Protection versus purification - assessing the benefits of drinking water quality

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Abstract Clean drinking water can be secured either through protection of the groundwater resource or via purification of polluted water. In this study, the choice experiment method is used to assess the benefits of groundwater protection compared with the benefits of purification. The choice experiment method has been chosen as it allows the effects on drinking water and those on surface water quality to be assessed separately. The benefits associated with clean drinking water are found to be significant for both management options, although the willingness to pay for protection exceeds the willingness to pay for purification.

Keywords Benefits; choice experiments; drinking water; groundwater; valuation; water quality

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Introduction

Water quality is of great concern among Europeans – a survey carried out by Eurobarometer found that almost half of Europeans are worried about ‘water pollution’ (47%) (EU Commission 2005)[1]. The highest concern for water quality is observed in the new Member States, e.g. Slovenia (71%). Lithuania (63%), Estonia (61%) and Poland (56%); and, in the EU15, Finland displays most concern (66%), followed by Greece (59%), Denmark and Portugal (both at 57%), Belgium and Spain (both at 52%), and Ireland (50%) (European Commission 2005). In Denmark there is special concern for groundwater quality, because groundwater represents almost the only source of drinking water in Denmark (GEUS 2007); in comparison, in the region of 60% of drinking water in the European Union comes from groundwater. Most of Danish groundwater is high quality drinking water and one of the cornerstones in Danish drinking water policy is that groundwater should be drinkable after just simple processing (oxygenation). This precautionary principle is regarded as important (Danish Environmental Protection Agency 2004), and preventive measures have been, and will be, further implemented as part of several EU directives – the Nitrate Directive (91/676/EEC), the Drinking Water Directive (98/93/EC) and the Water Framework Directive (2000/60/EC). But water pollution, including groundwater contamination, is difficult and costly to remedy (EuroGeoSurveys 2007).

This raises at least two questions: do the benefits of protection exceed the costs, and do the benefits of groundwater protection, as perceived by the population, exceed the benefits from purification, which is a complementary method to ensure safe and clean drinking water? By answering and testing the latter of these questions light will be shed on the extent to which

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[1]Eurobarometer conducted the survey by asking the respondents to tick from a list the five main environmental issues that they were worried about.

the cornerstones of Danish groundwater policy, i.e. the precautionary principle and that drinking water must come from clean and untreated groundwater, are socially beneficial. In this comparison it is assumed that the drinking water provided to the customers by both protection and purification is clean and equal regarding chemical status, taste and smell. The only difference between the methods is how the clean drinking water is processed.

The aim of this paper is therefore to estimate and compare the benefits of different options for securing clean drinking water by use of the economic valuation method Choice Experiments (CE). The remainder of this paper is arranged as follows. The second section contains a brief introduction to the theoretical basis of the CE method, along with a description of the scenarios and the survey design used in the present study. Then the next section contains a presentation and discussion of the empirical results, while the conclusions are presented in the final section.

Methods

The CE method is used for benefit assessment. This method has been frequently used over recent years to reveal the benefits of changes in environmental policy (cf. Hanley *et al.* 1998, 2001, 2002, 2005; Adamowicz and Boxall 2001; Bateman *et al.* 2002; Li *et al.* 2004; Hensher *et al.* 2005). Hensher *et al.* (2005) use the CE method to estimate consumers' willingness to pay (WTP) for specific water service levels, with the aim to reveal the benefits of securing the provision and disposal of water, avoidance of interruptions in water service and overflows of wastewater. The problem analysed by Hensher *et al.* (2005) is familiar with the problem in the present paper, but differs slightly as the primary focus of the present study is on groundwater protection versus purification.

The choice experiment method

The CE method is one of the methods in the family of stated preference methods. Randall (2002) provides a more elaborate description of these methods, including the choice experiment method. The CE method was originally developed for market analysis (Louviere 1988; Batsell and Louviere 1991) and in a CE study respondents are requested to make a choice from within a pre-defined set of alternatives, i.e. a choice similar to the choices made between market goods in everyday consumption situations. The alternatives are defined by a number of different attributes which can assume different levels. In the present context, examples of attributes are drinking water quality and surface water quality. Presented with a set of alternatives, respondents are requested to select their preferred alternative; usually, respondents are asked to repeat this exercise a number of times with different choice sets.

Based on the information inherent in such choices, consumer/respondents' preferences, not only for the goods as such, but also for the separate attributes, can be disclosed, and – provided that one of the attributes is presented in monetary terms – the respondents' willingness to pay (WTP) for the attributes can be estimated. The CE method belongs to the category of indirect methods as WTP is derived indirectly from the information inherent in people's choices rather than resulting from respondents' having to express their WTP directly, as is often the case when using the Contingent Valuation (CV) method. The method is recommended for valuation of complex problems as the CE set-up is more reflective of real market conditions than other forms of valuation method, implying that the cognitive burden imposed on respondents by the valuation task diminishes. Another advantage of the method is that the focus on the attributes characterising the goods rather than on the good *per se* may serve to reduce problems of multicollinearity and facilitate the measurement of more detailed marginal values of changes.

The method can be described formally as follows. Assume that an individual i's utility from a good $j(U_{ij})$ is partly deterministic (V) and partly stochastic (ϵ). The utility function describing an individual i's utility from good j can, thereby, be expressed as

$$U_{ij} = V(Z_{ij}, S_i) + \varepsilon \quad (1)$$

where Z represents characteristics of the good, e.g. water quality, and S represents the characteristics of the individual, e.g. gender, income, etc (see, for example, Adamowicz *et al.* (1994) and Bateman *et al.* (2002)).

Modelling CE data, the probability of a choice between alternatives is described as a function of the attributes characterising the alternatives and the characteristics of the respondent, and can be analysed by random utility models. Subsequently, WTP for non-monetary attributes can be estimated as the marginal rate of substitution between the individual attributes and the monetary attribute. The probability of an alternative being chosen can be expressed in terms of the logistic distribution (see Hanley *et al.* 2001) and, depending on the nature of the data, different logit models can be applied (Train 2003). In the present study, the multinomial logit model is applied.

Survey design

A professional survey institute (GfK-Denmark – Growth from Knowledge) was used to deliver the survey in October 2004. The questionnaire was sent to a panel of 900 respondents which were representative of the Danish population in terms of age, gender and geographical location.

The questionnaire. Prior to the choice questions, background questions on habits and attitudes were posed and after the choice questions the respondents were presented with follow-up questions on the choices and on socioeconomic characteristics (e.g. age, household size, income level). The questionnaire was tested by means of a focus group and individual interviews, as well as a small-scale pre-test. Following each test, the questionnaire and the attributes were revised according to the results of the tests. Detailed information of the experiences from the tests can be found in Hasler *et al.* (2005).

To ensure that the respondents had a certain minimum level of knowledge of the good being valued, a separate information sheet was enclosed with the questionnaire, and the levels of water quality were accordingly described in the questionnaire to inform the respondents of the alternatives. The information on this sheet was divided into three parts, comprising information on:

- 'The freshwater aquatic environment in Denmark',
- 'The price of water' and
- 'Groundwater pollution'.

In the first section, it is emphasised that groundwater has an influence on freshwater, including drinking water, watercourses and lakes. Emphasis is given to expressing the fact that almost all drinking water stems from groundwater which has only been treated in a simple way, this representing a special situation for Denmark compared with many other countries The sources of groundwater pollution are mentioned briefly. Concerning the price of water, the average price of water (35 DKK/m^3) and the average size of household water bills (4000 DKK/household/yr) in Denmark are listed as points of reference. In the final section of the sheet, the potential consequences of pesticide and nitrogen/phosphorus contamination of groundwater, both in relation to humans and the natural environment, are briefly touched upon. The potential carcinogenic effects of nitrogen and pesticides are mentioned, but no specific details or risk assessments are provided due to lack of more precise knowledge concerning how harmful these substances are for humans. This information was included to properly sketch the relevant context of the valuation scenario for the respondents. However, it is recognized that the information may have induced more concern for naturally clean drinking water than for purified water, albeit that the pesticide and nitrate contamination of the drinking water are avoided by both methods.

The attributes describing the alternatives in the choice sets. In the study, three attributes are used to describe the alternatives: the quality of drinking water, the quality of the living conditions for plants and animals in the aquatic environment, and one attribute specifying the hypothetical price of the alternatives. The attributes and their levels are described in Table 1.

In the description of attributes it is recognised that value-laden words can influence preferences and therefore the wording used in the description of the different levels is as neutral as possible to ensure that respondents' choices will reflect their personal preferences, rather than simply be the result of value-laden descriptions.

The definitions of the attributes and attribute levels in the present study assume a general, national perspective on groundwater protection, whereas a local case study would explain the effects in more detail. Both advantages and disadvantages are associated with the adoption of this general approach. However, as it is this perspective that has been chosen, it is important to ensure that the indicators used in the present study relate to this approach and do not induce respondents to think of, for example, the specific conditions prevailing in their local area. In this connection the use of both qualitative and quantitative indicators has been contemplated.

The qualitative approach has been criticised, among other reasons, for not being directly amenable to water managers in relation to the variety of policy outcomes (Poe and Bishop 1999). Poe and Bishop (1999), therefore, propose a reorientation of 'future groundwater contingent valuation research towards a focus on actual, objectively obtainable, exposure levels experienced at a study site'. The authors of the present paper agree that this proposed quantitative approach is likely to be desirable for case studies. However, it is found that a quantitative approach is difficult to adopt when the focus is on the effects of groundwater management at a general, national level where, due to environmental heterogeneity, it is impossible to derive common dose–response relationships. In the present study, therefore, qualitative indicators are employed. The wording used to describe the qualitative levels of the attributes has been chosen to reflect the wording in the Water Framework Directive and the regional water quality plans, thereby ensuring that the results from the valuation can be connected to real policy options.

The appropriateness of qualitative indicators was established in the testing of the questionnaire, which showed that respondents related more confidently to qualitative than quantitative indicators. Among other things, respondents stated a distrust of limit values as they considered them to have been arrived at politically. Also, quantitative indications of pollution and effects on flora and fauna were found to be more cognitively demanding to relate to and to understand than qualitative indicators. In the present context, therefore, it is assumed that the use of qualitative attribute levels increases the likelihood that the respondents understand the set-up and reduces any possible confusion arising from any potential differences between the actual situation in their local area (or another specific area for that matter) and the hypothetical scenarios presented to them. The qualitative approach is also used in several other studies, see, for example, Bergström and Dorfman (1994), Stenger and Willinger (1998) and Hanley *et al.* (2005).

The choice of payment vehicle forms a substantive part of the survey design and should have a plausible connection with the good it is being used to value (Garrod and Willis 1999). Hence the payment vehicle must be perceived as realistic, fair and equitable for all respondents in order to prevent non-responses and protest responses. Initially, consideration was given to the use of an increase in the water price per cubic metre as the payment vehicle,

Table 1 Attributes and attribute levels in the CE

Attributes used in the CE	Attribute levels	Attribute level explanation
Drinking water quality is introduced by stipulating that, while the quality of drinking water (taste, etc.) in a given area will depend on more specific local conditions, these three discrete levels can be used to describe the general quality of Danish drinking water:	Naturally clean drinking water	Measures aimed primarily at agricultural practices prevent groundwater pollution from pesticides and nitrogen. In this way, clean drinking water is secured, both now and in the future.
	Uncertain drinking water quality	The current situation, i.e. groundwater is protected as it is at the moment and no further measures to prevent pollution are introduced. When a groundwater borehole is found to be polluted it is closed and a new borehole is established. It is in this way that water authorities ensure a supply of clean drinking water for consumers today. It is uncertain whether sufficient supplies of clean drinking water can be provided in this way in the future. There is, therefore, a risk that in future tap water will exceed current limit values for pesticides and nitrogen.
	Treated/purified water	By cleaning polluted groundwater for pesticide and nitrogen residues, clean drinking water supplies can be ensured both now and in the future.
Surface water quality. The conditions for animal and plant life in the aquatic environment are affected both by the natural physical conditions and the degree of pollution. Conditions for animal and plant life will, therefore, vary from place to place. The following three quality levels characterise the conditions in Danish watercourses and lakes:	Very good	Animal and plant life is natural, varied and in balance. Slight to medium impact from human activity.
	Less good	Animal and plant life is markedly different than would be the case under natural conditions and is, to adegree, in a state of imbalance. This represents the current situation.
	Poor	Animal and plant life is significantly different than would be the case under natural conditions and is in a state of serious imbalance. Animal and plant life is often in a completely altered state due to human activity.
The price: an increase in the annual household payment in the water bill	O DKK	0 Euro
	300 DKK	41 Euro
	625 DKK	85 Euro
	1050 DKK	142 Euro
	1700 DKK	230 Euro
	2400 DKK	324 Euro

expecting that the water price, due to its consumption dependence, would be an intuitively understandable and uncontroversial payment vehicle for the respondents. In relation to the subsequent interpretation of results and aggregation of WTP estimates this would, however, require information on the households' annual water consumption. According to the results of our pre-tests this information was difficult to obtain, as most people do not know the size of the household's annual consumption of water. Based on this, the original idea of using the water price per cubic metre as payment vehicle was abandoned in favour of using a fixed annual increase in water bill per household, which – though probably being more controversial to the respondents – significantly eased the interpretation of the results. In this connection it may be noted that annual payments were chosen as, for most consumers, household water bills are paid on a yearly basis. By choosing the annual water bill as payment vehicle we also implicitly linked the provision of water to the respondent's normal provider of tap water. In this way we intended to make the respondents' think that clean drinking water from both protected and naturally clean water will be provisioned by an already known and reliable provider, to minimise the probability of provision biases.

The valuation and the respondents' budget constraints. The respondents are informed that the costs of implementing the policy alternatives are assumed to be covered by Danish consumers and that all consumers contribute equally to implementation of the alternatives. In this context, it may, however, be noted that nothing specific is mentioned regarding how it will be decided which management option to implement in practice. Due to the CE set-up, where focus is on expressing relative preferences for numerous alternatives rather than on voting for or against one specific bill we do not believe this to be problematic. Moreover, it is emphasised that the stated amount (WTP) represents a sum over and above that of their present water bill. Highlighting that all consumers must contribute, and that they must do so equally, is intended to discourage respondents from free-riding. Likewise, stipulating that the stated amounts are additional to the current water bill is considered relevant as it may serve to remind respondents that the amount they are asked to pay in the present survey is, in fact, only one among the many expenses that they generally have to consider in their household budget. In addition to the above-mentioned considerations, a so-called 'cheap talk' section is also included. According to Cummings and Taylor (1999), who introduced the concept, cheap talk may be defined as an attempt to eliminate hypothetical bias by including an explicit discussion of the problem. Cummings and Taylor (1999) found that cheap talk could effectively mitigate hypothetical bias in the cases considered. The effect of different cheap talk designs, implemented in various contexts, has been investigated in a number of studies in which experiences have been mixed. While Murphy *et al.* (2003) and Carlsson *et al.* (2004) found the inclusion of cheap talk to have a positive effect, Samnaliev *et al.* (2003) found it had no effect. Despite the inconclusive effect of cheap talk, it has been decided to incorporate a cheap talk section in the design of the present study. The cheap talk used in this study is as follows:

> Results from similar studies have shown that people have a tendency to over-estimate how much they are actually willing to pay for implementation of the various policy measures. Before you mark your selection, therefore, we would ask you to be totally sure that you are willing and able to pay the stated sum associated with an alternative.

Compared with other studies, it should be emphasised that the script used in the present study is significantly shorter than the ones usually applied. As an example, the cheap talk in Cummings and Taylor's (1999) article amounts to more than half a page. In relation to the present study, the inclusion of such an elaborate cheap talk section is considered inappropriate as it is expected that the resulting negative effect arising from increasing the length of the questionnaire would by far outweigh the potential positive effect arising from the cheap talk section itself. On this basis, it may be questioned whether what is termed 'cheap talk' in this study actually qualifies for what is usually implied by the term. However, as an explicit reference is made to the problem of hypothetical bias, it is considered acceptable to term it as such.

The design of the choice sets. Consulting the literature, it is often recommended, sometimes even required, that a status-quo alternative, or an 'opt-out' option, is included in the design, as failure to do so may imply that respondents are forced to choose alternatives which they do not desire (cf. Bateman *et al.* 2002). If this option is omitted, the observed choices should not be interpreted as expressions of respondents' true preferences, implying that they cannot be used as the basis for deriving valid estimates of welfare changes. A status-quo alternative, describing the baseline situation that will prevail if current initiatives are maintained while no further actions are taken, is therefore included in the present study. This alternative is characterised by an 'uncertain' water quality level, a 'less good' quality of the aquatic environment and zero additional costs, described as the 'current situation', cf. the section on results and discussion.

Apart from the status-quo alternative, which is constant across all choice sets, each choice set contains two alternatives. According to Bateman *et al.* (2002), it is important to ensure that respondents are not asked to perform too complex tasks, as this may induce respondents to provide unreliable answers or resort to using simplifying decision strategies instead of the compensatory decision strategies which are assumed in CE. In the present context, it is considered appropriate to operate with a choice set size of three alternatives per set. Upon exclusion of unrealistic and clearly dominated alternatives, a fractional factorial design containing 18 choice sets was created using SAS. Subsequently this design was, also using SAS, blocked into 3 blocks of 6 choice sets. Each respondent was then presented with one block. An example of a choice set is presented in Figure 1.

Econometric model

The multinomial logit model is used for the estimations. This model is based on the utility function described in Equation (1), where i denotes the individual respondent and j the alternative. Assuming that the error terms ϵ are independently and identically distributed (IID) and follow the Gumbel distribution, the probability that alternative k is selected out of K alternatives is given by

$$\Pr(respondent\ i\ chooses\ k) = \frac{\exp(V_{ik})}{\sum_{j=1}^{K}\exp(V_{ij})} \tag{2}$$

where V is the vector representing the attributes of the alternative, i.e. drinking water quality, living conditions for animal and plants, and price, as well as the characteristics of the respondent.

	Alternative 1	Alternative 2	Alternative 3
Drinking water:	Uncertain	Naturally clean	Treated
Animal and plant-life in watercourses and lakes:	Less good	Very good	Less good
Annual increase in water bill per household:	0 DKK.	2400 DKK.	625 DKK.
I would prefer (*please mark with a cross*):	☐	☐	☐

Figure 1 Example of choice set from the questionnaire

Results and discussion

In terms of the data underlying the survey, 584 respondents returned the questionnaire, which equates to a response rate of almost 65%. Of the 584 respondents, 11 had not answered any of the 6 choice questions and these respondents have subsequently been removed from the dataset, while another 41 respondents answered between 1 and 5 of the choice questions. Upon inspection of the data, 45 respondents are found to have chosen the status-quo alternative in all 6 choice sets. This suggests the use of a rule-of-thumb approach rather than a compensatory decision strategy. That this is indeed the case is supported by the fact that several of the non-selected alternatives offer a better quality of water or environment than in the status-quo option at no extra expense for the respondent. This proves irrational and, therefore, these 45 respondents have been excluded from the sample. The effective sample thus consists of 528 respondents and 3074 choices.

Main effects – the WTP for drinking water and surface water quality

The dependent variable in the model is the probability that the respondent chooses a given alternative. The results of the main effects model are presented in Table 2. The parameter estimates, and the derived WTPs, refer to changes in relation to the status quo situation.

In Table 2, it is seen that all the parameters are statistically significant at a 1% level and operate as expected. The cost parameter is negative whereas the parameters for both naturally clean and purified groundwater suggests positive utility. A change to very good conditions for animal and plants contributes positively to utility whereas a change to poor conditions contributes negatively. The adjusted pseudo-R^2 of the model is 0.19, suggesting a satisfactory fit. According to Louviere *et al.* (2000), the R^2 should be above 0.1 for the model to be accepted, whereas a value between 0.2 and 0.4 indicates a very good fit. It also appears that the model includes an alternative specific constant, which is associated with disutility. The parameter can be interpreted as a disutility attached to the status-quo alternative, i.e. the present situation, which is not captured by the attributes included in the experiment. An explanation for this negative alternative specific constant may be that people dislike the *laissez faire* character of the status-quo alternative.

In terms of the estimated WTPs, it can be seen in Table 1 that the household WTP for naturally clean groundwater is 1899 DKK/yr, which it should be emphasised represents an addition to the current average water bill for a household of 4000 DKK/yr. The WTP for good conditions for flora and fauna in waterways and lakes is 1204 DKK/yr. This relative ranking of attributes is as expected, and can most likely be explained by the fact that clean drinking water influences human health and hence private goods more directly than the

Table 2 Main effects, dominant choice of status quo removed from sample

	Parameter		Std. Error	WTP (DKK)
Price	−0.00059	***	0.0000	
Alternative specific constant	−0.7285	***	0.1018	
Naturally clean groundwater	1.1205	***	0.0882	1,899
Purified groundwater	0.5381	***	0.0852	912
Very good conditions	0.7105	***	0.0661	1,204
Bad conditions	−1.0379	***	0.0737	−1,759
N (no. of observations)	3,074			
Log *L*	−2,723.97			
χ^2	1,306.33			
Adjusted pseudo-R^2	0.193			

Significance levels at 1%, 5% and 10% are indicated by three, two and one asterisk(s), respectively quality of surface waters does. The household WTP for purified water is 912 DKK/yr. The fact that WTP for protection exceeds the WTP for purification by around 100% shows strong preferences for naturally clean groundwater and seems to support current Danish groundwater policy. Somehow it is quite puzzling that respondents express such strong relative preferences for naturally clean drinking water compared to purified drinking water, as both types of water – purified or natural – are assumed to be clean and fulfil current limit values, and therefore are fully identical in a chemical sense. One could therefore argue that respondents should hold identical preferences for the two types of water – had that been the case, we would, however, not have obtained the results shown in Table 2 where WTP for the two types of water are significantly different. This indicates that the estimated preferences are associated with the method by which the clean water is provided rather than the quality of the water itself, i.e. that preferences for drinking water are related to the water supply process just as much as to the objective, measurable quality of the water. Respondents may have different reasons for preferring a natural process compared to purification. Which potential side effects they might have assigned to the label 'natural' compared to 'purified' is not investigated in this study, but the long and strong political emphasis on protection may be an important explanation of the observed preferences for naturally clean as opposed to purified drinking water. Another potential explanation may be that respondents, despite the attribute descriptions, perceive there to be a health risk associated with purified water compared to naturally clean water, i.e. they may question the reliability of purification procedures.

In comparison, the resulting WTP for groundwater protection in Jensen *et al.* (1995), the only Danish study previously dealing with the benefits of groundwater protection, was 2100 DKK/household/yr, using CV and a close-ended format. In an Italian CV study Press and Söderquist (1996) found a WTP of 2483 DKK/household/yr, while Bergstrom and Dorfman (1994), who conducted two parallel CV studies in Georgia and Maine, respectively, found WTP to be between 242 and 691 DKK/household/yr for 'safe' drinking water, where the safety indicator was the level of nitrate in the water. In a French CV study, Stenger and Willinger (1998) present WTPs for groundwater of good quality between 700 and 1755 DKK/household/yr, depending on the question format used.

The results from the present study are of a magnitude comparable with the results of the above studies and it is believed that differences can be explained by methodological differences as well as differences in preferences in time and between countries of origin. At first glance, the WTP estimates for clean drinking water may appear quite high. Comparing the estimates to one of the alternatives to drinkable tap water – i.e. bottled water – the WTP estimates seem quite reasonable. Thus, the WTP for naturally clean drinking water corresponds to around 5 DKK/household/d, which is more or less equivalent to the price of 1 litre of conventional milk.

Interaction effects

Interactions between the main effects and the socioeconomic, behavioural and attitudinal characteristics of the respondent are modelled by dummy variables. The model is derived using a stepwise maximum likelihood estimation method, which starts out by estimating an empty model, then finds the most significant variable and adds it to the model, before starting the loop again by re-estimating the model. Applying this method with a significance threshold level of 0.15 results in the model shown in Table 3.

In Table 3, the main effects are marked in bold, while the respective interaction effects, which represent additions/deductions to the main effect, are listed below in italics. In most cases, the sign of the analysed effects are as expected, implying that the study supports the hypotheses set up prior to the study. Moreover, the significance of many of the interaction

Table 3 Main effects and interactions

	Parameter		Std. error	WTP (DKK)
Price	−0.0006	***	0.0000	
Alternative specific constant	−0.7407	***	0.1034	–
Naturally clean groundwater	0.8062	***	0.1347	1319
The authorities should use more resources for protection	0.6198	***	0.1013	1014
Saves water due to concern for environment	−0.2302	**	0.1008	−377
Tap water may be purified in substitute for natural	−0.2177	**	0.1100	−356
High income group	0.3544	***	0.1143	580
High education group	0.2295	*	0.1377	376
Purified groundwater	0.6011	***	0.1103	984
Knowledge of annual water consumption	−0.3564	***	0.0949	−583
Drinking water in Denmark is not clean	−0.5825	***	0.1979	−953
Blue collar worker group	0.3106	**	0.1217	508
High income group	0.2987	**	0.1163	489
Very good conditions	0.4444	***	0.1130	727
The authorities should use more resources for protection	0.3143	***	0.1065	514
Pollution of aquatic environment is exaggerated	−0.4087	***	0.1360	−669
Goes fishing very often	0.9886	**	0.4239	1618
Saves water due to future generations	0.1721	*	0.0988	282
High education group	0.2149		0.1386	352
Bad conditions	−0.6614	***	0.1232	−1082
The authorities should use more resources for protection	−0.3955	***	0.1418	−647
White collar workers group	−0.4659	***	0.1606	−763
Supervisor group	−0.3641	**	0.1787	−596
N (no. of observations)	3,074			
Log L	−2657.7			
χ^2	1448.86			
Adjusted pseudo-R^2	0.208			

Significance levels at 1%, 5% and 10% are denoted by three, two and one asterisk(s), respectively.

effects suggests that socioeconomic, as well as more attitudinal, variables are important determinants of preferences and willingness to pay. The interaction effects also show that preference heterogeneity exists in the population. As expected, the results indicate that respondents who believe the authorities should use additional resources to protect the aquatic environment tend to have a higher WTP for naturally clean water and for improved conditions for plant and animal life compared with the average respondent. These respondents also express more pronounced negative utility in relation to worse (bad) conditions for animals and plants in the aquatic environment. In contrast, respondents who feel that the problems of the pollution of the aquatic environment are exaggerated exhibit a lower WTP for very good conditions for plant and animal life compared with the average respondent. Not surprisingly, respondents who regard purified water as just as good as naturally clean groundwater have a lower WTP for naturally clean groundwater compared with the average respondent. People who save water for environmental reasons display a lower WTP than the average, which can be explained by the fact that they are already making an effort to protect the aquatic environment by saving water. As expected, people who often fish for recreational purposes pay greater attention to the utility of better living conditions for plants and animals in the aquatic environment compared with others, and they are willing to pay significantly more than the average respondent for better conditions in surface waters. This value represents a use value for this group of people.

Furthermore, it may be noted that estimations have shown correlations between household WTP and household income, education level of the respondent and household water consumption, i.e. WTP increases with income level, educational skills as well as water consumption. The increase in WTP with income and education was expected; thus, while increased income implies improved ability to pay, a higher level of education is expected to translate into a higher level of awareness and subsequent higher WTP. In this connection, though, it may also be noted that there tends to be a strong positive correlation between the level of income and the level of education. As far as the increase in WTP with higher water consumption is concerned, it can perhaps be explained by water quality being more important to heavy users than more moderate users. Furthermore, the WTP of females is found to be higher than that for males; this is not surprising, as such a gender difference is also noticed in other studies of environmental preferences (cf. Wier *et al.* 2005), but there is no ready explanation as to why this gender difference arises. More surprisingly, both age and children in the household are found to be insignificant factors, i.e. the WTP is not dependent on whether there are children in the household or the age of the members of the household.

The WTP in rural and urban areas

The sample has been divided with respect to the type of area in which the respondent lives in order to investigate whether WTP varies between rural and urban areas. This comparison is considered relevant as it is mentioned in the questionnaire that agriculture is the main contributor to groundwater contamination caused by pesticides and nitrate. As rural areas are more dependent on agriculture for income compared with urban areas (Hasler *et al.* 2002), it is expected that there may be regional differences in relation to the extent to which people feel that agriculture should be held responsible for the contamination.

In Table 4 the resulting estimations, where region of residence enters as a dummy variable, are presented.

Table 4 indicates that respondents in urban areas have higher WTP for naturally clean water as well as for purified water compared with respondents living in rural areas. In terms of naturally clean drinking water this finding conforms to the expectations held prior to the study, as people living in rural areas are expected to be less inclined than others to pay for a

Table 4 WTP for urban and rural areas

	Area	Parameter		Std. error	WTP (DKK)
Alternative specific constant		−0.72757	***	0.10191	
Price		−0.00059	***	0.00003	
Naturally clean groundwater	Urban	1.17037	***	0.09230	1976
	Rural	0.89333	***	0.14942	1508
Purified groundwater	Urban	0.59154	***	0.08927	999
	Rural	0.28570	*	0.15050	482
Very good conditions	Urban	0.71361	***	0.06982	1205
	Rural	0.71098	***	0.12701	1200
Bad conditions	Urban	−1.09399	***	0.08079	−1847
	Rural	−0.76865	***	0.16845	−1298
N (no. of observations)		3074			
Log *L*		−2720.57			
χ^2		1313.13			
Adjusted pseudo-R^2		0.191			

Significance levels at 1%, 5% and 10% are indicated by three, two and one asterisk(s), respectively.

groundwater protection scenario that imposes further restrictions on the agricultural sector. This argument, however, does not apply to purified water, as this entails no restrictions on agriculture. Instead, this difference may be explained by people living in rural areas having a different perspective on environmental problems due to their proximity to nature.

Conclusions

The WTP estimates derived for groundwater protection and purification represent payments in addition to the sums households presently pay for water, and reflect respondents' WTP for the good, 'good drinking water quality' obtained by protection or purification, as well as good living conditions for flora and fauna in lakes and watercourses. In terms of the size of the estimated WTPs, the CE has revealed positive WTP estimates for groundwater protection, split into WTP estimates of approximately 1900 DKK/household/yr for 'naturally clean groundwater for drinking water supply', and approximately 1200 DKK/household/yr for 'very good conditions for plant and animal life'. Compared with the present payment of 4000 DKK/household/yr, the CE result for naturally clean water resulting from protection of the groundwater resource represents a marginal increase in household expenses for water of almost 50% – from 4000 to 5899 DKK/yr.

These results also show that the value associated with clean drinking water exceeds the value associated with good quality of surface waters, as the WTP for good conditions in surface waters only amounts to 63% of the WTP for naturally clean drinking water. As mentioned, a likely explanation for this difference is that clean drinking water influences human health, and hence private goods, more directly than the quality of surface waters does, both for present and future generations.

Furthermore, the results of the estimations indicate that WTP differs between households in urban and rural areas as the WTP is higher in the former, indicating that the urban population is willing to pay more than the rural population for the imposition of restrictions in agriculture to protect groundwater, the latter being more dependent on agriculture for employment and income. As expected, the estimations also show that WTP is correlated with a number of factors, including education and gender.

As often experienced in hypothetical valuation studies, the study does not encompass assessments of how the respondents understand the difference between the alternatives and how they interpret the provision of the good, and therefore it is uncertain how the respondents have perceived this. However, a large part of the respondents indicated that they were rather certain in their answers, and the results indicate that the benefits of the alternatives are significantly different from each other. We therefore conclude that the results support one of the cornerstones of Danish drinking water policy, i.e. that the public prefers naturally clean groundwater to water that has been purified. The WTP for groundwater protection is found to be approximately twice as high as that for purified water. As the costs of implementing protective measures within the agricultural sector are not estimated as part of this study, it is not possible to determine the extent to which it will be socially optimal to impose further restrictions on agriculture. If the WTP for the protection scenario exceeds the WTP for purification with an amount likely to match the costs incurred by the imposition of restrictions within the agricultural sector it would be desirable, seen from society's point of view, to choose the protection scenario over the purification scenario. Despite the fact that no definite conclusions can be made regarding which scenario to choose, the magnitude of the estimated WTPs, and the magnitude of the difference between WTPs for naturally clean versus purified water, nevertheless suggest that there is significant room for implementation of new restrictive measures in agriculture to protect groundwater from further pollution.

References

Adamovicz, V. and Boxall, P. (2001). Future directions of stated choice methods for environment valuation. Paper prepared for Choice Experiments: A New Approach to Environmental Valuation, London, 10 April. Available at: http://thacher.us/jenn/Econ542/Articles/AdamowiczBoxall2001.pdf.

Adamowicz, W., Louviere, J. and Williams, M. (1994). Combining revealed and stated preference methods for valuing environmental amenities. *J. Environ. Econ. Mngmnt.*, **26**(3), 271–292.

Bateman, I.J., Carson, R.T., Day, B., Hanemann, M., Hanley, N., Hett, T., Jones-Lee, M., Loomis, G., Mourato, S., Özdemiroglu, E., Pearce, D.W., Sugden, R. and Swanson, J. (2002). *Economic Valuation with Stated Preference Techniques. A Manual*. Edward Elgar Publishing, Cheltenham.

Batsell, R.R. and Louviere, J.J. (1991). Experimental analysis of choice. *Marketing Lett.*, **2**(3), 199–214.

Bergstrom, J.C. and Dorfman, J.F. (1994). Commodity information and willingness-to-pay for groundwater quality protection. *Rev. Agric. Econ.*, **16**(3), 413–425.

Carlsson, F., Frykblom, P. and Lagerkvist, C.-J. (2004). *Using Cheap-Talk as a Test of Validity in Choice Experiments*. Working Paper in Economics, No. 128. Department of Economics, Gothenburg University.

Cummings, R.G. and Taylor, L.O. (1999). Unbiased value estimates for environmental goods: a cheap talk design for the contingent valuation method. *Am. Econ. Rev.*, **89**(3), 649–665.

Danish Environmental Protection Agency (2004). *More About Drinking Water*. Available at: http://www.mst.dk.

EuroGeoSurveys (2007). Available at: http://www.eurogeosurveys.org.

European Commission (2005). *The Attitudes of European Citizens Towards Environment*. Special Eurobarometer 217/Wave 62.1. Study requested by the European Directorate General Environment and conducted by. TNS Opinion & Social. European Commission. Available at: http://ec.europa.eu/public_opinion/archives/ebs/ebs_217_en.pdf.

Garrod, G. and Willis, K.G. (1999). *Economic Valuation of the Environment. Methods and Case Studies*, Edward Elgar Publishing, Cheltenham.

GEUS (2007). Available at: http://www.geus.dk/publications/div-artikler/aktuel-naturvidenskab-4-2003.pdf.

Hanley, N., Wright, R.E. and Adamowicz, V. (1998). Using choice experiments to value the environment: design issues, current experience and future prospects. *Environ. Res. Econ.*, **11**(3–4), 413–428.

Hanley, N., Wright, R.E. and Alvarez-Farizo, B. (2005). Estimating the economic value of improvements in river ecology using choice experiments: an application of the Water Framework Directive. *J. Environ. Mngmnt.*, **78**(2), 183–193.

Hanley, N., Wright, R.E. and Koop, G. (2002). Modelling recreation demand using choice experiments: climbing in Scotland. *Environ. Res. Econ.*, **22**(3), 449–466.

Hanley, N.D.,, Mourato, S. and Wright, R.E. (2001). Choice modelling approaches: a superior alternative for environmental valuation? *J. Econ. Surv.*, **15**(3), 435–462.

Hasler, B., Jensen, J.D., Madsen, B., Andersen, M., Huusom, H. and Jacobsen, L.B. (2002). *Scenarios for Rural Areas' Development – an Integrated Modelling Approach*, AKF forlaget, Copenhagen.

Hasler, B., Lundhede, T., Martinsen, L., Neye, S. and Schou, J.S. (2005). *Valuation of Groundwater Protection versus Water Treatment in Denmark by Choice Experiments and Contingent Valuation*. NERI Technical Report, No. 543. National Environmental Research Institute, Denmark.

Hensher, D., Shore, N. and Train, K. (2005). Households' willingness to pay for water service attributes. *Environ. Res. Econ.*, **32**(4), 509–531.

Jensen, P.R., Hallam, A.B., Hauch, J., Møllgaard, E. and Petersen, O.G. (1995). *En velfærdsindikator for Danmark 1970–1990* (in Danish). Arbejdsnotat nr. 8, Rockwoolfondens Forskningsenhed, Copenhagen.

Li, C., Kuuluvainen, J., Pouta, E., Rekola, M. and Tahvonen, O. (2004). Using choice experiments to value the Natura 2000 nature conservation programs in Finland. *Environ. Res. Econ.*, **29**(3), 361–374.

Louviere, J.J. (1988). Conjoint analysis modelling of stated preferences: a review of theory, methods, recent developments and external validity. *J. Transport Econ. Policy*, **22**(1), 93–119.

Louviere, J.J., Hensher, D.A. and Swait, J.D. (2000). *Stated Choice Methods. Analysis and Application*, Cambridge University Press, Cambridge.

Murphy, J.J., Stevens, T. and Weatheerhead, D. (2003). *An Empirical Study of Hypothetical Bias in Voluntary Contribution Contingent Valuation: Does Cheap Talk Matter?* Working Paper No. 2003-2. Department of Resource Economics, University of Massachusetts, Amherst, MA.

Poe, G.L. and Bishop, R.C. (1999). Valuing the incremental benefits of groundwater protection when exposure levels are known. *Environ. Res. Econ.*, **13**(3), 341–367.

Press, J. and Söderquist, T. (1996). *On Estimating the Benefits of Groundwater Protection: A Contingent Valuation Study in Milan*. Working Paper 1996/53. Fondazione Enrico Mattei, Milano.

Randall, A. (2002). Valuing the outputs of multifuctional agriculture. *Europ. Rev. Agric. Econ*, **29**(3), 289–307.

Samnaliev, M., Stevens, T. and More, T. (2003). *A Comparison of Cheap Talk and Alternative Certainty Calibration Techniques in Contingent Valuation*. Working Paper No. 2003-11. Department of Resource Economics, University of Massachusetts, Amherst, MA.

Stenger, A. and Willinger, M. (1998). Preservation value for groundwater quality in a large aquifer: a contingent valuation study of the Alsatian aquife. *Environ. Mngmnt.*, **53**(2), 177–193.

Train, K.E. (2003). *Discrete Choice Methods with Simulation*, Cambridge University Press, Cambridge.

Wier, M., Andersen, L. and Millock, K. (2005). Information provision, consumer and values – the case of organic foods. In *Environment, Information and Consumer Behaviour*, C. Russell and S. Krarup (Eds.), New Horizons in Environmental Economics Series. Edward Elgar Publishing, Cheltenham, pp. 161–178.