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VATT INSTITUTE FOR ECONOMIC RESEARCH

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Key words: hedonic price method; water quality; environmental amenities; valuation; waterfront properties

JEL classes: Q51, Q53, Q26

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1.Introduction

This paper uses the market of waterfront recreational properties to estimate the welfare impacts of reaching the good ecological status defined by the Water Framework Directive (WFD) and Marine Strategy Framework Directive (MSFD). The empirical challenge is that the ecological water quality measure proposed by the directives is non-specific to human uses. Water quality values are not, however, independent of use-related values. Therefore, the valuation of changes in water quality is likely to be affected by the measure of water quality chosen (see, e.g., Keeler et al 2012).

In the European Union, the WFD and MSFD are notable examples of economic valuation being formally recognized in environmental regulation (European Commission 2000 and 2008). In fact, the WFD is the first directive concerning the environment and environmental policies that considers economics formally. The directives set a Europe-wide target of good ecological status for surface waters by 2015 and for Europe's seas by 2020. Economics enters the directive guidelines through recognition of the costs of meeting the target. In particular, if the costs are considered high, the member countries may resort to valuation of benefits to show that the costs are disproportionate compared to the benefits. Yet, the benefits attainable from restorative actions are not easily estimable.

Hedonic pricing is widely used in environmental economics to value amenities. The method can be applied on property market data to infer the implicit price function for environmental amenities (on water quality, e.g., Leggett and Bockstael 2000, Gibbs et al. 2002, Poor et al 2007, Cho et al. 2011, Artell 2014, Walsh and Milon 2015). Economists have typically considered hedonic pricing as a more reliable valuation method than stated preferences methods, because it is based on revealed behavior. However, its application has not been limited to use values only; some scholars have proposed that it may be used even for monetizing ecological values where non-use values are an important element (e.g. Bertram and Rehdanz 2013).

We carry out valuation using the most comprehensive Finnish nationwide data set available in order to enable preference revelation for water quality and evaluation of the WFD. The novelty of our paper is that we have three alternative measures of water quality. The first is based on recreational waterfront property owners' own evaluation of water quality. The second contrasts these evaluations with a usability index that was the publicly available, official water quality measure at the time of purchase. The third then examines how the additional quality indicator, ecological status, developed for the directives compares with the two previous measures. The time at which the study data were collected provided us with a unique opportunity to carry out comparisons, as a shift in perspective was underway from usability to ecology when measuring water quality.

The rich data set on quality indicators allows us to investigate their relative performance in hedonic models on the waterfront property values. In particular, we can investigate whether the marginal benefits of improved water quality differ by indicator. This is of utmost policy importance as the official WFD measure is used for classification of ecological status of surface waters, and cost-benefit analysis, advocated by the directive, should be used to determine whether measures to reach the target of good ecological status can be justified on economic grounds. Moreover, the economic importance of water quality has been associated with water recreation activities, or use values, not necessarily with ecological criteria.

Indeed, perception of water quality is likely to be affected by a person's own experience of the use of water, and there can be considerable differences between individuals on how they perceive water quality. More importantly, the official or objective measures of water quality used by authorities may differ from the subjective perceptions of the owners of the recreational properties. In particular, we examine whether non-linearity of benefits plays a role here. This is investigated by exploiting the richness of the data set regarding the alternative water quality indicators as well as their categories. Several model alternatives are studied to determine the marginal benefits of water quality: 1) non-attainment vs. attainment of the WFD, 2) a five-point interval scale for water quality and 3) two categories of water quality – "satisfactory" and "excellent" – that lie below and above the limit of the WFD target of "good ecological status".

The issue of measurement of water quality is particularly relevant in the context of revealed preferences, as policy goals are set on the basis of official indicators rather than subjective perceptions. Accordingly, understanding water quality perceptions, or subjective measures, and the usability index in comparison to ecological status is vital for sound policy analysis.

The results suggest that improvements in water quality are associated with economically considerable and statistically significant changes in waterfront recreational property values. The target of good ecological status determined by the WFD seems economically justified. Yet, using ecological rather than usability criteria to measure the marginal benefits of attaining excellent water quality produces lower estimates of benefits. As usability is important for water recreation activities, our concern – perhaps more philosophical than economic - is related to the revealed preference valuation method: How can one measure the benefits of improvements in water quality determined on ecological grounds, that is, independent of use or other observed behavior by human beings?

The paper proceeds as follows. The next section provides background on EU water management and related policy as well as on the development of water quality indicators and targets. Section 3 discusses briefly hedonic theory and section 4 provides a rationale for its application in empirical econometric modelling. Section 5 describes the data sources and presents some summary statistics. Section 6 reports the empirical results and robustness checks. Empirical findings on the benefits of water quality improvements are discussed in section 7. Section 8 concludes.

2. The Water Framework Directive and measurement of water quality

Implementation of the WFD and the key milestones

The Water Framework Directive is a product of a long history in the development of the European Community's water policy. Notably, the focus of that policy has widened over time from health protection in the 1970s and 1980s, to pollution control in the 1990s, to its current form, which includes environmental protection (Kallis and Butler 2001). The directive entered into force in 2000, requiring management plans on the river basin level that aim to achieve a "good ecological status (GES)" of all surface waters by the end of the first management cycle in 2015. The two management cycles to follow are scheduled to end in 2021 and 2027, with the current requirement being that the GES objectives are to be met by the end of the third management cycle.

There are certain exemptions to the GES requirement in the case of artificial or heavily modified water bodies. Such status can be given to water bodies where improving the water quality would have "significant adverse effects" on the environment or economic activities and infrastructure. The WFD states that if improvements are beyond technical feasibility or their costs are disproportionate, the GES requirement can be relaxed. Such decisions must, however, be reviewed during each six-year management cycle. (European Commission 2000)

Assessment of good ecological status

Ecological status is determined in each member country based on the normative descriptions of "high", "good" and "moderate" status in the directive (European Commission 2000). In Finland, two additional quality levels have been added, making the scale a five-step one: excellent, good, satisfactory, passable, and poor quality. Ecological quality is determined through a complex process using a multitude of indicators, including the status of key flora and fauna species, hydro-morphologic factors, and chemical status of the water body. The components of ecological status in Finland are described in detail in Vuori et al. (2009). The ecological status indicator is endorsed by the Finnish Environment Institute and its regional collaborators[1]. In this study, we use the ecological quality assessment describing conditions in the year 2008, the earliest such assessment. The formation of the quality indicator coincides favorably with our study period, as the assessment is based on quality data from the years 2000 through 2007.

Alternative measures of water quality – a usability index and subjective measure

Before the requirements of the WFD came into force, the Finnish Environment Institute worked with a five-step use-oriented water quality measure. The "official" usability criteria had indicators similar to those in the ecological criteria, but the greatest weight in the expert-defined classification was given to aspects of use-related water quality, such as water clarity, amount of chlorophyll and algal blooming in the water and off-flavor in fish. The expert opinions were based on visual, chemical and ecological criteria. [2] The usability criteria emphasize water quality indicators that are simple to observe also by laypersons, which makes them an interesting counterpart to the ecological criteria. The classification rated quality in terms of five usability categories, from excellent (1) to poor (5). "Excellent" implies potability of fresh waters, and "good" good recreational opportunities. "Satisfactory" describes waters with occasional algal blooming, but without serious use-related harm. "Poor" and "passable" imply serious restrictions on using the water for recreation or consumption, and even warnings against physical contact at times. In this study, we use the latest usability index, published in 2004 and made available to the general public as well.

As is obvious from above, measuring water quality is not a straightforward procedure (see also Palmquist 2005, 789), and an official index produced by the environmental authorities is not necessarily well known to laypersons, who often rely on their own knowledge and perceptions. Apart from the water quality measures used by policy makers, recreational users of water areas have their own subjective assessment of quality, which figures significantly in decisions on recreation. In practice, it is the usability of water that matters most for summertime water recreation activities such as swimming and boating. In this study, we are presented with a unique opportunity to use a

[1] Finland has a total of 15 Centres for Economic Development, Transport and the Environment. They collect local water quality data for a national database.
[2] These are translated into English in Artell (2014).

subjective quality measure elicited from survey respondents using a five-step ladder from excellent to poor quality similar to that used in the ecological status and usability index.

Previous literature on valuation of water quality

Earlier hedonic studies on water quality have used a wide range of water quality measures. Some rely on single-measure indicators, predominantly water clarity (e.g. Boyle et al. 1999, Michael et al. 2000, Poor et al. 2001, Boyle and Taylor 2001, Gibbs et al. 2002, Krysel et al. 2003), in conjunction with other measures, such as coliform bacteria (Leggett and Bockstael 2000), nitrogen concentration, and suspended solids (Poor et al. 2007). Others use compound indicators (Phaneuf et al. 2008, Artell 2014) that include various indicators, both observable and unobservable to the layperson. While the use of single indicators has been based on their relevance to recreation, the compound indicators are thought to provide a more holistic view of water quality from the policy perspective, and possibly in terms of recreation quality as well. For example, using water clarity to measure the recreational quality of naturally humic lakes may severely underestimate their value. Additionally, Artell (2014) finds that single indicators may not sufficiently describe quality in the context of different water bodies and thus the diverse dynamics and expectations to be found among the public. For example, comparing coastal water clarity with rivers and humic lakes may make no sense with a single measure.

The literature has stressed the need for water quality measures to correspond to consumer perceptions of quality. This requirement has led to different approaches when direct survey information on subjective quality perceptions is lacking. For example, Boyle and Taylor (2001) had problems determining the quality of water perceived by the consumer before making a purchasing decision. They ultimately opted to use minimum water clarity over the summer months using official water clarity data. Michael et al. (2000) conducted a survey to determine whether water clarity was a good measure of quality by consumer standards, but still did not use subjective quality indicators in their analysis. Poor et al. (2001) took the step of comparing official seasonal minimum water clarity measures to consumer perceptions of the same figures. They found that respondents systematically underestimated the official water clarity measure and that objective water quality measures performed better in their hedonic analysis. Palmquist (2005) has suggested that this finding could be explained by the fact that the price of property is the result of a market equilibrium determined by the interactions of all potential purchasers, not just the winning bid. Before the implementation of the WFD and the ecological quality criteria, Hanley et al. (2006) assumed a set of three possible ecological criteria in a choice experiment approach to water quality valuation.

Notably, the three criteria - river ecology, aesthetics, and quality of the banksides - were chosen using focus group deliberation, rather than ecological considerations.

In more recent literature, Artell et al. (2014) express a concern that while the usability index and subjective assessment of quality provide similar quality assessments on average, they may not necessarily produce similar value estimates of quality improvements. Furthermore, official indices, such as the WFD's ecological status, may measure water quality with goals other than direct utility effects in terms of frequency and location of monitoring. As a result, water management using an ecological indicator instead of a more utility-oriented measure may prove difficult when benefits from quality improvements need to be quantified. From the viewpoint of successful implementation of the WFD it is thus important to use different quality indicators - from subjective assessment to official water quality indices – to understand how people behave in the market.

3. Research design for hedonic pricing of water quality assessed by alternative indicators

A formal hedonic model was established by Rosen (1974), who elaborated the idea of a differentiated good described by a vector of its characteristics. In this standard framework, the measurement of environmental amenities plays an important role in valuation, since equilibrium prices are affected by sellers' and buyers' preferences and perceptions of water quality (see, e.g., Taylor 2003).

In the case of a recreational property, the characteristics of a good basically include all structural and neighborhood attributes (x), and an environmental amenity, in our case, water quality (q). The market price of a property i is determined by the hedonic price schedule $P(x,q)$, which is generated by the equilibrium interactions of buyers and sellers

$$P_i = P(x,q) \qquad (1)$$

The partial derivative of $P(x,q)$ with respect to water quality, $\partial P/\partial q$, is the marginal implicit price for water quality.

Individuals buying a residential property participate in the competitive market by maximizing utility subject to a budget constraint. Formally, utility $U(x,q,z)$ depends on consumption of a numeraire, z (with price equal to one), and the level of attributes x and q. The budget constraint is given by I-z-

$P(x,q)=0$, where I is income. In equilibrium, individuals choose the level of water quality, q, to equate their marginal rate of substitution between q and z to the marginal implicit cost of q, or $\frac{\partial U(\cdot)/\partial q}{\partial U(\cdot)/\partial z} = \frac{\partial P(\cdot)}{\partial q}$. Because $\partial U/\partial z$ is the marginal utility of income, the lefthand side equals the marginal willingness to pay for q. Hence, the hedonic price schedule can reveal individuals' marginal willingness to pay for q at their chosen level of q. For a fixed level of utility u', a willingness to pay (WTP) for q is implicitly defined by

$$U[x, q, I - b(\cdot)] = u', \qquad (2)$$

where $b(\cdot)$ is referred to as a bid function, because it reveals the maximum amount that an individual would pay for a property with attributes x and q, given her/his income, while holding utility fixed at u'. Inverting (2) and holding constant all attributes of the property except q, the following expression for willingness to pay for water quality is obtained

$$b^q = b^q(I - P, x^*, q, u^*), \qquad (3)$$

where u^* is the highest level of utility attainable given the budget constraint and x^* are the optimal choices for the other attributes.

Figure 1 illustrates the equilibrium hedonic price schedule (HPS). Bid curves for water quality are depicted for three types of buyers. For a buyer with bid function #1, the equilibrium price for water quality q^1 is $p_1=P(x,q^1)$, which is observed from the market transaction by the time of purchase. In a similar manner, water quality levels q^2 and q^3 correspond to market prices $p_2=P(x,q^2)$ and $p_3=P(x,q^3)$, respectively, materialized in other market transactions for the bid functions of buyers #2 and #3.

The other side of the market is composed of heterogeneous sellers. Figure 1 depicts offer curves for three types of sellers. The HPS is formed by tangencies between the buyers' bid and sellers' offer functions. On the HPS, a marginal price of water quality is equal to a buyer's marginal WTP for quality and a seller's marginal cost of supplying it. The gradient of the HPS with respect to water quality gives the equilibrium differential that compensates buyers for lower water quality. Hence, the HPS can be used to infer the welfare effects of a marginal change in water quality. For sellers, the gradient of the HPS reveals the costs of supplying a better water quality.

Hypotheses on the assessment of water quality and its impact on hedonic prices

From the above it is clear that the hedonic pricing hinges upon determination of water quality and how it is perceived in the market. Buyers and sellers in the recreational property markets captured by our data set had usability index available to them in 2004. The subjective measure was elicited in 2008, and reflects the water quality perceived by buyers. Following this, we evaluated the policy goal of the WFD using the measure of ecological status launched in 2008 and reported to the EU in 2010. Using the alternative indicators, we normalize the scales of different water quality so that at the point of purchase in the hedonic price schedule bid functions with different water quality measures coincide. If the sales prices are negotiated on the basis of personal perceptions of water quality (and other attributes) by the seller and buyer and there is no other metric for water quality present, the perceived quality can be assumed to capture all water quality effects relevant to value estimation. If, however, there is an official water quality measure within the public's awareness, the sales prices can be partly or fully anchored to this measure.

Thus, in estimating the implicit price of water quality we may have a dual measure, where during the price negotiations the seller has an incentive to notify the buyer of officially good water quality if it exists. The buyer, on the other hand, could trust his/her personal perception of water quality or resort to official measures, which represent a longer-term assessment of water quality. In other words, the buyer should be aware that personal perception carries the risk of asymmetric information, especially in the winter, when most water bodies are covered in ice and there is no algal blooming.

On the other hand, if we use a quality metric that has no direct behavioral link to the purchaser, that is, the measure of ecological status, we run a risk of over- or understating the welfare effects of water quality improvement to an unknown extent. Furthermore, where endogenous sorting is an issue in hedonic property price analysis, it also requires buyers to consciously perceive the differences between attributes. While we could expect buyers with a low valuation of water quality to be located in areas with generally poorer water quality, this would also require them to make the effort to judge the water quality at sites they consider purchasing, and then actively choose worse sites.

4. Econometric model

The model described in section 3 provides the conceptual basis for revealed preference estimation. Combining transaction prices and the attributes of properties it is possible to estimate $P(x,q)$ based on the econometric model

$$p_i = f(x_i, q_i, \gamma, \varepsilon_i), i = 1 \dots I \,, \tag{4}$$

where (p_i, x_i, q_i) are the observed sales price and attributes for property i, $f(\cdot)$ is a functional specification for the price schedule, γ is a vector of parameters to be estimated, and ε_i is a disturbance term. A measure of each individual's marginal willingness to pay for q at his/her observed choice can be obtained on individual i's marginal willingness to pay curve based on

$$b_i^q(q_i, x_i, u_i^*) = \frac{\partial \hat{f}\,(x_i, q_i, \gamma)}{\partial q_i} = \hat{p}_{q_i}, 1 = 1, \dots, I, \tag{5}$$

where $\hat{p}_{q_i}$ denotes an estimate of the marginal implicit price of q for buyer i.

In the following estimations, we exploit the different types of information on water quality to study its impact on the prices of recreational properties. Our strategy is to study the association of water quality with the prices of recreational properties by systematically comparing the outcomes for the usability index, the ecological status, and the subjective measure, which is a self-reported evaluation by property owners. Our focus is on revealing preferences for water quality, and detecting non-linearity in the valuation of water quality. OLS and semilogarithmic form (log-linear) are used in the hedonic model on the association between property values and water quality. A number of robustness checks for econometric modelling are carried out.

As many of the indicator variables for water quality are dummies, the correct interpretation of the coefficients requires that they be transformed to exponential form to accurately measure the marginal impacts (see Halvorsen and Palmquist 1980).

5. Data sources and summary statistics

Our data have been collected from three main sources: the official property sales registry maintained by the National Land Survey of Finland, the national surface water quality database extensively tracked and indexed by the Finnish Environment Institute, and a survey addressed to those who bought a recreational property in Finland in 2004.

The real estate market price register contains the official information on all property ownership changes in Finland. There were 10 323 recreational property sales between non-relatives in 2004, from which a subsample of about 2 700 transactions was extracted. The subsample is limited to private, person-to-person sales of single waterfront summer houses and lots without buildings. Sales with special conditions such as restrictions on use rights, sales through compulsory auctions, and sales involving foreigners are excluded. The market price register provides information on the composition of the purchased land area, adjacency to water body, and the state of planning (zoning). The type of water body is determined by proximity using GIS software.

Each property sale is linked to a water quality index value using GIS mapping. Our analysis employs the usability index based on water quality data from the years 2000 to 2003, and the ecological status based on data from the years 2000 to 2007[3], which are available from the Finnish Environment Institute. Since water quality data are not available for all lakes and ponds, the subsample is restricted to sales within a limited distance from the nearest quality-indexed water body. Sensitivity analysis with respect to distance is carried out in the analysis proper. The data cover 82 % of the total area of lakes larger than 1 square kilometer in size, 16 % of the length of rivers wider than 2 meters, and all of the Baltic Sea coastal area within Finnish borders. Appendix A shows the spatial allocation of the sites where water quality was measured by usability index and ecological status.

The register data on recreational properties are complemented by information from a survey addressed to about 2700 people who purchased a recreational property in Finland in 2004. A pilot survey was carried out between late October and early December 2008, and the survey proper was posted at the beginning of December 2008. The respondents could participate in the survey either by filling in a mail questionnaire or completing a corresponding questionnaire on the Internet. A reminder was sent to the respondents in mid-January 2009, with a mail questionnaire enclosed for those who had not answered the Internet survey. A total of 1350 respondents ultimately participated in the survey, representing a response rate of 49.1%.

[3] The first assessment of the ecological and chemical status of Finnish waterbodies was reported in 2008 nationally and 2010 to the European Union. The assessment was based on quality monitoring data from the period between the years 2000 and 2007 (Vuori et al. 2009).

Water quality at the time of purchase was elicited by asking simply how the respondents perceived the water quality: *How did you find the water quality at the time of purchase?* The respondents indicated their assessment on a five-step scale – excellent, good, satisfactory, passable and poor. Hence, the measure captures a subjective evaluation, the respondents' personal perceptions. It should be underlined that the respondents were asked to evaluate the water quality at the time of purchase not at the time of the survey, four years later. However, as the current owners of properties, they have more experience and they are better informed about the water quality than they were at the time of purchase. Figure 2 contrast each water quality indicator used in the analysis with our cross-section data on property sales.

The questionnaire included an item asking respondents to indicate how they had assessed the water quality. We see from our sample that 97 % assessed water quality in more than two ways on average. Visual assessment and prior knowledge of the quality were the most important means even for sales made in winter time. Less than 15 % of the sample had requested water quality information from official sources (municipal information sources and internet sources), from which they would have received the then-official usability index figure. A comparison of summer house attributes in the purchasing decision shows that having a beach of one's own in a peaceful area with nice scenery is the most important consideration, followed by water quality. Price is only the seventh most important attribute in the set of thirteen attributes affecting purchasing decisions.

Correlations between the three water quality indicators and the sales price of the property are shown in Table 1. The correlation coefficient between usability index and ecological status is high, or 0.70, and highly significant (p-value 0.0000), whereas the correlation coefficient between ecological status and subjective measure is 0.37 (p-value 0.0000). In contrast, the sales price of the property and water quality indicators are not systematically correlated. While correlations do not provide conclusive evidence against reverse causality, the correlations observed in these data further support our assumption that poorer (better) water quality per se is not associated with smaller (larger) or less (more) expensive properties.

Figure 3 shows the distributions of the three indicators of water quality for recreational properties in the data. We can see that the mode class for each indicator is "good". The indicators differ with respect to the second-largest class, which is "excellent" for the usability index and subjective measure but "satisfactory" for ecological status.

Descriptive statistics for the sample are presented in Table 2. In the hedonic model, we control for characteristics such as physical properties, dimensions and location (region) of the recreational property, planning status of the area, as well as fixed effects, such as type of inland water body and time of year (quarter) at which it was purchased.

6. Results

We start the analysis by studying a policy goal of reaching a certain minimum level of water quality. We examine whether there are differences between property values in locations where the goal is not met, that is, the water quality is below the targeted "good" level. We then go on to study the impact of water quality in greater detail. All estimations are carried out for the three alternative quality indicators to gain insight into revealed preferences for water quality.

To start with, we carry out estimation where the target for water quality is set at "good". This is in the spirit of the policy implemented by the WFD, which calls for a good ecological status. We create a dummy variable for non-attainment of status, which means that water quality is below a "good" level of water quality as determined by the usability index, subjective measure and ecological status.

Table 3 reports the parameter estimates for a pooled data set of recreational properties in which a dummy variable, *building*, indicates whether the property is a waterfront lot with buildings (building=1) or a lot without buildings (building=0). The regressors presented in column one of Table 3 include property level characteristics (lot size (total area), floor space, building age, seashore and electricity); and neighborhood characteristics, proxied by a dummy for zoning status (existence of shore plan, master plan); services, proxied by distance to the nearest store, type of land (proportion of forested land); and type of inland water body (river, pond or island, lake being the reference water body). We also include the distance of the property from Helsinki, the capital of Finland. The regression also includes, as fixed effects, regional dummies (Southern, Eastern, Western or Northern, capital region being the reference region) and seasonal dummies for the time of purchase (winter, spring or fall, summer being the reference season).

The OLS results presented in Table 3 are consistent with our expectations regarding recreational property prices. Electricity, total area of lot and existence of a shore plan have positive impacts on the sales price of waterfront properties, whereas winter sales and riverside properties are less valued compared to summer and lakeside sales, respectively. Not surprisingly, properties by the seashore are highly valued. The composition of the lot matters as well, the proportion of forested land on it having a statistically significant, large negative impact on the sales price. The distance from Helsinki has a statistically significant and negative impact on sales prices.

The variable of greatest interest for us is water quality (the first three rows in Table 3). Water quality measured by a dummy indicating water quality below “good” has a statistically significant impact on the price of recreational properties. The magnitude of the dummy coefficient indicates that impairment of water quality to a category below “good” decreases the value of a recreational property by about 16% when measured by the usability index and when evaluated by the buyer using the subjective measure.[4] An ecological status below “good” decreases the property value by about 11%.

The above results reflect considerable marginal impacts. Next we wish to narrow down the magnitude of the change in water quality. Moreover, to improve the reliability of the objectively measured water quality indicators, usability index and ecological status, we impose a constraint on the maximum distance to the nearest measurement point of 250 meters. Furthermore, we analyze the association of water quality with the value of recreational property, introducing the quality categories linearly in the hedonic price equation. All three measures run from excellent (1) to poor (5). Table 4 reports the regression results. For comparison purposes, column (A) shows the results for the water quality dummy (WFD target of good ecological status not attained) with a distance constraint (<250 meters) similar to that used in column (B) for the three alternative five-point water quality indicators. Otherwise, the same covariates as in Table 3 are used in the estimations.

In column (A) of Table 4 we see that non-attainment of good quality decreases property values more when evaluated by a usability (17%) than a subjective (15%) or ecological measure (12%). In column (B) of Table 4, again, all water quality measures have a statistically significant impact on the price of recreational properties. The magnitude of the water quality coefficient indicates that a deterioration of one unit in water quality category decreases the value of a recreational property by about 13% when measured by a usability index, 8% when evaluated by the buyer using a subjective measure, and 7% when evaluated by ecological status.[5] Interestingly, the results mean that,

[4] Table 3 shows the coefficients, Coeff, for the water quality dummies, which are transformed to $(e^{Coeff} - 1)$, or accurate marginal impacts reported in the body of the paper (see Halvorsen and Palmquist 1980).
[5] The coefficients for the other explanatory variables are very similar to the ones reported in Table 3 (not reported here).

assuming a linear relationship between water quality and property prices, the usability measure generates a slightly stronger impact than the subjective and ecological ones. This finding leads us to believe that preferences for water quality may follow a different pattern for each measure. Accordingly, we proceed to identify these patterns by quality category.

Since we have few observations in the quality categories "passable" and "poor". we limit our analysis to the categories where 96% of our observations are "excellent", "good" or "satisfactory". The results for the parameter estimates are reported in Table 5. The baseline level of water quality is "good" and the coefficients for the two indicator variables of water quality are "excellent" and "satisfactory" in columns (A) of Table 5. To show the sensitivity of the analysis to the number of water quality categories, we include the category “passable” in the estimations reported in columns (B). The coefficients for water quality categories are very stable regardless of whether observations indicating “passable” water quality are included or not.

There is a considerable difference between the usability index and the other two indicators, subjective measure and ecological status. When the usability index is applied, properties whose associated water quality is rated “excellent” are 20% higher in value than those whose water quality is “good”. In contrast, in the case of the subjective and ecological indicators, there is a much smaller difference between the “excellent” and “good” categories, the magnitude being only about 2-5%, and the coefficient for the dummy for excellent water quality is not statistically significant. Interestingly though, the difference between the categories “good” and “satisfactory” is about the same magnitude for all three indicators and is slightly above 10% of the property value.

The results are also illustrated in Figure 4, which captures the different shapes of the hedonic price schedule when estimated for subjective, usability and ecological indicators. The hedonic price schedule based on the subjective evaluation is roughly concave in shape. It seems that property owners anchor themselves to the “good” quality level with no additional willingness to pay for an improved, “excellent” quality. Yet, they show a strong willingness to pay for an improvement from “satisfactory” to “good”. Given that the stated policy target for the Water Framework Directive is “good” quality status, this value can serve as a reference level for property owners. Hence, perceived water quality - reported by the owners of the recreational properties - would speak for a diminishing marginal benefit of water quality. The value of the ecological status seems to follow a concave pattern similar to that suggested by the subjective measure. In contrast, as shown in Figure 4, the usability index generates a convex shape for the hedonic price schedule.

Robustness using alternative samples and covariates

Water quality indicators in general, and the marginal improvement from satisfactory to good water quality in particular, seem to have an impact on waterfront property prices. To investigate further the robustness of the regression results in Table 5, we carried out estimations using several alternative model specifications. For comparison, Panel A in Table 6 shows the results for OLS models where the distance to the nearest measurement point for the usability index and ecological status is less than 250 meters (the baseline assumption for the results are reported in columns A) or less than 125 meters (reported in columns B). Both restrictions on maximum distances yield rather similar coefficients. Moreover, in the third column for each water quality indicator (columns C of Panel A), the results are reported for a sample restricted to cases in which water quality indicators are above "passable" (WQ>pass) simultaneously. The purpose here is to use exactly the same sample for every indicator specification even though this limitation may exclude some observations that are ranked "passable" for one of the indicators that are not considered in that particular estimation. As can be seen in columns (C), the coefficients are robust to the sample restriction on "above passable water quality", independent of indicator.

Furthermore, in Panel B of Table 6, we investigate the robustness of our results to the set of control variables. As columns (A), (B) and (C) for each water quality indicator show, the results are roughly the same. In contrast to the subjective measure and ecological status, the usability index generates a large and statistically significant coefficient for the excellent quality as compared to the baseline level of good quality. For the dummy indicating satisfactory water quality, the coefficients are very close to each other independent of the quality indicator or specification chosen and always statistically significant either at the 5% or 10% level. Our finding that the marginal benefit of an improvement from a good to excellent level is considerable, or about 20% for the usability index, but very modest (not even statistically significant) for the subjective measure and modest for the ecological status, holds throughout the alternative set of covariates.

Interpretation of the results

The usability index provides the most consistent and robust estimates for the categories of satisfactory and excellent water quality: the estimates are statistically significant and differ from those for good water quality. However, the subjective measure and ecological status also fit the property price data rather well in the hedonic models. The 95% confidence intervals for the implicit price of water quality contain all quality measures, where the ecological quality has slightly larger standard errors than the other two measures. Conducting a non-nested J-test[6] across models using different quality measures reveals a slight preference for the usability index. Somewhat surprisingly, there is no clear preference favoring one or the other of the models using ecological or subjective quality.

The most important policy question is: what is our assessment of the goal of the WFD, good ecological status? In light of our results, the value of improvement in ecological water quality from satisfactory to good is perhaps surprisingly close to the benefit estimated by the subjective measure. This is not necessarily unexpected as even the usability index produces a benefit of about the same or slightly smaller magnitude. Interestingly enough, the improvement from good to excellent water quality is valued much more modestly by the indicators of the ecological status and subjective measure than by the usability index. Hence, the WFD indicator seems to identify a target level – good ecological status – whose attainment brings large additional benefits, even from the point of view of recreational use, as the subjective measure and usability index highlight.

On the other hand, as shown in Figure 4, the usability index – the official measure at the time of purchase – places much more value on excellent water quality than the other two measures. The different shapes of the hedonic price schedules may be puzzling when trying to calculate the welfare impacts of water quality improvements. In particular, the subjective measure indicates that the marginal benefit of an additional increase in water quality from good to excellent is limited, whereas there is a stronger negative impact on the willingness to pay for a property located in an area whose water quality is lower than good, that's is, satisfactory. In other words, given that good water quality is a reference value for water quality, property owners are more sensitive to impairment than improvement in water quality relative to this value. This can be interpreted as an indication of an endowment effect in riskless choices (Barberis 2013).

Moreover, the different outcomes between the indicators of ecological status and usability index should be explained. The most straightforward reason for the difference may be the weight given to the many water quality criteria used in creating these indicators. A visual inspection of the two maps presenting the alternative indicators in the Appendix A, reveals considerable differences. The distinction made between good and excellent water quality in the ecological criteria does not seem as obvious as that between satisfactory and good. Of course, the considerable marginal benefits of

[6] Test results are available from the authors upon request.

reaching "good ecological status" justify rather high costs for protection measures. This finding leads to interesting policy implications in terms of cost-benefit analysis; we discuss these in the section to follow.

7. Calculation of aggregate benefits

It seems evident that the marginal impact of improved water quality is large and increases considerably a person's willingness to pay for a waterfront property. Using the estimated marginal impacts of water quality on the predicted sales price of a waterfront property, we can roughly approximate the magnitude of the impact of water quality on the value of such a property.

As can be seen from Panel A of Table 7, the average benefits of progressing from non-attainment (below good) to attainment (good or above) would be considerable. The benefits per property are largest for the usability index (€7667). The increase per property (€ 5389) is smallest in the case of ecological status, whereas the increase when using the subjective measure falls somewhere in between these two (€ 6419). These benefits are about 12-17% of the average sales price of the property in the data set. It must be borne in mind that this is a very roughly assessed change in water quality: non-attainment status includes cases of poor, passable and satisfactory water quality and whereas attainment status cases of good and excellent quality; the change in benefits has been calculated as an average difference between the attainment/non-attainment statuses.

If we are willing to assume that our sample is representative of the distribution of water quality in inland waters where waterfront properties are located, we can approximate the aggregate benefits of reaching the WFD target. The aggregate benefits would be about € 800 million when measuring the change by the usability index, about € 660 million for the improvement indicated by the subjective measure and about € 700 million when measured by ecological status.

The rough estimates on the benefits between non-attainment and attainment of the water quality target levels can be narrowed down by focusing on the two water quality categories on the limit of the target level of WFD or the difference between "satisfactory" and "good" water quality (see Table 7 Panel B). The benefits per property are smallest for the improvement indicated by the usability index (€ 4549) and largest when estimated using the subjective measure (€ 5316). An improvement from satisfactory to good quality generates aggregate benefits of roughly € 400 million when calculated by the usability index or the subjective measure. The corresponding improvement in ecological status is worth almost € 500 million. Again, these back-of-the-envelope calculations are only indicative of the magnitude of the aggregate benefits. To a certain extent they are sensitive to the assumption on the distribution of water quality among the locations in the whole stock of waterfront properties. In any event, if we alternatively assume that on average about 23% of the properties (mean of the share of properties with satisfactory water quality reported by the indicator in Panel B: 0.2201, 0.2001 and 0.2675) have a satisfactory water quality, the aggregate benefits of achieving good water quality lie somewhere between €400 and €470 million. These are sizeable sums.

It is useful to compare the benefits to the costs. The costs of implementing the WFD in the member states are related to expeditures for new wastewater treatment technologies, improved agricultural practices and the like. Concerns have arisen with respect to the high costs of controlling diffuse loading, or non-point source pollution. In particular, reducing emissions in sparsely populated or seasonally popular areas would require considerable micro-scale investments in waste water treatment equipment. The costs of property-specific investments in waste water treatment have been estimated as lying in the range of €500-8000. These costs should be compared with the added benefits from improved water quality, or the estimated benefit per property in Panel B of Table 7. Obviously, the least-cost investments in water treatment technologies would be beneficial to the property owner given that taking these measures would be sufficient to reach the target of good ecological status. Yet, there could be other, less expensive and more effective measures than those targeting scattered settlement or seasonal housing and second homes. The total costs of implementing the additional measures that meeting the target of the WFD requires have been estimated to be about € 235 million annually (Lehtoranta 2013).

8. Conclusions

This study has used the market for waterfront recreational property to develop estimates of the welfare impacts of improving water quality. The basis of the analysis is a comparison of three indicators – a usability index, a subjective measure and ecological status - to evaluate the policy goal of the Water Framework Directive. We find that achieving good water quality is associated with an economically large and statistically significant change in the value of recreational properties.

Our study has contributed to previous research by examining the shape of the benefit function for water quality improvements. We find that the marginal benefits of better water quality are highly non-linear for usability. Assuming the three alternative water quality indicators to be linear, our hedonic model would suggest an increase of some 7-13% in the sales price of a waterfront property per step up the water quality ladder (from poor to passable, from passable to satisfactory etc.). Yet, after analyzing individual categories we find that a linear marginal benefit of water quality improvement does not necessarily hold. For an improvement from satisfactory to good water quality, the corresponding increase in the sales price lies in a rather tight range of 10-12 % for every indicator. In contrast, the benefit estimates differ by indicator for an improvement from good to excellent quality. The usability index suggests a statistically highly significant price increase of about 20%, but the subjective measure and ecological status predict a far more modest impact, or about 2-5%, one which is not statistically significant. Hence, the marginal benefits of improvement in water quality are positive and increasing as measured by the usability index, and positive but decreasing as measured by the subjective measure or ecological status.

More broadly, this paper makes a contribution to a more fundamental valuation issue about use values of water quality and evaluation of an environmental policy goal determined by ecological criteria. Hedonic pricing based on an indicator measuring ecological status generates smaller differences in property values between water quality categories and reduces the marginal benefits of improved quality compared to the usability indicator. It seems that owners of recreational property perceive water quality such that the changes in property values indicated by a subjective measure coincide on the whole with the ecological one. Yet, valuation based on the usability index generates additional benefits beyond good quality and considerable benefits where excellent water quality is achieved.

References

Artell, J. 2014. Lots of Value? A Spatial Hedonic Approach to Water Quality Valuation. *Journal of Environmental Planning and Management* 57(6): 862–882.

Artell, J. Ahtiainen, H., Pouta, E. 2013. Subjective Vs. Objective Measures in the Valuation of Water Quality. *Journal of Environmental Management* 130: 288–296.

Barberis, N.C. 2013. Thirty Years of Prospect Theory in Economics: A Review and Assessment. *Journal of Economic Perspectives* 27: 173–196.

Bertram, C., Rehdanz, K. 2013. On the Environmental Effectiveness if the EU Marine Strategy Framework Directive. *Marine Policy* 38: 25–40.

Bockstael, N., McConnell., K. 2007. Environmental and Resource Valuation with Revealed Preferences: A Theoretical Guide to Empirical Models. The Economics of Non-Market Goods and Resources, vol 7. Dordrecht: Springer.

Boyle, K., Poor, P., Taylor, L. 1999. Estimating the Demand for Protecting Freshwater Lakes from Eutrophication. *American Journal of Agricultural Economics* 81(5): 1118–1122.

Boyle, K., Taylor, L. 2001. Does the Measurement of Property and Structural Characteristics Affect Estimated Implicit Prices for Environmental Amenities in a Hedonic Model? *Journal of Real Estate Finance and Economics* 22: 303–318.

Cho, S., Roberts, R.K., Kim, S.G. 2011. Negative Externalities on Property Values Resulting from Water Impairment: The Case of the Pigeon River Watershed, *Ecological Economics* 70: 2390–2399.

European Commission, 2000. Directive 2000/60/EC of the European Parliament and of the Council Establishing a Framework for Community Action in the Field of Water Policy. Official Journal (L 327/1) of 23 October 2000.

European Commission, 2008. Directive 2008/56/EC of the European Parliament and of the Council establishing a framework for community action in the field of marine environmental policy. Official Journal (L 164/19) of 17 June 2008.

Gibbs, J., J. Halstead, and K. Boyle. 2002. A Hedonic Analysis of the Effects of Lake Water Clarity on New Hampshire Lakefront Properties. *Agricultural and Resource Economics Review* 31 (1): 39–46.

Halvorsen, R., Palmquist, R.B. 1980. The Interpretation of Dummy Variables in Semilogarithmic Equations. *American Economic Review* 70: 474–475.

Hanley, N., Wright, R.E., Alvarez-Farizo, B. 2006. Estimating the Economic Value of Improvements in River Ecology Using Choice Experiments: An Application to the Water Framework Directive. *Journal of Environmental Management* 78: 183–193.

Kallis, G., Butler, D. 2001. The EU Water Framework Directive: Measures and Implications. *Water Policy* 3(2): 125–142.

Keeler, B.L., Polasky,S., Brauman, K.A., Johnson, K.A., Finlay, J.C., O'Neille, A., Kovacs, K., Dalzell, B. 2012. Linking Water Quality and Well-Being for Improved Assessment and Valuation of Ecosystem Services. *Proceedings of the National Academy of Sciences of the United States of America* 109: 18619–18624.

Kesämökkibarometri 2009. Ministry of Employment and the Economy Publications, Regional development 12/2010.

Krysel, C., Boyer, E., Parson, C., Welle, P. 2003. Lakeshore Property Values & Water Quality: Evidence from Property Sales in the Mississippi Head-waters Region. Mississippi Headwaters Board and Bemidji University.

Leggett, C. and Bockstael, N. 2000. Evidence of the Effects of Water Quality on Residential Land Prices. *Journal Environmental Economics and Management* 39, 121–144.

Lehtoranta, V. 2013. The Economic Value of Water Management for Lake Vesijärvi. Licentiate thesis, Aalto University.

Michael, H., K. J., Boyle, and R. Bouchard. 2000. Does the Measurement of Environmental Quality Affect Implicit Prices Estimated from Hedonic Models? *Land Economics* 76(2):283–298.

Palmquist, R.P. 2005. Property Value Models. In: Mäler, K.-G., Vincent, J.R. (eds) Handbook of Environmental Economics, vol 2, chapter 16. Elsevier.

Phaneuf, D.J., Smith, V.K., Palmquist, R.B., Pope, J.C. 2008. Integrating Property Value and Local Recreation Models to Value Ecosystem Services in Urban Watersheds. *Land Economics* 84(3): 361–381.

Poor, J., K. Boyle, L. Taylor, and R. Bouchard. 2001. Objective versus Subjective Measures of Water Clarity in Hedonic Property Pricing Value Models. *Land Economics* 77 (4): 482–493.

Poor, J., K. Pessagno, and R. Paul. 2007. Exploring the Hedonic Value of Ambient Water Quality: A Local Watershed-Based Study. *Ecological Economics* 60 (4): 797–806.

Rosen, S. 1974. Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition, *Journal of Political Economy* 82: 34–55.

Suomen vesiensuojeluyhdistysten liitto 2015. (Union of the Finnish Water Protection Associations) Jätevesijärjestelmän kustannukset (Costs of the wastewater treatment system) http://www.vesiensuojelu.fi/jatevesi/kustannukset.html [Accessed 3rd of July 2015]

Taylor, L. O. 2003. The Hedonic Method. In: Champ, P.A., Boyle, K.J., Brown, T.C. (eds) A Primer on Nonmarket Valuation, Kluwer Academic Publishers.

Vuori K.-M., Mitikka S., Vuoristo H. (eds.) 2009. Pintavesien ekologisen tilan luokittelu (Guidance on ecological classification of surface waters in Finland, Part 1: Reference conditions and classification criteria, Part 2: Environmental impact assessment). Ympäristöhallinnon ohjeita (Guidelines for environmental management) 3, 2009. Finnish Environment Institute. https://helda.helsinki.fi/bitstream/handle/10138/41785/OH_3_2009.pdf?sequence=1 [Accessed 3rd of July 2015]

Walsh, P.J., Milon, J.W., 2015. Nutrient Standards, Water Quality Indicators, and Economic Benefits from Water Quality Regulations. *Environmental and Resource Economics* (published online 25 February 2015).

Table 1. Correlations between three water quality indicators and logarithm of sales price.
(p-value for significance in parentheses)

	Usability index	Subjective measure	Ecological status	Log Price
Usability	1.0000			
Subjective	0.4967 (0.0000)	1.0000		
Ecological	0.7004 (0.0000)	0.3746 (0.0000)	1.0000	
Log Price	-0.0293 (0.3935)	-0.0601 (0.0327)	0.0321 (0.2751)	1.0000

Table 2. Summary statistics for properties in the data set

Variable	N	mean	std.dev.	min. value	max. value
Price (€)	1332	46130.53	34444.93	2354	210 000
Log price	1332	10.453	0.808	7.764	12.255
Water quality indicator					
Usability index (1=best quality)	863	2.001	0.891	1	5
Subjective measure (1=best)	1289	2.074	0.908	1	5
Ecological status (1=best)	1185	2.177	0.921	1	5
Property attributes					
Floor space (m2)	1279	57.977	87.464	0	2700
Lot size (ha)	1357	0.536	0.350	0.2	2
Building (dummy)	1357	0.643	0.479	0	1
Building age (years)	1321	16.537	21.267	0	154
Electricity (dummy)	1265	0.771	0.421	0	1
Seashore (dummy)	1262	0.126	0.332	0	1
Distance to Helsinki (km)	1357	268.615	181.035	18.461	1094.329
Region (dummy)					
Capital region	1361	.065	0.246	0	1
Southern (excl. capital reg.)	1361	0.300	0.459	0	1
Eastern	1361	0.281	0.450	0	1
Western	1361	0.222	0.416	0	1
Northern	1361	0.117	0.321	0	1
Season of year (dummy)					
Winter	1357	0.097	0.296	0	1
Spring	1357	0.246	0.431	0	1
Summer	1357	0.405	0.491	0	1
Fall	1356	0.251	0.434	0	1
Inland water body (dummy)					
Lake	1262	0.732	0.443	0	1
River	1262	0.083	0.276	0	1
Pond	1262	0.059	0.235	0	1
Island	1338	0.161	0.368	0	1
Neighborhood attributes					
Shoreplan (dummy)	1357	0.215	0.411	0	1
Masterplan (dummy)	1357	0.281	0.450	0	1
Forest land (share)	1357	0.026	0.154	0	1
Distance to nearest shop (km)	1350	2.405	1.013	1	5

Table 3. Estimation results for usability index, subjective measure and ecological status
Indicator variable of water quality: quality level below good. Dependent variable is logarithm of sales price.

	Usability index		Subjective measure		Ecological status	
Variable	Coeff.	Std.Err.	Coeff.	Std.Err.	Coeff.	Std.Err.
Water quality below good						
- usability index >2	-0.179***	0.055				
- subject. measure>2			-0.178***	0.052		
- ecological status>2					-0.112*	0.063
Property attributes						
Floor space (m2)	0.002***	0.001	0.002***	0.001	0.002***	0.001
Lot size (ha)	0.331***	0.064	0.343***	0.064	0.335***	0.064
Building (dummy)	0.904***	0.056	0.896***	0.056	0.899***	0.056
Building age (years)	-0.005***	0.002	-0.004***	0.002	-0.005***	0.002
Electricity (dummy)	0.280***	0.055	0.284***	0.055	0.286***	0.055
Seashore (dummy)	0.187**	0.077	0.132*	0.073	0.164**	0.082
Distance to Helsinki (km)	-0.002***	0.000	-0.002***	0.000	-0.002***	0.000
Region (dummy)						
Southern (excl. capital reg.)	0.042	0.110	0.097	0.109	0.073	0.110
Eastern	-0.212	0.129	-0.142	0.128	-0.184	0.130
Western	-0.101	0.120	-0.052	0.119	-0.088	0.121
Northern	0.000	0.197	0.086	0.196	0.037	0.199
Season of year (dummy)						
Winter	-0.199***	0.076	-0.199***	0.076	-0.188**	0.076
Spring	-0.044	0.055	-0.045	0.055	-0.038	0.055
Fall	-0.050	0.055	-0.072	0.055	-0.053	0.055
Inland water body (dummy)						
River	-0.337***	0.118	-0.331***	0.118	-0.331***	0.119
Pond	-0.112	0.185	-0.153	0.184	-0.165	0.185
Island	-0.164***	0.055	-0.168***	0.055	-0.158***	0.055
Neighborhood attributes						
Shoreplan	0.143**	0.062	0.149**	0.061	0.142**	0.062
Masterplan	0.150	0.053	0.153***	0.052	0.149***	0.053
Forest land (share)	-0.477	0.144	-0.471***	0.144	-0.476***	0.145
Distance to nearest shop (km)	0.015	0.022	0.014	0.022	0.013	0.023
Constant	10.126	0.156	10.134***	0.154	10.126***	0.157
Adj. R^2	0.50		0.50		0.50	
N	628		628		628	

Table 4. The effect of alternative water quality indicators on property values
The dependent variable is sales price in logs. Sample restriction: Maximum distance to the nearest water quality measurement point is 250 meters for usability index and ecological status.

	Usability index		Subjective measure		Ecological status	
	A	B	A	B	A	B
Water quality indicator						
Non-Attainment of WFD (dummy)	-0.189***		-0.158***		-0.132**	
(below good)	(0.058)		(0.055)		(0.067)	
Category (1-5)		-0.134***		-0.080***		-0.071**
(from excellent to poor)		(0.029)		(0.029)		(0.035)
Property attributes	yes	yes	yes	yes	yes	yes
Neighborhood attributes	yes	yes	yes	yes	yes	yes
Adj. R^2	0.50	0.51	0.50	0.50	0.50	0.50
N	582	582	582	582	582	582

Notes: Indicator variable for water quality: In Column A: dummy for non-attainment of Water Framework Directive (below good) and in Column B: category from 1 to 5 (excellent, good, satisfactory, passable, poor). All the models include the same dummies as in Table 3: region dummies, season of year dummies and inland water body dummies. OLS regression coefficient estimates; standard errors in parentheses; ***, **, * indicate significance at the 1%, 5%, and 10% levels, respectively.

Table 5. The effect of water quality categories on property values
The dependent variable is sales price in logs.

	Usability index		Subjective measure		Ecological status	
	A	B	A	B	A	B
Water quality						
Excellent	0.199***	0.198	0.019	0.019	0.045	0.045
	(0.057)	(0.057)	(0.053)	(0.053)	(0.058)	(0.058)
Satisfactory	-0.120*	-0.105	-0.131**	-0.131**	-0.122*	-0.115
	(0.067)	(0.066)	(0.062)	(0.062)	(0.072)	(0.071)
Passable		-0.168		-0.283		-0.167
		(0.110)		(0.141)		(0.141)
Property attributes	yes	yes	yes	yes	yes	yes
Neighborhood attributes	yes	yes	yes	yes	yes	yes
Adj. R^2	0.51	0.51	0.49	0.50	0.49	0.49
N	553	581	564	580	558	578

Notes: The baseline level of water quality is "good" in all models, and in Columns A the coefficients for water quality are "excellent" and "satisfactory" whereas also quality category “passable” is included in estimations reported in Columns B. All the models include the same dummies as in Table 3: region dummies, season of year dummies and type of water body dummies. OLS regression coefficient estimates; standard errors in parentheses; ***, **, * indicate significance at the 1%, 5%, and 10% levels, respectively.

Table 6. Robustness checks using alternative samples (Panel A) and covariates (Panel B)

Panel A	Usability index			Subjective measure			Ecological status		
	A	B	C	A	B	C	A	B	C
	Dist. <250	Dist. <125	WQ>pass	Dist. <250	Dist. <125	WQ>pass	Dist. <250	Dist. <125	WQ>pass
Excellent	0.199***	0.208***	0.192***	0.019	0.032	0.006	0.045	0.067	0.047
	(0.057)	(0.058)	(0.058)	(0.053)	(0.053)	(0.054)	(0.058)	(0.058)	(0.059)
Satisfactory	-0.120*	-0.109	-0.121**	-0.131**	-0.116*	-0.155**	-0.122*	-0.121*	-0.145*
	(0.067)	(0.068)	(0.071)	(0.062)	(0.062)	(0.068)	(0.072)	(0.074)	(0.080)
Property attributes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Neighborhood attributes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Adj. R^2	0.51	0.51	0.50	0.49	0.49	0.49	0.49	0.50	0.49
N	553	536	525	564	546	525	558	540	525

Notes: The dependent variable is sales price in logs. The distance to the nearest quality-indexed water body is less than 250 meters in Columns A and less than 125 meters in Columns B. In Columns C, samples restricted to observations where all three water quality indicators are simultaneously above the passable quality (WQ>pass). All the models include the same dummies as in Table 3: region dummies, season of year dummies and type of water body dummies. OLS regression coefficient estimates; standard errors in parentheses; ***, **, * indicate significance at the 1%, 5%, and 10% levels, respectively.

Panel B	Usability index			Subjective measure			Ecological status		
	A	B	C	A	B	C	A	B	C
Excellent	0.192***	0.208***	0.217***	-0.005	0.004	0.016	0.421	0.051	0.056
	(0.057)	(0.057)	(0.058)	(0.055)	(0.055)	(0.054)	(0.585)	(0.059)	(0.058)
Satisfactory	-0.116*	-0.111*	-0.111*	-0.139**	-0.134**	-0.136**	-0.173**	-0.163**	-0.128*
	(0.067)	(0.067)	(0.067)	(0.063)	(0.063)	(0.062)	(0.072)	(0.072)	0.072
Property attributes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Region dummies	yes	yes	yes	yes	yes	yes	yes	yes	yes
Season dummies	no	yes	yes	no	yes	yes	no	yes	yes
Inland water body	no	no	yes	no	no	yes	no	no	yes
Neighborhood attributes	no	no	no	no	no	no	no	no	no
Adj. R^2	0.49	0.50	0.51	0.46	0.47	0.48	0.48	0.47	0.48
N	560	559	555	571	570	565	566	565	506

Notes: The dependent variable is sales price in logs. All the models include the same property attributes and region dummies as in Table 3. OLS regression coefficient estimates; standard errors in parentheses; ***, **, * indicate significance at the 1%, 5%, and 10% levels, respectively.

Table 7. Benefits of improved water quality

Water quality indicator	A From non-attainment to attainment				B From satisfactory to good			
	Share of properties with water quality below good (non-attainment)	Number of properties[1]	Estimated benefit per property (€)	Aggregate benefits in total (million €)	Share of properties with satisfactory water quality	Number of properties[1]	Estimated benefit per property (€)	Aggregate benefits in total (million €)
Usability	0.2758	105494	7667	808.818	0.2201	84188	4549	382.972
Subjective	0.2700	103275	6419	662.922	0.2001	76538	5316	406.877
Ecological	0.3409	130394	5389	702.694	0.2675	102319	4863	497.576

[1]There are about 450,000 private recreational properties in Finland, and about 85% of these are waterfront properties. (Kesämökkibarometri 2009) Total population in Finland is about 5.4 million.

Figure 1. Hedonic price schedule

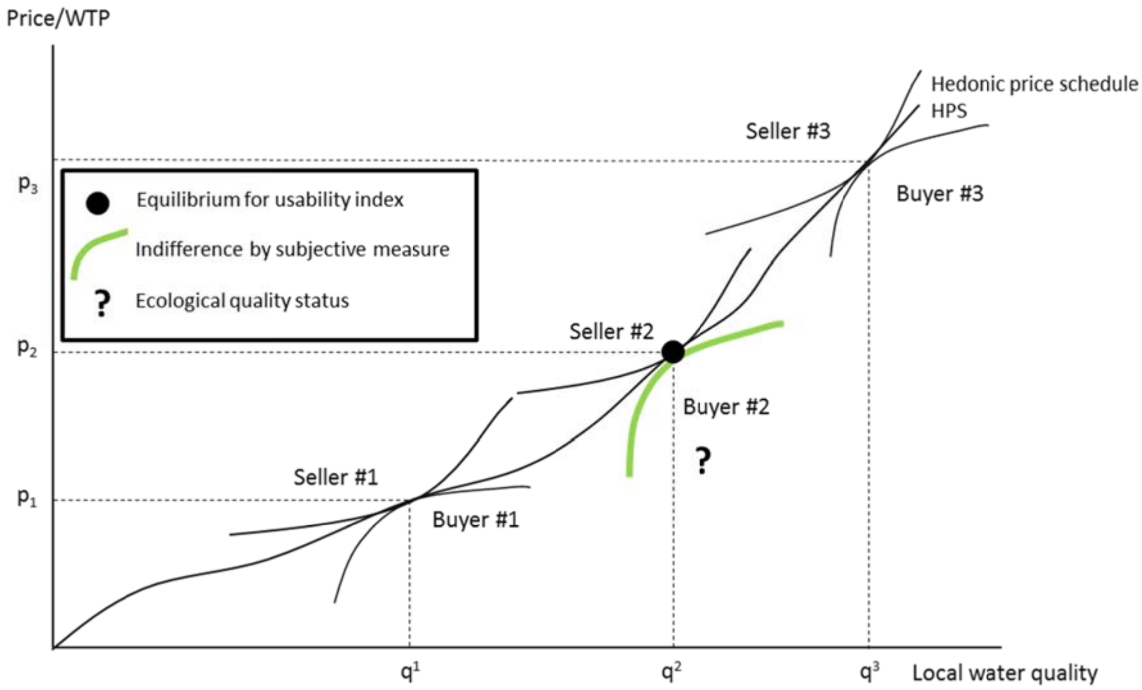


Figure 2. Data collection period and information availability for water quality assessment

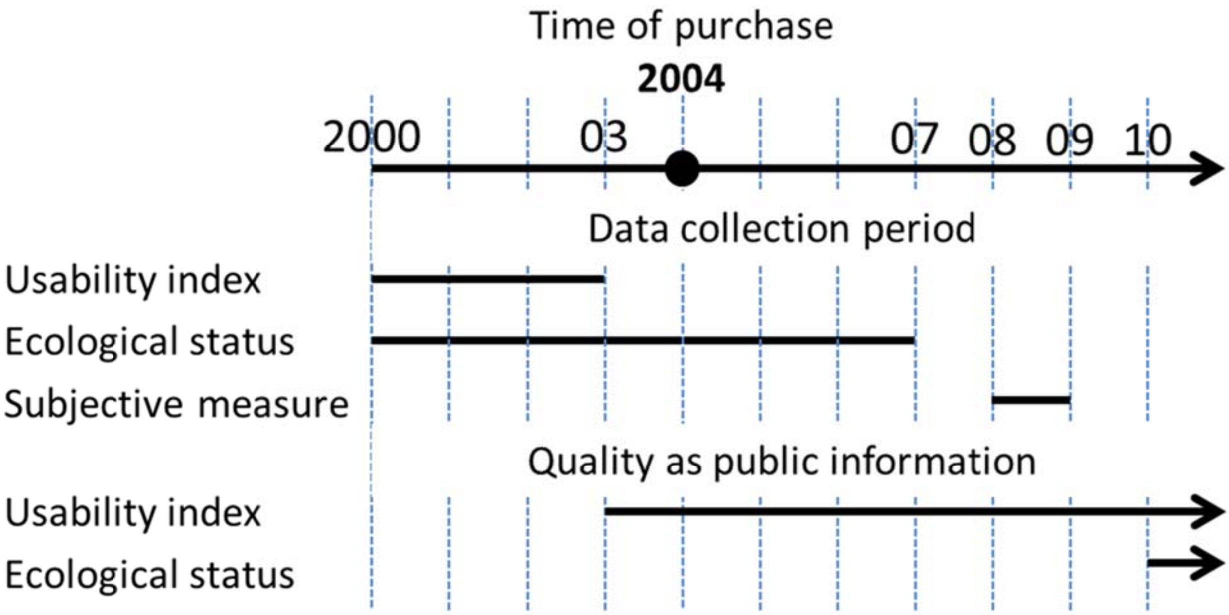


Figure 3. Distributions of water quality indicators for recreational properties

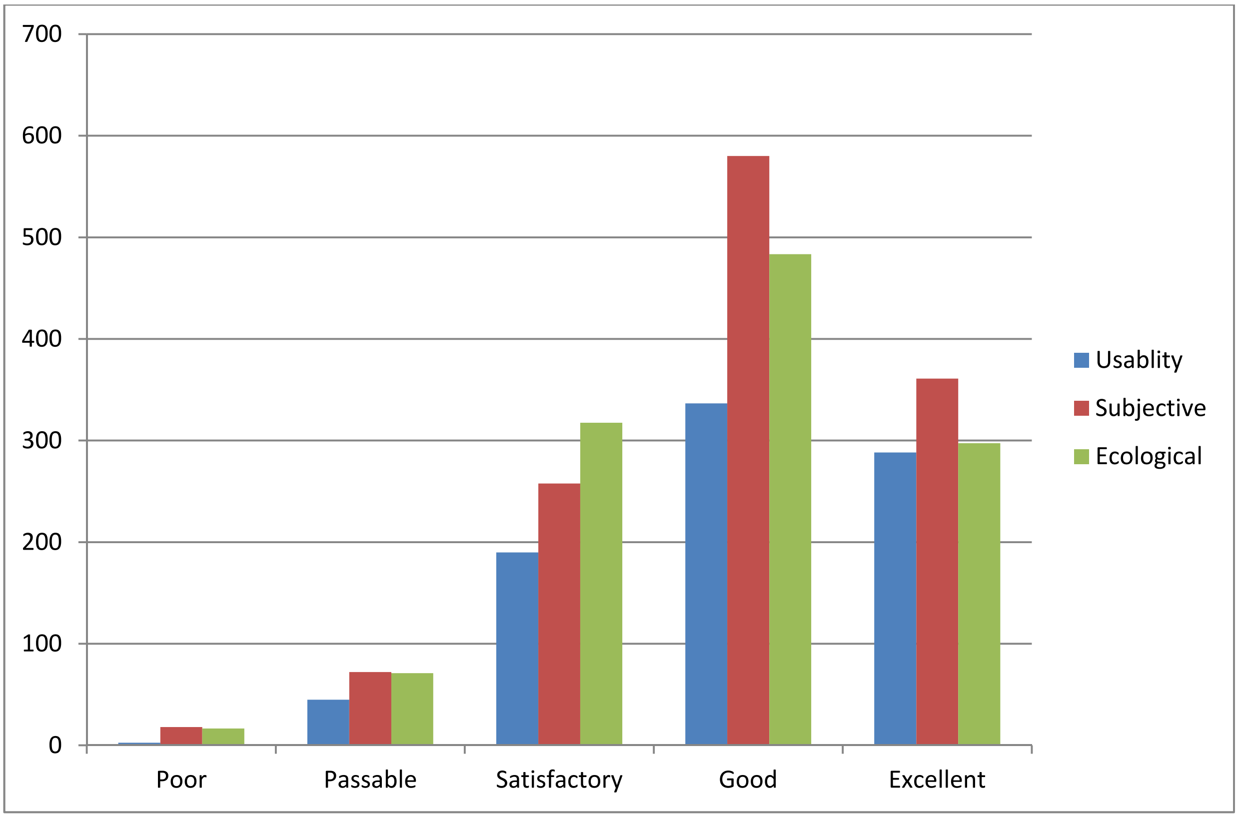
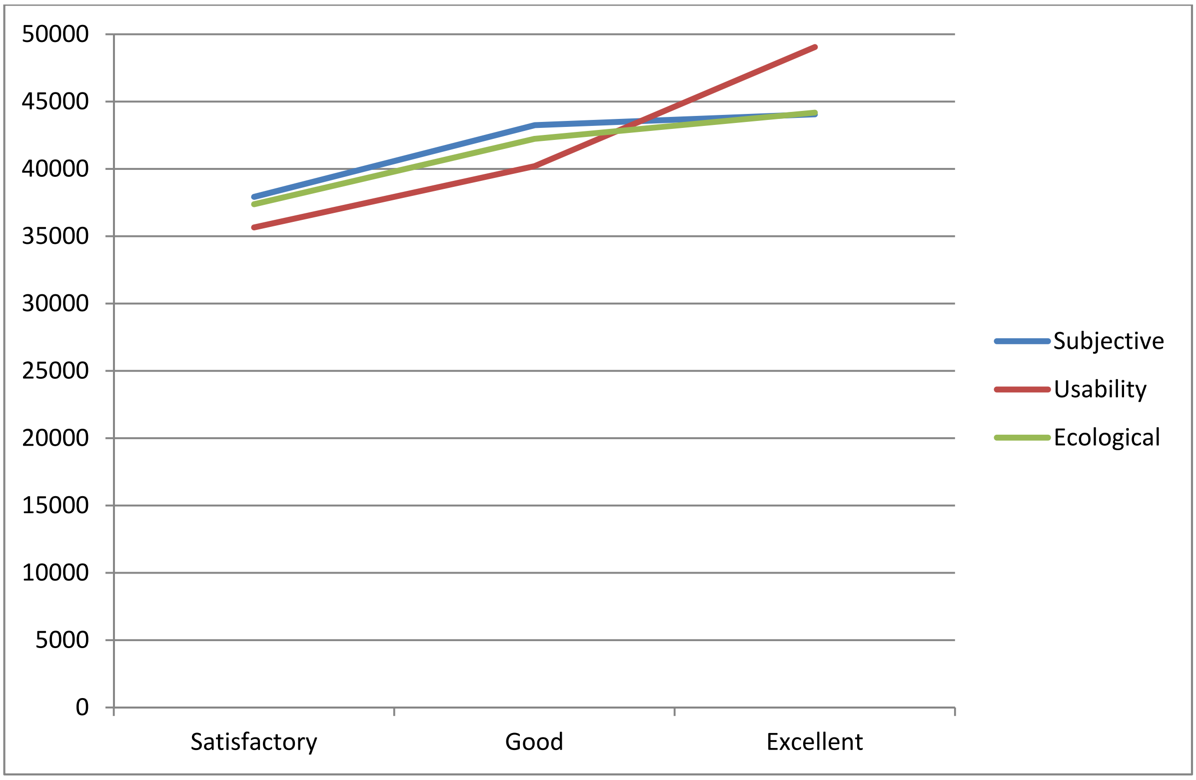


Figure 4. Hedonic price schedules for alternative indicators of water quality: predicted waterfront property prices by water quality category (in euros)



Appendix A.

Surface water quality map by usability index of 2000–2003 on the left and by ecological status of 2000–2007 (Finnish Environment Institute, 2004 and Ministry of the Environment, 2012)