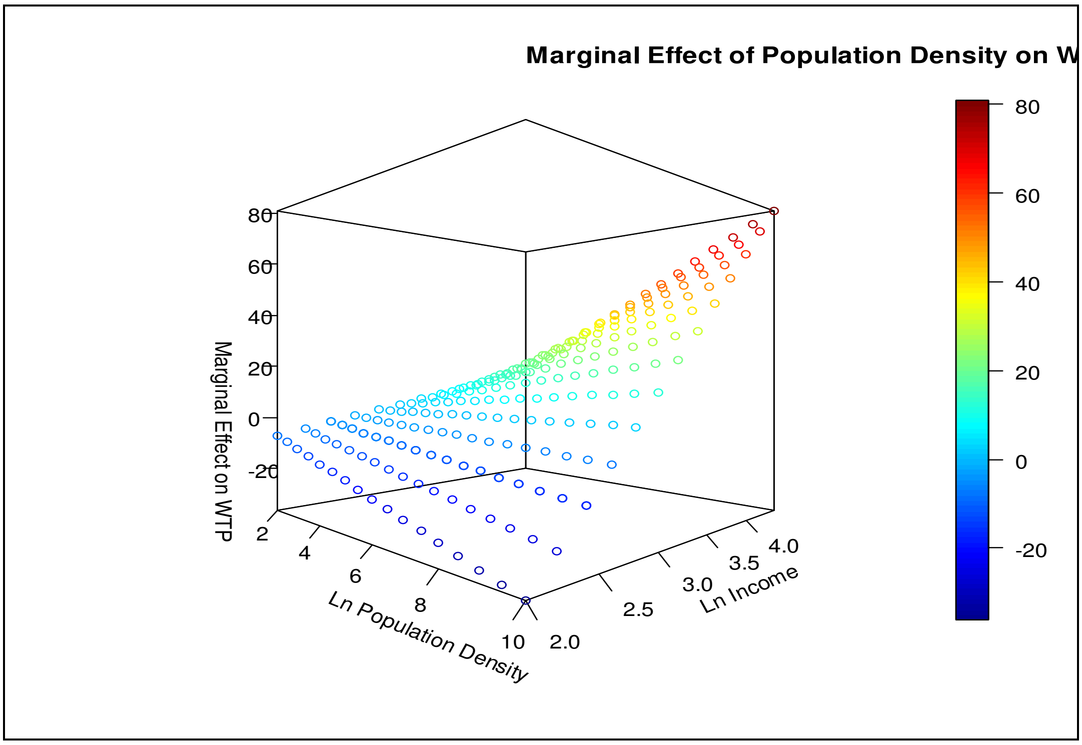
interactions, 3-dimensional plots of population, income and marginal effect on WTP were graphed for various ages. The plot for age 50 is shown below in figure 5. It shows that at lower incomes the relationship between marginal WTP and population density is negative and as income increases this relationship flips and becomes positive at higher incomes. The same effect can be seen for the other age plots also.

Figure 3. Distance Decay for Model 1 and Model 2



Having children in the household increases the WTP in both models (Model 1 - €5.46, Model 2 - €5.55); this is thought to represent part of the bequest element of non-use value, households with children may consider the state of the environment that their children will inherit. However, it is noted that this variable is insignificant. Males also tend to have a higher WTP and respondents who are married have high negative WTP that is also highly statistically significant. Age was modelled as a quadratic function and the linear element is significant and negative but as previously noted age is interacted with the natural log of population density and is positive.

Figure 4. Marginal Effect of Population Density on WTP for age 50



Examining the two spatial variables, distance decay and population density, it can be seen that in both models they are highly statistically significant. The distance decay variable in both models is negative as expected. The linear model suggests that WTP decreases by €0.25 per km. The log of population density is shown to have a positive effect when interacted with age and incomes, indicating that older, higher income residents living in higher density areas have a higher WTP.

Examining the attitudinal variables, the highest marginal impact on WTP was found for third level education interacted with rating ocean health as important or very important (based on a five point Likert scale) (model 1 - €19.46, model 2 - €19.83). Those who rated ocean health as important or very important without a third level degree also have a positive WTP. Those who agreed or strongly agreed with marine protected areas also have a positive marginal WTP which is statistically significant in both models.

In terms of which model performs better, model 1 (the linear distance decay) was found to have a smaller AIC and BIC and a larger log-likelihood. However, model fit should not determine which model is best for VT. Bateman (2009) noted the phenomenon whereby unit VTs often outperform function VTs as measured by transfer errors could be due to researchers typically transferring statistical best fit functions, a problem that could be mitigated through the use of functions that were derived solely from theoretical principles.

The estimated value for the average Irish individual's WTP to achieve GES was €29.83 in model 1 and €29.92 in model 2; a difference of 0.3%. It varied from a high of €38.31 for the Dublin NUTS3 region (model 1) to a low of €21.50 (model 1) for the Mid-West NUTS3 region. The models predicted the same values for all NUTS3 regions at the 95% confidence level except for the Midlands NUTS3. A t-test shows significant difference at the 95% level.

Table 6. Mean WTP per person predictions for each NUTS3 region in Ireland

NUTS3	n	Model 1	Model 2	Difference
Ireland	812	€29.83 (0.63)	€29.92 (0.62)	-0.31%
Dublin	231	€38.31 (1.29)	€37.91 (1.29)	1.06%
Mid-East	72	€26.55 (2.01)	€25.62 (2.03)	3.65%
Midlands	64	€22.28 (1.76)	€28.70 (1.74)	-22.35%
South-East	112	€28.13(1.58)	€27.59 (1.55)	1.96%
South-West	96	€30.81 (1.70)	€28.82 (1.68)	6.88%
Mid-West	69	€21.50 (1.48)	€22.67 (1.42)	-5.19%
West	80	€27.34 (1.97)	€27.75 (1.88)	-1.49%
Border	88	€25.64 (1.76)	€25.19 (1.76)	1.76%

Standard error in brackets.

Examining the results from the VT exercise it is noted that where the VT exercise generated negative values, the WTP was set at zero. Table 6 presents the results from the VT exercise. It shows the population weighted mean value for the five Atlantic MSs and the aggregated values for each MS. Both Ireland and Portugal have the highest individual WTP's in both models and this is followed by UK in model 1. However, model 2 shows that French individuals have a higher WTP compared to the average UK resident. Model 2 produces higher WTP estimates than model 1for three MSs; Ireland and Portugal being the exceptions.

Table 7. Mean WTP per person and in aggregate from VT exercise for each MS

Member State	Mean (Pop. Wt.)	Mean (Pop. Wt.)	Total (millions)	Total (millions)
(NUTS 3 n)	Model 1	Model 2	Model 1	Model 2
Ireland (8)	€25.50	€24.62	€87	€84
UK (139)	€19.88	€20.22	€989	€1,006
France (96)	€12.27	€22.37	€604	€1,101
Spain (59)	€12.36	€16.85	€475	€648
Portugal (30)	€24.78	€24.14	€214	€209
			€2,371	€3,048

At the aggregate level, model 2 produced higher estimates for achieving GES than model 1. Model 1 estimates suggest that the aggregated annual WTP for achieving GES in Atlantic MSs is €2.4 billion compared to over €3 billion for model 2. However, there is nothing to say which functional form of distance decay is more accurate.

Examining the results for the VT exercise across the five MSs whilst adjusting for the MAUP increases the overall value of GES across the five North-East Atlantic MSs to €2.78 billion using model 3 and to €3.64 billion using model 4, an increase of 12.7% and 14.1% respectively over the standard models 1 and 2. Table 10 shows the percentage differences for the alternative distance decay specifications and the MAUP. The difference between linear and logarithm distance decay specification was mixed ranging from -3% to 82%. Interestingly, while most MSs had similar results between the MAUP and non-MAUP, in the case of Spain using the population weighted LAU2 population densities increased the differences due to the distance decay function specification.

Table 8. Mean WTP per person and in aggregate from VT exercise for each MS with MAUP adjustment

Member State	Mean per person (Pop. Wt.)	Mean per person (Pop. Wt.)	Total (millions)	Total (millions)
	Model 3	Model 4	Model 3	Model 4
Ireland	€29.14	€28.48	€100	€98
UK	€22.68	€23.17	€1,128	€1,152
France	€15.29	€27.88	€752	€1,372
Spain	€14.58	€20.34	€560	€782
Portugal	€27.99	€27.66	€235	€239
			€2,783	€3,644

The MAUP adjustment caused an increase of between 13% (Portugal, Model 3) and 25% (France, both models) in the estimated WTP values with a mean increase in WTP of 17%. Portugal had the lowest level of adjustment and that is thought to relate to the high number of NUTS3 regions relative to its population (352,072 persons per NUTS3 region) which is less than 45% that of Spain (793,490 persons per NUTS3 region). However, there may be other factors, such as the heterogeneity of population density, affecting the adjustment rate as this relationship does not hold for all MSs. Figure 5 shows the relationship between predicted WTP per person (based on Model 4) and population density.

Table 9. Percentage differences between estimates for different distance decay and MAUP specifications

Member	Difference between linear and logarithm distance decay specification			Difference between NUTS 3 and LAU 2 population density measures		
	Model 1 vs Model 2	Model 3 vs Model 4	Mean difference	Model 1 vs Model 3	Model 2 vs Model 4	Mean difference
France	82%	82%	82%	25%	25%	25%
Ireland	-3%	-2%	-3%	14%	16%	15%
UK	2%	2%	2%	14%	15%	14%
Spain	36%	40%	38%	18%	21%	19%
Portugal	-3%	-1%	-2%	13%	15%	14%
Absolute			25%			17%

Figure 5. Map of estimated individual's WTP to achieve GES in their nation's marine waters using model 4.

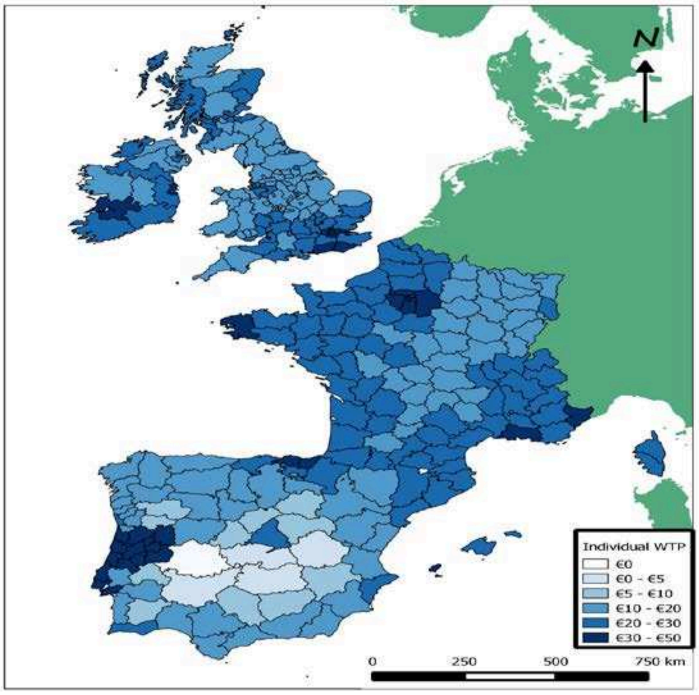
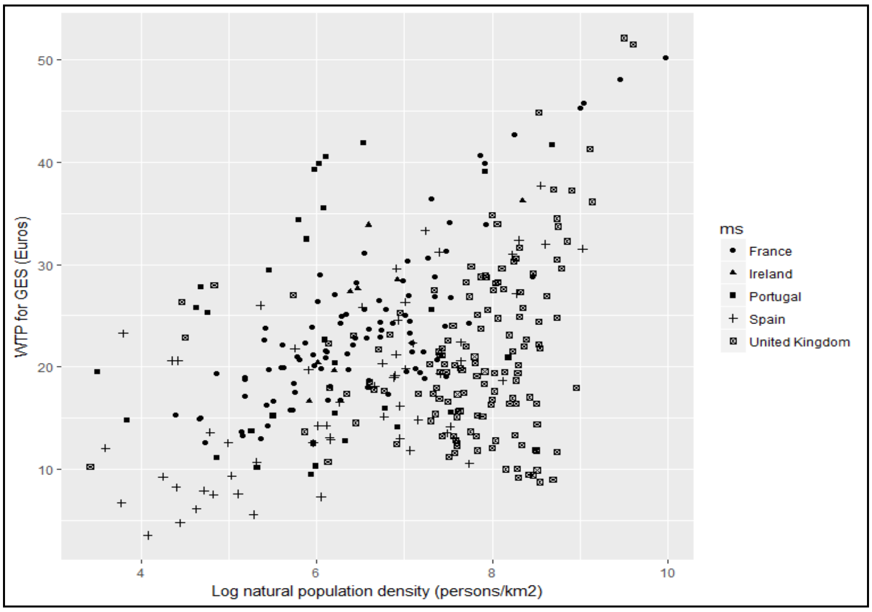


Figure 6. Change in predicted WTP for GES (Model 4) of NUTS3 regions along the population density gradient.



5. Discussion and conclusion

This paper presented the results of a CVM exercise examining the WTP of the Irish public to achieve GES as described in the MSFD. The results provide estimates of the non-market benefits generated by the implementation of the MSFD for possible use in CBA required under article 13 of the MSFD. The results could also be used to determine if there is evidence of disproportionate costs of measures as required under article 14 of the MSFD. The model results show that respondent's income, education, age and attitudes are important factors in determining WTP as well as the spatial factors of distance to the sea and their region's population density.

There was no clear choice of the functional form to use for distance decay. Based on the model fit it would appear that model 1 (linear distance decay) was the better choice, but model 2 (exponential distance decay) performed nearly as well. Population density has the biggest individual negative effect but is also controlled for via two interactions with income and age, which are both positive. Figure 4 showed how the interaction with income can affect how population density affects WTP for GES with a flip in the relationship depending on the income of the respondent. This is likely to lead to a cumulative effect for respondents in urban areas, which usually have higher incomes and higher population densities. As stated previously a number of studies (Bergmann et al., 2008, Hensher et al., 2009, Ericsson et al., 2007) found a positive relationship between WTP and urban areas. In a review of environmental psychology, Gifford (2014) noted that looking at factors affecting environmental concerns or behaviour, population density measured using the rural/urban divide had mixed results with different studies showing both positive and negative relationships between population density and environmental concerns or behaviour (Hinds & Sparks, 2008, Chen et al., 2011). Not using interaction terms as we have done may be a partial explanation for these mixed results.

Overall, as shown in figure 6, there is positive relationship between WTP for GES and population density. It is difficult to suggest a reason for this relationship but it is worth further investigation. Salka (2001) and Rodden (2010) suggest that environmental concerns have become a social and political issue in the rural/urban divide but there is not enough evidence in our survey to support this hypothesis.

The mean WTP generated by both models 1 and 2 are similar; €29.83 and €29.92 respectively. These are at the lower range of the biodiversity values reported by Ressurreição et al. (2012) and by Carson et al. (2003). They are significantly higher than the values estimated by Solomon et al. (2004) for the protection of the Florida manatee and of a similar range to that reported by Machado and Mourato (2002) for clean bathing water. Comparing the CVM values estimated in this report to the costs of implementing GES is difficult as many countries are currently fully implementing older EU environmental directives first before applying any new measures. This situation may change under the new Commission Decision based on a risk based approach to measuring GES (EC, 2017) which supersedes the previous commission decision on GES (EC, 2010). There is also a data gap with respect to costs involved in implementing the MSFD (Bertram et al., 2014).

Primary valuation studies on marine ecosystem service benefits resulting from implementation of the MSFD are important for use by decision makers working to achieve GES. Although it was hoped that there would be an increase in the number of studies related to the directive similar to those carried out after the introduction of the WFD (see for example Moran & Dann, 2008, Martin-Ortega and Berbel, 2010, Doherty et al, 2014, Brouwer et al., 2015),this has yet to happen. This is disappointing as introduction of the WFD saw the number of related valuation studies increase and a greater potential to use VT as a cost-effective tool (Bateman et al, 2011, Norton et al. 2012).

Looking at the VT exercise in this study, the main reason for Ireland and Portugal having such high WTP values is due to the high Likert scale rating that both MS respondents gave for ocean health in the EU Knowseas project. The high income in the Irish case and the high population density in the coastal area of Portugal, coupled with the closeness of the all NUTS3 regions in both countries to the coast also feed into the higher WTP estimates in each case. The biggest difference between models was for France where there was an 82% difference in the WTP estimates in two cases (between model 1 and model 2 and between model 3 and model 4). This is mainly driven by the difference between how the distance decay is modelled with most NUTS3 regions across Europe falling into area A in figure 3 but the French NUTS3 regions (especially around the Paris region) fallling into area B. This is in addition to the high incomes and high population density around Paris resulting in higher WTP estimates compared to the lower WTP estimates for NUTS3 regions closer to the coast. A similar but less extreme story can be used to explain the differences between models for Spain (36%).

The spatial variables show different effects on the predicted WTP with large variations in values (-1% to 82%) produced particularly for the distance decay effect which had a mixture of positive and negative effects depending on the functional specification used. The latter value exceeds the transfer range of 20% to 50% found by Brouwer (2000) and is over double the median of 39% found by Kaul et al. (2013). The MAUP adjustment had a smaller effect than the distance decay effect with an average WTP increase of 17% using the population weighted LAU2 population densities relative to using the NUTS3 population densities. The results highlight that while GIS may add more data and address some issues, if used incorrectly in VT, it may lead to poorer estimates. Practitioners of VT should be cognisant of the MAUP when using density variables at different scales and with respect to distance measurement if there is any reason to suspect that the socio-political units being used have been gerrymandered. As shown here, it can have a significant effect on aggregated results and may even be an insolvable problem (Sheppard and McMaster, 2004.

However, the use of GIS should not be dismissed. Tompkins and Southward (1999) noted that one of the benefits of GIS is its ease in presenting large volumes of data in a spatial manner to policymakers and other stakeholders as well as allowing for linkages between research, policy and practice. An example of this is a map of estimated individual's WTP to achieve GES in their nation’s marine waters as shown in figure 5. This map clearly shows the distance decay effect, especially for France and Spain, indicating that large swathes of both nations may have lower WTP values for the marine environment.

Another issue that arose surrounds obtaining socio-demographic data. While, much of the data was standardised and available either at Eurostat (EC, 2016) or through CensusHub2 (ESS, 2016), some MSs still have not made all their data available on these platforms. Future initiatives by such projects as the EU MARNET project (Foley et al., 2014) which collates and makes available a variety of comparable demographic and socio-economic data at a regional scale across the Atlantic member states (and in particular in the marine and coastal areas) may be alternative source of data for those undertaking similar functional VT exercises in marine related areas.

Additionally, there may be strong reservations about the robustness of using the values generated in a single stated preference study as the basis for a value transfer exercise, particularly when these have been collected in one country but are applied internationally. We also note that since this study there has been a limited amount of work on non-market valuation exercises related to the MSFD. The EU Commission in its review of implementation of the MSFD (EC, 2014) found inadequacies in Member States’ first assessments submitted to the Commission. In particular they commented on the many data gaps and that in many cases the environmental targets set out by the MSs were not sufficient to achieve good environmental status. We note that the results of this study should not be interpreted as a definitive estimate of the benefits of achieving GES in EU Atlantic MSs but instead spur on further study on the value of achieving the targets set out in the MSFD and fill in these data gaps.

This valuation exercise using VT shows that there are significant values attached to achieving GES in MS waters. We estimate the welfare effect of achieving GES for Atlantic MSs is between €2.3 billion and €3.6 billion per annum for marine areas within these MSs but again note that there is a high level of uncertainty associated with these values. As this paper demonstrates, there are still issues with the approach in terms of how much variability the VT function capture, the specification of the model, the spatial level at which data is obtained and the level at which it is applied. Those caveats aside, decisions that could affect the quality of coastal and marine ecosystems and the ecosystem services they generate are routinely made without taking into account any of the non-market benefits that would be foregone if the environmental quality of these ecosystems deteriorated. Better decision making could be achieved if both the level and accuracy of information on the non-market benefits of maintaining or achieving high environmental quality were improved for use in VT exercises such as that carried out in this study.

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