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Heini Ahtiainen

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Doctoral Dissertation

Heini Ahtiainen

Faculty of Agriculture and Forestry
University of Helsinki

Academic dissertation

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Supervisors:
Professor Eija Pouta
Natural Resources Institute Finland (Luke), Helsinki, Finland

Professor Markku Ollikainen
Department of Economics and Management, University of Helsinki, Helsinki, Finland

Pre-examiners:
Researcher Henrik Lindhjem
Norwegian Institute for Nature Research (NINA), Oslo, Norway

Professor Rauli Svento
University of Oulu, Oulu, Finland

Opponent:
Professor Bengt Kriström
Department of Forest Economics, Swedish University of Agricultural Sciences, Umeå, Sweden

Custos:
Professor Markku Ollikainen
Department of Economics and Management, University of Helsinki, Helsinki, Finland

Heini Ahtiainen
Natural Resources Institute Finland (Luke)
Latokartanonkaari 9
FI-00790 Helsinki
Finland
heini.ahtiainen@luke.fi

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Abstract

Eutrophication is a major problem in both marine and freshwater areas in Europe, changing the structure and functioning of the ecosystem and reducing its ability to produce human well-being, for example, in the form of recreation opportunities. Information on the monetary benefits of reduced eutrophication is needed to design economically efficient environmental policies. However, current knowledge on the benefits of mitigating eutrophication is limited and fragmented, and there is a lack of valuation studies that could support environmental decision-making. This thesis provides policy-relevant information on citizen’s willingness to pay for reduced eutrophication in Europe, the Baltic Sea area and Finland, contributing to the literature by providing up-to-date benefit estimates and examining methodological issues related to the economic valuation of environmental benefits.

Three valuation approaches are used: meta-analysis, contingent valuation and choice experiment. The meta-analysis provides an overall understanding of the benefits of reduced eutrophication in European marine areas, the contingent valuation study investigates the benefits of reaching a specific eutrophication reduction target in the Baltic Sea, and the choice experiment reveals Finnish summer house owners’ preferences and values for water quality changes. The contingent valuation results are further used in a cost-benefit analysis of nutrient abatement in the Baltic Sea. The methodological issues examined include conducting a meta-analysis when only few primary valuation studies are available, preference heterogeneity and asymmetry in choice experiments, and the use of international contingent valuation studies for cost–benefit analysis.

The results show that substantial benefits can be gained from reduced eutrophication in Europe, the Baltic Sea countries and Finland, with the annual benefits ranging from a few euros to hundreds of euros per person. However, the findings clearly indicate that the benefits differ between sea areas and countries. The benefits per person are greater in high-income countries and appear higher in the Baltic Sea compared to other sea areas in Europe.

The findings of the meta-analysis suggest that benefit transfers across marine areas may be questionable, even when controlling for differences in income levels and the scope of the change. Results obtained from the Baltic Sea area indicate that even when the sea area and the environmental change are the same and values are corrected using purchasing power parities, willingness to pay and its determinants differ between countries.

Based on the choice experiment, deterioration in water quality in Finland results in larger welfare losses compared to the gains from an improvement of the same size, indicating that it is particularly important to prevent the deterioration of water quality in Finnish waters.

The monetary benefits of reaching a good environmental status in the Baltic Sea with regard to eutrophication, which is the aim of current environmental policies, the European Union Marine Strategy Framework Directive and the HELCOM Baltic Sea Action Plan, are estimated at 3600 million euros per year. The results also serve as justification for implementing additional nutrient abatement measures in the Baltic Sea area, as the benefits of nutrient abatement exceed the costs. The findings of the Baltic Sea-wide contingent valuation study and cost–benefit analysis have already been acknowledged in the policy work of HELCOM, suggesting that benefit estimates and benefit–cost comparisons may play a role in the formulation of environmental policies.

Keywords: environmental benefits, valuation, willingness to pay, eutrophication, water resources, Finland, the Baltic Sea, Europe, meta-analysis, contingent valuation, choice experiment, cost–benefit analysis

Tiivistelmä

Rehevöityminen on merkittävä ongelma niin Suomen kuin Euroopankin merialueilla ja sisävesissä. Se muuttaa ekosysteemin rakennetta ja toimintaa vaikuttaen siten ihmisten hyvinvointiin esimerkiksi heikentämällä virkistyskäyttömahdollisuuksia. Ympäristön tilan parantaminen taloudellisesti kannattavasti ja tehokkaasti edellyttää tietoa rehevöitymisen vähentämisen rahamääräisistä hyödyistä. Nykyinen tieto rehevöitymisen vähentämisen hyödyistä on kuitenkin vähäistä ja hajanaista, eikä päätöksenteon tueksi ole juurikaan tutkimuksia. Tämä väitöskirja tutkii kansalaisten maksuhalukkuutta rehevöitymisen vähentämiseksi Euroopassa, Itämerellä ja Suomessa, tuottaa hyötyarvioita päätöksenteon tueksi ja tarkastelee ja kehittää ympäristöhyötyjen taloudellisen arvottamisen menetelmiä.

Väitöskirjassa käytetään kolmea ympäristöhyötyjen arvottamismenetelmää: meta-analyysia, ehdollista arvottamista ja valintakoetta. Meta-analyysissa vedetään yhteen aiempien arvottamistutkimusten tuloksia ja tuotetaan yleiskuva rehevöitymisen vähentämisen hyödyistä Euroopan merialueilla. Ehdollisen arvottamisen tutkimuksessa tarkastellaan Itämeren rehevöitymisen vähentämisen hyötyjä kaikissa Itämeren rannikkovaltioissa, ja hyötyarvioita käytetään edelleen ravinnepäästöjen vähentämisen kansainvälisessä kustannus–hyötyanalyysissa. Valintakokeella puolestaan tutkitaan kesämökinomistajien preferenssejä ja arvostuksia veden laadun muutoksista Suomessa. Väitöskirjassa tarkastellut menetelmälliset kysymykset liittyvät meta-analyysin tekoon kun analyysiin sopivia tutkimuksia on vähän, preferenssien heterogeenisuuteen ja asymmetrisyyteen valintakokeessa ja monta maata kattavan arvottamistutkimuksen ja kustannus–hyötyanalyysin suunnitteluun ja toteuttamiseen.

Tulosten perusteella rehevöitymisen vähentämisestä saataisiin merkittäviä taloudellisia hyötyjä Euroopassa, Itämeren maissa ja Suomessa, vuotuisten hyötyjen ollessa muutamasta eurosta satoihin euroihin henkilöä kohden. Tutkimuksista käy kuitenkin selkeästi ilmi, että hyödyt vaihtelevat merialueiden ja maiden välillä. Hyödyt ovat suurempia korkean tulotason maissa, ja Itämeren tilan parantaminen vaikuttaa tuottavan enemmän hyötyjä verrattuna muihin Euroopan merialueisiin.

Meta-analyysin tulosten perusteella tietyllä Euroopan merialueella arvioituja hyötyjä ei välttämättä voida siirtää merialueelta toiselle, vaikka siirrossa otettaisiinkin huomioon erot tulotasossa ja meren tilassa tapahtuvassa muutoksessa. Itämeren alueella tehdyn tutkimuksen tulokset osoittavat, että maksuhalukkuus ja siihen vaikuttavat tekijät eroavat rannikkovaltioiden välillä, vaikka rehevöitymisessä tapahtuva muutos on sama kaikissa maissa ja tarkastellaan ostovoimakorjattuja hyötyarvioita, jolloin maiden valuuttakurssit ovat ostovoimaltaan yhtäläiset.

Valintakokeen tulokset viittaavat siihen, että Suomessa veden laadun heikentyminen aiheuttaa enemmän haittoja verrattuna hyötyihin, joita saadaan vastaavansuuruisesta parannuksesta veden laadussa. Tämän perusteella on erityisen tärkeää estää veden laadun heikkeneminen Suomen vesistöissä.

Sekä Euroopan unionin meristrategiadirektiivi että Itämeren suojelukomission HELCOMin Itämeren suojelun toimenpideohjelma tavoittelevat Itämeren hyvää tilaa rehevöitymisen suhteen. Tämän väitöskirjatutkimuksen mukaan hyvän tilan saavuttamisen hyödyt rehevöitymisen osalta Itämerellä ovat 3600 miljoonaa euroa vuodessa. Tulokset antavat myös perusteen vähentää ravinnekuormitusta Itämeren alueella, sillä hyödyt rehevöitymisen vähentämisestä ylittävät sen kustannukset. Arvottamistutkimuksen ja kustannus–hyötyanalyysin tulokset on jo otettu huomioon Itämeren suojelukomission työssä, joten hyötyarviot ja hyötyjen ja kustannusten vertailut voivat tukea kansainvälisten ympäristön tila parantavien toimien arviointia ja toteuttamista.

Avainsanat: ympäristöhyödyt, arvottaminen, maksuhalukkuus, rehevöityminen, vesistöt, Suomi, Itämeri, Eurooppa, meta-analyysi, ehdollinen arvottaminen, valintakoe, kustannus-hyötyanalyysi

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Helsinki, 1st of February 2016

Heini Ahtiainen

List of abbreviations

ASC	alternative-specific constant
CBA	cost–benefit analysis
CE	choice experiment
CV	contingent valuation
HELCOM	Baltic Marine Environment Protection Commission (Helsinki Commission)
IIA	independence of irrelevant alternatives
MNL	multinomial logit
MSFD	Marine Strategy Framework Directive
RPL	random parameter logit
TEV	total economic value
WFD	Water Framework Directive
WTA	willingness to accept
WTP	willingness to pay

List of original publications

The thesis is based on the original papers listed below, referred to by their Roman numerals throughout this dissertation. All articles are reprinted with the kind permission of the publishers.

I Ahtiainen, H. & Vanhatalo, J. 2012. The value of reducing eutrophication in European marine areas – A Bayesian meta-analysis. Ecological Economics 83:1–10. http://dx.doi.org/10.1016/j.ecolecon.2012.08.010

II Ahtiainen, H., Artell, J., Czajkowski, M., Hasler, B., Hasselström, L., Huhtala, A., Meyerhoff, J., Smart, J., Söderqvist, T., Alemu, M., Angeli, D., Dahlbo, K., Fleming-Lehtinen, V., Hyytiäinen, K., Karlõseva, A., Khaleeva, Y., Maar, M., Martinsen, L., Nõmmann, T., Pakalniete, K., Oskolokaite, I. & Semeniene, D. 2014. Benefits of meeting nutrient reduction targets for the Baltic Sea – a contingent valuation study in the nine coastal states. Journal of Environmental Economics and Policy 3(3):278–305. http://dx.doi.org/10.1080/21606544.2014.901923

III Ahtiainen, H. Pouta, E. & Artell, J. 2015. Modelling asymmetric preferences for water quality in choice experiments with individual-specific status quo alternatives. Water Resources and Economics 12:1–13. http://dx.doi.org/10.1016/j.wre.2015.10.003

IV Hyytiäinen, K., Ahlvik, L., Ahtiainen, H., Artell, J., Huhtala, A. & Dahlbo, K. 2015. Policy goals for improved water quality in the Baltic Sea: When do the benefits outweigh the costs? Environmental and Resource Economics 61(2):217–241. http://dx.doi.org/10.1007/s10640-014-9790-z

Author contributions

The research idea for the first article was developed by Heini Ahtiainen. Heini Ahtiainen was responsible for the statistical analyses and the main body of the manuscript. Jarno Vanhatalo contributed to estimating the model comparison statistics in the methods section and their discussion. Heini Ahtiainen is the corresponding author of the article.

The research idea for the second article was jointly developed by all authors. Heini Ahtiainen was responsible for the statistical analyses and the main body of the manuscript, and coordinated the data gathering together with Janne Artell. Janne Artell, Mikolaj Czajkowski and Anni Huhtala contributed to the statistical analyses. Janne Artell, Mikolaj Czajkowski, Berit Hasler, Linus Hasselström, Anni Huhtala, Jürgen Meyerhoff, James Smart, Tore Söderqvist, Mohammed Alemu, Daija Angeli, Kari Hyytiäinen, Aljona Karlõseva, Yulia Khaleeva, Louise Martinsen, Tea Nõmmann, Kristine Pakalniete, Ieva Oskolokaite and Daiva Semeniene contributed to the data collection in each respective country. Kim Dahlbo, Vivi Fleming-Lehtinen and Marie Maar contributed to the ecological models behind the valuation scenarios. All authors contributed to editing the manuscript. Heini Ahtiainen is the corresponding author of the article.

The research idea for the third article was jointly developed by all authors. Heini Ahtiainen was responsible for the statistical analyses and the main body of the manuscript. Eija Pouta contributed to the statistical analyses and to editing the manuscript. Janne Artell collected the data and contributed to editing the manuscript. Heini Ahtiainen is the corresponding author of the article.

The research idea for the fourth article was jointly developed by all authors. Heini Ahtiainen was responsible for the statistical analyses of the benefit estimates used in the cost-benefit analysis and writing the section related to the benefit estimates. Janne Artell and Anni Huhtala contributed to the section on the benefit estimates. Lassi Ahlvik and Kari Hyytiäinen were responsible for the cost modelling. Kim Dahlbo contributed to the ecological modelling. All authors contributed to editing the manuscript. Kari Hyytiäinen was responsible for the main body of the manuscript and is the corresponding author of the article.

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1. Introduction

The world's marine and freshwater ecosystems are threatened by many anthropogenic pressures, which are affecting their ability to provide goods and services that improve human well-being. One of the major problems in water ecosystems is eutrophication, which is caused by an excessive supply of nutrients, most importantly nitrogen and phosphorus, to the water system. Eutrophication alters the structure and functioning of the ecosystem, and causes, inter alia, water turbidity, blue-green algal blooms and oxygen depletion. These, in turn, may cause aesthetic impacts, reduce biodiversity, change fish species composition and harm or even prevent water recreation. Thus, eutrophication affects the supply of several ecosystem services, i.e. ecosystem characteristics that produce goods and benefits to humans (Millennium Ecosystem Assessment 2005, Fisher et al. 2009).[1]

In Europe, eutrophication is a serious problem in the Baltic Sea (HELCOM 2009) and the Black Sea (Borysova et al. 2005), but also affects some areas of the Mediterranean and the North Sea (EEA 2001). In Finland, the effects of eutrophication can be observed in both coastal areas and inland waters, and its reduction is the most important objective of Finnish water protection policies (Finnish Government decision-in-principle on Water Protection Policy Outlines to 2015, 2007).

Designing economically efficient policies to protect and manage water resources requires information on the economic impacts of environmental policies, including estimates of the associated costs and benefits in monetary terms. Although water protection in Europe has mainly relied on ecological information and targets, socio-economic analyses have gained greater emphasis in the recent European Union directives on water resources, the Water Framework Directive (WFD) (2000/60/EC) and the Marine Strategy Framework Directive (MSFD) (2008/56/EC) (European Parliament 2000, 2008). Both aim at reaching a good environmental status of waters, also with regard to eutrophication, and advance the integration of economics into water management and decision-making. In the WFD, the estimation of benefits is related to the analysis of disproportionate costs, which may be used to justify exemptions from reaching the targets in the given time. The MSFD calls for analysis of the costs of degradation of the marine environment, which may be interpreted as the benefits forgone if there is no improvement (WG ESA 2010). In addition, programmes of measures to improve the condition of the sea in the MSFD should include a cost–benefit analysis prior to introducing new measures. The MSFD also implies a high level of international cooperation, as marine resources are often shared by several countries.

The benefits of reduced eutrophication cannot be fully estimated based on information about market prices, as water quality is an environmental good. Similar to water quality, environmental goods are often non-market goods, meaning that they are either not sold in the markets or their markets are incomplete. Thus, instead of founding value estimates on market prices, economic valuation methods are needed to determine the monetary benefits of mitigating eutrophication. Several economic valuation methods have been developed, which all have their requirements, advantages and drawbacks (for a review, see Champ et al. 2003). Revealed preference methods, such as the travel cost method and hedonic pricing, rely on information about people's actual behaviour to estimate environmental values, while stated preference methods, such as contingent valuation and choice experiment, use surveys to elicit people's willingness to pay for changes in environmental goods. In addition

1 Although the concept of ecosystem services is useful for describing the relationship between ecosystems and human well-being, this dissertation uses the conventional terminology in the environmental economics literature and refers to environmental goods instead of ecosystem services.

to these primary valuation methods, there are approaches that utilize existing studies and results to take stock of the literature and apply value estimates to other sites and contexts, such as meta-analysis and benefit transfer.

There is some literature on the benefits of reduced eutrophication in European freshwater and marine areas. However, studies are often very context-specific, rarely providing information for several scopes of environmental change, areas or countries. Recent freshwater valuation studies have often been motivated by the requirements of the Water Framework Directive (e.g. Ferrini et al. 2014, Söderberg & Barton 2014, Meyerhoff et al. 2014). Turning to consider the marine environment, most studies in the Baltic Sea area have focused on a specific marine region, for example the Stockholm archipelago or the Gulf of Finland (e.g. Frykblom 1998, Söderqvist & Scharin 2000, Atkins et al. 2007, Kosenius 2010, Östberg et al. 2012). The only large-scale valuation study on nutrient abatement in the Baltic Sea was carried out in the mid-1990s, with research conducted in Lithuania, Poland and Sweden to enable a cost–benefit analysis of eutrophication (reported in Gren et al. 1997b, Markowska & Zylicz 1999, Turner et al. 1999). However, due to changes in the social, economic and environmental conditions, there is a need for updated benefit estimates and analysis in the Baltic Sea area. In addition, there has been considerable development and diversification in valuation techniques, giving rise to a need for new applications. Compared to the Baltic Sea, fewer valuation studies have been conducted for the Mediterranean (Kontogianni et al. 2003, Stolte et al. 2003), the North Sea (Le Goffe 1995, Stolte et al. 2003, Longo et al. 2007), and the Black Sea (Taylor & Longo 2010).

Despite a growing number of studies, information on the monetary benefits of water quality improvements in Europe is considered to be limited and fragmented, at least in coastal and marine areas (Remoundou et al. 2009, Bertram & Rehdanz 2013). Due to context specificity, generalizations based on individual studies are problematic. For example, previous studies have not provided original benefit estimates concerning reduced eutrophication for the entire Baltic Sea, although it is recognized as one of the most prominent threats to the marine environment in the area (HELCOM 2009).

The aim of the research presented in this dissertation was to examine the monetary benefits of reduced eutrophication in Finland, the Baltic Sea area and Europe using different economic valuation methods, and to illustrate how the results of a valuation study can be incorporated into societal cost–benefit analysis of mitigating eutrophication. The purpose was to provide policy-relevant monetary benefit estimates for environmental changes that cover a wide geographical area and can be used to improve the efficiency of decision-making. The policy relevance is reflected in the design and implementation of the valuation studies and the presentation of the results. The first three studies assessed the benefits of reduced eutrophication at three different geographical scopes: Europe, Finland and the Baltic Sea area. The fourth study comprised a cost-benefit analysis of eutrophication policies in the Baltic Sea.

In addition to providing up-to-date benefit estimates to support eutrophication-related decision-making, this dissertation examines several challenges in applying economic valuation methods, which complicate the estimation of environmental benefits. First, it examines how to perform a meta-analysis when only a small number of suitable primary valuation studies can be identified. Second, it illustrates an application of the choice experiment method with individual-specific reference levels of environmental quality, and examines preference heterogeneity and asymmetry in this setting. Third, it presents an example of an internationally coordinated contingent valuation study for a shared environmental resource, the Baltic Sea, and its use in cost–benefit analysis and policy support. On the whole, the methods and findings of this research support the assessment of environmental values when the conditions or research questions pose additional challenges.

The research questions addressed in this dissertation are as follows: How large are the monetary benefits of reduced eutrophication in Europe and the Baltic Sea area? How do the benefits differ between geographical areas and individuals? Do the benefits of nutrient abatement exceed the costs? How can a meta-analysis be performed when the sample of studies is small? Are preferences for water quality heterogeneous and asymmetric? How can an international valuation study and cost–benefit analysis be implemented to support environmental policy? Answering these questions improves our knowledge of the socio-economic significance of mitigating eutrophication and supports the planning and implementation of evidence-based policies that take into consideration the environmental benefits. The research questions were addressed in four studies:

Study I comprised a meta-analysis to summarize the results of valuation studies of the benefits of reduced eutrophication in European marine areas, and provided welfare predictions for different areas and scopes of the change in eutrophication. Bayesian estimation techniques were employed in the econometric analysis to address the challenges related to the small number of valuation studies available. The study was novel in the sense that it exclusively examined marine resources and European valuation studies.

Study II was a contingent valuation study of the benefits of reduced eutrophication conducted in the countries around the Baltic Sea. The study was the first to include all nine coastal countries, and the largest international contingent valuation study to consider improvements to the marine environment. The benefit estimates were comparable across countries due to the similar surveys used. The study illustrated the implementation of international valuation surveys that are based on an existing environmental policy.

Study III applied the choice experiment method to study the preferences of summer house owners for changes in eutrophication-related water quality in Finland. The modelling approach allowed for preference heterogeneity, asymmetry and nonlinearity for water quality attributes, with the reference water quality level defined by the respondents themselves. The study adds to the limited literature on the use of perceived reference levels in choice experiments and asymmetric preferences for environmental goods.

Study IV used the results of Study II to perform a societal cost–benefit analysis of a trans-boundary environmental problem, i.e. reduced eutrophication in the Baltic Sea. It demonstrated how the results of valuation studies on the benefits of environmental improvements can be incorporated into cost–benefit analysis, resulting in a more comprehensive analysis of the economic efficiency of the policy. The study developed a spatial and dynamic ecological-economic modelling framework, with an explicit link between the benefits and the costs of nutrient abatement through nutrient load reductions.

This dissertation rests on taking stock of existing research in a meta-analysis and conducting primary valuation studies with stated preference methods. The meta-analysis can be thought of as the first stage in examining the value of the environmental good, where the researcher reviews the relevant literature and identifies possible gaps in existing knowledge. The information gathered and evaluated in the meta-analysis can be utilized in the planning of primary valuation studies, i.e. contingent valuation and choice experiment, which examine specific issues and aim to fill the identified gaps. Naturally, primary valuation studies are needed to conduct meta-analyses, as they compose the data. Furthermore, the findings of both meta-analyses and primary studies can be used in a cost–benefit analysis to provide additional policy support (Figure 1).

In this dissertation, the meta-analysis was chosen as a research method to obtain an overall understanding of the benefits of reduced eutrophication in Europe, to present benefit estimates suitable for various areas and changes, and to provide background information for the contingent valuation study. Stated preference techniques were used to capture a variety of values from marine and freshwater ecosystems, reflecting the benefits people derive from both the use of water resources and from the existence of healthy water ecosystems. The results of the contingent valuation study were used in the cost-benefit analysis.

The dissertation is organized as follows. The second section presents the methods employed in the analyses and describes their specific applications and the data. The third section summarizes the results of the four studies one by one, and discusses their overall contribution. The final section provides discussion and conclusions on the implications of this work.

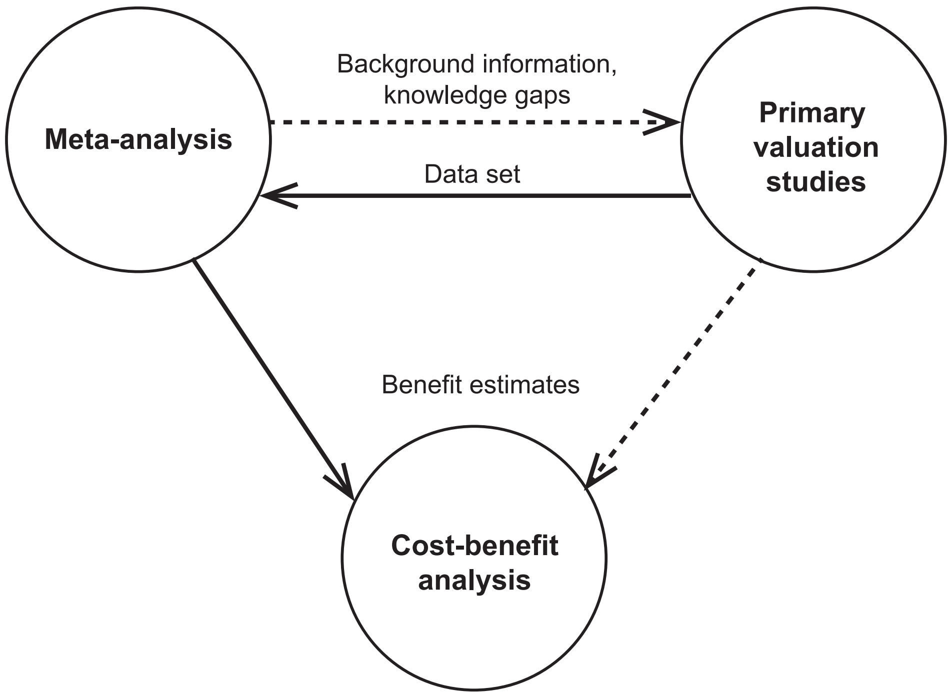

Figure 1. Relationships between the methods used in this dissertation research (dashed arrows show the links between the articles in this dissertation).

2. Methods

Environmental goods, such as air quality, biodiversity and landscape, are often non-market goods. As market prices cannot generally be used to estimate environmental values, specific economic valuation methods have been developed to estimate the monetary benefits (or damage) resulting from changes in the quality or quantity of environmental goods (see e.g. Champ et al. 2003). These economic valuation methods include primary valuation techniques, most importantly stated and revealed preference methods, and techniques that utilize existing studies and results, such as meta-analysis and benefit transfer.

Monetary welfare measures estimated with economic valuation methods can be represented using the concepts of willingness to pay (WTP) and willingness to accept compensation (WTA), or the concepts of compensating and equivalent variation (Haab & McConnell 2002). They both measure the change in income that would make an individual indifferent to a change, for example, in an environmental good. WTP is defined as the maximum amount of money a person is willing to pay to gain an improvement or to avoid a loss, whereas WTA measures the minimum compensation required to forego an improvement or to accept a loss. Compensating variation refers to the amount of money that leaves the individual at the initial (before change) level of utility, and equivalent variation is the amount of money that leaves the individual at the final (after change) level of utility (Hicks 1943). These concepts are related such that for improvements in welfare, WTP corresponds to the compensating variation and WTA to the equivalent variation. For decreases in welfare, WTP measures the same as the equivalent variation and WTA the same as the compensating variation. In environmental applications, where individuals cannot choose the quantity of the environmental good, the welfare measures are typically referred to as compensating and equivalent surplus instead of variation. Conceptually, stated preference methods typically provide Hicksian welfare estimates (compensating and equivalent surplus) and revealed preference methods Marshallian welfare estimates (consumer surplus), which measure welfare at the original level of utility and environmental good.

The concept of total economic value (TEV) describes all the relevant values for the environmental good (see e.g. Bateman et al. 2002). TEV captures both use values, which are related to the actual current and future use of the good, and non-use (or passive use) values, which refer to the benefits people obtain from environmental goods, even though they would never use them. Non-use values can only be measured using stated preference methods. Option value, which refers to the preservation of a possibility to use the good in the future, has raised opposing views. To some, it may be considered as part of use values (Bateman et al. 2002), whereas others argue that option value is not a unique component of value (Freeman 2003).

2.1. Meta-analysis

Meta-analysis refers to techniques that evaluate and summarize the results of empirical studies. Glass (1976) is typically credited with introducing meta-analysis to social sciences. The first meta-analyses in the field of environmental valuation appeared in the late 1980s and early 1990s, with applications on recreation (Smith & Kaoru 1990a, 1990b, Walsh et al. 1990). To date, meta-analyses have been used to examine a variety of environmental goods, such as air quality, wetlands, forests and biodiversity. Meta-analyses of water quality values include studies focusing on both freshwater (Johnston et al. 2003, 2005, 2006; Van Houtven et al. 2007) and marine resources (Liu & Stern 2008), and some studies have had a specific focus on coastal recreation values (Ghermandi & Nunes 2013, Ghermandi 2015). The current popularity of meta-analysis can be explained by the increased demand for benefit estimates and, at the same time, the limited availability of resources for conducting primary studies. In addition, a larger number of primary valuation studies enable meta-analyses of various environmental goods.

In environmental valuation, the purpose of meta-analysis is to synthesize existing research, test hypotheses and predict values in other policy contexts (Smith & Pattanayak 2002, Bergstrom & Taylor 2006). The interest may lie in providing a mean value (WTP) across studies and examining the determinants of WTP (Nelson & Kennedy 2009). An important application of meta-analysis is to predict WTP by constructing a value function for benefit transfer (Rosenberger & Loomis 2000, Bergstrom & Taylor 2006, Shrestha et al. 2007, Lindhjem & Navrud 2008, Boyle et al. 2013, Johnston et al. 2015). This allows the evaluation of benefits in previously unstudied sites and contexts to support policy decisions. Some degree of transfer error[2] is expected, as the populations and environmental goods are prone to differ (Kristofersson & Navrud 2005). This has led some to suggest that it may be more useful to define an acceptable level of transfer error instead of expecting equality of the primary and the transferred estimate.

Meta-analytical data are usually analysed using meta-regression models, where the value (WTP) estimates obtained in the primary studies are explained with factors describing the environmental good, geographical location, population and study methodology.

The studies included in a meta-analysis need to meet several consistency requirements (Smith & Pattanayak 2002). All studies should value a similar (enough) environmental good. This may require adjustments of the dependent variable, or controlling for inconsistencies with independent variables (Bergstrom & Taylor 2006). A common view is that the welfare measure should be consistent across studies, i.e. only Hicksian or Marshallian value measures should be included (Bergstrom & Taylor 2006, Nelson & Kennedy 2009, Boyle et al. 2013). In addition, the explanatory variables that describe the study population and methodology should be uniformly specified across studies (Bergstrom & Taylor 2006).

These consistency requirements are relatively restrictive, and have not been adhered to in many meta-analyses (Smith & Pattanayak 2002). For example, several meta-analyses have included both stated and revealed preference studies (i.e. Hicksian and Marshallian welfare measures), and have used independent variables to control for method-related differences (Nelson & Kennedy 2009). The consistency requirements have also been debated in the literature, especially in relation to the use of meta-analysis for benefit transfer. Moeltner & Rosenberger (2008) discussed the optimal scope of meta-analyses, suggesting that the inclusion of a larger number of diverse studies alleviates problems resulting from a small sample size, and produces more efficient benefit transfer estimates. Furthermore, Johnston & Moeltner (2014) argued based on empirical evidence that there is no strict impediment for pooling Hicksian and Marshallian welfare measures in a meta-model.

While the use of meta-analysis has rapidly increased during recent years, a number of issues affect the credibility of its results (Nelson & Kennedy 2009). These include sample selection criteria, data summary, primary data heterogeneity, heteroskedasticity, and the dependency of observations that originate from the same study. Most meta-analyses in environmental economics have utilized ordinary least squares methods to estimate the meta-regression model, although weighted least squares, panel data models for fixed or

2 $Transfer\ error = \frac{|WTP_T - WTP_P|}{WTP_P}$, where WTP_T is the transferred and WTP_P is the primary value estimate.

random effects, and multilevel models have also been relatively common (Nelson & Kennedy 2009). Some of the problematic issues may be addressed with statistical modelling. The correlation between observations from a single study can be dealt with using multilevel or panel data models. Heteroskedasticity, which is likely to occur as sample sizes differ across primary studies, can be addressed by estimating heteroskedasticity-robust standard errors, for example, with the Huber-White variance estimator (Nelson & Kennedy 2009), or by using a random parameters specification or Bayesian regression techniques (Moeltner et al. 2007).

One of the main advantages of meta-analysis is that it requires fewer resources than conducting a primary valuation study. In addition, a large number of studies can be included in the analysis, which may result in a value function that is less sensitive to the features of individual studies, thus providing more robust predictions (Shrestha et al. 2007, Stapler & Johnston 2009, Johnston & Rosenberger 2010). Moreover, the use of meta-regression for benefit transfer may reduce benefit transfer errors compared to simple unit value transfers from a single application, as it combines data from multiple sources (Smith & Huang 1995, Kaul et al. 2013), although this result has not been confirmed in all studies (e.g. Lindhjem & Navrud 2008). However, meta-analyses may be restricted by the lack of relevant studies and sufficient reporting of the study details to allow for incorporation in the meta-analytic data set (Loomis & Rosenberger 2006). Notably, meta-analysis can only be as good as the primary studies that are used as the sample. Thus, the drawbacks in the primary valuation studies and methods also have a bearing in meta-analyses.

2.1.1. Bayesian estimation

The majority of meta-regression models have been estimated in the classical frequentist estimation framework (Moeltner et al. 2007). If the consistency requirements set for the primary studies are strictly followed, the sample of available studies for the meta-analysis may be small. In this case, modelling cannot rely on asymptotic properties, and for example, estimating heteroskedasticity-robust standard errors is inappropriate. Therefore, Bayesian techniques have been proposed for estimating meta-regression models, especially in benefit transfer (Moeltner et al. 2007, Moeltner & Rosenberger 2008, Moeltner & Woodward 2009).

Bayesian methods are based on Bayes' rule, which is used to update the probability of a hypothesis with the acquisition of new evidence (data) (Koop 2004). In Bayesian inference, probability represents the state of knowledge or belief instead of frequency, as in the classical framework. In addition to the interpretation of probability, the main differences between frequentist and Bayesian inference are the inclusion of prior information in the Bayesian context, the treatment of unknown variables, and the presentation of the results.

In Bayesian econometrics, the interest lies in the regression coefficients (unknown) given the data (known), which can be summarized using a conditional probability. The conditional probability (i.e. the posterior) is defined as the likelihood function multiplied by the prior, and it is used as the basis for inference. In standard Bayesian methods, priors are determined outside the data or, if no information is available, are set to noninformative values. By contrast, in empirical Bayes, the prior distributions are estimated from the data, which has been criticized for double-counting the data (Koop 2004).

The advantages of using a Bayesian approach in meta-regression include the treatment of heteroskedasticity, incorporating additional information in the form of prior distributions, and providing model-averaged welfare predictions (Moeltner & Woodward 2009). Study-specific heteroskedasticity can be modelled by adding a single parameter to the model, which is convenient with a small sample. It is possible to use the results of previous meta-analyses of a similar environmental good to construct priors for the explanatory variables in the meta-regression, which may improve the accuracy of the predictions. In addition, in the Bayesian framework, studies that fail to report details of all the independent variables can be utilized in constructing priors instead of discarding them altogether (Moeltner et al. 2007). Posterior model weights can be calculated based on marginal likelihoods, and further used in providing model-averaged welfare predictions. These advantages of the Bayesian approach help address the problems associated with a small sample size, and improve the predictions for benefit transfer.

2.1.2. Research data and methods

Study I used meta-analysis to summarize the information on the value of reducing eutrophication in European marine areas, and to provide benefit transfer estimates useful in various policy contexts. The meta-analytic data included primary valuation studies that focused on marine eutrophication in Europe and were conducted between 1990 and 2011. Studies from both peer-reviewed and "grey" literature were included to avoid publication selection bias, which refers to mainly publishing results that are statistically significant or conform to theoretical expectations, and may reduce the validity and reliability of the meta-analysis for benefit transfer (Rosenberger & Stanley 2006). The data set consisted of 20 valuation studies and 29 WTP observations. Despite the small sample size, the studies covered 11 countries and all European marine areas: the Baltic Sea, North Sea, Mediterranean and Black Sea. Most studies employed the contingent valuation method, and estimated both use and non-use values. In the studies, eutrophication was typically presented in terms of observable characteristics, such as algal blooms and water clarity, and the state of marine flora and fauna. All studies estimated the benefits of maintaining or improving the condition of the sea area. As there was variation in the extent of the change in eutrophication, the geographical area and population characteristics, the mean annual WTP per person varied considerably across studies, from $11 to $636 per person.

Regression analysis was used to estimate the effects of study-specific explanatory variables on WTP and to construct benefit transfer functions. Due to the small sample size, the meta-regression models were estimated using Bayesian techniques. The model employed was a Bayesian linear meta-regression model with heteroskedasticity of unknown form (Geweke 1993, Koop 2004, Koop et al. 2007). The advantages of the Bayesian approach were utilized in the analysis. Heteroskedasticity was modelled by adding a single parameter to the model, and information outside the data was used construct informative prior distributions for the independent variables. Welfare predictions for benefit transfer were calculated through model averaging based on posterior model weights.

The dependent variable in the meta-regressions was the WTP for reduced eutrophication observed in the primary study, and independent variables described the environmental good, the study population and the sea area. Variables pertaining to the valuation methods were excluded from the models on the grounds of a small sample size and high methodological consistency across the sample. All WTP estimates were converted to the year 2010 using country-specific consumer price indices and expressed in purchasing power parity adjusted international dollars.

The heteroskedasticity was accounted for by specifying a non-constant variance for the error term in the regression model. Error variances were assumed to originate from the gamma distribution, which is convenient, as the form implies that the model corresponds to the linear regression model with Student t-errors. The posterior distribution for the model parameters was obtained by combining the priors with the likelihood function, using the Metropolis-within-Gibbs algorithm to draw samples from the posterior distributions.

Eight models were estimated, which differed in three respects: i) the distribution of the error term (heteroskedastic, homoskedastic), ii) the functional form (semilog, loglinear), and iii) the prior distributions for the explanatory variables (informative, noninformative). Informative priors were based on previous meta-analyses of water quality values (Johnston et al. 2003, 2005, Van Houtven et al. 2007). WTP predictions were calculated through model averaging based on posterior model weights, constructed using the estimated marginal likelihoods. In addition, the model fit was described with several statistics on the prior and posterior predictive abilities of the models, including the in-sample mean absolute percent error and statistics based on leave-one-out cross-validation. The meta-analysis provided an overview of the existing information on the benefits of eutrophication reduction in Europe, which was utilized in planning and implementing the primary valuation studies.

2.2. Contingent valuation method

Contingent valuation (CV) is a survey-based stated preference method that elicits respondents' valuations for a specific change in the quality or quantity of an environmental good (for reviews of the method see Mitchell & Carson 1989, Hanemann 1994, Carson & Hanemann 2005, Alberini & Kahn 2006). CV is thought to have its roots in the 1940s, when Bowen (1943) and Ciriacy-Wantrup (1947) proposed the use of surveys to value public goods. Davis (1963) conducted the first empirical CV implementation on outdoor recreation. Since 1975, the use of CV has steadily increased to 400–500 published papers and studies per year (Carson & Hanemann 2005). A recent CV bibliography by Carson (2011) includes over 7000 CV papers and studies, spanning over 130 countries and 50 years.

CV surveys elicit respondents' willingness to pay (WTP) to obtain a specific change in environmental quality or quantity. The core section of the survey, the valuation scenario, describes the change to be valued, the constructed market and the payment vehicle (Bateman et al. 2002). The scenario specifies the reference (status quo) and target levels of the environmental good and possible substitutes. The constructed market includes information on the feasibility of the change, who will have to pay for the good and the timing of the provision. The payment vehicle can either be voluntary or coercive, although voluntary payments are not considered incentive-compatible (Carson & Groves 2007). In addition, the payment vehicle needs to define the timing of the payment and whether the payment is individual or household-specific.

WTP can be elicited using an open-ended question, bidding game, payment card or a binary choice question. Nowadays, payment cards and discrete choice questions, including binary choice, are the most common elicitation formats (Carson & Czajkowski 2014). In addition to the valuation scenario, the survey instrument typically includes debriefing questions on WTP motivations and views of the scenario, and questions on attitudes, knowledge, use and socioeconomic characteristics. An important consideration is that CV questions are consequential, i.e. respondents care about the environmental change and believe that their responses affect the implementation of the change (Carson & Groves 2007, Carson et al. 2014).

One of the main advantages of CV is that it is capable of measuring both use and non-use (or passive use) values (Carson & Hanemann 2005, Carson et al. 2001, Carson et al. 1999). Krutilla (1976) introduced existence values into economics literature, arguing that people might be willing to pay for environmental resources, such as wilderness areas, even though they would never visit them. In addition to existence values, non-use values are thought to encompass bequest and altruistic values, and sometimes even option values. At present, it is recognized that non-use values may form a significant component of the total value of an environmental good (Carson & Hanemann 2005), especially in the case of unique environmental goods and irreversible losses (Freeman 2003). Non-use values cannot be measured based on observed behaviour (Carson et al. 1999), and thus they can only be estimated using stated preference methods.

Another major advantage of CV and other stated preference methods is the possibility to value goods or changes that have not been observed in the past, increasing the applicability of the method. CV is considered more flexible than revealed preference methods, which are typically limited to specific environmental goods or fields. For example, the travel cost method can mainly be used for valuing recreation, and hedonic pricing is limited to the analysis of housing or labour markets (Whitehead & Blomquist 2006). CV can be applied to the valuation of almost any environmental good.

CV has also been subject to severe critique. Some opponents have claimed that CV responses do not reflect well-defined preferences but are formed in the course of the survey, and thus should not be considered in policy decisions (e.g. Diamond & Hausman 1994, Hausman 2012). In turn, proponents have argued that CV is a practical alternative in cases where values cannot be based on market behaviour and prices (Hanemann 1994, Carson 2012). Much of this discussion took place in relation to the Exxon Valdez oil spill in Alaska and related court proceedings, and resulted in the NOAA panel concluding that CV studies can provide useful and reliable information if certain conditions are met (Arrow et al. 1993). The issue was revisited after the BP Deepwater Horizon Spill in 2010 (Carson 2012, Hausman 2012).

Perhaps the most important drawback of CV is that is based on survey responses instead of observed behaviour. Apart from general issues pertaining to surveys, this has been argued to lead to hypothetical response bias, where respondents overstate their WTP (Hausman 2012). However, strategic behaviour can also result in underestimates of WTP (Carson 2012). Two meta-analyses have found hypothetical values to be on average about 3 times larger than those based on real choices (List & Gallett 2001, Little & Berrens 2004), whereas Murphy et al. (2005) have reported a median ratio of the hypothetical to the actual value of 1.35, with 70% of observations having a ratio of less than 2. In addition, meta-analyses of environmental values have found CV estimates to be lower than revealed preference estimates of similar goods (Carson et al. 1996, Shrestha et al. 2007). Kling et al. (2012) provide evidence that the hypothetical bias may be smaller when responses are consequential. Other possible remedies for hypothetical bias include cheap talk or oath scripts in surveys, and adjusting for respondent certainty (Haab et al. 2013).

Aside from hypothetical bias, criticism has been directed towards the disparity between WTP and WTA observed in many empirical studies (Hausman 2012, Horowitz & McConnell 2002). Divergence of WTP and WTA has been shown to exist in terms of both neoclassical economic theory (Hanemann 1991) and behavioural economics (Kahneman & Tversky 1979). Haab et al. (2013) noted that the gap between WTP and WTA is not unique to CV, but has been discovered in many laboratory and natural experiments (see e.g. Knetsch 2010).

Concerns have also been raised around embedding (or nesting) and scope insensitivity, where the quantity of the environmental good does not influence WTP as economic theory would predict (Kahneman & Knetsch 1992, Hausman 2012). Although insensitivity to scope has been observed in some empirical studies (e.g. Desvousges et al. 1993), a review by

Carson (1997) showed a significant scope effect in a large number of CV studies of various goods. Some meta-analyses have also provided evidence to support the existence of the scope effect (Smith & Osborne 1996, Ojea & Loureiro 2011).

2.2.1. Research data and methods

Study II employed the contingent valuation method to estimate the benefits of reduced eutrophication in the Baltic Sea. The data were collected using a specially designed CV survey aimed at eliciting annual WTP per person for improvements in the level of eutrophication in the nine coastal countries. The survey instrument was created in international cooperation in 2010–2011, pre-tested in all countries and simultaneously implemented in autumn 2011. To ensure comparability across countries, an identical questionnaire in separate national languages was used. The questionnaire comprised six sections: 1) introduction, 2) leisure time at the sea, 3) effects of eutrophication, 4) valuation scenario and WTP question, 5) debriefing questions, and 6) socio-economic background. The English version of the CV survey can be found in Ahtiainen et al. (2012).

The data were collected using Internet surveys in Denmark, Estonia, Finland, Germany and Sweden, and face-to-face interviews in Latvia, Lithuania, and Russia. In Poland, both Internet and face-to-face surveys were used. Samples were randomly drawn from the entire population and stratified to represent the socio-demographic characteristics of the national population in all countries except Russia, where two samples were constructed: one from the coastal areas of the Baltic Sea and one from the rest of the country (mainly Western Russia). In total, 10 564 completed surveys were received across the nine countries, ranging from 500 (Estonia) to 2000 (Poland) responses per country. The response rate varied between 32% and 69%, being higher in countries where face-to-face interviews were used. Compared to the national population in each country, respondents were generally characterized by larger households, a lower net income and higher educational levels.

The CV survey described an improvement in the Baltic Sea eutrophication status arising from reaching the nutrient load reduction targets specified in HELCOM's Baltic Sea Action Plan (2007), which aims at reaching a good environmental status of the sea with regard to eutrophication. The baseline and target levels of eutrophication were introduced using both verbal descriptions of the associated environmental changes and colour-coded maps illustrating the condition in different parts of the Baltic Sea. To connect the benefit estimates rigorously to ecological conditions, the change in eutrophication was derived from the predictions of marine models. In the survey, respondents were requested to state their willingness to pay for an improved level of eutrophication in the year 2050. The payment vehicle was a special Baltic Sea environmental tax, to be collected from all individuals and firms in the coastal countries. The elicitation format was a payment card with country-specific bid amounts.

The statistical analysis of the CV responses followed the standard treatment of CV data (see e.g. Hanemann 1984, Hanemann & Kanninen 1999, Haab & McConnell 2002). In general, the statistical model and thus the econometric analysis of the WTP distribution depends on the elicitation format of the valuation question. With the payment card used in Study II, CV responses can be interpreted as yielding either interval data (Cameron & Huppert 1989) or point observations of WTP, similar to open-ended WTP questions (Mitchell & Carson 1981). Three modelling approaches were used in Study II: 1) the spike model (Kriström 1997), 2) the interval regression model (Cameron & Huppert 1989) and 3) ordinary least squares (OLS) (e.g. Greene 2007). Both the spike and interval regression models took into consideration the interval nature of the data, and in addition, the spike model accounted for the substantial number of responses with zero WTP by having a discontinuity in its probability density function at WTP = 0. The OLS model assumed that the mid-point of the payment interval represents WTP. The spike model was used in the estimation of mean and aggregate WTP to appropriately account for those respondents who are not willing to pay. The determinants of WTP were explored with the OLS and interval regression models. All models were estimated separately for each country. The CV study provided information on the value of eutrophication mitigation in the nine countries, and enabled comparisons of the benefits with the costs of nutrient abatement.

2.3. Discrete choice experiment

The discrete choice experiment (CE) method can be considered to be a stated preference method in itself (e.g. Hanley et al. 1998, Bateman et al. 2002), a variant or extension of the contingent valuation method (Adamowicz et al. 1998) or merely an elicitation format of CV (Carson & Louviere 2011). In CE, respondents are asked to choose between two or more alternatives that are described using attributes and their levels, which are constructed using experimental design. Typically, CE surveys present a sequence of choice questions to the respondent.

CE has its underpinnings in the characteristics theory of value (Lancaster 1966, 1971), according to which utility is derived from the characteristics (attributes) of a good rather than the good itself. Different goods can be created by varying attribute levels. The first applications of CE were conducted by Louviere & Hensher (1982) and Louviere & Woodworth (1983) in transportation. In the field of environmental valuation, Carson et al. (1990) and Adamowicz et al. (1994) were the first to utilize CE. Since then, the popularity of the method has rapidly increased.

CE shares many of the features of CV. The data are collected using a carefully constructed survey, with the valuation scenario as the core part. The difference lies in the portrayal of the environmental good and the valuation question. In CE, the environmental good is defined in terms of its attributes and their levels. Some of the attributes may be qualitative and some quantitative, and one of the attributes typically represents the cost to enable the calculation of WTP. In a choice task, respondents are asked to choose between alternatives that have varying attribute levels. There can be a sequence of these choice tasks in a single survey, and thus, each respondent carries out several choice tasks. This approach generates more data per respondent than, for example, a single binary choice question in CV, thus leading to cost savings (Carson & Czajkowski 2014). In addition, instead of valuing a particular scenario as a whole, it is possible to value changes in each attribute separately and any attribute combination. CE is considered especially suitable for estimating marginal values (Hanley et al. 1998, Carson & Czajkowski 2014). In addition to having some of the same advantages as CV, such as the capability of estimating both use and non-use values and applicability to a wide range of contexts, CE has been argued to avoid some of the problems associated with CV, such as insensitivity to scope (Adamowicz 1995, Adamowicz et al. 1998, Hanley et al. 1998). However, Carson & Czajkowski (2014) note that problems in CV surveys typically have a counterpart in CE.

A drawback of CE is its complexity as an elicitation format, which adds challenges to the survey design and econometric analysis. In addition to choosing the relevant attributes and their levels to describe the environmental good, the formulation of the valuation scenario entails deciding how the attributes vary within and between the alternatives, choice tasks and surveys. This is called experimental design (see e.g. Johnson et al. 2006). The aim is to find a design that provides the most statistical information possible (Kanninen 2002). Additional important properties of the design include orthogonality, which implies that the attributes are statistically independent (i.e. uncorrelated), and attribute level balance, where each attribute level occurs an equal number of times.

There are different approaches to experimental design (Hensher et al. 2005, Johnson et al. 2006). A full factorial design includes all possible attribute level combinations, which frequently results in a large number (hundreds) of choice tasks. Thus, fractional factorial designs, which use only a portion of all the possible attribute level combinations, are often generated. The combinations can be chosen randomly, or preferably by selecting the optimal (most efficient) design (Johnson et al. 2006, Street et al. 2005). The most common fractional factorial design type is the orthogonal design (Rose & Bliemer 2009). More recently, efficient designs have been proposed as an alternative to orthogonal designs (Rose & Bliemer 2009, Bliemer et al. 2009, Bliemer & Rose 2009). The aim is to create designs that are statistically as efficient as possible in terms of the standard errors of parameter estimates. To outperform orthogonal designs, efficient designs require the use of prior information on the parameter estimates, obtained, for example, from previous literature or pilot surveys (Rose & Bliemer 2009).

Choice models are set in the random utility model (RUM) framework (McFadden 1973, Manski 1977). In CE, the dependent variable is discrete. There are several modelling alternatives (Louviere et al. 2000, Hensher et al. 2005, Train 2003). The simplest and most common approach is the multinomial (or conditional) logit model (MNL). A limitation of the multinomial logit model is the independence of irrelevant alternatives (IIA) property, which states that the ratio of choice probabilities of any two alternatives is unaffected by the presence or absence of any other alternative in the choice task. This formulation is computationally convenient, but the IIA property is restrictive and may be violated. Alternative modelling approaches, which allow for relaxing the IIA assumption, are the nested logit, random parameter logit (RPL, also called mixed logit) and latent class model (Train 1998, Louviere et al. 2000, Greene & Hensher 2003, Hensher et al. 2005).

2.3.1. Individual status quo and asymmetric modelling

One of the alternatives in the choice tasks of a CE is typically the status quo alternative (also called the reference or opt-out alternative), commonly defined as either “no choice” or “current state” and associated with zero additional cost. The inclusion of the status quo alternative in CEs is justified, for example, in order to produce WTP estimates that are consistent with the usual measures of welfare change (Bateman et al. 2002), to make the choice task more realistic (Carson et al. 1994) and to avoid forced choices (Batsell & Louviere 1991). However, it has been observed that the inclusion and the format of the status quo alternative may affect choice in several ways (Marsh et al. 2011, Dhar & Simonson 2003, Kontoleon & Yabe 2003).

The most common format of the status quo alternative is a uniform status quo that represents the scientific measure of the current state and is provided to the respondents in the survey. The use of a uniform scientific status quo implicitly assumes that all respondents understand and accept the description of current conditions, and also interpret it equally. However, this is not necessarily the case (Artell et al. 2013, Kataria et al. 2012). If respondents’ perceptions of the current state differ from the status quo description provided in the survey, it may result in unexplained variation and even bias in the welfare estimates (Kataria et al. 2012, Marsh et al. 2011).

To avoid unrealistic status quo alternatives and possible biases, it is possible to use the perceived status quo, i.e. respondents' own assessment of the current state, to construct individual-specific status quo alternatives. The status quo attribute levels are then used in the CE models similarly to the attribute levels of the policy alternatives. Individual status quo alternatives can be more meaningful to the respondent (Rose et al. 2008), and increase the credibility of the CE (Glenk 2011). In addition, they may avoid bias if respondents' perceptions of the current conditions differ from the researcher-defined status quo alternative (Kataria et al. 2012). Data on individual perceptions may also be needed when there is no scientific knowledge of the state of the environment or there is high variation in conditions across respondents (Glenk 2011, Artell et al. 2013).

Although the use of a uniform status quo across respondents is more common, some CEs have included respondent-specific status quo options in the valuation of environmental goods. Banzhaf et al. (2001) found that using the "usual fishing site" as the opt-out alternative statistically outperformed the "no choice" option in a CE on angler's preferences for fishing sites. In a study of agrobiodiversity and maize characteristics, the attribute levels for the reference alternative were determined by the characteristics of the maize currently cultivated by the farmer (Birol et al. 2009). Barton & Bergland (2010) incorporated individual-specific status quo characteristics in models for irrigation water preferences to address a large share of respondents choosing the status quo option.

Few studies have compared provided and perceived status quo alternatives in the stated preference setting (Domínguez-Torreiro & Soliño 2011, Marsh et al. 2011). Marsh et al. (2011) observed that those respondents who adopted their own perceived status quo alternative were on the one hand willing to pay more for water quality improvements, but on the other hand chose the status quo alternative more often than those who relied on the provided status quo information. Similarly, Domínguez-Torreiro & Soliño (2011) found differences in the welfare estimates between the status quo formats, with the perceived status quo typically producing higher WTPs than the provided one.

When individual-specific status quo alternatives are used, the attribute levels in the policy alternatives may represent either increases or decreases compared to the status quo. This allows testing of the implications of prospect theory, i.e. reference dependence (gains and losses are defined relative to a reference point) and loss aversion (losses loom larger than corresponding gains) (Kahneman & Tversky 1979, Tversky & Kahneman 1991). Previous research on the reference point has suggested that when expectations and the current situation are different, expectations may determine the reference point (Kahneman & Tversky 1979, Kőszegi & Rabin 2006, Ericson & Fuster 2011, Abeler et al. 2011). This would suggest taking expectations into account in formulating the status quo alternative.

Studies that have examined both individual status quo alternatives and asymmetric preferences in discrete choice models are relatively scarce. Hess et al. (2008) investigated travel route choices and observed preference asymmetry for increases and decreases in the attribute levels relative to the status quo for several attributes, but found no consistent evidence of loss aversion. Masiero and Hensher (2010) accounted for asymmetry and nonlinearity of preferences in a freight transport CE, finding strong evidence of loss aversion and some evidence of decreasing marginal values. In the context of a rural development and conservation programme in Indonesia, Glenk (2011) used respondents' own assessment of current conditions and found evidence of asymmetric preferences for some attributes and respondent groups. Altogether, previous CE studies indicate that the results concerning the presence of both asymmetric preferences and loss aversion are somewhat ambiguous, warranting further research.

2.3.2. Research data and methods

Study III used a choice experiment to examine preference heterogeneity and asymmetry for water quality changes. Data were collected using a survey sent to Finnish summer house owners, with the focus being on the water body adjacent to the respondent's summer house. The summer houses were located along lakes, rivers and the Baltic Sea coast. In addition to the CE, the survey included applications of the travel cost and CV method. Along with the valuation questions, the survey collected information on the attitudes, use and socio-demographic characteristics of the respondent.

After a pilot study, the survey was sent in late 2008 and early 2009 to all Finns (2547 individuals) who had purchased a private summer house in 2004, chosen from the official real estate market price registry maintained by the National Land Survey of Finland. The administration format combined mail and Internet surveys, with an initial letter providing instructions on completing an online survey, followed by two further contacts with a possibility to fill out a paper survey and reply by mail. The response rate for the final survey was 51%, i.e. there were 1266 responses.

In the CE part of the survey, respondents were requested to choose between alternatives that depicted the development of water quality in the water body adjacent to their summer house. In each choice task, respondents were offered a status quo and two unlabelled policy alternatives. Four eutrophication-related attributes were used to describe water quality: water clarity, fish species, blue-green algal blooms and sliming. Each attribute had three levels, ranging from satisfactory to excellent, which were described in the survey. The cost attribute was specified as an obligatory water protection payment to the household during the years 2009–2019, said to be collected from all summer house owners and local households.

The status quo alternative was specified as the present development of water quality, defined based on the respondent's own assessment of current water quality and its development in the next 10 years. To elicit the present development, respondents were asked to assess the current level of each water quality attribute (excellent, good, satisfactory, worse than satisfactory) and their development in the future (will improve, stay the same or deteriorate) in the water body adjacent to their summer house. This information was combined to define the status quo alternative.

The experimental design was created using Sawtooth software's paper-and-pencil approach. The random design employed random sampling with replacement in choosing concepts. It permitted an attribute to have identical levels across all alternatives, but did not permit two identical alternatives (on all attributes) to appear in the same choice task. Each respondent was presented with six choice tasks, and altogether 720 choice tasks were created, resulting in 120 questionnaire versions.

Respondents' choices were modelled using the random parameter logit model, which allows for preference heterogeneity between individuals through random parameters that have both a mean and a standard deviation (Train 1998). All water quality attributes and the alternative-specific constant (ASC) were treated as random variables with a normal distribution. The cost parameter was specified as non-random to avoid problems with a random cost parameter and ease the calculation of willingness to pay measures (Hensher & Greene 2003, Train 2003).

Three models were estimated: i) a symmetric model, assuming similar preferences for improvements and deteriorations in water quality, ii) an asymmetric model, allowing for differing preferences for improvements and deteriorations in water quality relative to the status quo alternative, and iii) an asymmetric and nonlinear model, allowing for nonlinearity in utility in addition to differing preferences for improvements and deteriorations in water quality. The CE study enabled the examination of heterogeneous and asymmetric preferences for water quality in Finland.

2.4. Use of environmental valuation in cost-benefit analysis

Cost–benefit analysis (CBA) is a policy assessment method that investigates the desirability of a project or a policy by estimating its net social benefits. CBA can be seen as a tool for measuring the policy's economic efficiency or contribution to social welfare (Boardman et al. 2006), although this interpretation is not accepted by all academics (e.g. Nyborg 2014). The basic decision rule applied in CBA is to recommend the implementation of the policy if the net benefits are positive, i.e. benefits are higher than costs. In addition to evaluating whether to implement a particular policy, CBA is often used to rank policy alternatives. CBA can be considered as one of the possible decision procedures to be used together with other criteria (Posner & Adler 1999).

CBA entails determining and monetizing the impacts of the policy throughout its course, and discounting the identified benefits and costs to their present values. After calculating the net present value, sensitivity analysis is often conducted on the most important assumptions and impacts, e.g. the discount rate. Benefits and costs are evaluated in terms of changes to human welfare, with the value of the policy outputs measured as willingness to pay or willingness to accept compensation, and the value of inputs as opportunity costs (Boardman et al. 2006).

Environmental policies often have both market and non-market impacts. Market impacts can be monetized using information on market prices and quantities, whereas the valuation of non-market (environmental) impacts requires the use of valuation methods, either stated or revealed preferences. Inclusion of the monetary value of environmental impacts in CBAs began with revealed preference studies in the 1970s, and stated preference applications became more common in the 1980s (Pearce 1998).

In the United States, CBA has an important role in the environmental policy context, as CBA has been required of new environmental regulations since the 1980s (Pearce et al. 2006). In Western Europe, the introduction of CBA to environmental policy assessments has been slower (Pearce 1998), but since the early 1990s, economic appraisals, including the assessment of costs and benefits, have become more common (Pearce & Seccombe-Hett 2000, Hanley 2001). Nowadays, the European Union requires a CBA for all major infrastructure projects above €50 million that are funded from the European Regional Development Fund (ERDF) and the Cohesion Fund (European Commission 2014). CBA has also obtained more weight in the implementation of recent EU environmental policies. For example, in the Water Framework Directive (European Parliament 2000), CBA may be used as a means of evaluating whether the costs of improving the ecological status of waters are disproportionate, and further to justify less stringent targets or extensions in the time frame. In the Marine Strategy Framework Directive (European Parliament 2008), programmes of measures to improve the state of the marine environment should include a CBA prior to introducing new measures.

While CBA is used frequently, it remains controversial, especially in the context of environmental policies (Pearce 1998). Proponents of CBA see it as a useful policy analysis tool, which offers an explicit and transparent framework for systematically organising information and deciding how to allocate society's resources (Hanley & Spash 1993, Arrow et al. 1997, Hanley 2001, Pearce et al. 2006). Other advantages include the incorporation of environmental impacts and social values into decision-making (Hanley 2001). CBA has also been seen as a useful method in legislative and regulatory policy debates (Arrow et al. 1997).

Criticism has been directed towards both the theoretical foundations and practical implementation of CBA. Many of the problems are related to the concept of efficiency in CBA, i.e. the potential Pareto efficiency (or Kaldor-Hicks compensation criterion), which requires that those who gain could in principle compensate the losers, but no actual compensations are needed. For example, inconsistencies have been connected to the identification of potential Pareto improvements and changes in the income distribution (Pearce et al. 2006, Turner 2007).

A weakness of CBA is that the standard approach, i.e. using equal weights for each individual, attaches less social importance to the interests of people with higher marginal utility of income. This implies that when the marginal utility of income declines with income, CBA gives less weight to the welfare change of those with a lower income (Nyborg 2014, Posner & Adler 1999). A possible solution to this problem is to use distributional weights based on income. However, these weights are rarely used in practical applications (Nyborg 2014), and reflect value judgements even when they are used. Another possibility is to disaggregate costs and benefits to particular groups to allow consideration of distributional consequences and their acceptability (Posner & Adler 1999).

Valuation of environmental impacts is an especially contentious issue in CBA (Pearce 1998, Boardman et al. 2006, Turner 2007). In addition to the general reluctance of putting a "price" on the environment, severe criticism has been directed towards valuation methods (especially stated preferences), which in turn has raised questions concerning the reliability of the environmental benefit estimates (see Sections 2.2 and 2.3). Estimates of non-use values have particularly been criticized, which has increased the interest in producing conservative value estimates and calibrating values downward (Hanley 2001). However, some consider stated preference methods to have advantages over revealed preference methods in CBAs for the very reason that they can capture non-use values (Whitehead & Blomquist 2006), and argue that cost–benefit analyses that omit non-use values are incomplete and even misleading (Carson et al. 2001). In relation to this, Turner (2007) has argued that environmental CBA could be limited to include only use and option values, whereas non-use values would be assessed with other complementary techniques, such as deliberative valuation. In addition to the possible problems associated with primary valuation, the use of valuation methods that are based on existing data and benefit transfers are becoming increasingly common in CBAs, as there are insufficient resources to conduct primary valuation studies specially designed for the CBA. The use of benefit transfer introduces additional uncertainty in the estimates compared to primary valuation methods.

Some scholars are willing to discard environmental valuation altogether from CBAs. For example, Nyborg (2014) has argued that monetary estimates of environmental values do not necessarily increase the acknowledgement of environmental concerns, and recommended the use of "cost–impact analysis", where all impacts are described but not necessarily valued in monetary terms.

Even though the valuation of environmental impacts is controversial, many prefer it compared to excluding environmental values altogether from the analysis or considering hidden (implicit) values in policy decisions (Pearce & Seccombe-Hett 2000, Hanley 2001). Valuation may also help in identifying how the non-market impacts of a policy are distributed, i.e. who are the gainers and losers, which may be useful for policy implementation. Despite the controversy, according to Pearce & Seccombe-Hett (2000) and Carson (2012), the most common use of economic valuation and especially contingent valuation estimates is in CBAs.

Taking the criticism towards environmental valuation and possible uncertainty about the value estimates into consideration, it is useful to conduct a sensitivity analysis of the environmental benefits in CBA. This entails assessing the robustness of the results by varying the assumptions on the benefits.

2.4.1. Research data and methods

In Study IV, a cost–benefit analysis was conducted to assess the economic efficiency of policies to reduce nutrient pollution of the Baltic Sea. The policy evaluated was the HELCOM Baltic Sea Action Plan (2007), which aims at reaching a good environmental status of the sea by 2021 with nutrient load reduction targets for each coastal country. For the purpose of the CBA, the study developed a spatial and dynamic modelling framework that encompassed both ecological and economic data. The aim was to compare the costs and benefits of reaching nutrient abatement targets defined in the Baltic Sea Action Plan and to solve for an optimized level of water protection, that is, the level of water protection at which the net benefits are maximized. The modelling frameworks consisted of: 1) a catchment model that described the effects of abatement measures on nutrient loads; 2) a cost function that specified the costs of abatement measures; 3) a marine model that predicted the impact of nutrient loads on the condition of the sea; and 4) a benefit function that depicted the monetary benefits from improvements in the marine environment.

The catchment area of the Baltic Sea was divided into 23 sub-catchments, and loads were projected at yearly time steps for a period of 40 years. Ten nutrient abatement measures on nitrogen and phosphorus loads were included, with measures in the agricultural sector, wastewater treatment and a ban on phosphate in laundry detergents. The marine model translated nitrogen and phosphorus concentrations into an estimate of phytoplankton biomass, divided into cyanobacteria and other algae. The modelling framework was used iteratively to obtain cost-effective solutions to five policy goals, differing in their targets and restrictions.

The spatially explicit benefit functions were constructed based on the data from the contingent valuation survey on people's willingness to pay for reduced eutrophication (Study II). The valuation study was specifically designed to be used in the CBA. To connect the benefit estimates to the nutrient abatement measures and the cost estimates, the change in eutrophication presented in the survey was based on the marine model predictions on nutrient loads and state of the sea in different areas of the Baltic Sea. To create the verbal descriptions and maps depicting the change in eutrophication for the CV survey, the marine model outcomes were translated into a single descriptor of the overall state of the marine environment. The state assessment was then discretized into a five-step water quality ladder for use in the valuation survey, with each level described using five ecosystem characteristics: water clarity, blue-green algal blooms, underwater meadows, fish species and oxygen conditions in deep sea bottoms. This allowed incorporation of the benefit estimates from the CV study in the CBA, and estimation of the optimized level of water protection.

The benefit functions were constructed using the aggregate national WTPs from the OLS models estimated in Study II. The functions were computed separately for each of the seven sub-basins, based on the number of people who considered the entire Baltic Sea and some particular sub-basin(s) in responding to the valuation question. In addition, shares of the damage were attributed to cyanobacteria (0.61) and algae (0.39) based on responses to a survey item on water quality characteristics. Thus, the results of Study II were further developed to adapt them to the CBA framework and to enable more detailed analysis.

3. Summaries of studies

3.1. Study I: The value of reducing eutrophication in European marine areas – A Bayesian meta-analysis

The first study employed meta-analysis to summarize the existing information on the benefits of reducing eutrophication in European marine areas. The paper examines the effects of study-specific explanatory variables on WTP and constructs a benefit transfer function that can be used to predict the benefits for different water quality scenarios. The data consisted of 20 European valuation studies that have focused on public preferences and presented willingness to pay (WTP) estimates for reduced eutrophication. Due to the small sample size, the meta-regression models were estimated using a Bayesian linear regression model that allows for heteroskedasticity of errors. The novelty of the study lies in its focus on marine resources and European valuation studies, and it adds to the limited literature of Bayesian meta-analyses of environmental goods.

The findings indicate that the benefits of eutrophication mitigation in European marine regions vary considerably, stemming from differences in the environmental good, the study population and geographical factors. The predicted annual WTP ranges from $6 to $235 per person. The results of the meta-regression models show that larger changes in eutrophication status lead to higher WTPs, and a higher gross domestic product per capita in the study country increases WTP. In addition, both the geographical extent of the change and the study area affect WTP. Local changes are valued lower than those that affect large marine areas. Interestingly, values diverge between marine regions, despite accounting for differences in the extent of the change in eutrophication and in the population characteristics, as values estimated for the Baltic Sea are higher than for other sea regions. This emphasizes the importance of examining the benefits in previously unstudied European marine areas.

Based on model comparisons with prior and posterior checks, the use of informative priors improves the predictions, and there is weak evidence of heteroskedasticity of errors in the data. As the marginal likelihoods typically used in model comparisons are sensitive to the choice of prior distributions, the paper suggests using leave-one-out cross-validation to compare models, if the aim is to choose a single model.

Opportunities for comparison with other studies are relatively limited, as few other meta-analyses of water quality values have reported comparable WTP estimates. Van Houtven et al. (2007) predicted mean annual WTPs in the range of $5–$60 for small changes and $40–$165 for large changes in water quality based on valuation studies conducted in the United States. These estimates are of a similar magnitude to ours.

In cases where primary valuation studies are lacking, the results of Study I can be utilized in assessing the benefits of improving the eutrophication status to support the implementation of environmental policies, such as the EU Marine Strategy Framework Directive. Compared to unit value benefit transfers from single studies, transfers based on a meta-analysis may lead to more robust predictions (Stapler & Johnston 2009) and increased reliability in the form of lower transfer errors (Kaul et al. 2013).

While providing evidence that small-sample meta-analyses are possible, Study I supports prior findings that information on the benefits of improving the state of the marine environment is relatively limited and fragmented (Remoundou et al. 2009). Despite the small number of investigations, eutrophication is probably one of the most studied problems of the marine environment in Europe, also in terms of economic valuation studies (Bertram & Rehdanz 2013). Thus, for other water-related problems, obtaining benefit estimates to support environmental policy-making is even more challenging.

3.2. Study II: Benefits of meeting nutrient reduction targets for the Baltic Sea – a contingent valuation study in the nine coastal states

The second study estimated the benefits of reducing marine eutrophication for the nine coastal countries of the Baltic Sea using the contingent valuation method. The CV survey was simultaneously implemented in all nine countries using identical questionnaires in the autumn of 2011. In total, 10 564 responses were obtained with Internet and face-to-face surveys across the nine countries, with at least 500 respondents per country. Data from all coastal countries makes it possible to estimate the total benefits of eutrophication mitigation for the whole Baltic Sea area, and to compare the values between countries. This was the first valuation study to cover all the littoral countries of the Baltic Sea, and the largest international valuation study to consider the marine environment.

The CV survey described an improvement in the Baltic Sea eutrophication status arising from reaching the nutrient load reduction targets specified in HELCOM's Baltic Sea Action Plan (2007). The change in eutrophication was introduced using both verbal descriptions and colour-coded maps of the associated environmental changes in different parts of the Baltic Sea. In the survey, respondents were requested to state their WTP for attaining an improved level of eutrophication in the entire Baltic Sea by the year 2050. WTP functions were estimated using three modelling approaches and separately for each country.

The findings indicate that the proportion of people willing to pay varies substantially between countries, from 31% in Russia to 67% in Sweden. The annual mean WTP per individual is highest in Sweden (€76), followed by Finland (€42), Denmark (€32), Germany (€25) and Estonia (€24). The lowest mean WTPs are observed in Latvia (€6), Lithuania (€9), Russia (€9) and Poland (€12). This heterogeneity in the average WTP is likely to stem from differences in income levels, culture, geography, and trust in the implementation of the program and in the use of funds between countries. According to the results, the mean WTP is highest in countries that have the highest average income, i.e. Sweden, Denmark, Finland and Germany. Cultural factors and a long coastline may explain the high WTP in Sweden. The large difference between values in Sweden and Finland is somewhat surprising, but similar findings of a higher WTP for marine water quality improvements in Sweden have been obtained in previous studies (Kosenius & Ollikainen 2015, Ahtiainen et al. 2013). Denmark and Germany have substitute marine areas, as they also border the North Sea, which may explain the lower values compared to Sweden and Finland. The share of respondents who had doubts about the implementation of the programme was highest in Latvia, Lithuania and Russia. The low WTPs in these countries are corroborated by the findings of a separate survey of public attitudes towards the Baltic Sea, where respondents in these countries were significantly less willing to pay to clean up the Baltic Sea than respondents in the other coastal countries (Ahtiainen et al. 2013). In addition to reporting the average values, it is worth noting that most respondents cared about the state of the entire Baltic Sea, and all the effects of eutrophication.

Significant determinants of WTP in most countries include income, future planned visits, experience of eutrophication and concern over the state of the Baltic Sea, which all increase individual WTP. Income elasticities of WTP are below 1 in all countries, but the elasticities range from 0.1 to 0.5. Comparison across countries indicates that the income elasticity of WTP decreases with income. In addition, age, gender, education and substitutes are significant determinants of WTP in some countries. Although common explanatory variables can be identified, the strength of their influence differs between countries. As the effect of the determinants of WTP differs from one country to another even though the environmental good is similar, generalizations based on the results from one country to others seem inadvisable.

The overall aggregate WTP is estimated at €3600 million per year, implying substantial benefits from reduced eutrophication. These estimates may serve as justification for additional nutrient abatement efforts in the Baltic Sea, and can be compared with the costs of nutrient abatement measures needed to achieve the targets in the HELCOM Baltic Sea Action Plan. The benefit estimates also allow for assessing the benefits of reaching the EU MSFD good environmental status with regard to eutrophication. Although the change in eutrophication is likely to differ somewhat from the change required in the directive, the scenario depicted in the CV survey corresponds reasonably well with reaching a good status of the sea.

3.3. Study III: Modelling asymmetric preferences for water quality in choice experiments with individual-specific status quo alternatives

Study III examined the use of perceived and individual-specific status quo alternatives in discrete choice experiments, and explored heterogeneous, asymmetric and nonlinear preferences for changes in water quality. The study adds to the limited literature on perceived reference alternatives and asymmetric preferences for environmental goods in CEs. The CE questionnaire was sent to 2547 Finnish summer house purchasers in late 2008 and early 2009 using a combination of mail and Internet surveys, with a final response rate of 51%.

In the CE part of the survey, respondents were requested to choose between alternatives that depicted the development of water quality in the water body adjacent to the respondent's summer house. There were four eutrophication-related attributes: water clarity, fish species, blue-green algal blooms and sliming, and each attribute had three levels. The cost attribute was an obligatory water protection payment to the household during the years 2009–2019. The status quo alternative was specified as the current development of water quality, defined based on the respondent's own assessment of current water quality and its development in the next 10 years.

Respondents' choices were modelled using random parameter logit modelling, treating all water quality attributes and the alternative-specific constant (ASC) as random variables. The cost variable was specified as non-random. Three models were estimated with differing assumptions concerning respondents' preferences: symmetric, asymmetric, and asymmetric and nonlinear.

All three models indicated significant heterogeneity in preferences for water quality. Although there was a general tendency to choose the policy alternatives over the status quo, some respondents favoured the status quo alternative. A possible explanation for this may be that in some cases the current development is better for some of the water quality attributes than the policy alternatives. There is consistent evidence of asymmetric preferences and loss aversion for the water quality attributes, as the welfare losses associated with a decline in water quality are larger than the corresponding gains. Thus, the symmetric model, which assumes similar preferences for improvements and deteriorations in water quality, produces biased results and welfare estimates. There is no evidence of nonlinear preferences, as utility functions appear linear for most attributes and domains. These results are consistent with earlier studies on asymmetric and nonlinear preferences (Glenk 2011, Hess et al. 2008, Masiero & Hensher 2010).

The willingness to pay estimates support the model results. A deterioration in the attributes was found to lead to annual losses of €83–150, while improvements were valued at €28–102 per household. Thus, losses were valued at 1.5–5 times the corresponding gains, depending on the attribute.

The findings suggest that higher welfare gains may result from water resource policies that prioritize preventing the deterioration of a current good water quality status and focus on blue-green algal blooms and water turbidity. Despite the use of the perceived reference water quality for the status quo, the welfare estimates can be linked to actual policies that bring about water quality changes to support water resource management and policies.

3.4. Study IV: Policy goals for improved water quality in the Baltic Sea: When do the benefits outweigh the costs?

The fourth study employed cost–benefit analysis to assess the economic efficiency of policies to reduce nutrient pollution in the Baltic Sea. The policy evaluated was the HELCOM Baltic Sea Action Plan (2007), which aims at reaching a good ecological status of the marine environment by 2021, with nutrient load reduction targets for each coastal country. The benefit estimates used in the cost–benefit analysis were based on the contingent valuation study conducted in Study II. There are several advantages in the analysis compared to previous studies: the CBA includes an explicit link between the benefit estimates and nutrient load reductions, uses primary valuation results for all countries, develops benefit functions and solves for the level of eutrophication mitigation at which the net benefits are maximized, and assesses several policy goals.

For the purpose of the CBA, the study developed a spatial and dynamic modelling framework that encompasses both ecological and economic data. The modelling framework included a catchment model that describes the effects of abatement measures on nutrient loads, a cost function that specifies the costs of abatement measures, a marine model that predicts the impact of nutrient loads on the condition of the sea, and a benefit function that depicts the monetary benefits from improvements in the marine environment.

The results of the CBA suggest that the benefits (€4600 million) of mitigating eutrophication according to the current policy target (HELCOM Baltic Sea Action Plan) outweigh the costs (€2800 million). However, benefits and costs are unevenly distributed between the coastal states, with benefits exceeding costs in Finland, Sweden, Germany and Russia, and costs exceeding benefits in Poland, Denmark and the Baltic states. In Denmark, the sign of the net benefits depends on the policy goal assessed.

The findings also suggest that compared to the nutrient abatement efforts specified in the Baltic Sea Action Plan, considerable cost savings (17–47%) can be achieved with a cost-effective allocation of measures across regions and countries. According to the CBA, the optimized level of water protection, i.e. the level that produces the highest net benefits, is somewhat lower than the Baltic Sea Action Plan target. The optimized solution results in significantly reduced costs, while benefits are 95% of those from meeting the full policy targets. In addition, in the optimized solution, phosphorus reductions are given greater emphasis compared to the Baltic Sea Action Plan targets. However, the costs and benefits remain unevenly distributed between the countries in the cost-effective and optimized solutions.

The results of the CBA can be considered robust, as the costs were probably overestimated and benefits underestimated. New low-cost measures may be identified in the future, which will reduce the marginal costs of abatement measures. The benefit estimates, in turn, exclude the benefits that would accrue from water quality improvements in inland waters.

The findings indicate higher cost savings from a cost-effective allocation of abatement measures compared to previous static cost-and-effect studies (Gren et al. 1997a, Elofsson 2003). The estimated overall benefits are of a similar magnitude to those estimated in the 1990s (Gren et al. 1997b, Turner et al. 1999), but there are some differences in the distribution of the costs and benefits between countries. For example, both Gren et al. (1997b) and Turner et al. (1999) predicted positive net benefits for Denmark, while in our study they were only positive in the optimized solution of nutrient abatement.

4. Discussion

This dissertation examines the monetary benefits of reduced eutrophication to the general public in Europe, the Baltic Sea area and Finland. The studies illustrate how eutrophication mitigation can be valued using different approaches: meta-analysis, by summarizing the results of existing studies (Study I), contingent valuation, by valuing a complete eutrophication reduction scenario (Study II), and choice experiment, by describing eutrophication with attributes and their levels (Study III). In addition, the thesis shows how environmental benefit estimates can be further used in a cost–benefit analysis (Study IV). The meta-analysis provided an approximate estimate of the benefits of reduced eutrophication in European marine areas, which was refined in the contingent valuation study for the Baltic Sea area. The choice experiment yielded more detailed information on the preferences of a particular group of people in Finland, summer house owners, who are active users of water bodies.

The analyses indicate that the general public values clean waters and reduced eutrophication, and substantial benefits can be gained from nutrient abatement in Finland, the Baltic Sea area and Europe. Based on the meta-analysis, the annual mean willingness to pay ranges from €5 to €210 per person in Europe, depending on the geographical area and the extent of the change in eutrophication. These estimates are of a similar magnitude to those found in Van Houtven et al. (2007) in a meta-analysis of water quality in the United States.

In the coastal countries of the Baltic Sea, annual benefits of reduced eutrophication are between €6 per person in Latvia and €76 per person in Sweden, and the aggregate benefits in all nine countries are €3600 million per year. Compared to previous research on the benefits of reducing Baltic eutrophication in the mid-1990s (Gren et al. 1997b, Markowska & Zylicz 1999, Turner et al. 1999), these benefit estimates are lower, especially for Denmark, Finland and Germany. The discrepancy may be explained by the differences in the valuation scenarios and time frames for the environmental change, and the use of benefit transfer in the previous study. The cost–benefit analysis indicates that the nutrient abatement targets for the Baltic Sea are economically justified, as reaching them increases, on aggregate, the welfare of the citizens in the coastal countries around the sea. However, although the overall benefits exceed the costs, the costs and benefits are unevenly distributed among the coastal countries, with some countries gaining and some losing if the policy measures are carried out. Similar findings were obtained in the previous studies (e.g. Gren et al. 1997b, Turner et al. 1999).

For Finnish summer house owners, willingness to pay depends on the attribute of eutrophication and whether the change is an improvement or deterioration, ranging from €28 to €150 per household. The results indicate preference heterogeneity across individuals for all water quality attributes, corresponding to the findings of Kosenius (2010) in a choice experiment on water quality in the Gulf of Finland. In the present study, the relative importance of blue-green algal blooms was the highest, followed by water clarity, while Kosenius (2010) observed water clarity to be the most important water quality attribute. The diverging results may be explained by the differences in the study area (all water bodies versus the Gulf of Finland) and the population (summer house owners versus the general population).

Although reducing eutrophication brings about benefits in all contexts, the findings clearly show that the magnitude of these benefits varies between sea areas, countries, individuals and the characteristics of eutrophication. As one would expect, willingness to pay per person is higher in countries that have higher income levels, and larger changes in eutrophication lead to higher values. The benefits of reduced eutrophication seem especially high in the Baltic Sea area, where eutrophication is recognized to be one of the most severe problems of the marine environment. In Finland, some summer house owners are more willing to contribute to water quality improvements than others, and deterioration in water quality results in larger welfare losses compared to the gains from a corresponding improvement.

4.1. Evaluation of the methods used in this thesis

The methods applied in this dissertation can be compared from the perspective of the researcher and the decision-maker to assess their suitability for investigating the economic impacts of eutrophication. This dissertation primarily applied classical frequentist methods in the econometric analyses, using a Bayesian approach only in Study I, the meta-analysis. Bayesian techniques are also applicable to the analysis of contingent valuation and choice experiment data. For example, Araña & León (2004) and León & León (2006) discussed Bayesian modelling and inference for contingent valuation. In the choice experiment context, Bayesian modelling is considered to be an expanding area (Lenk 2014). Bayesian approaches are also useful in cost–benefit analysis, as applications of Bayesian networks result in probabilistic models that involve explicit consideration of uncertainty. There have already been several cost–benefit analyses of eutrophication using Bayesian networks (Ames et al. 2005, Barton et al. 2005, Barton et al. 2008). Valuation results can also be incorporated into Bayesian cost–benefit analyses.

Meta-analysis provides a summary of several studies and thus a rich outlook on the issue at hand. This also means that the data collection phase is relatively laborious, and despite efforts to identify all relevant studies, the sample may remain small. This, in turn, complicates the statistical analyses and reduces the number of explanatory variables that can be included in the model, as seen in Study I, where variables describing valuation methods were excluded from the meta-analytic models. Meta-analysis generally leads to resource savings compared to primary studies, as the data collection does not require resources apart from the working time. However, the reliability and applicability of results may cause problems if they are used for benefit transfer. Previous meta-analyses have generated transfer errors in the range of 30–125% (e.g. Shrestha & Loomis 2001, Lindhjem & Navrud 2008). Although errors from transfers that use several studies may be lower than in transfers based on individual studies (Kaul et al. 2013), the question remains whether they are acceptable from the policy point of view. The possible transfer errors, although not specifically examined in Study I, should be considered when interpreting and utilizing its results.

Both contingent valuation and choice experiment rely on carefully constructed surveys to collect the data. The survey design and testing phase may easily take over a year. One of the challenges is to ask the right questions in a clear, neutral and plausible manner to produce valid value estimates. Conducting identical international surveys, as in Study II, requires coordination between countries and ensuring that the survey is equally applicable and valid in all countries. This further increases the importance of the survey design phase.

Contingent valuation is especially useful when there is a need to evaluate the benefits of one or two specific policy scenarios, such as the eutrophication reduction targets of the HELCOM Baltic Sea Action Plan in Study II. When more detailed information on the attributes and their trade-offs is required, the choice experiment method used in Study III is a better option. In cost–benefit analyses, the choice experiment has advantages over the contingent valuation method when the policy affects several environmental issues or there is uncertainty over the after-policy level of environmental quality. It is good to note that in choice experiments, more information is obtained at the cost of increased complexity in the design and analysis stages, and more expertise is needed to assess the quality of a choice experiment study compared to contingent valuation.

Incorporating valuation results in environmental cost–benefit analysis requires careful planning. In an ideal case, the valuation study is designed for the purposes of the cost–benefit analysis, as in Study IV, to ensure that the benefits are evaluated specifically for the policies appraised in the analysis. The cost–benefit analysis influences the valuation study in many ways, including the valuation scenario and the scope of the environmental change, the geographic area, and the sample (Whitehead & Blomquist 2006).

Generally speaking, value estimates are most useful when they can be linked to measurable quantitative indicators used in the formulation of policy targets, such as nutrient concentrations (micrograms per litre), water clarity (sight depth in metres) or the chlorophyll-a concentration (micrograms per litre). This facilitates the connecting of benefits to changes in environmental conditions, policy targets and costs of measures. Moreover, measuring benefits for several different levels of environmental change enables the estimation of a benefit function and the evaluation of various policy targets.

Establishing a rigorous connection between environmental conditions and benefit estimates was also a challenge in the contingent valuation study (Study II), in which the nutrient concentrations in the sea had to be translated into written descriptions of eutrophication effects and maps of environmental state that could be easily understood by the respondents in different countries. In the study, cooperation between multiple disciplines was a key factor in creating the link between the ecosystem model results and descriptions in the questionnaire. The inclusion of two scopes of change allowed an estimation of the marginal benefits of reduced eutrophication, which were used in the cost–benefit analysis in Study IV to assess the optimized level of water protection efforts.

4.2. Validity and consequentiality

Validity refers to the extent to which a study measures the theoretical construct it intended to, i.e. its ability to measure the amount of money respondents would actually pay for the environmental good in the market. As this cannot typically be observed, several characteristics of the valuation study can be examined to assess its validity. Validity types include criterion, content and construct validity. In addition, it is important to ensure consequentiality.

One of the most important considerations for the validity of stated preference surveys is that they are consequential, i.e. respondents believe their responses affect an environmental change they care about (Carson & Groves 2007). The surveys in Studies II and III were designed to be perceived as consequential by the respondents. The contingent valuation survey in Study II was motivated by stating that the answers would help governments around the Baltic Sea to develop appropriate water quality improvement programmes. In addition, based on the responses, the majority of the respondents cared about reducing eutrophication, and all effects of eutrophication were seen as problematic. The choice experiment survey in Study III stated that local authorities could improve the state of nearby water bodies by collecting a water protection payment, with an aim to ascertain respondents' opinions on the issue. The summer house owners' responses reflected their interest in water quality. Half of the respondents stated that eutrophication had a negative impact on their being at the summer house, and for 70%, water quality had had a substantial effect on their property purchase.

The validity of the findings can be further evaluated by examining the criterion, content and construct validity of the studies (Mitchell & Carson 1989, Bateman et al. 2002, Kling et al. 2012). In assessments of criterion validity, stated preference values are compared against real payments. In our case, such comparison was impossible, as there were no corresponding laboratory or field experiments. In general, hypothetical bias has been found in many stated preference studies, but the bias can be reduced, for instance, by adhering to consequentiality requirements (Kling et al. 2012), as was done in Studies II and III.

Content validity refers to the success of the survey instrument in measuring what it intended to, most importantly the willingness to pay for the environmental good. Significant efforts were put into the design and testing of the surveys in Studies II and III to ensure they were understandable and plausible to the respondents and to obtain valid willingness to pay estimates, following the current state of the art and guidelines set for survey design and implementation (e.g. Dillman et al. 2009). For example, the valuation scenarios were described in detail in the surveys, and the contingent valuation survey used graphics to depict the change in eutrophication. The surveys were also extensively pre-tested before implementation.

Construct validity can be assessed based on how well the effect of explanatory variables on willingness to pay corresponds to theoretical and empirical expectations (expectations-driven validity), and by comparing the findings obtained with different valuation methods (convergent validity). While there are some method-wise differences, overall the findings of the studies show that WTP increases with income and the extent of the change in eutrophication, as economic theory suggests. Furthermore, people are willing to pay more to avoid deterioration than to improve water quality, a result consistent with the implications of the prospect theory and previous empirical evidence on loss aversion (Kahneman & Tversky 1979). The findings of the meta-analysis can support convergent validity in themselves by explaining the variation in WTP across studies in accordance to prior expectations (Bateman et al. 2002). Comparisons across the three valuation studies of this dissertation suggest that mean WTPs from different methods are roughly of a similar magnitude, but exhibit variation depending on the country, sea area and individual.

4.3. Future research

Interesting future research topics emerge based on the analyses presented in this thesis. The dissertation only focuses on the benefits and economic efficiency of a reduction in eutrophication. However, sound water protection and management requires a comprehensive analysis of the characteristics of water ecosystems and their interactions, warranting additional research. For example, there is limited knowledge of the benefits of reaching a good environmental status with regard to many of the descriptors in the EU Marine Strategy Framework Directive, such as biodiversity, fish species, contaminants and non-indigenous species, and how the benefits from the improvement of these descriptors depend on each other.

The uneven distribution of costs and benefit of reduced eutrophication in the Baltic Sea countries provides an interesting setting for game theoretic analysis. For example, the benefit and cost estimates could be used in game theoretic analysis of the environmental agreements in the Baltic Sea area.

In the choice experiment, an interesting addition would be to examine the sources of preference heterogeneity for water quality by interacting the random parameters with variables that may be a source of this heterogeneity. For example, individual socio-economic characteristics or water body-specific factors could be interacted with the water quality attributes. This would reveal whether the heterogeneity of preferences can be explained by differences in these factors. Another option would be to examine scale heterogeneity across individuals, in addition to preference heterogeneity, using the generalized mixed logit model (GMXL) (Greene & Hensher 2010).

Method-wise, attention should also be focused on the acceptability and format of the status quo in stated preference studies, as it may affect people's responses and welfare estimates. As part of exploring the acceptability of the valuation scenario and proposed environmental change, the premise that respondents understand and accept the description of the reference state should be investigated to ensure the validity of the value estimates. More research is needed on the differences in the status quo formats, with comparisons between the uniform and individual, as well as the provided and perceived status quo alternatives.

Future research should continue to examine what is needed for successful international benefit transfer. Despite efforts (e.g. Ready et al. 2004, Czajkowski and Ščasný 2010, Bateman et al. 2011, Hynes et al. 2013), there are no generally accepted guidelines for how to improve the reliability of transfers between countries, as results and recommendations differ between studies. This context specificity reduces the applicability and reliability of benefit transfers and impedes their widespread use in policy support.

5. Conclusions

The benefits of reduced eutrophication vary between countries and sea areas. As one of the main results of this dissertation, it has both methodological and practical implications. Increased demand for benefit estimates and the limited availability of resources have resulted in environmental benefit transfers becoming increasingly popular. These transfers are often made from one country or water body to another due to the unavailability of suitable primary estimates from the area in question. The results of this dissertation suggest that in Europe, benefit transfers across sea areas may exhibit large errors, even when controlling for income and the extent of the change in eutrophication. In addition, the results obtained from the Baltic Sea area indicate that even when the sea area and the environmental change are the same and values are corrected using purchasing power parities, willingness to pay and its determinants differ considerably between countries. For example, transferring Swedish benefit estimates to other countries without additional adjustments seems inadvisable, as the benefits are notably higher than in other countries with similar income levels and access to the Baltic Sea (e.g. Finland). Although other studies have indicated a similar pattern of Swedish values being higher than in other countries (e.g. Kosenius & Ollikainen 2015), no clear explanation has emerged. Cultural factors might offer a partial reasoning for the divergence, even though Hynes et al. (2013) found that adjusting for cultural factors had only a small impact on the accuracy of international benefit transfer when differences in income levels had been accounted for. Regardless of the reason for the observed differences, the results of the Baltic-wide study suggest there are challenges in transferring water quality values across countries, and imply that despite our best efforts to control for differences between countries and sea areas, international benefit transfers may be inaccurate. Acknowledging that some level of inaccuracy is unavoidable, one of the key questions is whether the transfer errors are acceptable for the transferred value estimates to be used for policy-making purposes.

The findings of this dissertation also pertain to the implementation of environmental policies to improve the condition of water bodies. Sea areas are often shared by several countries, which causes challenges in their management and the enforcement of international agreements. As indicated by the cost–benefit analysis of eutrophication in the Baltic Sea area, although the overall benefits exceed the costs, the costs and benefits are unevenly distributed among the coastal countries, with some countries gaining and some losing if the policy measures are carried out. Previous literature suggests that cooperation between asymmetric countries may be easier, as net gainers can buy protection from those countries that have lower net benefits (Barrett 2001, Pavlova & De Zeeuw 2013). A possible means of reaching an agreement accepted by all countries is to compensate countries that lose with side-payments, which may also take the form of implementing abatement measures in other countries (Ahlvik & Pavlova 2013). In the Baltic Sea area, countries with positive net benefits, i.e. Sweden, Finland, Germany and Russia, may need to consider compensation to Estonia, Latvia, Lithuania and Poland to reach an international agreement on nutrient abatement. This course of action would also be accepted by the general public, as the findings of this dissertation suggest that the majority of people value improvements in the entire Baltic Sea area and not only in their own part of the sea.

The studies provide an estimate of the monetary benefits of reaching a good environmental status in the Baltic Sea with regard to eutrophication as required in the EU Marine Strategy Framework Directive and the HELCOM Baltic Sea Action Plan. The estimated benefits can also be interpreted as the costs of degradation of the marine environment, as these benefits are forgone if eutrophication is not reduced. In the Baltic Sea area, the results also serve as justification for implementing additional nutrient abatement measures, as the benefits of nutrient abatement exceed the costs. These results can be considered quite robust, as the benefits are probably underestimated and the costs overestimated. In addition to the primary valuation results for the Baltic Sea, this dissertation allows an evaluation of the benefits for different European sea areas, income levels and changes in eutrophication based on the meta-analysis. Thus, the welfare predictions are applicable to a wide range of contexts, with caution due to possible transfer errors.

The findings of the Baltic Sea-wide contingent valuation study and cost–benefit analysis have already been acknowledged in the HELCOM Copenhagen Ministerial Declaration (2013), in which the countries also agreed to intensify efforts to study the economic value of marine and coastal ecosystems and incorporate socio-economic analysis in the work of HELCOM. This is encouraging, as the aim of the studies in this dissertation was to provide information and support for the implementation of environmental policies.

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Natural Resources Institute
Finland
Viikinkaari 4
FI-00790 Helsinki, Finland
tel. +358 29 532 6000