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Economic assessment of the value of drinking water management in Denmark by groundwater protection and purification of polluted groundwater[1]

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[1] This discussion paper is a slightly modified version of a published paper by Lundhede et al [15]. More details of the study behind the paper can be found in Hasler et al [3].

Economic assessment of the value of two scenarios for drinking water management in Denmark – Groundwater protection versus purification of polluted groundwater[2]

Abstract

The benefits of groundwater protection are estimated to assess the non-marketed benefits associated with increased protection of the groundwater resource, as compared to the current level of groundwater protection, and compared to purification of groundwater for drinking water purposes. The study comprises valuation of the effects on both drinking water quality and the quality of surface water recipients, expressed by the quality of the living conditions for wild animals, fish and plants in lakes and waterways. The Discrete Choice Experiments method (CE) was used for the valuation. The results indicate that there is a significant positive willingness to pay for groundwater protection, where the willingness to pay for drinking water quality exceeds that for surface water quality. This result supports the current Danish groundwater policy and the Water Framework Directive that aims on a holistic government of the aquatic environment.

Keywords: Valuation, non-market goods, integrated groundwater management

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1 Introduction

The provision of water for drinking purposes is a very central issue in Denmark. In Denmark 99 percent of drinking water comes from groundwater which has not been treated more than trough simple oxygenation processes. The current Danish groundwater policy is based on protection - cleaning of water (water treatment) is basically unwanted and only allowed a few places due to local lack in sufficient water supply (cf. Andersen et al. [1], Danish Environmental Protection Agency [2]). A valuation study on the effects of Danish options for groundwater protection is carried out, and the results from this study can be used in the further work to obtain "standard" values of different water uses in Denmark. More details on this study can be found in Hasler et al [3].

The valuation study has its' point of departure in different scenarios for how good drinking water quality can be obtained, now and in the future. The two most prevalent ways are to either protect the resource of natural groundwater or to clean/treat water which exceeds the border values for pollution.

Protection of the groundwater resource results in secondary benefits in the shape of the positive effect on biodiversity in and around lakes and watercourses, i.e. the living conditions for animals and plants are affected by groundwater protection. Purification of polluted groundwater will not have these positive, secondary effects. Both good drinking water quality and good conditions for the living conditions for flora and fauna are mainly public and non-marketed goods.

2 Objectives and hypotheses

The provision of drinking water and other use-water from tap water has a price in Denmark, and in average Danish households pay 530 EUR annually for water supply. This price is not a market price, though, as it is set by the municipalities with the aim to cover the costs of drinking water supply. Consequently, the value of the goods created by groundwater protection has to be derived by valuation methods. The non-marketed value of the effects of protection of the groundwater resource are estimated comprising the value of both clean drinking water protection and the secondary effects of protecting freshwaters and the flora and fauna therein. This value of protection is compared to the estimated benefits of purification of polluted groundwater.

One of the hypotheses in this study is that consumers prefer clean groundwater, which is not in need of purification or other treatment, to water that has been polluted and treated to clean, thereafter. This brings along that the willingness to pay (WTP) for groundwater protection exceeds the WTP for purified water. By valuation we analyse these preferences and assess' the strength of them.

Another hypothesis is that the value associated with clean drinking water exceeds the value associated with good quality of surface waters. The rationale behind is that clean drinking water influences human health and hence private goods more directly than the quality of surface waters does.

3 Valuation of non-marketed benefits by the choice experiment method

The choice experiment (CE) method was, like the other Choice modelling (CM) techniques, originally developed for market analysis (Batsell & Louviere [4]; Louviere [5]). The methods have been increasingly used and further developed for the valuation of non-marketed goods, though. (Adamowicz [6], Boxall et all [7], Hanley et al. [8], Hanley et al. [9], Hanley et al. [10]). In a CE study, respondents are asked to choose between sets of pre-defined alternatives which each are connected with different implementation costs, drinking water quality, other environmental impacts, etc. Respondents are requested to select their preferred alternative and, in contrast to the CV method, 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 WTP. Respondents are, hereby, provided with an explicit basis for assessing costs in relation to effects and, therefore, the method is recommended in complex situations, where the good has several characteristics, referred to as 'attributes'. 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 respondents in a situation more reflective of real market conditions than with other forms of valuation exercise - all things being equal. In other words the choice situation is created to resemble a market situations that respondents are used to in everyday life.

To approach the valuation as a market choice the CE-method describes public goods in terms of the attributes, defining the goods and attribute levels. 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 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. [11]; Bateman et al. [12])

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). The attributes in the present study are drinking water quality, surface water quality and costs.

The probability of an alternative being chosen can be expressed in terms of the logistic distribution, and the WTP is estimated as the marginal rate of substitution between the attributes and the monetary attribute.

4 The scenarios for groundwater protection

The valuation of groundwater protection versus purification of water in the present study is based on scientific and monitoring results from literature on groundwater, as well as from consultation of water experts. We have utilised information from these sources to establish relevant scenarios or alternative policies and indicators for the valuation of effects of groundwater protection and use of groundwater in the future.

Consequently, the alternatives, which respondents are asked to choose between in the CE, each represent different policy proposals concerning future groundwater resource management options. The alternatives are defined by three attributes; two qualitative attributes related to the effects of different management options in relation to the quality of drinking water and the aquatic environment, respectively, and one quantitative attribute specifying the cost/price of the option. The inclusion of the monetary attribute is necessary in order to facilitate the derivation of monetary estimates of the value that respondents attach to the qualitative effects of different management options.

All the choice sets comprise a status quo alternative and two other alternatives varying between increased protection, purification of polluted groundwater for drinking water purposes and living conditions for plants and animals. More specific, the status quo scenario describes the situation as it is now and in the future if no further measures are anticipated. The protection alternative assumes a more comprehensive protection of the groundwater resource compared to the present protection, so that further contamination and pollution of groundwater are prevented. The purification alternative assumes that polluted water is treated and purified, and used for drinking water supply.

The attributes describing the alternatives (policy alternatives) are chosen to reflect the effects on good characteristics that is used and perceived by the population, i.e. drinking water and surface water quality.

The choice of attributes, and proper attribute levels, are done by consulting former water valuation studies as well as by focus group testing. One result obtained in focus group interviews in the present study was that respondents related more confidently to qualitative indicators than to quantitative. Among others the reason for this were that some of them did not trust the politically decided border limits, and because quantitative indications of pollution and effects on flora and fauna were found to be more cognitive demanding to relate to and understand than the qualitative indicators. The quantitative indicators just seemed as numbers, which the respondents couldn't relate properly to and would thus only serve to confuse the respondents. One of the reasons for choosing qualitative indicators is therefore that they intend to increase the likelihood that the respondents understand the constructed scenario. The second reason is that these qualitative indicators do not confuse respondents too much 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. Consequently, the basic purpose of the specifications of the indicators in this study is to emphasise general and overall perspective of groundwater protection.

5 The questionnaires

The valuation is performed by postal questionnaires sent out to 900 respondents, and the response was approximately 74%. Beside choice questions the respondents answered background questions on habits and attitudes, and to secure that the respondents have the same minimum level of information a background information sheet was enclosed to the questionnaire as well.

In addition to the information sheet the attributes were defined before the presentation of the choice sets, to inform the respondents of the attributes, the attribute levels and the scenarios. The wordings used in the description of the different attributes and levels was 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. More information about the design of the study can be found in Hasler et al [1].

6 Analysis and results

To get a preliminary impression of the respondent's preferences, we look at the answers to some of the qualitative questions in the questionnaire. After have being carrying out the choice exercise, the respondents were asked to mark what they put greatest weight upon during the exercise. The distribution of answers is shown in Figure 1.

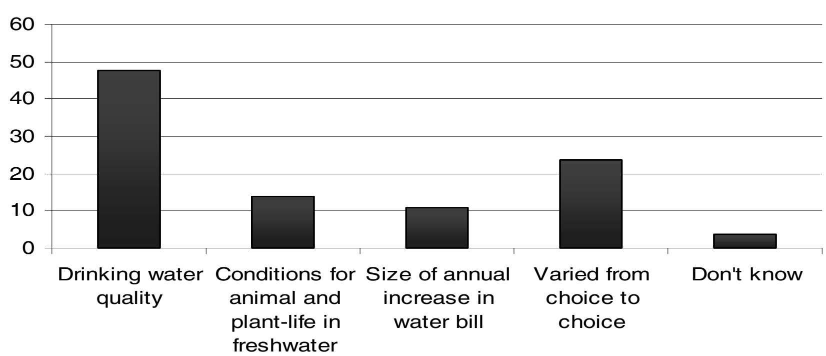

Figure 1: Respondents' weightings

Figure 1 shows that the respondents foremost have put weight upon drinking water quality thus confirming the hypothesis that the value associated with clean drinking water exceeds the value associated with good quality of surface waters. The other hypothesis was that consumers prefer clean groundwater, which is not in need of purification or other treatment, to water that has been treated. Figure 2 shows the distribution of the respondent's attitudes towards this. The figure shows that almost half of the respondents favour natural clean groundwater compared to treated water and thus also leaves the impression that the hypothesis is confirmed.

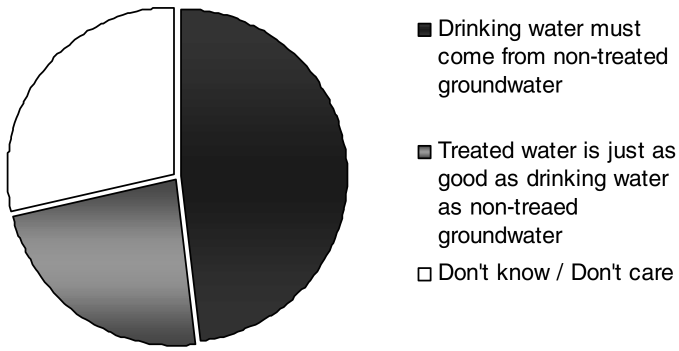

Figure 2: Attitudes, drinking water

The econometric analysis was carried out using a conditional logit model. This model is based on the utility function described in formula 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:

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

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.

The main effects have been estimated, where the dependent variable is the probability that the respondent chooses or not chooses an alternative. The results are presented in table 1. The estimates in this model are based on a change from the status quo situation that equal an uncertain quality of drinking water and less good conditions for animal and plant-life in watercourses and lakes.

The model includes an alternative specific constant, which is associated with disutility, and this parameter we interpret 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.

Table 1. Main effects

	Parameter		Std. error	WTP (EUR)
	-0.00056	***	0.0958	
Alternative specific constant	-0.3504	***	0.0000	
Natural clean groundwater	1.0288	***	0.0834	245
Purified groundwater	0.4791	***	0.0815	114
Very good conditions	0.6380	***	0.0634	152
Bad conditions	-1.0298	***	0.0724	-245
N	10.050			
Log L	-3,186.46			
χ^2	987.78			
Adjusted pseudo R^2	0.133			

Significance levels at 1%, 5% and 10% are indicated by three, two and one asterisk(s), respectively. WTP are converted from DKK to EUR by a factor 7.5

As apparent from table 1, the WTP for protected groundwater which is naturally clean and not in the need for purification, is 245 EUR/year, which should be interpreted as an additional payment to the average water bill for a household, being approximately 530 EUR/year. The WTP for good conditions for flora and fauna in waterways and lakes is 152 DKK/year, and the WTP for purified water is 114 DKK/year. In other words the hypothesis that WTP for protection exceed the WTP for purification holds, and so does the hypothesis that the WTP for drinking water quality exceed that for surface water quality.

Al 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 0.13. 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. [13], is considered as extremely good fit.

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. We have recognised that 45 of the 652 respondents have 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. If these 45 respondents are removed from the sample the results of the estimation is as shown in table 2.

Table 2. Effects without dominant choice

	Parameter		Std. error	WTP (EUR)
Price	-0.00059	***	0.0000	
Alternative specific constant	-0.7285	***	0.1018	
Natural clean groundwater	1.1205	***	0.0882	253
Purified groundwater	0.5381	***	0.0852	122
Very good conditions	0.7105	***	0.0661	161
Bad conditions	-1.0379	***	0.0737	-235
N	9,222			
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

Only the alternative specific constant is highly influenced by the omission of these respondents. At the same time the adjusted pseudo R^2 changes from 0.13 to 0.19, which indicate a better model-fit. These respondents are therefore omitted from the estimations.

After the omission the WTP for protected groundwater which is naturally clean and not in the need for purification, is 253 EUR/year. The WTP for good conditions for flora and fauna in waterways and lakes is 161 EUR/year, and the WTP for purified water is 122 EUR/year.

The WTP has furthermore been analysed in connection to self reported (un)certainty. The question of uncertainty was presented as a choice of 7 levels arranged on a Lickert scale, and the depicted distribution could be a symptom of anchoring to the middle answer. Dividing the sample in 7 sub samples according to the certainty level makes it possible to estimate parameters for each certainty level. The estimations indicate that WTP increase with increasing level of certainty.

7 Conclusions and discussion of the results

Estimations of the willingness to pay for groundwater protection and the resulting effects on drinking water quality and surface water quality have been conducted. Significant WTP estimates are obtained which show that the Danish population has strong preferences for natural clean water, i.e. clean groundwater that is protected from pollution. This preference is followed by preferences for good conditions for plant and animal life, and subsequently preferences for purified water. Qualitative statements in the questionnaire confirm these econometric estimations of preferences as well.

The estimated WTP for protected and naturally clean groundwater, not in the need for purification, is 253 EUR/year. The WTP for good conditions for flora and fauna in waterways and lakes is 161 EUR/year, and the WTP for purified water is 122 EUR/year. In other words the hypothesis that WTP for protection exceed the WTP for purification is not rejected, and the analysis also indicates that the WTP for drinking water quality exceed that for surface water quality.

Only one Danish study has previously investigated WTP for groundwater protection. Jensen et al. [14] asked respondents to value several environmental problems, and as part of this study the respondents were asked how much they were willing to pay for substantially reduced groundwater pollution. The study did not elucidate WTP for purification versus protection. The willingness to pay for groundwater protection was between 135 –285 EUR /year, where the lower and upper bounds were elicited by an open-ended and closed ended payment format, respectively.

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