Are agricultural measures for groundwater protection beneficial when compared to purification of polluted groundwater?

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ARE AGRICULTURAL MEASURES FOR GROUNDWATER PROTECTION BENEFICIAL WHEN COMPARED TO PURIFICATION OF POLLUTED GROUNDWATER?

Abstract

The groundwater resource, the drinking water areas and the surface water quality can be protected by measures, e.g. by reductions of pesticide and nutrient applications, conversion of arable land to grasslands or forests etc. The objective of the paper is to estimate the benefits of groundwater protection by the valuation method choice experiments. This method allows for separate estimation and comparison of the different attributes connected to groundwater protection i.e. the effects on drinking water and surface water quality as compared to the benefits from cleaning and treatment of polluted drinking water to make it suitable for drinking water consumption. The results indicate that the benefits are significant, and that the willingness to pay for protection of the groundwater exceeds that from purification.

Keywords: Groundwater**,** pollution, drinking water, valuation, choice experiments
JEL classification: Q25, Q26, Q28, C42, D62

1. Background and objectives

The main political goal in Danish drinking water policy is that groundwater should be able to be used more or less after just simple processing (oxygenation). Further treatment of groundwater is not desirable with regard to both national and regional targets for the existing and future drinking water supply (cf. Danish Environmental Protection Agency 2004). Drinking water of good quality is below the limit values for nitrates and pesticides in drinking water, which are 50 mg /l and 0,1 µg/l of water, respectively.

Pesticide and nitrate residues in the water are the reason for waterworks boreholes to be closed where pollution is the culprit (GEUS, 2003), and agriculture represents, together with industry, road traffic, landfill sites and sewerage systems, an important source of the pollution of the Danish groundwater resource. Half of the boreholes under countrywide groundwater surveillance contain nitrates, 16% contains nitrate over the limit value for drinking water of 50 mg/l. The Geological Survey of Denmark and Greenland (GEUS) assesses that, nationally, an indication of a fall in nitrate content is apparent in the youngest groundwater (GEUS, 2003), and this fall can potentially be ascribed to changing cultivation practices since adoption of the Danish Aquatic Action Plan in 1987. The latest additions and amendments in this plan are from 2004 (Jacobsen et al., 2004). The measures in the Action Plan are primarily directed towards agriculture. Even though the nitrate content is decreasing, the average concentration of nitrates in the youngest groundwater exceeds the limit value for drinking water (GEUS, 2003). These problems are most significant in the Northern part of the country, in the so-termed "nitrate belts", where agricultural production is the dominant land-use and the soil is sandy or where aquifers are not deep-lying (GEUS, 2003). Despite the tendency for concentrations to decrease in younger groundwater, GEUS (2003) comes to the conclusion that the agricultural measures previously implemented are not likely to be adequate to reduce the nitrate content in groundwater sufficiently. This also hold for pesticides, as pesticides or pesticide residues were found in 27% of the boreholes in 2002 (GEUS, 2003), and 9% exceeded the limit for drinking water.

The non-point leaching of nutrients and pesticides mainly stem from agriculture, and protection of the groundwater resource, the drinking water and the surface water quality can take place by locating polluting agricultural activities in an appropriate distance from aquifers or by restricting the activity, itself. Measures in agriculture do, for example, include environmental management practices in the form of reductions in pesticide and nitrogen applications, planting of forest areas and taking land out of production. These measures limit the loss of pesticides, nitrogen and phosphorous to both groundwater and surface waters (cf. Østergaard et al., 2004; Bach et al., 2002; Henriksen et al., 2004; Hasler

et al., 2005). The measures can be implemented so that current and future generations can drink untreated groundwater, which at the same time is clean, but the effects depend on the scope of protection measures and how the measures are put in place.

Valuation of the benefits of these measures, i.e. drinking water of good quality from protective measures, as well as better living conditions for animals and plants in surface waters, facilitates estimations of these benefits in monetary terms, and hereby comparisons with e.g. the implementation costs are possible. The calculation of implementation costs has not been a part of this study, though.

One of the main hypotheses in this paper is that consumers prefer protected and clean groundwater, which is not in need of purification or other treatment, to water that has been polluted and treated to clean, thereafter. By valuation we can analyse these preferences and also assess the strength of them. The hypothesis is also that the willingness to pay (WTP) for groundwater protection exceeds the WTP for purified water. Another hypothesis is that the value associated with clean drinking water exceeds the value associated with good quality of surface waters. The rationale here is that clean drinking water influences human health and hence private goods more directly than the quality of surface waters does. Differences in households' WTP between urban and rural area are also investigated.

2. Methodology: The Choice Experiment method (CE)

The CE method was, like choice modelling techniques, developed for market analysis (Batsell & Louviere, 1992; Louviere, 1988), but the methods have been increasingly used and further developed for the valuation of non-marketed goods (Adamowicz, 1995; Boxall et al., 1996; Hanley et al., 1998a; Hanley et al., 1998b; Hanley et al., 2001; Randall, 2002).

In a CE study, respondents are requested to choose between pre-defined alternatives which each are connected with different implementation costs, drinking water quality, other environmental impacts, etc. The respondents are requested to select their preferred alternative and the term 'indirect method' is used as consumer preferences are estimated on the basis of preferred situations and not on the basis of actual expressed willingness to pay as it is the case for the much used valuation method named contingent valuation. Respondents are, hereby, provided with an explicit basis for assessing costs in relation to effects and, therefore, the method is recommended for valuation of complex problems, where the good consists of several characteristics, referred to as 'attributes'. Consequently the power of the CE method is that it split into attributes and choice sets, and can avoid response difficulties, reduce problems of multicollinearity and measure the marginal value of changes. The method is also suitable if the nature of the environmental good is relatively removed from characteristics possessed by traditional consumer goods, because the choice situation places the valuation in a situation more reflective of real market conditions than with other forms of valuation exercises - all things being equal.

The method can be described formally by the following utility function. An individual i's utility from a good j (U_{ij}) can be described as a function of a deterministic part (V) and a stochastic element (ε) as follows:

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

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

The probability of a choice between alternative options for changes in water quality is described as a function of the attributes, and the probability for choice between the alternatives can be analysed by random utility models (RUM). Examples of attributes are drinking water quality, surface water quality and costs, but other attributes could be mentioned as well: groundwater exposure to pesticides and nitrates, human exposure as well as landscape changes. In the present study the costs are expressed as a fixed amount reflecting an increase in the yearly payment per household for water supply.

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). WTP for non-monetary attributes can hereafter be estimated as the marginal rate of substitution between the attribute and the monetary attribute.

3. Scenarios for groundwater management in Denmark

The scenarios are described all together in table 1.

Table 1. Description of scenarios

Scenario characteristics	**Status quo**	**Increased protection**	**Purification (treatment to clean)**
Short description of scenario and measures	No protection takes place further to that currently in place.	Groundwater protected against further pollution, now and in the future.	Polluted groundwater is cleaned (purified) of pesticides and nitrates by means of active carbon, osmosis, etc.
Drinking water quality and source	Consumers are provided with clean drinking water from new boreholes, however, localised problems with availability of clean drinking water from untreated groundwater can arise, and drinking water quality will be uncertain in the future.	Consumers are provided with clean drinking water from untreated groundwater and clean groundwater is secured, now and in the future.	Consumers are provided with clean drinking water in the form of treated water or via purchase of bottled untreated water from groundwater and tap water.
Resultant effects on surface waters (watercourses and lakes)	Risk for pollution of watercourses with pesticides, impacts on fish and other organisms in watercourses. Eutrophication of nutrient-poor lakes. Rare cases of fish mortality in lakes.	Improved conditions in watercourses and lakes in those areas where groundwater additions are large. No difference in relation to the status quo in areas where runoff from fields is considerable.	Risk of pollution of watercourses with pesticides, negative impact on fish and other organisms. Eutrophication of lakes. Occasional cases of fish mortality.

We have not found it reasonable to focus on the groundwater quality as such, but on the effects that groundwater quality and quantity cause on goods that is used and perceived by the population, i.e. drinking water and surface water. Therefore, we have not focused on the pollution sources themselves in this study, neither on pesticides and nitrates respectively, but on the effects that pesticide and nitrate emissions affects on groundwater and hereby on surface waters and drinking water. This distinguishes this study from other studies that focus on e.g. pesticides.

The policy implication of the scenarios is that the results can be used in connection to the some of the effects of implementation of the Water Framework Directive.

4. The development of the questionnaire and the choice sets

4.1. The questions

The questionnaire contains background questions on habits and attitudes, choice questions, follow up questions on the choices and questions on socio-economic characteristics (e.g. age, household size, income level). The questionnaire has been carefully tested in focus group and individual interviews, as well as by pre-test, and the questionnaire and the attributes were revised according to the results of these tests. Detailed information of the experiences from the tests can be found in Hasler et al. (2005).

To secure that the respondents have the same minimum knowledge of the good being valued, a separate information sheet was enclosed with the questionnaires. This information was divided into three parts, comprising information on:

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

We have chosen to emphasise that groundwater has an influence on freshwaters, including drinking water, watercourses and lakes. Emphasis is laid on expressing the fact that nearly all drinking water stems from groundwater, which has only been treated in a simple way, this representing a special situation for Denmark compared to many other countries.
The sources of pollution are mentioned briefly, but numbers are not mentioned. Pollution limit values are also mentioned.

The alternatives, which the respondents are asked to choose between in the choice experiment, each represent different combinations of the scenarios described in section 3. These alternatives are defined by these three attributes; the quality of drinking water and the living conditions for plants and animals in the aquatic environment, respectively, and one attribute specifying the cost/price of the option. The inclusion of the monetary attribute is necessary in order to facilitate the estimation of implicit prices for the attribute levels, i.e. the implicit values that respondents attach to the qualitative effects of different management options.

4.2. The attributes

The basic purpose of the specifications of the attributes in the present study is to emphasise general and overall perspectives of groundwater protection. There are both advantages and disadvantages associated with the adoption of this general approach, however, as this perspective has been chosen it is important to ensure that the indicators used relate to this approach. The respondent should not relate to, e.g. the specific conditions prevailing in their local area – a such approach would require many local studies.

Quantitative indicators ascribed to the attribute levels have some a priori advantages. Such indicators could be based on information on absolute or relative reductions of nitrate and pesticide additions to the recipients, or absolute or relative numbers of plants and animals that would have worse/better living conditions if nutrient and pesticide emissions were reduced. Dosis-response relationships would serve policy purposes because it is possible to connect changes directly to the measures. But different recipients, and especially the lakes, react very differently to reductions in nutrient and pesticide emissions and loads, and no general quantitative indicator can therefore be applied. Therefore, the quantitative indicators derived by dosis-response functions can be used in case studies, but not in studies where general indicators are used, as in this study. We have therefore chosen to use qualitative attribute levels. This choice was supported by tests of the questionnaire, which showed that respondents related more confidently to qualitative indicators than to quantitative. Among other reasons, one explanation was that respondents did not trust limit values, as they considered them to have been arrived at politically, and quantitative indications of pollution and effects on flora and fauna were found to be more demanding cognitively to relate to and to understand than qualitative indicators.

We therefore assume that the qualitative attribute levels increase the likelihood that the respondents understand the constructed scenario, and should reduce respondents' possible confusion by 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 e.g. Bergström & Dorfman (1994), Stenger & Willinger (1998) and Hanley et al. (2005).

A critique of the qualitative approach has, among other things, been that the approach is not directly amenable to water managers in relation to the variety of policy outcomes it is necessary for them to consider (Poe & Bishop, 1999). Poe & Bishop (op cit), therefore, propose a reorientation of "future groundwater contingent valuation research towards a focus on actual, objectively obtainable, exposure levels experienced at a study site". We agree that this is a recommendable approach in case studies, but the approach is not possible when the aim is to value the effects of groundwater manage-

ment at a general, national level. Instead, the wordings used for the description of the qualitative levels of the attributes in the questionnaire are similar to the wordings used in the Water Framework Directive and the regional water quality plans, and hereby the results from the valuation can be connected to real policy options.

The following three quality levels describes the general quality of Danish drinking water in the CE:

- 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 future. There is, therefore, a risk that in future water from our taps will exceed current limit values for pesticides and nitrogen.
- Treated/purified drinking water*:* By cleaning polluted groundwater for pesticide and nitrogen residues, clean drinking water supplies can be ensured both now and in the future.

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 a degree, in a state of imbalance. This represents the current situation.
- Poor: Animal and plant-life is significantly different that would be the case under natural conditions and is in a state of serious imbalance. Animal and plant-life is often completely changed due to human activity.

The wording used in the description of the different levels is as “neutral” as possible to take into consideration that choices should be a matter of taste/preferences, and value-laden words that can influence preferences should be avoided.

An additional payment amount to the annual water bill is chosen as payment vehicle, as we assume this payment to be credible, relevant, acceptable and coercive (Bateman et al., 2002), because consumers are accustomed to pay for households’ water use this way. 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 & Willis, 2000). This implies that the payment vehicle shall be perceived as realistic, fair and equitable for all respondents to prevent non-responses and protest responses, and avoid giving the respondent an opportunity for free riding. Other aspects of payment are the timing of payment, whether it is individual or household payments, and the choice of format to elicit the payment bid. Annual payments are chosen as opposed to monthly payments, as it is assumed that the WTP can be higher if monthly payments were introduced. Household payment is chosen because the water bill is paid per household and not individually.

It was also considered to use an increase in the water price per cubic metre as payment vehicle, expecting that the water price due to its consumption dependence would be an intuitively understandable and uncontroversial payment vehicle for the respondents. It would, however, require information on the households annual water consumption in relation to the subsequent interpretation of results and aggregation of WTP-estimates. According to the results of our pre-tests this information was difficult to obtain, as most people do not know the size of their households annual consumption of water. Based on this, the original idea of using the water price per cubic metre as payment vehicle was aban-

doned in favour of using a fixed annual increase in water bill per household, which – though probably being more controversial to the respondents – has significantly eased the interpretation of results.

4.3. Budget constraints

The information on the payment is specified in order to ensure that the respondents consider both the payment vehicle and the households' budget constraints. The respondents are informed that the costs of implementing the policy alternatives is assumed covered by the Danish consumers, and that all consumers will contribute equally to implementation of the scenarios by means of a fixed annual sum per household, paid once a year via the water bill. The respondents are told that their stated amount (WTP) represents a sum over and above their present water bill. Furthermore, a so-called "cheap talk" is added to the standard budget reminder:

"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."

This text is intended to induce respondents to provide as valid and reliable responses as possible and to discourage the exhibition of strategic behaviour. 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 many expenses that they have to consider.

According to Cummings and Taylor (1999:650) who introduced the "cheap talk" concept, a cheap talk may be defined as an attempt to eliminate hypothetical bias by including an explicit discussion of the problem. In their study Cummings and Taylor (1999) found that cheap talk could effectively if not eliminate, then at least mitigate, hypothetical bias in the cases considered. Subsequently the effect of different cheap talk designs, implemented in various contexts, has been investigated in a number of studies, and the experiences hereof have been mixed. While Carlsson et al. (2004) and Murphy et al. (2003) found the inclusion of a cheap talk to have a positive effect, Samnaliev et al. (2003) found it had no effect, whereas Aadland and Caplan (2003) actually found it to have a negative effect.

Despite this inconclusive effect of cheap talk it has been decided to incorporate the above mentioned cheap talk in the design of the present study. Compared to other studies it should however be emphasised that the script used in the present study, which only amounts to a couple of lines, is significantly shorter than the ones usually applied. As an example the cheap talk in Cummings' and Taylor's (1999) article amount more than half a page. In relation to the present study, the inclusion of so elaborate cheap talks is considered inappropriate as it is expected that the resulting negative effect arising from increasing the length of the questionnaire by far would outweigh the potential positive effect arising from the cheap talk. Based on this it may be questioned if what we term "cheap talk" in this study actually qualify 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 do so.

4.4. The number of alternatives

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. The reason being that failure to do so may imply that respondents are forced to choose alternatives, which they do not desire. If this is the case, the observed choices should not be interpreted as expressions of respondents' true preferences, implying that they should not (or perhaps rather: cannot) be used as the basis for deriving valid estimates of welfare changes (Bateman et al., 2002). A status-quo alternative option is therefore included in the present study , characterised by an "uncertain" water quality level, a "less good" quality of the aquatic environment and zero additional costs, cf. table 1 and figure 1. Accordingly, it defines the baseline situation that will prevail if current initiatives are maintained while not further actions are taken.

Apart from the status quo alternative, which is constant across all choice sets, each choice set contains 2 alternatives. This is in line with the approach adopted in other environmental valuation studies, where 2-3 alternatives per choice set appears to be the standard (Adamowicz & Boxall, 2001:20). According to Bateman et al. (2002:265) 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 3 alternatives per set. Fractional factorial design was used, and the alternatives blocked so that 6 choice sets were presented to each respondent. An example of a choice set is apparent from figure 1.

	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 kr.	2.400 kr.	625 kr.
I would prefer (***please mark with a cross***):	☐	☐	☐

Figure 1. Example of choice set from the questionnaire

4.5. Follow-Up Questions

It is recommended to ask a set of follow-up questions upon completion of the valuation question(s). In the present study, 6 questions regarding respondents' experience of the choice exercise and how they made their choices are asked immediately after the choice sets.

In one of these questions respondents are asked whether or not they found it difficult to make the choices. One of the motives for asking this question is that respondents' answers may indicate something about the reliability of the choices. Respondents are furthermore asked to specify which of the three attributes they put greatest weight on when choosing between the different alternatives, to be able to see whether or not respondents have applied choice strategies that are potentially conflicting with the assumption of compensatory decision-making.

5. Estimations and results

5.1. Data and model

A professional survey institute (GfK-Denmark - Growth from Knowledge) has been used for the submission of the survey, using a panel of respondents which is representative of the Danish population. GfK sent the questionnaires to 900 respondents. Based on statistical considerations, sample sizes between 250 and 1,000 (depending on the format) respondents are recommended for each subgroup of the population in contingent valuation surveys. Extending the recommendation from the contingent valuation case, the required sample size for a CE study is smaller due to the increased amount of information collected from each respondent through the multiple choice tasks (Bateman et al., 2002:111). 584 respondents returned the questionnaire, which equates to a response rate of almost 65 percent. As mentioned each questionnaire contained 6 CE choice sets (questions). 11 respondents did not answer any of these 6 questions why these responses subsequently have been removed from the data-set. Another 41 respondents have answered between 1 and 5 of the CE questions and these respondents are included. The CE model is based on the idea that respondents make a trade-off between the price of the good and the different attributes. However, it is not always one can be sure that the respondents has been considering the trade-offs which can be due to various circumstances. Some of the respondents might try to influence the results by answering strategically instead of answering the questionnaire according to their preferences. 45 of the 584 respondents have been identified as chosen alternative number 1 in all 6 choice sets; i.e. the status quo situation. This could suggest the use of a rule-of-thumb rather than a reflection of the trade-offs between the alternatives. This is supported by

the fact, that more alternatives offer a better quality of water or environment than status quo at no expense for the respondent. These 45 respondents are removed from the sample. The sample thus consists of 528 respondents making 3,074 valid choices

The conditional logit model is used for the estimations. This model is based on the utility function described above in equation 1, where *i* denote the individual respondent and *j* the alternative. If 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 calculated as:

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

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

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

The dependent variable in the conditional logit model based on the main effects is the probability that the respondent chooses or not chooses an alternative. The results are presented in table 2. The estimates in this model are based on a change from the status quo situation.

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	
Natural 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

As apparent from table 3, the WTP for protected groundwater which is naturally clean and not in the need for purification, is 1,899 DKK/year, as an additional payment to the average water bill for a household, being approximately 4,000 DKK/year in average. The WTP for good conditions for flora and fauna in waterways and lakes is 1,204 DKK/year, and the WTP for purified water is 912 DKK/year. In other words the hypothesis that WTP for protection exceeds the WTP for purification is supported, and so is the hypothesis that the WTP for drinking water quality exceeds that for surface water quality.

All the parameters are statistically significant at a 0.1 percent level and operate as expected. The cost parameter is negative whereas both natural clean and purified groundwater suggests positive utility. A change to very good conditions for animal and plants contribute positively to utility whereas a change to poor conditions contributes negatively. The model's adjusted pseudo R^2 is 0.19. The adjusted pseudo R^2 should be above 0.1 to accept the model whereas a value between 0.2 and 0.4, according to Louviere et al. (2000), is considered as a very good fit.

As apparent the model includes an alternative specific constant, which is associated with disutility. The parameter should be interpreted as the disutility connected to the status quo alternative, i.e. the present situation, which is not described by the attributes drinking water quality and plant- and animal life.

5.3. Certainty

The WTP has been analysed in connection to self reported (un)certainty. The question of uncertainty was presented as a choice of 7 levels arranged on a line, and most respondents showed up to be medium secure or secure. These certainty indications are used to exclude observations pertaining to respondents with a self-reported level of certainty below a certain threshold.

Table 3. Certainty of choices and WTP

	Parameter		Std. error	WTP (DKK)
Price	-0.0005	***	0.0000	
Alternative specific constant	-0.7748	***	0.1192	-1,436
Natural clean groundwater	1.1442	***	0.1027	2,120
Purified groundwater	0.5521	***	0.0989	1,023
Very good conditions	0.7030	***	0.0766	1,303
Bad conditions	-1.0627	***	0.0853	-1,969
N (no. of observations)	2,256			
Log L	-1,975.42			
χ^2	1,006.09			
Adjusted pseudo R^2	0.200			

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

Excluding approximately 25% of the sample that had stated a certainty level below 3 results in the parameter estimates shown in table 3. The results indicate that a higher level of certainty is connected to higher WTP.

In accordance with Hasler et al. (2002) the sample has been divided in respect to region of residence in order to estimate WTP for rural and urban areas.

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	
Natural clean groundwater	Urban	1.17037	***	0.09230	1,976
	Rural	0.89333	***	0.14942	1,508
Purified groundwater	Urban	0.59154	***	0.08927	999
	Rural	0.28570	*	0.15050	482
Very good conditions	Urban	0.71361	***	0.06982	1,205
	Rural	0.71098	***	0.12701	1,200
Bad conditions	Urban	-1.09399	***	0.08079	-1,847
	Rural	-0.76865	***	0.16845	-1,298
N (no. of observations)		3,074			
Log L		-2,720.57			
χ^2		1,313.13			
Adjusted pseudo R^2		0.191			

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

Table 4 indicates that respondents in urban areas have higher WTP for natural clean water as well as purified water compared to respondents living in rural areas.

5.5. Interaction effects

Interactions between the main effects and the socio-economic, behavioural and attitudinal characteristics of the respondent are modelled by dummy variables. A stepwise maximum likelihood estimation is carried out in order to estimate interaction effects. The method used is a so-called "forward selection" which starts out by estimating an empty model, finds the most significant variable and adds it to the model before starting the loop again by re-estimating the model including the variable. Applying this method with a significance threshold level at 0.15 results in the model shown in Table 5.

Table 5. 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	1,319
The authorities should use more resources to protect	0.6198	***	0.1013	1,014
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
Group of blue collar worker	0.3106	**	0.1217	508
Group of high income	0.2987	**	0.1163	489
Very good conditions	0.4444	***	0.1130	727
The authorities should use more resources to protect	0.3143	***	0.1065	514
Pollution of aquatic environment is exaggerated	-0.4087	***	0.1360	-669
Does fish very often	0.9886	**	0.4239	1,618
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	-1,082
The authorities should use more resources to protect	-0.3955	***	0.1418	-647
Group of white collar workers	-0.4659	***	0.1606	-763
Group of supervisors	-0.3641	**	0.1787	-596
N (no. of observations)	3,074			
Log L	-2,657.7			
χ^2	1,448.86			
Adjusted pseudo R^2	0.208			

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

The main effects are marked in bold and the respective interaction effects are listed below and represent an addition/deduction to the main effect WTP. Among other things, 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 conditions for plant and animal life compared with the average respondent. On the contrary, respondents who think that the problems of pollution of the aquatic environment are exaggerated exhibit a lower WTP for very good conditions for plant and animal life. Not surprisingly, respondents who regard purified water as just as good as non-purified groundwater have a lower WTP for naturally clean (non-purified) groundwater compared with the average respondent.

Respondents who disagree with drinking water in Denmark as being clean have a lower WTP for purified water compared to the sample. This is also the case for respondents who have knowledge of their household's annual water consumption.

Further estimations have shown correlation between the household WTP and household income, education level of the respondent and household water consumption, i.e. the WTP increases with income level, educational skills as well as water consumption. Furthermore, the WTP of females is higher than that for males. Both age and children in the household are 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.

6. Conclusions and discussion of the results

The Danish drinking water policy is based on the assumption that the public prefers clean groundwater to water that has been treated by purification methods to remove nitrates and residues from pesticides. This policy assumption is supported by the results of the CE study, i.e. the estimated WTP for groundwater protection is higher than the WTP for purified water. Hereby it is justified that the utility of agricultural measures for groundwater protection exceeds the utility of cleaned water. The costs of these actions are not measured as part of this study, however.

The WTP results represent water service payments in addition to households' present annual water bills, and reflects the 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. The initial average payment of 4,000 DKK/year represents the present cost of water delivery and wastewater disposal, as well as some of the costs for the present level of drinking water protection. The CE has resulted in positive WTP estimates for groundwater protection, split into WTP estimates at approximately 1,900 DKK per household as a yearly payment for "natural clean groundwater for drinking water supply", and approximately 1,200 DKK per household per year for "very good conditions for plant and animal life". The CE result for naturally clean water resulting from protection of the groundwater resource represents a marginal increase of almost 50%; from 4,000 to 5,899 DKK/year. It is apparent that the WTP for groundwater protection exceeds the WTP for purification and the WTP for purified water from the CE survey is only 30% of the total WTP for groundwater protection.

As mentioned, one of the hypotheses in this study is that consumers prefer clean groundwater to purified water, and this hypothesis has been supported by the CE results. Another hypothesis is that the value associated with clean drinking water exceeds the value associated with good quality of surface waters. This hypothesis has also been supported by the CE results, which indicate that the WTP for good conditions in surface waters accounts for 63% of the WTP for good drinking water quality obtained by protection. One 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. Seen in relation to foreign valuation studies, as well as Danish, the results are in accordance with the assumptions.

The results of the estimations indicate that WTP differs between households in urban and rural areas, as the WTP is higher in urban than in rural areas, and further estimations have shown that WTP is correlated to a number of factors including education and gender.

References

Adamovicz, V. and P. Boxall (2001): Future Directions of Stated Choice Methods for Environment Valuation, Paper Prepared for "Choice Experiments: A New Approach to Environmental Valuation", London, April 10th 2001.

Adamowicz, W, J. Louviere and M. Williams (1994): Combining revealed and stated preference methods for valuing environmental amenities. *Journal of Environmental Economics and Management.* 26(3), 271-92

Adamowicz, W. (1995): Alternative Valuation Techniques: A Comparison and Movement to a Synthesis. In Willis, K.G. & J.T. Corkindale (eds.): *Environmental Valuation*, Cab International.

Andersen, J.M., Boutrup, S., Svendsen, L.M., Bøgestrand, J., Grant, R., Jensen, J.P., Ellermann, T., Rasmussen, M.B., Jørgensen, L.F. & Laursen, K.D. (2003): Vandmiljø 2003. Tilstand og udvikling - faglig sammenfatning. Danmarks Miljøundersøgelser. Faglig rapport fra DMU 471: 50 s.

Bach, H,; N. Christensen & P. Kristensen (eds)(2002): The State of the Environment in Denmark, 2001. National Environmental Research Institute, Roskilde, Denmark. 368 pp. NERI technical report No. 409.

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

Batsell R.R. & J.J. Louviere (1992): Experimental Choice Analysis. *Marketing Letters* 2, pp. 199-214.

Bergstrom, J.C. & J.F. Dorfman (1994): Commodity Information and Willingness-to-Pay for Groundwater Quality Protection, *Review of Agricultural Economics* 16(3), 413-425.

Boxall P.C, V. Adamowizc, J. Swait, M. Williams & J. Louivere (1996): A comparison of stated preference methods for Environmental valuation. *Ecological Economics* 18, 243-253.

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

Copenhagen County/Roskilde county, see: Københavns Amt/Roskilde Amt

Cummings, R. G. & L. O. Taylor (1999): Unbiased Value Estimates for Environmental Goods: A cheap Talk Design for the Contingent Valuation Method, *American Economic Review*, 89(3):649-665.

Danish Environmental Protection Agency (EPA) (2004): More about drinking water. www.mst.dk

DØR (Det Økonomiske Råd) (2004) Dansk Økonomi 2004. København Findes på www.dors.dk.

Environmental Opinion Research Group(2002) Eurobarometer 58.0 The attitudes of Europeans towards the environment. Directorate-General Environment.

Garrod, G. & K.G. Willis, 1999. *Economic Valuation of the Environment. Methods and Case Studie*s. Edward Elgar.

GEUS (2003): Groundwater monitoring 2003. København. Danmarks og Grønlands Geologiske Undersøgelse. http://www.geus.dk/publications/grundvandsovervaagning/g-o-2003.htm

Georgiou S., I. Bateman, M. Cole & D. Hadley (2000) Contingent ranking and valuation of river water quality improvements:testing for scope sensitivity, ordering and distance decay effects. CSERGE working paper GEC 2000-18.

Hanley, N.; D. Macmillan, R. Wright, C. Bullock, I. Simpson, D. Parrison & B. Crabtree (1998a): Contingent Valuation versus Choice Experiments: Estimating the benefits of Environmentally Sensitive Areas in Scotland. *Journal of Agricultural Economics* 1(15).

Hanley N.; R.E. Wright & V. Adamowicz (1998b): Using Choice Experiments to Value the Environment: Design Issues, Current Experience and Future Prospects. *Environmental and Resource Economics* 11(3-4), pp. 413-28.

Hanley, N.D.; S. Mourato & R.E. Wright, (2001): Choice Modelling Approaches: A Superior Alternative for Environmental Valuation? *Journal of Economic Surveys* 15(3), pp. 435-62.
Hasler,B. (ed.), J.D. Jensen, B. Madsen, M. Andersen, H. Huusom; L. B. Jacobsen (2002) *Scenarios for Rural Areas development – an Integrated Modelling Approach*. AKF forlaget.

Hasler, B., Lundhede, T., Martinsen, L., Neye, S. & Schou J.S. 2005: Valuation of groundwater protection versus water treatment in Denmark by Choice Experiments and Contingent Valuation. National Environmental Research Institute, Denmark. 162 pp. - NERI Technical Report no. 543. http://technical-reports.dmu.dk.

Hasler, B. & Schou, J.S. 2004: Samfundsøkonomisk analyse af sikringen af naturvenlig drift på pa. 3-arealer og naturskovarealer. Danmarks Miljøundersøgelser. - Arbejdsrapport fra DMU 197: 90 s. (elektronisk). http://www2.dmu.dk/1_viden/2_Publikationer/3_arbrapporter/rapporter/AR197.pdf

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

Henriksen, H.J., Rasmussen, P., Brandt, G., von Bülow, D., Nyegaard, P. and Jørgensen, F.L. (2004) Test of Bayesian belief network and stakeholder involvement. Danish MERIT case study. Danmark og Grønlands Geologiske Undersøgelse og Københavns Energi. http://www.geus.dk/program-areas/water/denmark/rapporter/merit_aug_04-dk.htm

Institut for konjunkturanalyse (IFKA)(1999) Danskerne 2000. Rapport, København.

IMV- Environmental Assessment Institute (2003): BAM forurening af drikkevandet (Pollution with BAM in the drinking water) (In Danish, abstract in English). Copenhagen.

Jacobsen, B.H., Abildtrup, J., Andersen, M., Christensen, T., Hasler, B., Hussain, Z.B., Huusom, H., Jensen, J.D., Schou, J.S. & Ørum, J.E. 2004: Omkostninger ved reduktion af landbrugets næringsstoftab til vandmiljøet - Forarbejde til Vandmiljøplan III = Costs of Reducing Nutrient Losses from Agriculture - Analyses prior to the Danish Aquatic Programme III. Fødevareøkonomisk Institut. - Rapport 167: 299 pp. Available at: http://www.foi.dk/Publikationer/Rapporter/rap167.pdf

Jensen P.R., A.B. hallam, J.hauch, E. Møllgaard & O.G. Petersen (1995): En velfærdsindikator for Danmark 1970 –1990. Arbejdsnotat nr. 8, Rockwoolfondens Forskningsenheed, København.

Louviere, J.J. (1988) Conjoint Analysis Modelling of Stated Preferences: A review of theory, methods, recent developments and external validity. *Journal of Transport Economics and Policy* 10, pp. 93-119.

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

Mitchell , R.C. & R.T. Carson (1989): *Using Surveys to Value Public Goods. The Contingent valuation Method. Resources for the Future*, Washington D.C.

Murphy, J. J.; Stevens, T. and D. Weatheerhead (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.

Poe, G.L. & R.C. Bishop, 1999: Valuing the incremental benefits of Groundwater Protection when exposure levels are known. *Environmental and Resource Economics* 13, 341-367.

Press , J. & T. Søderquist (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. *Eurpopean reviw of Agricultural Economics.* 29(3), 289-307.

Rasmussen, S. (2004) Driftsøkonomiske tab ved pesticidfri dyrkning af landbrugsafgrøder evd havelse kildeplads. Bilag i rapporten : Henriksen (ed): Test of Bayesian belief Network and stakeholder involvement. GEUS og Københavns E. 177 ss. + appendix.

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

Scarpa, R.; Willis, K. G.; Acutt, M. and S. Ferrini (2004): Monte Carlo Simulation Evidence on the Effect of the Status-Quo in Choice Experiment Models for Water Supply, Paper Presented at the Thirteenth Annual European Association of Environmental and Resource Economists Conference, Budapest, June 25-28th 2004.

Schou, J. (2004) Samfundsøkonomisk analyse af indvindingsstrategier for grundvand i oplandet til Havelse å. Bilag i rapporten : Henriksen (ed): Test of Bayesian belief Network and stakeholder involvement. GEUS og Københavns E. 177 ss. + appendix.

Stenger A. & M. Willinger (1998): Preservation value for groundwater quality in a large aquifer: a contingent valuation study of the alsatian aquifer. Journal of Environmental Economics and Management. 53. 177-193.

Swait, J. and W. Adamowicz (1997): Choice Task Complexity and Decision Strategy Selection, Staff Paper, Department of Rural Economy, University of Alberta.

Train, K.E. (2003) Discrete Choice methods with Simulation. cambridge. 334 pp.
Vinggaard, A.M., E.Bonefeld-Jørgensen, H.R. Andersen, U. Hass, C. Nellemann, M. Birkhøj, K. Jarfelt, M. Dalgaard, H.R. Lam, H. Jacobsen (2004): Hormonforstyrrende effekter af kombinationer af pesticider Bekæmpelsesmiddelforskning fra Miljøstyrelsen.

Watson, V.; Phimister, E. and M. Ryan (2004): Testing the Assumption of Compensatory Decision-Making in Discrete Choice Experiments: An Application to the Decommissioning of Off-Shore Oil Installations, Paper Prepared for the Thirteenth Annual European Association of Environmental and Resource Economists Conference, Budapest, June 25-28th 2004.

Østergaard, H.S.; J.E. Jensen, N.B. Jensen & L.V. Pedersen (2004) Reduceret brug af kvælstof og pesticider. Økonomisk og miljømæssig effekt. Arbejdsrapport fra Miljøstyrelsen nr. 3. 22 ss.