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Economic valuation of drinking water quantity and quality: A literature review

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A literature review

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Abstract

This literature review is a part of the research project *Risk-based prioritization of water protection in sustainable spatial planning* (WaterPlan), funded by the Swedish research council Formas. The aim of the project is to enable well-informed analyses and prioritization of measures for protecting water sources as a part of future urban development. One key to prioritization is knowledge about the economic values of drinking water quality and quantity. The purpose of the literature review is therefore to map earlier studies of such values, and to use this mapping for (a) evaluating the opportunities to transfer results from earlier studies to a Swedish setting, and (b) learning from earlier experience how potential new primary valuation studies in a Swedish setting could be designed.

The literature review allowed some main valuation situations among the studies to be identified. Based on these different situations, the following rough categorization of studies was performed:

i. Improvements in water quality/quantity (10 studies)
ii. Preservation of water quality/avoiding water quality deterioration (5 studies)
iii. Avoiding quantity restrictions/ensuring stable supply (6 studies)
iv. WTP to reduce risks to drinking water sources (5 studies)
v. Meta and benefit transfer studies (8 studies)
vi. National valuation studies (6 studies)

The report includes a listing of all identified studies according to this categorization.

The results from the literature review indicate that there is a lack of suitable value estimates to allow for benefit transfer to Swedish conditions to evaluate the drinking water service in relevant policy scenarios. It is therefore concluded that new valuation studies might be needed for fulfilling the objectives of the WaterPlan project.

One possible approach for carrying out new valuation studies is to follow the demand function approach. This approach is therefore reviewed, but it is found that the approach entails some important weaknesses for the case of Sweden. One important reason is that there is not an actual well-functioning market for drinking water in Sweden. The report therefore also reviews the use of stated preference studies for valuing drinking water quantity and quality. This review indicates experiences that can be helpful in the development of new valuation studies in Sweden which follow the stated preference approach.

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1. Introduction

1.1 Background

This literature review is a part of the research project *Risk-based prioritization of water protection in sustainable spatial planning* (WaterPlan), funded by the Swedish research council Formas. The aim of the project is to enable well-informed analyses and prioritization of measures for protecting water sources as a part of future urban development. Access to drinking water of good quality is fundamental to a sustainable society. In addition to providing drinking water, water resources constitute a necessary part in the supply of other goods and services, such as food products, energy and cultural and aesthetic resources. Human activities, increased water demand and climate change create significant risks for water resources. For long-term water protection, various actions are implemented in accordance with Swedish and EU legislation and norms, e.g., water protection areas (WPAs). A deficiency in prioritization and design of risk reduction measures in Sweden is a lack of a basis to motivate the measures, considering positive and negative effects on society. Major parts of the WaterPlan project are: (1) characterization of drinking water sources and identification of services, risks and effects; (2) economic valuation of protective measures for drinking water sources based on value transfer and primary valuation studies; and (3) economic decision analysis of water protective measures. This literature review belongs to part 2 of WaterPlan.

1.2 Purpose and delimitation

The purpose of the literature review is to map earlier studies of the economic value of drinking water quality and quantity, and to use this mapping for (a) evaluating the opportunities to transfer results from earlier studies to a Swedish setting, and (b) learning from earlier experience how potential new primary valuation studies in a Swedish setting could be designed.

A delimitation for the review is a focus on economic values of drinking water quality and quantity. As indicated above, drinking water sources such as surface freshwater bodies and groundwater aquifers, also provide a substantial number of other goods and services. A comprehensive list of all such *water system services* is compiled in another part of the project (see Gärtner et al. (In prep) and www.waterplanproject.org), but studies of the economic values of other water system services than the provision of drinking water have not been included in this review. Another delimitation is a focus on studies which has investigated people's preferences related to drinking water quality and quantity. This means that studies on the economic values associated with drinking water provision to businesses and the public sector are not covered by the review. See Sjöstrand et al. (2019) for an example of how economic consequences of water supply disruptions on different sectors in the economy can be estimated. Primary data on such economic consequences are currently being collected and analyzed in another research project (*Värdet av vattenförsörjning*, funded by Svenskt Vatten Utveckling), to be reported later in 2021.

1.3 Outline

The search for relevant literature has included economic valuation studies on drinking water quality aspects as well as quantity aspects. An extensive search process was pursued following a broad perspective regarding valuation methods, valuation scenarios and case study sites. The probing of literature resulted in a bundle of interesting drinking water valuation studies. These are listed in the Appendix together with a description of their overall scope and key results with respect to the purposes of the literature review. The findings are summarized and discussed in Chapter 2. One way to value changes in supplied tap water quantity is to estimate a demand function for tap water, based on tap water prices and people's actual tap water consumption, and deduce the change in consumer surplus from such an estimated function. This demand function approach, and its relevance in a Swedish context, is reviewed in Chapter 3. The final step in the literature review work focused on the design of valuation studies which has applied stated preference methods in a way that is likely to be of relevance for WaterPlan. The results of this final step are reported in Chapter 4.

The next and last section in Chapter 1 is a general introduction to methods for economic valuation of environmental change. Readers already familiar with such methods may skip this section and go directly to Chapter 2.

1.4 Methods for economic valuation of environmental change[1]

Welfare economics theory suggests that changes in people's well-being can be measured as economic values, revealed by their trade-offs between scarce resources. As a consequence, environmental change – manifested in, for example, an increased supply of a water system service – involves an economic value as soon as people are willing to make trade-offs between such a change on the one hand, and other resources, such as income or time, on the other hand. These trade-offs are typically measured as people's willingness to pay (WTP) for environmental improvements or for avoiding environmental damage. However, it is in some circumstances more appropriate to measure people's willingness to accept compensation (WTA) for environmental damage or no environmental improvement.

A number of valuation methods are available for estimating people's WTP or WTA for environmental change. For environmental changes that are about goods and services traded in markets, demand functions for such goods and services can be used for estimating WTP (see also Chapter 3). However, this is of limited help whenever one is dealing with environmental change affecting goods and services that contribute to human well-being without being traded at any market, such as many water system services. To still be able to identify and estimate economic values associated with such non-market goods is a major methodological challenge. Most of the valuation methods developed for coping with this problem are found in either of two approaches: Revealed preference (RP) methods and stated preference (SP) methods.

The RP methods are based on the idea that information about people's preferences for environmental improvements can be obtained from their behaviour at markets for goods and services that somehow are linked to the environmental change in question. An example of an RP method is the travel cost method (TCM), which focuses on the costs of travel associated with people's use of the environment for recreational purposes. For example, the recreational value of angling might be estimated from data about people's

[1] For details about valuation methods and their welfare economics foundations, see, e.g., Freeman et al. (2014). Johnston et al. (2017) provide recommendations for how SP methods should be applied.

travels to and use of various fishing sites. Use might be measured by a catch variable. While it is often viewed as an advantage that a TCM study uses data about people's actual behaviour, TCM studies typically have to consider problems such as finding a reasonable value of the opportunity cost of time, accounting for substitute recreational sites and adjusting for the fact that a travel might have more than one purpose.

While survey instruments such as mail or web questionnaires, telephone interviews and face-to-face interviews might be necessary for obtaining RP data, SP methods usually rely completely on the use of such instruments and in most cases on hypothetical market behaviour. That is, actual market transactions, including payments, do not take place. Two common SP methods are the contingent valuation (CV) method and choice experiments (CE). A typical CVM application involves a description of a valuation scenario involving an environmental change in relation to a reference alternative. This description is communicated to a usually random sample of individuals, followed by questions about respondents' WTP for a realization of the valuation scenario. The CV method thus focuses on obtaining information on people's preferences for a whole scenario, i.e., the consequences of a particular environmental change. The CE method is different in the sense that it is based on descriptions of the valuation scenario in terms of individual attributes that characterize the environmental change. This allows the analyst to obtain information about people's preferences not only for the whole valuation scenario, but also for the individual attributes. This can be an advantage when assessing policies that in fact can deliver different levels of the attributes. On the other hand, the CE method introduce additional methodological complexities in comparison to the CV method.

SP methods are widely used, but has also been subject to much criticism, not least because of their hypothetical nature; no actual market transactions involving real trade-offs are taking place. However, the hypothetical nature of SP methods provides a possibility to estimate potential economic values associated with non-use of the environment, such as the well-being derived from the mere knowledge of the existence of an environmental resource. Ignoring such non-use values might introduce a systematic bias when policies are assessed in a cost-benefit analysis.

Sometimes economic values are estimated by using cost-based valuation methods, which neither belong to the RP approach nor the SP approach since they avoid the challenge of obtaining information about people's preferences. One commonly applied cost-based valuation method is the replacement cost method, which focuses on the costs of programs providing substitutes for goods and services provided by nature. Using the costs of starting to use an alternative water source for valuing a protective measure for the current water source might be an example. Another example might be the costs of manmade construction of flood protection measures along a river as a way of valuing the loss of moderation of water flows resulting from destruction of wetlands. The replacement cost method resembles the defensive expenditure method, which is an RP method using data on people's expenditure for protecting themselves against environmental damage, e.g., installing water filters as a protective measure against reduced tap water quality. However, in contrast to the replacement cost method, the defensive expenditure method makes use of people's actual market behaviour and thus have the capacity to say something about people's preferences. The fact that market behaviour does not constitute the basis for the replacement cost method means that its results at best are approximations of economic values. In general, the precision in such approximations is dependent on how well the following three conditions are fulfilled: (i) the substitute system provides functions that are equivalent in quality and magnitude to the resource it would replace; (ii) the substitute system is the least cost alternative way of replacing the resource; and (iii) individuals in aggregate would be willing to incur the replacement costs if the original resource was no longer available.

2. Valuation of drinking water quantity and quality

2.1 Structure and method

The literature review was primarily carried out in Google Scholar by using relevant search terms related to economic valuation of drinking water. The search terms which initiated the review can be retrieved in Table 1. Articles deemed relevant for the WaterPlan project, based on heading, abstract and journal, were saved and further scrutinized. Interesting studies cited in these articles were also investigated. Besides from the readable articles found at Google Scholar, some pertinent literature had already been identified at earlier stages in the WaterPlan project. These studies have also been reviewed and are included in this report.

Table 1. Terms used in initial literature search in Google Scholar.

Search terms	
price elasticity water Sweden	option value standby water supply
economic value reserve water	economic value standby water
willingness to pay back-up water	willingness to pay standby water
willingness to pay potable water reserves	willingness to pay reserve water supply
marginal user cost water	valuation water reserves
option value water	roy brouwer drinking water
replacement cost water resources	roy brouwer meta
replacement cost water	roy brouwer meta water
willingness to pay reserve water	wtp good quality drinking water
willingness to pay water reserves	willingness to pay good quality drinking water
willingness to pay unexploited water	wtp drinking water sanitation
valuation of reserve water sources	wtp preservation of water quality
willingness to pay water reserves	wtp break domestic water supply
option value standby water	wtp avoid interruption domestic water supply
option value standby water source	wtp to avoid pollution drinking water tap

2.2 Findings from the literature

Based on the broad literature review of WTP studies related to quality and quantity aspects of drinking water supply, some main valuation situations among the studies were identified. Based on these different situations, the following rough categorization of studies was performed (the number of studies within each category is presented inside brackets and the listing of studies in the Appendix is presented according to this same categorization).

i. Improvements in water quality/quantity (10 studies)
ii. Preservation of water quality/avoiding water quality deterioration (5 studies)
iii. Avoiding quantity restrictions/ensuring stable supply (6 studies)
iv. WTP to reduce risks to drinking water sources (5 studies)
v. Meta and benefit transfer studies (8 studies)
vi. National valuation studies (6 studies)[2]

[2] Note that the six studies listed under "National studies" are also listed under one of the previous categories.

That is, the studies could be divided into those focusing on improvements in drinking water quality or quantity, where the drinking water source at the case study site typically is contaminated or in another way negatively affected by human activities. The second and third categories contain studies focusing on the opposite situation, i.e., preservation of a good water quality/quantity and avoiding water quality deterioration or supply shortages. The fourth category comprises literature estimating people's WTP to reduce different risks to drinking water sources, the fifth is about meta and benefit transfer studies and the last category includes valuation studies with a national sample of respondents. The latter category was included to further investigate the possibilities of carrying out a national valuation study within the WaterPlan project.

A variety of valuation methods have been applied in the previous drinking water valuation literature, although SP methods are most common. The most frequently used SP methods are Contingent Valuation (CV) and Choice Experiment (CE) methods. A couple of studies applying the SP framework have also utilized so called "water quality ladders" to describe the different levels of water quality to the respondents (see Carson & Mitchell, 1993 and Martin-Ortega & Berbel, 2010). For example, the highest water quality could then be described as "drinkable", the middle one "swimmable" and the lowest level "boatable". Martin-Ortega & Berbel (2010) also combined their CE approach with a multi-criteria analysis, more specifically the Analytical Hierarchy Process (AHP).

Some articles on drinking water valuation have used RP methods to carry out welfare analyses. McConnell & Rosado (2000) uses a logit regression model and Roibas et al. (2018) introduced a set of sufficient conditions with respect to the utility function which allows for evaluation of compensating or equivalent surpluses. These conditions can then be used to compare the welfare losses associated with supply cuts. Alcubilla & Lund (2006) use, for example, stochastic optimization to estimate the WTP of households for changes in a combination of probabilistic water supply reliability and retail price of water.

2.3 Discussion

The results from the broad literature review indicate that there is a lack of suitable WTP estimates to allow for benefit transfer to Swedish conditions to evaluate the drinking water service in relevant policy scenarios. Findings in previous meta-studies support this indication: Brouwer et al. (2009) concluded that provisioning services, including drinking water, is not as well represented as other water services and Reynaud & Lanzanova (2017) only found 25 observations for the provisioning services "water for drinking" and "water for non-drinking purposes".[3] In addition, according to the results from the literature review, many CV and CE studies have been carried out in developing countries. The conditions at those study sites are characterized by poor drinking water quality and supply in general, i.e., not in resemblance to the typical drinking water situation in Sweden. Beaumais et al. (2014) found in an international survey that 92 % of respondents from Sweden stated that they were satisfied with the quality of their tap water. Moreover, most of the previous studies are very case study specific, focusing on a particular drinking water

[3] As a comparison, the authors found many more observations for different recreational services, e.g., 265 for "fishing" and 183 for "boating". For regulation and maintenance services, Reynaud & Lanzanova (2017) identified 206 observations, where the majority of the economic values focused on the service "maintaining populations and habitats".

source or population, e.g., drinking water supply in a specific region or city. This impedes the possibility for benefit transfer, since the conditions at the case study area where the valuation study originally was performed, and those at the case study area where the estimates are to be transferred, should resemble each other as much as possible. These conclusions suggest that for fulfilling the objectives of the WaterPlan project, there might be a need for carrying out primary valuation studies in Sweden, to enable proper monetary valuation of the drinking water service.

There are however several interesting observations and recommendations to be found in the previous SP literature, which should be considered when carrying out novel primary valuation studies. For example, Magat et al. (2000) and Rolfe & Windle (2005) concluded that people are willing to pay for water quality improvements with low or zero probabilities of use, and for keeping reserve water sources (which are not to be used for the time being). This suggests that there are, possibly significant, non-use values related to the protection of drinking water sources, which are important to capture. Moreover, studies have found that the value of a certain improvement in water quality is not independent of where it takes place. That is, location matters, which is important to keep in mind when constructing valuation scenarios in both CV and CE surveys. Also, people's willingness to pay depends on the baseline water supply service option, i.e., the reference alternative, and not only on the supply option considered, as well as on the socio-economic conditions of the consumers (Gunawardena et al., 2017).

Another challenge when carrying out a valuation study which focuses solely on the drinking water service, is to enable for separation of the value of this specific service from other services provided by the drinking water source. This could be a challenge. For example, if one asks for the WTP to accomplish some level of water quality for a water source, or to avoid the risk of contamination, respondents might associate this level of water quality or avoided risk with the provision of different services such as the possibility to drink it, swim in it or good conditions for aquatic animals.

As previously mentioned, a couple of studies have utilized water quality ladders in their choice experiment surveys where water activities such as "fit for boating" and "fit for drinking" are used to describe the different levels of water quality to the respondents. Although this is an appealing approach since it allows for estimation of values for different services and at what water quality levels these are provided, like all methods, it involves some issues. Magat et al. (2000) and Martin-Ortega & Berbel (2010) discuss a few of these. For example, it cannot be ruled out that the respondents already have pre-defined preferences regarding some of the water activities used to describe the water quality levels and these preferences might not be consistent with the ranking suggested by the water quality ladder. How various levels of drinking water quality can be described in a valuation scenario is further investigated in Chapter 4.

3. The demand function approach

Water demand modelling might contribute to the understanding of market and non-market use values related to drinking water (Reynaud, 2015). Such knowledge supports decision-makers and other stakeholders in the management of drinking water sources e.g. concerning water protection measures or policies aiming to incentivise sustainable water usage. Water demand functions also provide tools for carrying out welfare analysis (Reynaud, 2015). For example, welfare effects from pricing policies can be approximated by analysing changes in consumer surplus, see the example below (Figure 3.1).

3.1 Findings from the literature

A couple of previous studies have estimated household water demand functions in Sweden, of which the oldest one is a study conducted by Hanke and de Maré in 1982. The authors used pooled cross-section series data in an Ordinary Least Squares (OLS) analysis, assuming a linear relationship amongst the variables. The data was collected between 1971-1978 for a sample of 69 single family houses in the city of Malmö. The dependent variable was quantity of metered water per house, while the explanatory variables were real marginal price of water, real gross income per house, number of adults per house, number of children per house, rainfall, and a dummy variable for the age of the house. The estimated price elasticity was -0.15. Around 15 years later, Höglund (1999) used annual community level data for 282 communities in Sweden, covering the years 1980-1992, to estimate a household demand function for water. By using panel data methods, static and dynamic demand functions were estimated showing a long-run price elasticity of -0.10 for marginal price models and -0.20 for average price models. Höglund (1999) noted that consumers might be more likely to respond to average prices, because the default information provided to consumers are typically total cost incurred and total quantity consumed, and not marginal prices.

The most recent study on Swedish drinking water demand functions can be found in the report "Modelling Household Water Demand in Europe", from 2015. In this report, Reynaud (2015) estimated household water demand functions for each of the EU-28 countries along with a new set of price elasticities. The estimations were carried out by using a new dataset on household water consumption and household water prices for the EU-28 countries with a NUTS 3-level (county) resolution. For Sweden, the data included water consumption in m^3 per capita, water prices, climate conditions, household income and socioeconomic conditions for the year 2010. Most of the data were collected from Statistics Sweden and the Swedish Water & Wastewater Association. As water price, Reynaud (2015) applied the user charge for a normal house (inclusive of VAT).[4] To estimate the residential demand function Reynaud (2015) chose a double-log model:

$$\ln(y) = \alpha \ln(p) + \beta \ln(I) + \gamma \ln(Z)'$$

where α, β and γ are regression coefficients to be estimated, of which α and β can be interpreted as the price elasticity of water demand and the income elasticity of water demand, respectively. The chosen specification of the demand function implies that these elasticities are constant. The variables y, p, I and Z refer to water consumption per capita

[4] "A normal house is a detached family house with 5 rooms, bathroom with toilets, laundry room, extra toilet room and a garage. Floor area is 150 m^2 including garage 15 m^2, garden area 800 m^2. The annual water consumption is 150 m^3 of water. The property is assumed to be connected to water, wastewater and stormwater." (Reynaud, 2015, p. 211).

or household (y), unit price (p), household income (I) and a vector of exogenous variables (Z) assumed to influence water consumption (climate conditions, housing and household characteristics, etc.).

Two models were run, one simple OLS model and one with an instrumental variable approach where the two instruments considered were (i) share of water used by non-household users and (ii) the logarithm of the average size of municipalities. The estimated price elasticities, both significant, were −0.28 for the simple OLS model and −0.58 for the instrumental model. According to the author, the model performs relatively well for most of the municipalities.

As another example of a demand function for drinking water, Brozović et al. (2007) proposed the following specification of an inverse demand function, also assuming a constant price elasticity:

$$P(Q) = \exp\left[\frac{\ln(Q)}{h} + C\right]$$

where P is price, Q is quantity, h is the price elasticity of demand, and C is a constant of integration. This specification has been used by Sjöstrand et al. (2019, 2020) for valuation of water delivery disruptions in Sweden, assuming elasticities of −0.378 (mean price elasticity for developed countries as estimated by Sebri, 2013) and −0.2 (following the average price models of Höglund, 1999).

To value the effect of disruptions on residential water consumers the inverse demand function, $P(Q)$, is integrated yielding consumer's willingness to pay (WTP) to avoid water shortages (Brozović et al., 2007). The WTP to avoid any water shortage equals the area under the demand curve between the unrestricted consumption quantity and the restricted quantity, which is also equivalent to the loss in consumer surplus due to the shortage. The expression derived by Brozović et al. (2007) for the daily loss in welfare W for residential water consumers is as follows:

$$W = \frac{\eta}{1+\eta} \cdot P_{baseline} \cdot Q_{baseline} \cdot \left[1 - \left(\frac{BWR}{Q_{baseline}}\right)^{\frac{1+\eta}{\eta}}\right]$$

where W is the loss of welfare per capita/day, $P_{baseline}$ is the average water price if no interruptions, $Q_{baseline}$ is the average amount of water consumed per capita/day if no interruptions, BWR is the basic water requirement, which is the minimum amount of water required for drinking and personal hygiene per capita/day, and η is the price elasticity of water demand.

By using the proposed equation by Brozović et al. (2007), together with Swedish water prices and quantity data from 2015, Sjöstrand et al. (2019) estimated the loss in welfare when water supply decreases from an average consumption of 160 litre/capita/day, to the BWR level of 25 litres/capita/day. The average water price used was 0.035 SEK per litre. The loss in welfare is presented in Figure 3.1. It is the blue shaded area under the demand curve (and above the average price of 0.035 SEK/litre).

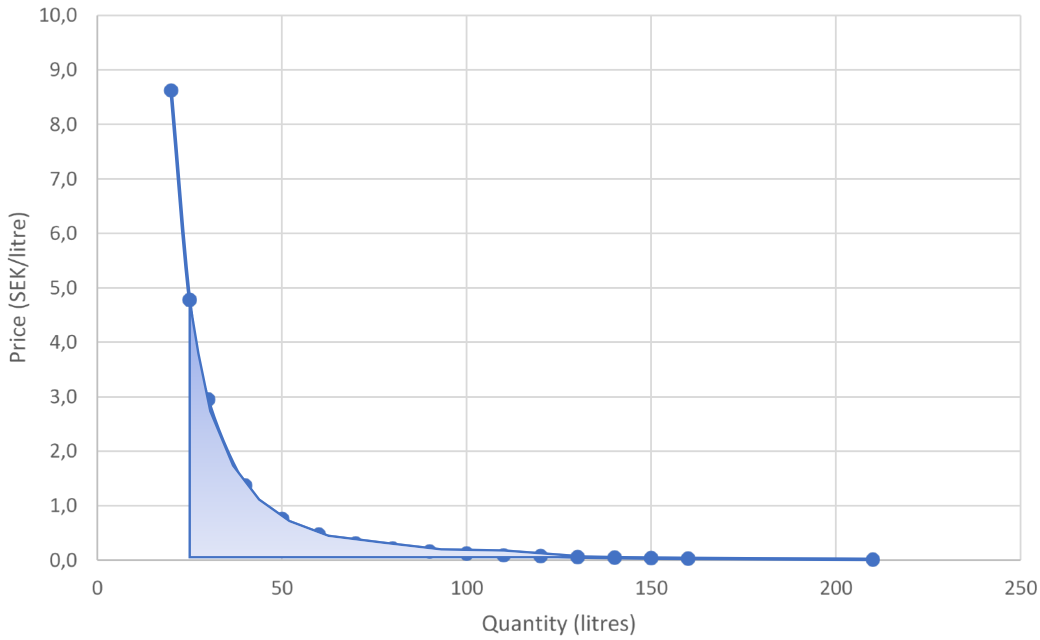

Figure 3.1. Estimated change in welfare for residential consumers by going from a water supply of 160 litre per capita/day to BWR, equivalent to 25 litre per capita/day. (Sjöstrand et al., 2019).

The estimated welfare loss from the decreased water supply from 160 to 25 L/capita/day equates to 69 SEK per capita per day. However, it is not possible to derive consumer's WTP for a reduction from the *BWR* of 25 litres per day (which is assumed to be secured by the municipality) to zero because the demand function is not defined for Q=0. Different approaches could be applied to find a proxy value for this loss in welfare, and Sjöstrand et al. (2019) used the cost of providing bottled water. This resulted in a total economic impact of water supply disruption for residential consumers amounting to 288 SEK per capita and day.

In general, household water demand functions are inelastic, implying that for every 1 % increase in price, water consumption decreases by less than 1 % (Reynaud, 2015). The same results can be found in most of the previous literature on water demand elasticities (e.g., see Schleich & Hillenbrand, 2007; Nauges & Thomas, 2002; Buck & Nemati, 2017). According to the three studies presented above, the same conclusion holds for water price elasticities in Sweden. For most studies on European water demand, price elasticities range from −0.2 to −0.4 (De Paoli et al., 2016), which is consistent with −0.378 as a mean estimate for developed countries in a meta-analysis of Sebri (2013).

Reynaud (2015) noted that there are significant differences in average water consumption per capita among the EU-28 countries, of which Sweden appears as one of the countries with a high level of household water consumption per capita (>60 m^3/capita/year). Besides Sweden, this is mainly the case for Southern European countries. When it comes to average water prices, Sweden belongs to the group of countries which are considered to have 'high' water prices for household users. Factors driving the differences in water prices include cost and quality of the water supply service, whether the cost-recovery principle is used (this is the case in Sweden), presence of subsidies and market regulations.

Moreover, previous literature shows that price elasticities vary depending on the time horizon i.e., short versus long run (see literature review in Reynaud, 2015). In the short run, elasticities tend to be smaller whereas long run elasticities are greater. This finding suggests that consumers need time to adjust their water usage as a response to changes in water prices. For example, they might not change their behaviour until they have learned how a price change affects their water bills.

3.2 Discussion

While the demand function approach is technically convenient, in particular when assuming a constant price elasticity of demand, and can be defended as the only reasonable option available if data are scarce, scholars point out some considerable problems using the demand function approach for welfare analysis. Firstly, a functioning competitive market for water does not exist in most countries, as is the case in Sweden where the cost recovery principle is applied (De Paoli et al., 2016). This means that the price level is set by water utilities to the cost of providing the water service, and it might be argued that it only corresponds to the minimum willingness to pay for the service. Also, many Swedish inhabitants is likely to tend to view the water supply as an abundant resource, instead of a scarce tradable resource, in particular because many households connected to the public water supply system are not individually metered. For these reasons, prices are not likely to directly influence the water demand in Sweden, resulting in lack of actual market transactions, i.e., transactions that are the results of the forces of supply and demand.

Secondly, water pricing structures usually have complex set-ups consisting of both fixed and variable costs (Arbués et al., 2003). The share of fixed costs embedded in the volumetric water price, generally stemming from high infrastructure costs, entails some theoretical problems when assessing welfare losses related to water supply disruptions (Buck et al., 2016). Normally, changes in consumer surplus are calculated to determine such welfare losses, but since a fixed cost is sunk when a disruption occurs, it has no bearing when analysing welfare outcomes. Buck et al. (2016) presents evidence suggesting that volumetric water prices mainly focus on fixed cost recovery.

Thirdly, the functional form of the water demand function substantially affects the outcome of welfare analyses. For example, in previous studies, a common approach has been to apply a constant price elasticity of demand when modelling water demand functions. To assume a constant elasticity is technically convenient, but in reality, the price elasticity might vary along the demand curve, i.e., for different quantities of water supplied.

In conclusion, the review of the demand function approach suggests some weaknesses in this approach when applied to a Swedish context. Firstly, there is not an actual functioning market for water in Sweden. While Reynaud (2015) showed that relationships between quantity and price still can be estimated, interpreting it as a demand function giving information about consumer surplus is problematic in a Swedish context since the estimation is not based on market behaviour data.

Secondly, the lack of market behaviour data also makes it difficult to assess if the technically convenient assumption of a constant price elasticity of demand is reasonable.

For example, the shape of the demand function suggested by Brozović et al. (2007) is very sensitive for the size of the price elasticity at relatively low levels of water quantity. This is illustrated by Figure 3.2, in which the demand curve is plotted using two different estimates of the price elasticity. The first one, −0.2, is from the Swedish study by Höglund (1999) and the second one, −0.378, is from the meta study by Sebri (2013). The figure shows the resulting considerable difference in the shapes of the demand curve at low values of *Q*, which also affects the size of the consumer surplus at low values of *Q*.

The discussion above suggests that alternatives to the demand function approach should be explored for the case of Sweden. Two main options are 1) to use benefit transfer or 2) to carry out new primary SP studies. The findings in Chapter 2 suggested that the former is not a promising option. It is therefore of particular interest to learn from earlier SP studies how such studies can be designed, and this is reviewed in the next chapter.

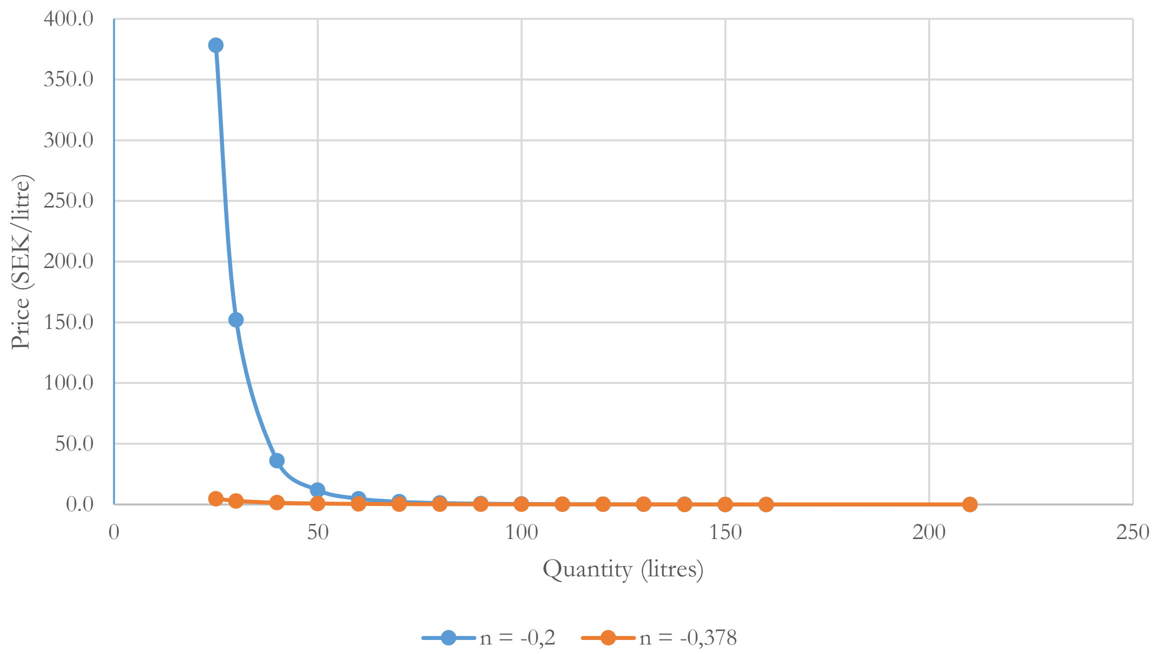

Figure 3.2. Illustration of the shape of the demand curve, presented by Brozovic et al. (2007), when using two different price elasticities (Höglund, 1999, vs. Sebri, 2013).

4. Design of stated preference studies

In this chapter, we review the design of stated preference (SP) studies, such as contingent valuation (CV) and choice experiments (CE), that are particularly relevant in a Swedish decision context and whose design might therefore be helpful in the development of primary studies in Sweden.

4.1 Introduction

A specific decision situation that is of considerable relevance in a Swedish setting and thus for the WaterPlan project is the introduction or enhancement of a water protection area (WPA, *vattenskyddsområde*). In this situation, important environmental changes that are expected to be relevant to value are reduced risks for (i) undiscovered contaminants in tap water, (ii) acute temporary presence of contaminants implying disruption of tap water delivery, (iii) less drinking water supply because of activities involving soil sealing, drainage, etc., and (iv) negative impact on the environment due to, e.g., contaminants. Reducing such risks entail in turn a reduced risk for having to introduce drinking water treatment of contaminants and possibly also a reduced risk for having to start using an alternative but hitherto un-used drinking water source. The introduction or enhancement of a WPA could thus involve securing the provision of safe and good quality drinking water in both near and far future and also protecting the water source environment and associated water system services. Hence, both use values and non-use values might be associated with the introduction or enhancement of a WPA.

Given a WPA setting, the review was further focused on (1) how the valuation scenarios in the SP studies were designed, and (2) SP studies having a nationally representative sample of respondents. The former focus was motivated by the fact that details about how the different valuation scenarios were designed and described will be informative for developing SP studies to be applied in Sweden. Relevant previous studies have been scrutinized in terms of, for example, descriptions of the valuation scenarios, assumptions made, survey design and recommendations. The latter focus is because the effects of a water protection measure such as WPA might be homogenous enough to allow for national SP studies, and the experience gained through such national studies is therefore of interest.

4.2 Findings from the literature

The studies included in the review were identified following a comprehensive literature search in Google Scholar (see Chapter 2) and by using the 'snowball method'[5] to elicit previous SP studies with valuation scenarios relevant in a Swedish context and for the decision situation of interest in WaterPlan. The studies examined in more detail included: Hasler et al., 2005, 2007; Beaumais et al., 2014; Adamowicz et al., 2011; Genius et al., 2008; and Tanellari et al., 2015, where the two latter ones are "local" case studies whereas the first three have a national perspective. The original list consisted of additional literature, of which some were deemed irrelevant due to dissimilar settings / conditions at a closer glance and some due to their considerable age. These were: Schultz & Lindsay, 1990; Sun et al., 1992; Rolfe & Windle, 2005; Powell et al., 1994; and Jordan & Elnaghee,

[5] The snowball method is a way of identifying literature by using a key document, e.g., an article or a report on the subject of interest as a starting point.

1993. We begin by having a look at the national studies and subsequently list some observations related to the valuation scenarios for the studies having a local focus.

4.2.1 National studies

The objective of the national study by Hasler et al. (2005, 2007) was to estimate the benefits of groundwater protection to assess whether there are welfare gains associated with increased protection of groundwater resources, compared to the current level of protection and to purification of groundwater for drinking water purposes. Groundwater is a crucial resource in Denmark because 99 % of the country's drinking water supply stems from groundwater. The focus was on the groundwater resource in Denmark as a whole, and not on local groundwater pollution issues. To determine the benefits of groundwater protection Hasler et al. (2005, 2007) carried out a CV and a CE study where they asked Danish consumers about their WTP for different scenarios involving groundwater protection and purification of drinking water. Groundwater quality as such was not described in the scenarios, because the groundwater resource was judged to be too abstract for laymen (despite the almost total reliance on this resource for drinking water in Denmark). Instead, focus was placed on two goods affected by groundwater use and protection: Drinking water quality and surface freshwater quality. Qualitative indicators were chosen for both these goods, because focus group testing indicated greater confidence in qualitative indicators than in quantitative ones, and that qualitative indicators of effects on flora and fauna were less demanding cognitively than quantitative ones. Overall, testing indicated that experts asked for more detailed information whereas non-experts were satisfied with the general approach to the groundwater pollution issue.

Three quality levels were described for each of the two goods and examples of describing expressions used for each level are given for each quality level:

- Drinking water quality:
    - Naturally clean
        - Prevent pollution, clean drinking water, secured
    - Uncertain
        - Ensure supply of clean drinking water today, uncertain supplies in future, a risk in future for tap water to exceed current limit values
    - Treated
        - Cleaning polluted groundwater, ensure supplies of clean drinking water now and in the future
- Conditions for animal and plant-life in watercourses and lakes
    - Very good
        - Natural, varied, in balance
    - Less good
        - Marked different from natural conditions, state of imbalance, representative of current situation
    - Poor
        - Significantly different from natural conditions, serious imbalance

In an information sheet about the freshwater aquatic environment, the price of water and groundwater pollution, no numbers with respect to current pollution or risks were included. Instead, words such as the following were included in the information: Polluted, most common reason, affects, impact on human health, poisonous for animals and plants, no precise knowledge, suspected to contribute to hormone disturbance, carcinogenic, under suspicion for having carcinogenic effect, too rich in nutrients, cloudy water, poor visibility, fish mortality in rare cases. However, the average price of water was stated in numbers: 35 DKK per m^3, 4000 DKK per household (1500 DKK per person) per year.

The valuation scenarios involved the following:

- The reference alternative:
  - "The current situation
    - At the moment, a range of measures is carried out with regard to protection of groundwater against pollution from pesticides and nitrogen. When a groundwater borehole is found to be polluted, it is closed and a new one is established.
    - It is uncertain whether clean drinking water can be provided in sufficient amounts by this method in the future. There is, therefore, a risk that tap water will exceed current limits for pesticides and nitrogen content in the future.
    - Conditions for animal and plant-life in watercourses and lakes are not so good. Animal and plant-life is in a state of imbalance in many places and is markedly different than would be so if conditions were natural. The primary reason for changes in the condition of the aquatic environment is human activity.
    - In the following, you will be presented with two proposals which could ensure clean drinking water, both now and in the future. For each proposal you will be asked to state your willingness to pay for the proposal to be implemented."
- "Proposal to secure naturally clean drinking water:
  - By carrying out measures, primarily in agriculture, naturally clean drinking water can be secured both now and in the future. At the same time, very good conditions can be secured for animal and plant-life in watercourses and lakes. This means that animal and plant-life will be more natural, varied and balanced, and affected by human activity to only a slight to average degree.
  - It is assumed that the Danish consumer should cover the costs of implementing the proposal. This will take place in the form of a fixed annual sum per household claimed once a year via the water bill.
  - What is the maximum price that your household would be willing to pay for this type of groundwater protection?"
- "Proposal to treat water:
  - Via treatment of polluted groundwater, pesticide and nitrogen residue can be removed, so that the treated water can be used as water for drinking and other purposes. In this way, clean drinking water can be provided both now and in the future. In contrast with the previous proposal, however, groundwater is not protected from pollution with pesticides

and nitrogen. Implementation of the treatment proposal will not involve improvements in conditions for animal and plant-life in watercourses and lakes, therefore, conditions will remain less than good. This means that animal and plant-life in watercourses and lakes will be markedly different than would be so under natural conditions and will be in slight imbalance.

- As previously, the costs connected with implementation of the proposal are to be covered by the Danish consumer in the form of a fixed annual sum per household charged via the water bill.
- What is the maximum price that your household would be willing to pay for treatment of groundwater so that it could be used for drinking water?"

In the CV study, the respondent was after each scenario asked to select one of ten monetary amounts or to state an amount himself / herself. In the CE study, the two goods and their associated quality levels (see above) were used as attributes and attribute levels together with a cost attribute having six different cost levels.

The following WTPs could be estimated:

- In the CV study, a WTP for obtaining *both* naturally clean groundwater and very good conditions for plant and animal life. In the CE study, a WTP for naturally clean groundwater separately and a WTP for very good conditions for plant and animal life separately. The sum of those separate WTPs per household in the CE study was more than 4 times higher than the WTP in the CV study (measured as mean WTP per household).
- In both the CV study and the CE study, a WTP for purified water. This WTP was almost twice as high in the CE study than in the CV study.

The second "national perspective" study examined was Beaumais et al. (2014). The authors estimated the WTP for better tap water quality based on a cross-section sample from 10 OECD countries, including Sweden. The survey was carried out by asking respondents whether they were satisfied with the quality of their tap water or not, and if they were drinking water from the tap or not. Respondents indicating that they were dissatisfied could also state whether they were more troubled about taste or health impacts (or neither of the two).

Of the total sample of respondents, only those who declared NOT to be satisfied with the current tap water were inquired about how much they would be willing to pay for an improvement. In particular, these respondents were asked to answer the following question: "*What is the maximum percentage increase that you would be willing to pay above your actual water bill to improve the quality of your tap water, holding water consumption constant?*"[6] (Beaumais et al., 2014). Sweden belonged to the group of countries with "high quality tap water", since 92 % of the Swedish respondents stated that they were satisfied with the quality of their tap water. Hence, many Swedish (and other) respondents were not asked to indicate their WTP for an improvement in tap water quality. This caused missing data on WTP observations, which could be regarded as a shortcoming of this survey design.

[6] There were six potential answers to the question, namely (1) nothing, (2) less than 5 %, (3) between 5% and 15 %, (4) between 16 % and 30 %, (5) more than 30 %, and (6) don't know.

A noteworthy observation from the study is that the "improvement" in the valuation scenario was not described in any detail regarding what level of improvement was to be accomplished or how this was intended to be achieved. This is probably because the data comes from the 2008 OECD Survey on Household Environmental Behaviour, which covers several topics related to, e.g., food and waste, except for people's attitudes and behavior regarding water. Hence, there was probably no room for any details.

The third "national" CV study explored in more detail was carried out in Canada by Adamowicz et al. (2011). The characteristics of the sample respondents were compared to those of the Canadian population to ensure proper representation. On average, the survey respondents showed very good compliance with Canada as a whole. In the study, Adamowicz et al. (2011) examined the value of health risk reductions related to microbial illnesses or deaths and bladder cancer illnesses or deaths, in the context of drinking water quality treatment in public water systems. The way in which the authors choose to describe the changes in health risks in the survey was of specific focus when reviewing this article.

In the CV scenario, total risk reductions were described to take place over a 35-year period for a community of 100 000 people. For cancer, the risk reduction consisted of 50 fewer cancer cases, of which 10 would have resulted in death. For microbials, the risk reduction consisted of 15 500 fewer microbial cases, of which 10 would have resulted in death. In the scenarios, the respondents were informed that symptoms of microbial illnesses would start soon after infection and that a death outcome would occur soon after infection. For bladder cancer, the respondents were informed that symptoms would take years before appearing and that a death outcome would occur within five years of symptoms. Symptoms of microbial illnesses and bladder cancer were also included in the information.

4.2.2 Local studies

The two "local" studies identified as having valuation scenarios possibly relevant from a WaterPlan perspecitve were Genius et al. (2008) and Tanellari et al. (2015). The aim of Genius et al.'s paper (2008) was to elicit the WTP of residents in Rethymno (Crete, Greece) for the completion of future projects that the Municipal Enterprise for Water Supply and Sewerage of Rethymno (MEWSS) intends to implement to improve the tap water quality and to avoid shortages. In Rethymno, the water supply is more or less continuous during off-season periods, but during the tourism intense months August and September the demand increases a lot. Because not all demand can be satisfied at the same time, this results in water cuts. This is aggravated in periods of draught when some farmers in particular areas use scarce water for irrigation purposes. Moreover, these water cuts have negative effects on the tap water quality supplied to the water consumers.

The authors used the CV methodology where the questionnaire consisted of four parts including an initial warm up part with questions concerning different issues of modern society. The second part included questions related to drinking water availability and already implemented measures to save water and prevent shortages. The third part focused on people's perceptions and attitudes towards water quality.

Following the third part was an information section clearly describing the proposed projects, the improved situation and the expected benefits coming from these projects. The bids were expressed as a percentage increase in the water bill since any additional fees charged by the municipality are calculated on the basis of percentage increases of the bill. The percentage increases were directly converted to money amounts by using the average water bill to ease the understanding of the percentage increases of the respondents. Finally, they were asked for the maximum amount they were willing to pay.

Respondents answering with a zero bid were also asked some debriefing questions to find the motivations for the zero response. By doing this, the authors could separate respondents with zero WTP (real zeros) from protest voters, i.e., those who actually have a positive WTP but oppose one or several aspects of the valuation scenario. The last questionnaire section consisted of standard questions regarding socio-economic characteristics of the respondents.

The last SP study reviewed in more detail was a CV study conducted by Tanellari et al. (2015). They examined the determinants of consumers' WTP for improvement programs concerning three drinking water issues: (1) water quality (2) pinhole leaks in home plumbing infrastructure, and (3) aging public infrastructure. The respondents consisted of water consumers in Northern Virginia and the Maryland suburbs of Washington, D. C. T. and the survey was distributed by e-mail.

People's WTP for improvements in water quality and infrastructure was estimated by letting the respondents choose between three different water improvement programs or alternatively, no program. For example, Program 1 aimed to further improve the quality of water in terms of taste, odour, colour, and safety. It was described as follows:

"*Your water utility tests the water multiple times a day and your water is of high quality. Suppose there is a program to further improve the quality (taste, odor, color, and safety) of your tap water supply. The cost of this program per quarterly billing cycle is shown in the table below. This cost would be in addition to your current water bill."* (Tanellari et al., 2015).

One appealing feature of this study was that the sample of respondents was randomly split into three separated subsamples where each group got different information set at the top of the survey containing facts about drinking water. This enabled the authors to estimate how different information sets affect the WTP for drinking water.

Moreover, one part of the article focuses on consumers' risk attitudes and perceptions toward water quality and infrastructure which is of interest since it relates to consumers' WTP for improvements. To reveal people's perceived risk and risk-related behaviour with respect to their tap water, the survey included a series of questions related to this. In particular, the respondents were asked to answer questions about their use of tap water: if they use their water for all household needs or if they limit their use to not include drinking and/or cooking. They were also asked if they use bottled water and/or other water treatment methods with the purpose of improving the safety of their water.

To capture the risk perceptions of the consumers based on their answers to the questions, an index was constructed that incorporating all answers. The risk index serves as a composite measure of risk and reflects the respondents' true perceived risk as it is based on actual consumer behaviour and beliefs concerning water safety issues.

4.3 Discussion

The SP studies reviewed above illustrate the substantial number of considerations that must be taken when designing valuation scenarios related to drinking water. One such consideration is the specification of a reference alternative to which the respondents are to compare the outcome of the valuation scenarios. It is crucial that the survey instrument is able to make the respondents understand that the WTP that they are stating is about the consequences of the valuation scenario in comparison to the consequences of the reference alternative, which is not necessarily equal to today's situation.

Another consideration is the description of consequences. Two of the national studies reviewed above showed a considerable difference in this respect in the sense that Hasler et al. (2005, 2007) used qualitative descriptions of consequences, whereas Adamowitz et al. (2011) described risk reductions in quantitative terms (reduced number of cancer cases including reduced number of risks). The latter approach is the generally preferred option in SP studies because of its higher precision (Johnston et al., 2017), but still involves the risk that respondents differ in how they perceive the quantitative information, possibly in a systematically biased way. This implies that independent of how consequences are described, pre-testing is necessary for ensuring that respondents understand the descriptions in an appropriate way. Questions could also be included in the final survey instruments that aim at checking respondents' understanding.

Describing risk reductions can be expected to be particularly challenging because they are combinations of probabilities and outcomes. One simplifying option might be to ask respondents to only value the outcome, cf. the formulation in Hasler (2005, 2007) that drinking water treatment *ensures* that there are supplies of clean drinking water now and in the future. When using respondents' WTP for assessing a treatment policy that after all does not imply a 100 % probability of clean drinking water now and in the future, some kind of adjustment of the WTP has to be made. One option for the policy assessment is to compute the benefit of the policy by multiplying the WTP for the outcome with an appropriate probability, say 0.9, but it should be observed that this way of calculating the benefit of a risk reduction might not give the same result as asking for people's WTP for an outcome that occurs with a 0.9 probability. This is because the latter (i.e., risk valuation ex ante, see Freeman et al., 2014) take into account respondents' preferences with respect to risk, whereas the former (i.e., risk valuation ex post) does not.

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Appendix: WTP studies related to drinking water quality and quantity

The studies listed below are described with respect to their overall scope and key results. Please note that the descriptions of scope and key results are *directly* reproduced from the articles. Occasionally, some minor adjustments of the article text were made to make it more concise, yet still understandable for the reader.

A.1 Improvements in water quality / quantity

Martin-Ortega, J. & Berbel, J., 2010. Using multi-criteria analysis to explore non-market monetary values of water quality changes in the context of the Water Framework Directive. Science of the Total Environment, vol. 408, pp. 3990–3997. https://doi.org/10.1016/j.scitotenv.2010.03.048

Scope: The research presented here builds on a recent line of investigation that combines monetary stated preference tools, in this case a choice experiment, with multi-criteria analysis, in this case the Analytical Hierarchy Process (AHP). We argue that the AHP can contribute to a better understanding and interpretation of the choice experiment results by exploring the criteria involved in respondents' trade-off between the attributes. The AHP provides relevant insights for the application of use-based water quality ladders in the valuation of environmental benefits in the context of the WFD.

An innovate choice experiment has been applied here using maps to elicit non-market welfare measures for water quality improvements, and accounting for the different water quality levels and the spatial distribution of the improvements.

Key results: One important aspect of the water quality ladder is that it implies a certain hierarchy of the water uses that are associated with the levels of water quality. For example, in Carson and Mitchell's water quality ladder, the lowest quality level corresponded to 'boatable water', the second level to 'fishable water' and the highest to 'swimmable water'. It was assumed that fishable water required a better quality than boatable water. However, it cannot be ruled out that the public has pre-existing preferences regarding some of these water uses.

Our results have some implications for the use of the water quality ladder as a tool for the estimation of non-market benefits of the WFD related water quality improvements. We found that the valuation of certain quality changes could have been influenced by the preferences that respondents held for the water uses that functioned as indicators for quality.

The AHP also proved that the location of the environmental change matters to the public. The value of a certain improvement in water quality is not irrespective of where it takes place. This supports the argument that there is a spatial heterogeneity of preferences: environmental benefits of the water quality improvements will not be homogeneously distributed throughout river basins.

Magat, W.A., Viscusi, W.K. & Bell, J., 2000. An Iterative Choice Approach to Valuing Clean Lakes, Rivers, and Streams. Journal of Risk and Uncertainty, vol. 21(1), pp. 7-43. https://doi.org/10.1023/A:1026565225801

Scope: This article introduces an iterative choice procedure for valuing inland water quality. This approach breaks up the valuation into a series of component tasks. The water quality ladder approach is not valid empirically. Consequently, respondents in Colorado and North Carolina assessed the value of making water quality rated "good" by EPA, which has a value of $22.40 per additional percent improvement.

Key results: People are willing to pay disproportionately high values for water quality improvements with low or zero probabilities of use. Whether such non-use values reflect cognitive limitations given the survey task or valid underlying preferences remains an open question.

In their contingent valuation study of the quality of fresh water, Mitchell and Carson (1989) used water quality rankings on an ordinal scale from zero to ten. […]. By using a single ladder, gradations in water quality can be converted into a single dimension. The cognitive difficulties for respondents in terms of the thinking about water quality consequently will be less than if they have to consider a multi-dimensional good in which each of the attributes may change independently of one another. However, the ladder becomes a scientifically invalid characterization in contexts where the implied hierarchical ranking does not in fact hold. Put differently, the ladder cannot be used to assess the values of shifts in values that violate the hierarchy.

Kataria, M. et al., 2011. Scenario realism and welfare estimates in choice experiments – A non-market valuation study on the European water framework directive. Journal of Environmental Management, vol. 94, pp. 25-33. https://doi.org/10.1016/j.jenvman.2011.08.010

Scope: Using choice experiment data for economic valuation we analyse how disbelief in survey information could affect the retrieved welfare estimates.

Key results: We find that although the majority of respondents agree with the described status quo level, there is a non-negligible probability that some respondents disagree. In particular, approximately 25 per cent of the respondents perceive the current water quality to be worse than presented in the survey information.

It is of course crucial in development of a survey only to include policy scenarios that are realistic, but people will always have different opinions, i.e. dispersed beliefs, on what is realistic or not, especially when it comes to complex environmental change […].

The problems we have discussed can partly be reduced through thorough preparation of the survey that allows scenarios perceived as unbelievable to be avoided, but when dealing with complex environmental issues there will always be inherent risks that survey information is perceived differently than intended, and correcting for the bias is important for further use in welfare economic assessments.

Brouwer, R, 2006. Valuing water quality changes in the Netherlands using stated preference techniques. In D. Pearce (Ed.), Environmental Valuation in Developed Countries (Case Studies) (pp. 132-147). Cheltenham, UK: Edward Elgar.

Chapter not accessible.

Jordan, J.L., & Elnaghee, A.H., 1993. Willingness to Pay for Improvements in Drinking Water Quality. Water Resources Research, vol. 29(2), pp. 237-24. https://doi.org/10.1029/92WR02420

Scope: In this paper, data from a 1991 survey of Georgia residents were used to study people's willingness to pay (WTP) for improvements in drinking water quality.7 The contingent valuation method was used to estimate WTP using a checklist format.

Key results: The median estimated WTP was $5.49 per month above their current water bills for people on public systems and $7.38 for those using private wells, after rejecting outliers and using the maximum likelihood method.

Vásquez et al., 2009. Willingness to pay for safe drinking water: Evidence from Parral, Mexico. Journal of Environmental Management, vol. 9, pp. 3391–3400. https://doi.org/10.1016/j.jenvman.2009.05.009

Scope: A referendum-format contingent valuation (CV) survey is used to elicit household willingness to pay responses for safe and reliable drinking water in Parral, Mexico. Households currently adopt a variety of averting and private investment choices (e.g., bottled water consumption, home-based water treatment, and installation of water storage facilities) to adapt to the existing water supply system. […].

Key results: Results indicate that households are willing to pay from 1.8% to 7.55% of reported household income above their current water bill for safe and reliable drinking water services, depending upon the assumptions about response uncertainty.

Genius, M., Hatzaki, E., Kouromichelaki, E. M., Kouvakis, G., Nikiforaki, S. & Tsagarakis, K. P., 2008. Evaluating Consumers' Willingness to Pay for Improved Potable Water Quality and Quantity, vol. 22, pp. 1825–1834. https://link.springer.com/content/pdf/10.1007/s11269-008-9255-7.pdf

Scope: The aim of this work is to elicit Rethymno residents' willingness to pay (WTP), by applying the CVM methodology, as the percent over their water bill, for the completion of future projects that the Municipal Enterprise for Water Supply and Sewerage (MEWSS) of Rethymno intends to implement to avoid shortages and improve tap water quality.

Key results: The mean WTP for these future projects was estimated to be 10.64 € (17.67% of the average bill).

Latinopoulos, D., 2014. Using a choice experiment to estimate the social benefits from improved water supply services. Journal of Integrative Environmental Sciences, vol., 11 (3-4), pp. 187-204. https://doi.org/10.1080/1943815X.2014.942746

Scope: The major focus was to assess the WTP for water supply improvements, aiming also to provide benefit estimates for both drinking water quality and water availability issues. The case study for this research was the municipality of Nea Propontida, in northern Greece, where serious problems of water quality and quantity have been experienced for a number of years.

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[7] Note that the study focuses on the risk of nitrite contamination.

Key results: The results of a CL model showed that the average household's WTP for ensuring good water quality is almost EURO 95.6/year. This corresponds to about 40% of the existing water bills, as well as to about 60% of current averting expenditures in the study area. The average WTP for addressing the problem of water supply interruptions is found equal to about EURO 12/year/household, corresponding to about 5% of current water bills.

It is difficult to compare in detail these results with those from similar studies in other countries due to differences in hydrological and climatic conditions, in actual water supply services, as well as in the socio-economic, institutional and cultural environment.

Concerning the positive side-effects of water supply improvements on agriculture, the present work contrasts with previous studies (Hanley et al. 2006), which have documented a positive utility on protecting agricultural income or jobs. In fact, this study shows that respondents expressed a strong reluctance to pay for this attribute, indicating the higher priority that should be given to the domestic use of water in the study area.

Beaumais, O., Briand, A., Millock, K. & Nauges, C., 2014. What are Households Willing to Pay for Better Tap Water Quality? A Cross-Country Valuation Study. FEEM Working Paper No. 24.2014. https://hal.archives-ouvertes.fr/hal-02430307/document

Scope: We estimate willingness to pay (WTP) for better quality of tap water on a unique cross-section sample from 10 OECD countries.

Key results: On the pooled sample, households are willing to pay 7.5% of the median annual water bill to improve the tap water quality. The highest relative WTP for better tap water quality was found in the countries with the highest percentage of respondents being unsatisfied with tap water quality because of health concerns.

In the survey, respondents were asked whether or not they were satisfied with the quality of their tap water and whether or not they were drinking water from the tap. Respondents who declared being dissatisfied could indicate whether they were more concerned about taste or health impacts (or neither of these).

Only those respondents who declared NOT being satisfied with their tap water were asked how much they would be willing to pay for improvement. More precisely, the analysis of respondents' WTP for better tap water quality is based on the answer to the following question: "What is the maximum percentage increase that you would be willing to pay above your actual water bill to improve the quality of your tap water, holding water consumption constant?".

The "high quality tap water" group includes the Netherlands (95%), Sweden (92% of respondents satisfied with their tap water) and Norway (90%).

McConnell, K.E. & Rosado, M.A., 2000. Valuing discrete improvements in drinking water quality through revealed preferences. Water Resources Research, vol. 36 (6), pp. 1575-1582. https://agupubs.onlinelibrary.wiley.com/doi/pdf/10.1029/2000WR900043

Scope: We show how nonmarginal benefits from higher drinking water quality can be measured doing a standard welfare analysis, where the parameters for the analysis are obtained through a nested logit model structured according to the defensive inputs available for drinking water treatment.

Key results: The estimated parameters show that households in Espirito Santo, Brazil are willing to pay, on average, $3 per month to have safe drinking water. This estimate means that if the urban water system could provide water with similar potability as boiled water, the average household would be willing to pay around $3. The estimates relate only to the households who are connected to the water system but do not have continuous 24-hour service

A.2 Preservation of water quality / avoiding water quality deterioration

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. 176 pp. NERI Technical Report no. 543.
https://www2.dmu.dk/1_viden/2_Publikationer/3_fagrapporter/rapporter/FR543.PDF

Note: English Questionnaire can be found in Annex 3.

Scope: This report covers a valuation study where Danish consumers' willingness to pay for groundwater protection and purification of drinking water is assessed.

Key results:

Tabell 1. WTP-results from CE and CV, expressed in DKK/year. (From Hasler et al., 2005, p. 14).

	CE	CV
Naturally clean groundwater	1 899	711 (joint for both attributes)
Very good conditions for plant and animal life	1 204	
Total	**3 104**	**711**
Purified water	**912**	**529**

Rolfe, J. & Windle, J., 2005. Valuing options for reserve water in the Fitzroy Basin. AARES, vol. 49 (1), pp. 91-114.
https://onlinelibrary.wiley.com/doi/pdf/10.1111/j.1467-8489.2005.00265.x

Scope: The key focus of the present paper is to estimate option values associated with reserving water in the Fitzroy Basin. For this purpose, the target was to estimate option values separate to use values and existence values. Choice Modelling (CM) experiments were used for this purpose, where one of the component attributes was framed in a way to explicitly capture option values. These CM studies have presented water development in terms of a number of associated social and environmental attributes. One of those attributes, 'amount of water in reserve', has been framed in terms of assessing option values.

Key results: The individual WTP values elicited in the survey were annual payments to be paid for a 20-year period. The results suggest that Brisbane respondents are prepared to pay $A9.36 for each 1 per cent of water reserve in the Comet/Nogoa/Mackenzie (CNM) system. Survey respondents were informed that current reserves in the CNM system (the 40 000 megalitres (ML) identified in the Fitzroy WRP) equated to approximately 4 per cent of the system. For the Dawson system, respondents were willing to pay $A2.24 to preserve each 1 per cent of water reserve. The total reserves in the Dawson were nominated as being 10 percent of water resources in the valley. For the Fitzroy system, respondents were willing to pay $A1.52 to preserve each 1 per cent of water reserve. The total reserves in the Fitzroy were nominated as being 15 per cent of water resources in the basin.

This means that the value of preserving all of that reserve was $A22.80 per household per year. Total willingness to pay was approximately equivalent across the Fitzroy and Dawson catchments, but the values were much higher in the CNM valley where there were smaller reserves of water. As expected, this implies that marginal values appear to be higher as reserves become diminished.

The experiment results presented in the present paper represent one approach to the estimation of option values as a separate component of non-use values. By describing the retention of water in reserve as an available option in the CM experiments, the intention was to specify preference trade-offs and, hence, values, for an option value concept. However, there were a number of practical and theoretical issues that made it difficult to demarcate the attribute clearly in this way.

Cerda, C., Ponce, A. & Zappi, M., 2013. Using choice experiments to understand public demand for the conservation of nature: A case study in a protected area of Chile. Journal for Nature Conservation vol. 21 (3), pp. 143-153. https://www.researchgate.net/deref/http%3A%2F%2Fdx.doi.org%2F10.1016%2Fj.jnc.2012.11.010

Scope: We conducted a choice experiment for the economic valuation of benefits of components of biodiversity that are provided by the natural systems protected in the Peñuelas Lake National Reserve, located in the Mediterranean zone of Chile. […]. Specifically the attributes of the study were the following: existence of endemic orchid species; chances of observing animals with scenic attraction; additional protection for an endemic amphibian; and, availability of drinkable water in the future. A rate of entry to the area was incorporated to estimate WTP for additional protection for the selected attributes. WTP data were obtained from a representative sample of Chilean tourists that visit the area. Factors influencing the visitors' WTP were also explored. Three hundred and four Chilean visitors of the reserve were randomly selected for interviews.

Key Results: Multinomial Logit and Random Parameter Logit models results show that visitors are willing to pay to protect the selected attributes. Marginal mean WTP/visitor for the single levels of variation of the attributes range from about $1.7 per visitor per visit for securing the existence of five species of endemic orchids to about $8.9 for guaranteeing the availability of drinkable water for 50 years.

Tanellari, E., D. Bosch, K. Boyle, & E. Mykerezi, 2015. On consumers' attitudes and willingness to pay for improved drinking water quality and infrastructure. Water Resour. Res., vol. 51, pp. 47–57.
https://agupubs.onlinelibrary.wiley.com/doi/pdf/10.1002/2013WR014934

Scope: This paper examines the determinants of consumers' willingness to pay for improvement programs for three drinking water issues: water quality, pinhole leaks in home plumbing infrastructure, and aging public infrastructure. The research is based on a mail survey of consumers in Northern Virginia and the Maryland suburbs of Washington, D. C. T.

Key results: Results indicate that the willingness to pay for any of the programs is negatively affected by the cost of the proposed improvement. Consumers' risk perceptions, the external information provided in the survey, and whether they read the annual report from their water utility affect consumers' willingness to pay for improvement programs.

Xu, L., Yu, B. & Li, Y., 2015. Ecological compensation based on willingness to accept for conservation of drinking water sources. Frontiers of Environmental Science & Engineering, vol. 9, pp. 58–65.
https://link.springer.com/article/10.1007/s11783-014-0688-3

Scope: We established an ecological compensation accounting system based on respondents' willingness to accept (WTA).

Key results: The average WTA value for Miyun Reservoir residents was approximately 1186 CNY per family in 2012, which could be set as a suitable compensation standard, since it is slightly higher than the local protection cost. The results suggest some useful information for establishing ecological compensation mechanisms for conservation of drinking water sources.

A.3 Avoiding quantity restrictions / ensuring stable supply

Roibas, D., Garcia-Valiñas, M.A. & Roberto Fernandez-Llera, R., 2018. Measuring the Impact of Water Supply Interruptions on Household Welfare. Environmental and Resource Economics, vol. 73, pp. 159–179.
https://doi.org/10.1007/s10640-018-0255-7

Scope: In this paper, we propose a set of sufficient conditions with respect to the utility function that allows for the evaluation of the compensating or equivalent variations/surpluses associated with changes in goods' quality, even if those goods are considered to be essential for consumers. We use these conditions to compare the welfare losses associated with the water supply cuts implemented in Seville (Spain) to those that would result if water was instead rationed using price changes.

Key results: Our results reveal that a rationing method based on price increases would have had a lower impact on consumer welfare than the supply cuts that were actually implemented in Seville during the examined period. We develop a simulation analysis that suggests that the targeted reduction in consumption could have impact on welfare calculations.

In particular, the welfare difference favors the price rationing scheme in 18.44 e for the average household. This fact implies that the aggregate benefits of switching to this method amounts to approximately 3651000 e per quarter. On top of that, this figure would grow for large targeted reductions in water consumption.

Amponin, J.A.R. et al., 2007. Willingness to pay for watershed protection by domestic water users in Tuguegarao City, Philippines. Poverty Reduction and Environmental Management (PREM) Working Paper.
http://www.premonline.org/archive/5/doc/PREM%20WP%2007-06.pdf

Scope: This paper investigates the value that domestic water users in Tuguegarao City place on watershed protection. Using the Contingent Valuation Method (CVM), this study established the willingness to pay of domestic water users in Tuguegarao City. Payments would contribute to a fund that would provide for the watershed protection of the Penablanca Protected Landscape and Seascape (PPLS). This would help to ensure the provision of a reliable water supply for their households.

Key results: The study finds that domestic water users in Tuguegarao City have a positive willingness to pay to ensure a reliable water supply. This may possibly be used as potential revenue for watershed protection. Debriefing responses revealed that domestic water users do not directly relate the reliable water supply condition to watershed protection. Most households could not associate that water problems may exist due to deforestation and insufficiency of raw water during the dry season. Only a small number are even aware on where their water is sourced and what could possibly affect their water supply. Thus, the study could not directly say that the respondents are willing to pay for watershed protection services but rather for reliable water supply.

Metcalfe, P.J. & Baker, W., 2011. Willingness to Pay to Avoid Drought Water Use Restrictions. London School of Economics and Political Science Working Paper, London.
https://www.researchgate.net/profile/Paul_Metcalfe5/publication/299532651_Willingness_to_Pay_to_Avoid_Drought_Water_Use_Restrictions/links/56fd5ccd08ae1408e15b2d93.pdf

Scope: We investigate the value of avoiding drought water use restrictions in London, UK, by means of a stated preference survey of households and businesses that sought to measure willingness to pay for reductions in the chances, duration and severity of future restrictions. […]. The primary objective for this valuation was to appraise the benefits of a proposed desalination plant in East London – the Beckton plant – which would have a substantial impact on the chances of needing restrictions in future. A secondary aim was that the results could also be used to inform future water resource investment appraisals.

Key results: The findings indicate that customers attach a sizeable value to avoiding the most severe restrictions (including rota cuts to supply), but are much less concerned with lesser restrictions such as a hosepipe ban.

The principal output from the study was a quantitative model capable of providing welfare comparisons between asset strategies, given external data on the impact of those asset strategies on the expected numbers of days of restrictions over time. We applied our methodology and estimates to the appraisal of a desalination plant proposal in East London. The appraisal found that the benefits of the plant substantially exceeded the costs, and partly as a consequence, the plant was approved, and built, and began operating in June 2010.

It is well known amongst economists that scarcity-based pricing is a superior tool for rationing water during drought [Woo, 1995; Roibás, García-Valiňas and Wall, 2007; Grafton and Ward, 2008]. In many places however, including London, a majority of properties are not metered but rather are charged for water on an unmeasured basis. This precludes scarcity pricing, and so usage restrictions become the only means of rationing water. Measures of WTP to avoid drought water use restrictions are thus likely to continue to be useful despite the greater efficiency inherent in scarcity pricing.

Hensher et al., 2005. Households' Willingness to Pay for Water Service Attributes. Environmental & Resource Economics, vol. 32, pp. 509–531.
https://link.springer.com/content/pdf/10.1007/s10640-005-7686-7.pdf

Scope: In an attempt to establish how much customers are willing to pay for specific levels of service, we use a series of stated choice experiments and mixed logit models to establish the willingness to pay to avoid interruptions in water service and overflows of wastewater, differentiated by the frequency, timing and duration of these events. […].

Key results: The average water and sewerage bill for residential customers is A$759, which gives an average MWTP of 0.0547*759=A$41.51 […]. Since this is a marginal WTP, it means that customers are willing to pay, on average, approximately A$4.15 per year to reduce the frequency of interruptions by 0.1 - from 2 per year to 1.9 per year. The MWTP to reduce the frequency of interruptions decreases as the number of interruptions per year rises.

Tapsuwan, S., et al., 2007. Household willingness to pay to avoid drought water restrictions: A case study of Perth, Western Australia. Accepted Conference Paper Submitted to the 36th Australian Conference of Economists Hobart, September 2007.
http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.527.427&rep=rep1&type=pdf

Scope: This study examined consumer preferences for source development options and for avoiding outdoor water restrictions using choice experiments (CE).

Key results: The study found statistical evidence that if households were willing to move away from the status quo (a scenario in which they would have to endure severe water restrictions) they would be willing to pay 22 percent more on their water usage bill to be able to use their sprinklers up to 3 days a week. Additionally, on average, households would pay a higher water bill of approximately 50% more to finance a new source of supply instead of enduring severe water restrictions.

Alcubilla, R.G. & Lund, J.R., 2006. Derived Willingness-to-Pay for Household Water Use with Price and Probabilistic Supply. ASCE, vol. 132 (6).
https://watershed.ucdavis.edu/shed/lund/papers/Garcia2006.pdf

Scope: Stochastic optimization is used to estimate the willingness-to-pay (WTP) of individual households and groups of households for changes in a combination of probabilistic water supply reliability and retail price of water. By modeling the financial and "perceived" costs of implementing long- and short-term conservation options and assuming rational expected value cost minimizing behavior, economic demand curves for water and expected water use can be estimated for a household. Monte Carlo-simulation techniques are used to represent variability in the household model parameters and derive estimates of aggregate household WTP for water supply reliability, and demand curves for water and conservation measures.

Key results: The household's WTP to avoid a specific shortage probability distribution decreases as the retail price of water increases […] because higher price levels provide economic incentive to implement conservation options and reduce use voluntarily. These results are consistent with contingent valuation findings onwater supply reliability (Griffin and Mjelde 2000).

A.4 WTP to reduce risks to drinking water sources

Snowball et al., 2008. Willingness to pay for water service improvements in middle-income urban households in South Africa: A stated choice analysis. South African Journal of Economics, vol. 76 (4), pp. 705-720. https://doi.org/10.1111/j.1813-6982.2008.00209.x

Scope: Estimate WTP for improvement in water services (improved drinking water quality and reduced water supply interruptions) in South Africa.

Key results: 15.72% in addition to water bills for a decrease in bacterial quality from slight risk to no risk; 0.12% and 0.13% increase in their water bills separately for every reduction of one household experiencing water discoloration or interrupted water supply.

Schultz, S.D. and B.E. Lindsay, 1990. The Willingness to Pay for Groundwater Protection. Water Resources Research 26(9), 1869-1875. https://doi.org/10.1029/WR026i009p01869

Scope: To determine the willingness to pay (WTP) for a hypothetical groundwater protection plan in Dover, New Hampshire, a mail contingent valuation survey was conducted.

Key results: The median WTP value among Dover residents was estimated to be $40 per household, and the community WTP value is estimated to be at least $100,000 annually for a groundwater protection plan.

Sun, H., J.C. Bergstrom and J.H. Dorfman, 1992. Estimating the Benefits of Groundwater Pollution Control. Southern Journal of Agricultural Economics 24 (2), pp. 63-71. https://ageconsearch.umn.edu/record/29641

Scope: Sun, Bergstrom and Dorfman (1992) use CV to estimate the WTP to reduce pesticide and nitrate contamination of groundwater on a sample of households in Georgia, USA. Their estimate, which is very high, is based on an option value model.

Key results: The mean value on the sample is USD 641.

Adamowicz, W., Dupont, D. Krupnick, A. & Zhang, J., 2011. Valuation of cancer and microbial disease risk reductions in municipal drinking water: An analysis of risk context using multiple valuation methods. Journal of Environmental Economics and Management, Elsevier, vol. 61 (2), pp. 213-226, March. https://doi.org/10.1016/j.jeem.2010.10.003

Scope: We examine the value of health risk reductions (microbial illnesses/deaths and bladder cancer illnesses/deaths) in the context of drinking water quality treatment by public systems.

Key results: When we assume that combined mortality and morbidity risk reductions are equally spread in the future; our results suggest that microbial risk-reduction programs have higher value than cancer risk-reduction programs, but that mortality risk reduction values are not significantly different for cancer and microbials.

Powell, J.R., D.J. Allee, and C. McClintock, 1994. Groundwater Protection Benefits and Local Community Planning: Impact of Contingent Valuation Information. American Journal of Agricultural Economics, vol. 76 (5), pp. 1068-1075. https://doi.org/10.2307/1243393

Scope: Over 50% of the population of the northeastern United States relies on groundwater sources for its drinking water supplies. Groundwater contamination is becoming an important. […] The federal government lacks the resources and political will to pass national groundwater legislation and has turned the problem of protection over to the states (EPA). Many states, citing the importance of land use controls, have left it to local governments to solve the problem. Despite these difficulties, some communities have managed to implement effective groundwater protection policies. Is it possible to educate communities about contamination possibilities or use information to persuade them that prevention is more effective than remediation? The objective of this study was to investigate the use of contingent valuation (CV) information as a tool to persuade local government decision makers to implement water supply protection policies.

Key results: Respondents were told that a water supply protection district could be established and all those benefiting from such a district would be asked to pay by an increase in their water utility bills. Respondents were asked to circle a dollar range on a payment card (values ranged from $0 to $350) to indicate their annual household willingness to pay for increased water supply protection. Results of the survey revealed a mean WTP of $61.55/household/year (S.D. = 84.79; N = 1,006).

A.5 Meta and benefit transfer studies

Gunawardena, A., Zhang, F., Fogarty, J. & Iftekhar, S., 2017. Review of non-market values of water sensitive systems and practices: An update. Melbourne, Australia: Cooperative Research Centre for Water Sensitive Cities. https://watersensitivecities.org.au/content/review-of-non-market-values-of-water-sensitive-systems-and-practices-an-update/

Scope: This review presents the findings from an extensive survey of the literature on the key benefits and services delivered through the use of water sensitive systems and practices. The information is summarized in terms of major services: values associated with green infrastructure; ecological and environmental values of water; benefits of climate change mitigation; non-point source pollution reduction; flood hazard reduction; improved groundwater conditions; securing reliable water supply; and wastewater management. The review is primarily focused on non-market benefits, but in some cases estimates of market benefits (or tangible benefits captured through existing markets) and cost information are also presented.

Studies on water supply and pricing provide a comprehensive assessment of people's willingness to pay to ensure a reliable supply of good quality water. The review did not consider the standard economic analyses of income and price elasticities, but rather had a focus on non-market value estimates. The non-market value estimates reveal that people's willingness to pay depends on not only the supply option considered, but also the baseline water supply service option, and the socio-economic conditions of customers.

From the literature review, CV studies:

- In addition to the specific summaries of individual papers provided below, specific attention is drawn to **Van Houtven et al. (2017)**, which is a meta-analysis of estimates of household's willingness to pay for improved water supply. The study relies on 171 WTP estimates from 60 stated preference studies and found that predicted WTP values ranged from approximately $3 per month (with a 90% confidence interval (90% CI) of $1.1-$6.1) for modest improvements through to $33.5 per month (90% CI $17.9-$66.0) for more substantial improvements. Other general observations were that households where there was an existing high level of water supply services were willing to pay less.

- **Carson and Mitchell (1993**) estimated the national benefits of freshwater protection in the USA. Water quality was defined in increasing levels of quality as: fit for boating activities; fit for boating and fishing activities; and fit for boating, fishing, and swimming activities. Based on 813 survey responses the study found that the annual mean WTP per household to keep freshwater resources at a quality level suitable for: boating activity was $93; boating and fishing activity was $163; and boating, fishing and swimming activity was $241.

- The WTP of Canadians to support a program to repair water distribution and sewage treatment systems to prevent a decline in current water services was investigated in **Rollins et al. (1997).** Based on 1,511 household surveys across Canada the study estimated that the mean WTP to support a program to repair water distribution and sewage treatment systems to prevent a decline in current water services was about CA$26 per month in addition to household current water bills. The study claimed that as the differences of WTP among Canadian regions were not significant, the results of the survey can be used to estimate the WTP for the whole nation. On this basis the national WTP was estimated as CA$1.1 billion less than the amount required to cover the estimated marginal costs of maintaining, renovating, and upgrading water infrastructure to ensure adequate water services.

- **Dupont (2013)** reported results from a double bounded contingent valuation survey on people's willingness to pay to avoid summer water use restrictions by using reclaimed wastewater. They found that the mean WTP per household per year was between $142 and $155. The values depended on the scale of the project and expectations on neighbouring compliance with summer water use restrictions.

- The WTP of residents in ten districts in California, USA to avoid water shortages was investigated in **Koss and Khawaja (2001).** Using 3,769 completed survey the authors were able to establish that residents were willing to pay US$11.61 per month per household to avoid a 10% water shortage once every ten years; and US$16.92 per month to avoid a 50% shortage occurring every twenty years.

- **Hurlimann (2009)** conducted a survey on WTP per kilolitre (kL) of water among office workers in Bendigo bank head office, Australia in February 2007.

  The survey was conducted during a period of extreme water shortages in Victoria. Melbourne dam water storage was around 25%, and in Bendigo the situation was much worse. In 2007, with the Bendigo reservoir recorded its lowest ever storage level, which was 4%, and there were significant restrictions on local government water use to maintain public open green space due to water shortages. Because of the water shortage, water was being carted to and sold in the Bendigo region.

  The study found a mean WTP of AU$7.7/kL based on 305 responses. This value was around six times higher than the price of mains supplied water. The result was, however, within the retail price range for trucked water, which at the time was between AU$6.3 and AU$17.1/kL depending on water quality and the transportation distance. The research indicated that residents would be willing to pay prices several times higher than normal water price to avoid strict usage restrictions during drought periods. The study also demonstrated that the estimated WTP from studies can be a reasonable representation of the marginal price of water supplies.

- In **Laughland et al. (1996)** 226 households in Milesburg, Pennsylvania, USA were surveyed. At the time of the survey the local water supply was contaminated with Giardia. The authors found that households were willing to pay $18 per month in addition to their current water bills to connect to an alternative water source that would provide drinking quality water.

- **Howe et al. (1994):** Estimate the WTP for improved water service (supply reliability) in three Colorado towns.

- **Genius and Tsagarakis (2006):** Estimate the WTP of residents in urban areas to ensure a fully reliable water supply.

- **Polyzou et al. (2011):** Estimate citizens' monetary valuation for the improvement of tap water quality.

- **Cooper et al. (2011):** Estimate consumers' WTP to avoid urban water restrictions.

From the literature review, CE studies:

- **Blamey et al. (1999)** used a multinomial logit model to investigate preferences across 294 households in Canberra, Australia. Residents were faced with choices between using recycled water for outside use, construction of new dams, and water restrictions. Use of recycled water for outdoor use was the highest ranked water supply option among the choices. The mean WTP for the provision of recycled water for outdoor use was AU$47 per year. There was, however, a clear difference in preferences between using recycled water for drinking and using recycled water for outdoor use: residents had a clear preference for avoiding drinking recycled water.

- **Tapsuwan et al. (2007)**
  The article was already included in the literature review.

- **Hensher et al. (2005)**
  The article was already included in the literature review.

- **MacDonald et al. (2005):** Estimate the WTP for improved continuity of water supply.

- **Willis et al. (2005):** Estimate the benefits to water company customers of changes across various water service factors.

- **Snowball et al. (2008):** Estimate WTP for improvement in water services (improved drinking water quality and reduced water supply interruptions) in South Africa. 15.72% in addition to water bills for a decrease in bacterial quality from slight risk to no risk; 0.12% and 0.13% increase in their water bills separately for every reduction of one household experiencing water discoloration or interrupted water supply.

- **MacDonald et al. (2010):** Estimate WTP for improved reliability of household water services (reduced duration of water outage). The authors explore the use of choice modelling for obtaining implicit prices for attributes associated with changes in the reliability of household water services.

From the literature review, other studies:

- **(Buck et al., 2016)**
  The article was already included in the literature review.

- **Molinos-Senante and Sala-Garrido (2017)** used directional distance function approach to estimate monetary value for compensation for interruptions in drinking water supply. They used a balanced panel from the 23 main Chilean water companies over the period of (2010–2014). According to study findings, on average, customers should receive a compensation of €0.135 for each hour of unplanned water supply interruptions.

Reynaud, A. & Lanzanova, D. A, 2017. Global Meta-Analysis of the Value of Ecosystem Services Provided by Lakes. Ecological Economics, vol. 137, pp. 184-194. https://doi.org/10.1016/j.ecolecon.2017.03.001

Scope: This study presents the first meta-analysis on the economic value of ecosystem services delivered by lakes. A worldwide data set of 699 observations drawn from 133 studies combines information reported in primary studies with geospatial data.

Key results: We provide an estimation of the average value of ecosystem services provided by lakes: between 106 and 140 USD$2010 per respondent per year for non-hedonic price studies and between 169 and 403USD$2010 per property per year for hedonic price studies.

On average, the values we find for ecosystem services provided by lakes are higher than the ones reported by Brouwer et al. (1999) for wetlands.

For provisioning services, we have only 25 observations for the "water for drinking" and the "water for non-drinking purposes" services.

Since some services may depend on water quality (e.g. drinking water) whereas others may rely more on the quantity of water available in the lake (e.g. flood control), we include as moderator the type of scenario used in the primary study to infer lake values. In particular, we make the distinction between a scenario of change in lake water quantity and a scenario of change in lake water quality.

Brouwer, R. et al., 2009. Economic Valuation of Environmental and Resource Costs and Benefits in the Water Framework Directive: Technical Guidelines for Practitioners. AquaMoney. https://www.researchgate.net/profile/Julia_Martin-Ortega/publication/265287734_Economic_Valuation_of_Environmental_and_Resource_Costs_and_Benefits_in_the_Water_Framework_Directive_Technical_Guidelines_for_Practitioners/links/5491fd9a0cf2484a3f3e0862/Economic-Valuation-of-Environmental-and-Resource-Costs-and-Benefits-in-the-Water-Framework-Directive-Technical-Guidelines-for-Practitioners.pdf

Scope: Existing non-market valuation studies were collected, and their results synthesized in a meta-analysis. The results presented here focus on contingent valuation studies of different ecosystem services provided by water resources. 154 contingent valuation studies were collected and reviewed that estimate values for ecosystem services related to surface water quality.

Key results: The ecosystem service that is best represented in the data is non-use value related to preservation or improvement in water quality unrelated to any current or potential future use of the resource. Direct use values related to water are also well represented in the studies. These are mainly related to recreational activities. Provisioning services such as drinking water and irrigation are less well represented. This arguably reflects the priorities for water use at the locations where valuation studies have been conducted.

From the 54 selected studies that provide complete information on all the explanatory variables that we include in the statistical meta-analysis we are able to code 388 separate value observations.

The estimated coefficient on the water quality change variable is very small and positive but not statistically significant. One would expect the scale of change in water quality to positively influence willingness to pay for the change, but we do not find evidence of this. […]. The coefficient on the base water quality variable is negative and statistically significant at the 1% level, indicating that WTP for water quality improvement is lower when water quality is already high. The corollary is that the public is willing to pay more to improve bad water quality.

Gunawardena, A., Iftekhar, S. & Fogarty, J., 2020. Quantifying intangible benefits of water sensitive urban systems and practices: an overview of non-market valuation studies. Australian Journal of Water Resources, vol. 24 (1), pp. 46-59.
http://www.scopus.com/inward/record.url?scp=85084218705&partnerID=8YFLogxK

Scope: The monetary value of intangible benefits can be estimated using non-market valuation techniques. Here, we provide a review of over 190 existing non-market valuation studies related to water sensitive urban systems and practices that have reported dollar value estimates for intangible benefits. The empirical evidence suggests that communities are willing to make financial contributions towards projects that deliver intangible benefits.

Key results: Several studies on water supply and pricing provide a comprehensive assessment of public preferences for a reliable supply of good quality drinking water. The value estimates reveal that people's willingness to pay depends on the supply option considered, the baseline water supply service option, and the socio-economic conditions of customers (Beaumais et al. 2014; Buck et al. 2016; Cook, Kimuyu, and Whittington 2016; Del Saz-Salazar et al. 2016).

MacDonald, D. H., M. D. Morrison, and M. B. Barnes. 2010. Willingness to Pay and Willingness to Accept Compensation for Changes in Urban Water Customer Service Standards. Water Resources Management, vol 24, pp. 3145-3158.
https://link.springer.com/article/10.1007/s11269-010-9599-7

Scope: In this paper, we explore the use of choice modelling for obtaining implicit prices for attributes associated with changes in the reliability of household water services.

Key results: The results indicate that respondents have implicit willingness to accept of $4.19 to increase the duration of an outage by one hour, and $29.10 for an additional outage. For the willingness to pay treatments, respondents were prepared to pay $0.15 to reduce the duration of an interruption by one hour and $4.05 to reduce the number of annual outages by one. For these attributes the willingness to accept measure exceeds willingness to pay, which is consistent with the literature.

Del Saz-Salazar, S., M. A. García-Rubio, F. González- Gómez, and A. J. Picazo-Tadeo. 2016. Managing Water Resources under Conditions of Scarcity: On Consumers' Willingness to Pay for Improving Water Supply Infrastructure. Water Resources Management, vol. 30, pp. 1723-1738. https://link.springer.com/article/10.1007/s11269-016-1247-4

Scope: This study uses the contingent valuation method in order to assess willingness to pay (WTP) by consumers in the Guadalquivir River basin in Spain for improving urban water supply infrastructure and reducing leakages.

Key results: On average, individuals would be willing to pay an extra charge on their water bill ranging from €8.23 to €9.65. In addition to the expected positive effect of income on WTP, respondents with negative perceptions of their drinking water quality as well as those most affected by the economic crisis have a lower WTP. Conversely, WTP is higher for men and respondents showing greater commitment to the environment.

Brouwer, R. & Neverre, N., 2018. A global meta-analysis of groundwater quality valuation studies. European Review of Agricultural Economics, vol. 47 (3), pp. 893-932. https://doi.org/10.1093/erae/jby043

Scope: A global meta-analysis consisting of almost three decades of groundwater quality valuation studies is presented. New in this study is the focus on the uncertainties surrounding different groundwater quality levels and the control included for groundwater contaminants originating from agriculture and other sources. Separate meta-regression models are estimated for the USA, Europe and the World, detecting sensitivity to scope and reference dependence.

F Public willingness to pay appears more sensitive to uncertainty in the baseline scenario than in the policy scenario. The high explanatory power of the estimated meta-regression models and low prediction errors provide confidence in their usefulness for reliable benefits transfer.

Bateman, I.J. et al., 2009. Making benefit transfers work: Deriving and testing principles for value transfers for similar and dissimilar sites using a case study of the non-market benefits of water quality improvements across Europe, CSERGE Working Paper EDM, No. 09-10, University of East Anglia. https://www.econstor.eu/bitstream/10419/48815/1/609263668.pdf

Scope: We develop and test guidance principles for benefits transfers. These argue that when transferring across relatively similar sites, simple mean value transfers are to be preferred but that when sites are relatively dissimilar then value function transfers will yield lower errors. The paper also provides guidance on the appropriate specification of transferable value functions arguing that these should be developed from theoretical rather than ad-hoc statistical principles.

Key results: The results presented in this paper provide straightforward principles for the application of benefit transfer. When transferring across similar sites, mean value approaches are to be preferred. When transferring across heterogeneous sites, value function transfers are preferable, and the specification of those functions should be restricted to include only those generic variables for which we have prior economic expectations.

A.6 National valuation studies

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. 176 pp. NERI Technical Report no. 543.
https://www2.dmu.dk/1_viden/2_Publikationer/3_fagrapporter/rapporter/FR543.PDF

Note: English Questionnaire can be found in Annex 3.

Scope: This report covers a valuation study where Danish consumers' willingness to pay for groundwater protection and purification of drinking water is assessed.

Respondents: A professional survey institute has been used in the pre-tests and the submission of the surveys. The institute has been chosen in order to secure a good response rate, using a panel of respondents which is representative of the Danish population. The institute GfK-Denmark (Growth from Knowledge) has been used. The questionnaires were sent to 1,800 households, 900 for the CV study and 900 for the CE study.

Key results:

Tabell 2. WTP-results from CE and CV, expressed in DKK/year. (From Hasler et al., 2005, p. 14).

	CE	CV
Naturally clean groundwater	1 899	711
Very good conditions for plant and animal life	1 204	
Total	**3 104**	**711**
Purified water	**912**	**529**

Carson, R.T. & R.C. Mitchell. 1993. The Value of Clean Water: the Public's Willingness To Pay for Boatable, Fishable, and Swimmable Quality Water. Water Resources Research 29(7): 2445-2454.
https://doi.org/10.1029/93WR00495

Scope: This paper presents the findings of a study designed to determine the national benefits of freshwater pollution control (in the US). Water quality was defined in increasing levels of quality as: fit for boating activities; fit for boating and fishing activities; and fit for boating, fishing, and swimming activities.

Respondents: By using data from a national contingent valuation survey, we estimate the aggregate benefits of meeting the goals of the Clean Water Act.

Key results: Based on 813 survey responses the study found that the annual mean WTP per household to keep freshwater resources at a quality level suitable for: boating activity was $93; boating and fishing activity was $163; and botenteating, fishing and swimming activity was $241.

Kataria, M. et al., 2011. Scenario realism and welfare estimates in choice experiments – A non-market valuation study on the European water framework directive. Journal of Environmental Management, vol. 94, pp. 25-33. https://doi.org/10.1016/j.jenvman.2011.08.010

Scope: Using choice experiment data for economic valuation we analyse how disbelief in survey information could affect the retrieved welfare estimates.

Respondents: The panel consisted of approx. 35,000 individuals from all over Denmark and is representative of the Danish population.

Key results: We find that although the majority of respondents agree with the described status quo level, there is a non-negligible probability that some respondents disagree. In particular, approximately 25 per cent of the respondents perceive the current water quality to be worse than presented in the survey information.

It is of course crucial in development of a survey only to include policy scenarios that are realistic, but people will always have different opinions, i.e. dispersed beliefs, on what is realistic or not, especially when it comes to complex environmental change […].

The problems we have discussed can partly be reduced through thorough preparation of the survey that allows scenarios perceived as unbelievable to be avoided, but when dealing with complex environmental issues there will always be inherent risks that survey information is perceived differently than intended, and correcting for the bias is important for further use in welfare economic assessments.

Beaumais, O., Briand, A., Millock, K. & Nauges, C., 2014. What are Households Willing to Pay for Better Tap Water Quality? A Cross-Country Valuation Study. FEEM Working Paper No. 24.2014. https://hal.archives-ouvertes.fr/hal-02430307/document

Scope: We estimate willingness to pay (WTP) for better quality of tap water on a unique cross-section sample from 10 OECD countries.

Respondents: The sample in the OECD Household Survey was stratified by income, age, gender and region in each of the ten countries. Along with stratification, the sample size from each country was adjusted to ensure a representative sample. In particular, a smaller sample was taken from the Czech Republic (around 700) where internet penetration rates are low and the survey provider could not ensure that a larger sample would be representative.

Key results: On the pooled sample, households are willing to pay 7.5% of the median annual water bill to improve the tap water quality. The highest relative WTP for better tap water quality was found in the countries with the highest percentage of respondents being unsatisfied with tap water quality because of health concerns.

In the survey, respondents were asked whether or not they were satisfied with the quality of their tap water and whether or not they were drinking water from the tap. Respondents who declared being dissatisfied could indicate whether they were more concerned about taste or health impacts (or neither of these).

Only those respondents who declared NOT being satisfied with their tap water were asked how much they would be willing to pay for improvement. More precisely, the analysis of respondents' WTP for better tap water quality is based on the answer to the following question: "What is the maximum percentage increase that you would be willing to pay above your actual water bill to improve the quality of your tap water, holding water consumption constant?".

The "high quality tap water" group includes the Netherlands (95%), Sweden (92% of respondents satisfied with their tap water) and Norway (90%).

Adamowicz, W., Dupont, D. Krupnick, A. & Zhang, J., 2011. Valuation of cancer and microbial disease risk reductions in municipal drinking water: An analysis of risk context using multiple valuation methods. Journal of Environmental Economics and Management, Elsevier, vol. 61 (2), pp. 213-226, March. https://doi.org/10.1016/j.jeem.2010.10.003

Scope: We examine the value of health risk reductions (microbial illnesses/deaths and bladder cancer illnesses/deaths) in the context of drinking water quality treatment by public systems.

Respondents: […] Table 2 compares the characteristics of sample respondents to the Canadian population using 2001 Census statistics. For most characteristics, average values for survey respondents are virtually the same as those for Canada. The only socio-demographic characteristic that differs in any appreciable way from that of the general Canadian population is the percentage of individuals educated beyond high school. The 2001 Census estimate is 55%, while the corresponding value for our sample, collected in 2004, is 79.1%.

Key results: When we assume that combined mortality and morbidity risk reductions are equally spread in the future; our results suggest that microbial risk-reduction programs have higher value than cancer risk-reduction programs, but that mortality risk reduction values are not significantly different for cancer and microbials.

Rollins, K., Zachariah, O., Frehs, J. & Tate, D., 1997. Resource valuation and public policy: Consumers' willingness to pay for improving water servicing infrastructure. Canadian Water Resources Journal, 22, 185-195. https://www.tandfonline.com/doi/pdf/10.4296/cwrj2202185

Scope: The WTP of Canadians to support a program to repair water distribution and sewage treatment systems to prevent a decline in current water services was investigated in.

Respondents: Based on 1,511 household surveys across Canada […].

Key results: […] the mean WTP to support a program to repair water distribution and sewage treatment systems to prevent a decline in current water services was about CA$26 per month in addition to household current water bills. The study claimed that as the differences of WTP among Canadian regions were not significant, the results of the survey can be used to estimate the WTP for the whole nation. On this basis the national WTP was estimated as CA$1.1 billion less than the amount required to cover the estimated marginal costs of maintaining, renovating, and upgrading water infrastructure to ensure adequate water services.

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