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Working Paper No. 121
August 1996

Working Paper Series
in Economics and Finance

RECREATIONAL BENEFITS FROM IMPROVED WATER QUALITY: A RANDOM UTILITY MODEL OF SWEDISH SEASIDE RECREATION.*

29 July 1996

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Abstract

In this paper, a random utility maximization (RUM) model of Swedish seaside recreation is used to estimate the benefits from reduced eutrophication of the seas around Sweden. Sight depth data from around the Swedish coast are used as a quality index related to eutrophication. The model is estimated using the nested multinomial logit (NMNL) and conditional logit (CL) specifications.

In order to test the relationship between this quality variable and the nutrient concentration in the water, a regression of sight depth on the concentration of phosphorus and nitrogen has been run. The results are used to make policy simulations.

Two sets of such simulations have been undertaken. One set assumes a uniform change of the nutrient load along the entire Swedish coastline. The consumer surplus from a reduction of the nutrient load by 50 percent is estimated to be around 240 mSEK if the NMNL model is used, and 540 mSEK if the CL model is used.

The other set of policy simulations assumes a change in the nutrient load in the Laholm Bay in south-west Sweden. The consumer surplus for a 50 percent reduction in the nutrient load in the bay is estimated to be 12 mSEK if the NMNL model is used, and 32 mSEK if the CL model is used.

Keywords: random utility, recreation, water, Baltic Sea, eutrophication, discrete choice

JEL classification: C51, Q25, Q26

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* I am indebted to Professor Lars Bergman and Professor Per-Olov Johansson, at the Stockholm School of Economics. Professor Bengt Kriström at the Department of Forest Economics, Swedish University of Agricultural Sciences, Umeå has provided invaluable advise. The analysis of the Tourism and Travel Database has been carried out in cooperation with, and with assistance from, Professor Lars Hultkrantz and Reza Mortazavi, CTS, Dalarna University, Borlänge. The work would not have been possible without the scores of people who have kindly assisted me with data on water quality and other data. Seminar participants at the Stockholm School of Economics and at CTS has given clear-sighted comments. Any remaining errors are the responsibility of the author. Financial support from the National Swedish Environmental Protection Board is gratefully acknowledged.

1. Introduction

The eutrophication of the seas around Sweden has been a source of increasing concern. Eutrophication, which is caused by an oversupply of nutrients to the water[1], has been suspected of causing changes in the macroalgal flora (Wennberg, 1987) and of increasing the frequency of algal blooms (Granéli et al, 1989). The public reaction was especially strong in 1988, when a toxic algal bloom that affected the entire Swedish west coast caused massive death among fishes, invertebrates and seaweed. The reasons behind this catastrophic event are not clear, but there is a strong suspicion that the increased nutrient load played an important role (Lindahl and Rosenberg, 1989). Eutrophication also causes oxygen deficiency in the bottom waters, which can result in dead sea floors, and has seriously impaired the reproduction of the Baltic cod.

In response to worries about the state of the Baltic Sea[2], a ministerial declaration was signed in 1988 by the states around the Baltic, committing these countries to reducing the emission of nutrients and other harmful substances by half, between 1987 and 1995. However, this goal has not been met (HELCOM, 1994). The primary reason for the failure to live up to the 1988 declaration is that a reduction of the nutrient load on such a scale would be very costly. Estimates of the cost for a reduction of the nutrient load range between 32 billion SEK per year (Gren, Elofsson and Jannke, 1995) for a fifty percent reduction, and 47 billion SEK (Johannesson and Randås, 1995) for a forty percent reduction.

It is thus of great importance to obtain estimates of the benefits of a reduced nutrient load. A major part of the benefits from reduced eutrophication can be expected to be due to the increased value of seaside recreation. Bockstael, Hanemann and Strand (1987) cite Freeman's (1979) assertion that over half of the value from improved water quality is usually due to recreational values. In the present study, the travel cost method will be applied to try to capture recreational benefits from reduced emissions of nutrients into the seas around Sweden.

In Europe, only a few travel cost studies have been undertaken. In Sweden, Bojö (1985) estimated the value of virgin forest in the Vålådalen area of northern Sweden. (See Johansson, 1987 for a summary.) The value of ski recreation in northern Sweden was estimated by Boonstra (1994). Strand (1981) used the travel cost model to estimate the value of recreational fishing in the river Gaula in Norway.

The nature of recreational behavior - usually the individual chooses one or a few among a very large number of alternatives - has led to attempts to use models of discrete choice for travel cost studies. The utility theoretical background to this kind of model is the random utility maximization model (see e.g. Smith, 1989, Bockstael, McConnell and Strand, 1991, Small and Rosen, 1981, Maddala, 1983 or McFadden,

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[1] Rosenberg, Larsson and Edler (1986) estimate that the load of nitrogen supplied to the Baltic Sea today is about four times that at the end of the 19th century, while that of phosphorus is about eight times as large. They also claim that between 1930 and 1980, the load of nitrogen supplied to the Kattegat/Skagerrak increased four times and the load of phosphorus increased between three and seven times.

[2] In this agreement, the Kattegat is also treated as part of the Baltic Sea.

1976). Discrete choice models have seen a large number of applications, mainly in the USA. The most popular models of this kind, which will be utilized in this paper, are the conditional logit (also termed multinomial logit), and the nested multinomial logit (NMNL) models.

Two recent examples of NMNL models are given by Kaoru (1995), who estimated the benefit of water quality improvement to marine recreational fishing in the Albemere-Pamlico Estuary in North Carolina, and Hausman, Leonard and McFadden (1995), who used a travel cost model to evaluate the damage from the Exxon Valdez oil spill. To my knowledge, no discrete choice model of recreational demand has been estimated using European data, previous to the present study.

The travel data used for the study come from the Tourism and Travel Database (TDB). The TDB was initiated by the Swedish Tourist Council, and is based on 2000 telephone interviews each month (4000 in June and July) on travel behavior. The database contains detailed information, both on trips undertaken and on the socioeconomic characteristics of the interviewees. The detailed data make it possible to estimate a cost function for recreational trips based on the stated cost. In this paper, such an estimated cost function will be used to calculate the travel cost for the different available destinations, instead of using the standard approach of multiplying the distance to the different sites by a hypothetical kilometer cost.

Naturally, the question of how environmental quality should be measured is crucial for the evaluation of environmental benefits. In the present study, a quality index is constructed from a very simple measure of water quality: sight depth. This variable is simple, as it is one-dimensional, and easy to measure. Also, it is available for most stretches of the coastline. It is probably directly related to the recreationist's perception of water quality. It is also correlated with other potential quality measures. Finally, and this is of crucial importance, it is highly correlated with the nutrient load. In the paper, I present the results of an estimation of a regression of sight depth on nutrient concentration in the water.

The model which has been developed makes it possible to perform simple policy experiments in order to estimate welfare effects of hypothetical changes in water quality. Two sets of experiments are carried out, one on a change in quality along the entire coastline, and one on a change in quality on only a small part of the coast.

The paper is structured as follows. In Section 2, the theoretical background of the model is provided. The issue is addressed of how a welfare measure for a change in quality can be derived. The travel cost method is then put in a household production framework. Next, the model is extended to a discrete choice context, and the random utility maximization (RUM) model is described. Finally, the econometric specifications leading to the conditional logit and nested multinomial logit (NMNL) models are discussed. In Section 3, the model is specified and empirical considerations are discussed. The data are described. In particular, the sight depth variable is analyzed. A regression is run to establish the link between this variable and the concentrations of the pollutants we are concerned with, i.e. nitrogen and phosphorus. The results of the estimations for the cost function and the actual travel cost model are given in Section 4. In Section 5, results from simulations of hypothetical changes in water quality are presented. In the final section of the paper, the findings are summarized, and some unresolved issues are indicated. The question of how the TDB could be used for other studies of recreational benefits from environmental quality changes is also addressed.

2. Theoretical background

2.1 The travel cost method

The traditional travel cost approach, proposed by Harold Hotelling (1948) in a letter to the US National Park Service, was primarily intended to value one single recreational site. The area surrounding the site is divided into concentric zones at increasing distances from the site. The demand of a representative individual is then obtained by regressing the travel frequency of each zone on average values of income and other characteristics of the zone. By combining the representative demand curve with zonal population characteristics, an aggregate demand curve is constructed. For each zone, the area between the demand curve thus derived and the access cost is interpreted as a consumers' surplus, which if summed over the zones gives the ”value” of the site (Bockstael, Hanemann and Strand, 1987).

In later years, the focus of recreational demand analysis has shifted almost entirely from the aggregate approach to studies based on micro data (Smith, 1989). Instead of using zonal averages, estimation is based on data on individuals' travel behavior.[3] Recreational demand models based on individual data have been extensively used to evaluate environmental quality. In particular, this kind of model has been used to measure the benefits from water quality improvement (Bockstael, McConnell and Strand, 1991).

The travel cost method used as a tool to evaluate environmental resources is an indirect, or market based, valuation method. In other words, we attempt to infer the value of some quality factor - usually with the characteristics of a public good - by studying a market which is related to the quality factor. Once we have found such a market, we have to specify how it is linked to the quality factor, and derive a welfare measure. In Section 2.2 below, there is a discussion on how a Hicksian welfare measure for a change in quality can be derived, and under which conditions it is valid.

In the case of a change in prices, the relationship between Hicksian demand and Marshallian demand is well established, as is the relationship between the related welfare measures. For a change in quality, however, additional complications arise. This issue is addressed in Section 2.3.

The household production function (HPF) approach has been used to provide a theoretical background to the travel cost method. Bockstael, Hanemann and Strand (1987, p. 9) state that ”it [the HPF approach] provides a justification for the use of the travel cost model in certain instances, as well as a way in which to generalize the traditional model to incorporate other elements.” Smith (1991, p. 71) writes: ”The household production framework has proved especially helpful in describing the basic structure of the model and in developing specifications for site demand models.” In

[3] The case of aggregate models v. individual observation models is not closed. Using Monte Carlo simulations, Hellerstein (1995) shows that in many cases aggregate models perform markedly better than individual observation models. However, his multi-site model only allows for a few choice alternatives. It is not obvious that his results also hold in a setting with a large number of sites.

Section 2.4, the results from the previous two sections are reinterpreted within the HPF framework.

In this paper, the HPF approach is mainly used for two purposes. Firstly, it serves as an explanation for the cost function which is estimated for recreational trips. This issue is dealt with at the end of Section 2.4. Secondly, it provides a justification for the chosen approach of incorporating the cost of time in the travel cost model. Time in the HPF framework is discussed in Section 2.5.

The nature of recreational consumption implies that many individuals will choose corner solutions, in the sense that they will make zero visits to some sites. In other words, the non-negativity constraint on consumption will be binding. If more than a few sites are included, it is likely that no consumer will visit all sites. This characteristic of recreational demand has led to the adoption of discrete choice modeling techniques. In Section 2.6, welfare measurement in discrete choice models is discussed. In particular, the discussion focuses on the random utility maximization (RUM) model and the econometric specification leading to the conditional logit, and nested multinomial logit (NMNL) models. The discrete model is also extended to the HPF framework.

2.2 Welfare measures for a change in quality[4]

A theoretical justification for the use of the travel cost method to evaluate changes in environmental quality is the assumption that we can attempt to value a public good by treating it as a quality characteristic of a private good. In other words, we postulate that the individual's utility is some function, u, of a row vector of private goods, **x** - the individual's decision variable - and some quality aspect, b, which affects the utility derived from at least one of the x:s, say the utility of x_1###**x**, but is not part of the individual's decision set.[5] Thus the individual's decision problem becomes:

(1) $$\max_{\mathbf{x}} \; u = u(\mathbf{x}, b), \text{ s.t. } \mathbf{px}' = y$$

where **p** is the price vector associated with **x**, y is exogenous income, and a prime denotes a transposed vector. (The prime will be subsumed throughout the rest of the paper.) The quality characteristic, b, is thus treated as a parameter.[6]

Provided the utility function meets the usual regularity requirements, we can derive demand functions for the x:s conditional on a given level of b. From the dual of the maximization problem, we can derive an indirect utility function, v=v(**p**,b,y), and an expenditure function, m=m(**p**,b,u). The expenditure function gives us the lowest income at which the individual can achieve a given level of utility, given prices and quality.

We can then define the compensating variation[7] for a ceteris paribus change in quality from b^0 to b^1:

[4] Sections 2.2 and 2.3 are based on Bockstael and McConnell (1993).

[5] Throughout, b will be assumed to be a good, i.e. $\partial u/\partial b \geq 0$.

[6] We could instead have a vector, **b**, of quality characteristics, but for the sake of expositional clarity this section will only deal with the case of a scalar b.

(2) CV(b^1,b^0)=m($\mathbf{p^0}$,b^0,u^0)-m($\mathbf{p^0}$,b^1,u^0)

where $\mathbf{p}^0$ is the vector of initial (unchanged) prices, and u^0 is initial utility. For an increase (decrease) in quality, the compensating variation will be the amount of income that can be taken from (needs to be given to) the individual in order to put him at his initial level of utility. For a quality increase, CV could thus be interpreted as the individual’s maximum willingness to pay to secure the change, while for a decrease in quality, it would be the minimum amount he would have to be paid to accept the change.

It is well known that CV (EV) for a price change can be measured as the area to the left of the compensated demand curve for the initial (final) level of utility between the initial and final prices. Mäler (1974) suggests that this result can be extended to a change in quality, by measuring the change in the area to the left of the Hicksian demand curve, induced by a change in quality. In other words, we should try to measure the difference between the following two integrals:

(3) $$\int_{p_1^0}^{\bar{p}_1(b^1)} x_1^h(p_1,\hat{\mathbf{p}},b^1,u^0)dp_1 - \int_{p_1^0}^{\bar{p}_1(b^0)} x_1^h(p_1,\hat{\mathbf{p}},b^0,u^0)dp_1$$

where $x_1^h(\bullet)$is the compensated (Hicksian) demand for good 1, $u^0 = v(p^0,b^0,y)$ is initial utility[8], $\bar{p}_1$, the choke price, is a price high enough to cause demand to fall to zero,[9] and $\hat{\mathbf{p}}$, is the vector of all prices except p_1.

Evaluating the integrals, using $\partial m/\partial p_i = x_i^h$, we get:

(4)

$$m[\bar{p}_1(b^1),\hat{\mathbf{p}},b^1,u^0] - m(p_1^0,\hat{\mathbf{p}},b^1,u^0) - m[\bar{p}_1(b^0),\hat{\mathbf{p}},b^0,u^0] + m(p_1^0,\hat{\mathbf{p}},b^0,u^0)$$

If the first and third terms in this expression are equal, this will yield CV according to the definition (2) above. This will be the case under two conditions: x_1 must be non-essential, and b must be weakly complementary to x_1.

x_1 is said to be non-essential if it is possible to reduce the consumption of it to zero, while compensating the individual completely, i.e. to preserve his utility level by increasing his consumption of other goods. In other words, x_1 is non-essential if:

(5) $\exists \hat{\mathbf{x}}^1$ such that $u(x_1^0,\hat{\mathbf{x}}^\mathbf{0},b) = u(0,\hat{\mathbf{x}}^\mathbf{1},b)$

where $\hat{\mathbf{x}}^\mathbf{i}$, $i = 0,1$ is the vector of all goods except x_1, and $(x_1^0,\hat{\mathbf{x}}^\mathbf{0})$ is the utility maximizing bundle of goods, given prices, income and quality.

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[7] Throughout this paper, CV and EV for a fall in prices, or for an increase in quality, are defined to be non-negative. In other words, if CV or EV are positive for a change affecting an individual, his welfare has increased, and vice versa. This has sometimes necessitated changes in the notation of some of the works quoted.

[8] Replacing initial utility with final utility would yield EV instead of CV.

[9] The choke price will depend on the level of b, on the other prices, and on the level of utility. All arguments other than b will be subsumed.

Weak complementarity is a term due to Mäler (1974) and implies that the consumer's utility should be unaffected by the level of b when x_1 is not consumed. In other words, if b is weakly complementary to x_1, then:

(6) $$\frac{\partial u(0,\hat{\mathbf{x}},b)}{\partial b}=0$$

The two conditions, (5) and (6), are equivalent to:

(7) $$\lim_{p_1\to\infty} m(p_1,\hat{\mathbf{p}},b,u^0)=k,\forall b$$, where k is a constant.

Thus the first and third terms of expression (4) will net out. In terms of equation (2), (7) implies that the CV for a reduction in quality will always be finite, i.e. it will always be possible to compensate the individual by increasing his consumption of other goods.

In effect, weak complementarity rules out non-use values. Also, it rules out the case when b affects the utility not only from the consumption of x_1 but also from some other $x_i \in \hat{\mathbf{x}}$. This may be appropriate in some circumstances, but not in others. However, we can usually determine in which direction the bias would work from the nature of the quality aspect under analysis.

It is hardly surprising that an indirect valuation method will fail to capture non-use values if such values exist. It is the link between a marketed good and a non-marketed good that enables us to infer something about the value of the latter by studying the former. If the non-marketed good also appears independently in the utility function, i.e. with no link to the marketed goods, it is obvious that no inference on this part of the value can be drawn with this method. If the non-marketed goods also have a link to some other marketed good, the link we are studying can usually not give us the whole story.

We must thus keep in mind that the travel cost method will in general only measure part of the value accruing from a change in a quality factor. However, in many instances it is likely to be a considerable part of the total value. As mentioned earlier, Bockstael, Hanemann and Strand (1987) cite Freeman (1979) as stating that more than 50 percent of the value from improved water quality will usually be due to recreational values.

2.3 Welfare measures from Marshallian demand functions

Hicksian demand functions are not observable. In order to obtain welfare estimates from ordinary demand curves use may be made of Willig's (1976) result; this states that under quite general conditions, the ordinary consumer's surplus for a price change will closely approximate CV and EV. The so-called ”Willig bounds” specify how good this approximation will be. Also, it is well known that for a normal good, the Marshallian consumer's surplus for a single price change will be bounded from above by CV and from below by EV. None of these results applies in general to a quality change.

Intuitively, it is quite clear why the Willig results do not apply to a change in quality.[10] The cornerstone of his analysis is that at the original price, the ordinary demand curve coincides with the compensated demand curve for the original level of utility, and at the final price, it coincides with the compensated demand curve for the final level of utility. By the same line of reasoning, it should be clear why the Marshallian consumer's surplus for a price change of a normal good is bounded by CV and EV.

When the price changes, consumption moves along the ordinary demand curve. However, when quality changes, the Marshallian demand curve shifts. We will thus have two sets of ordinary and compensated demand curves, for the initial and final levels of quality.

In order to be able to use the Willig results, we would need the crossing point of the ordinary and compensated demand curves to be at the same price for both sets of curves. This will usually not be the case. The compensated demand at initial utility will by definition be equal to the ordinary demand at the (unchanged) price of the good. However, the compensated curve for the final level of utility will cross the ordinary curve for the final level of quality at the same price only when either a) there is no income effect, in which case Marshallian and Hicksian demand curves will coincide or b) quality does not matter, in which case the two sets of Hicksian and Marshallian curves (for initial and final quality) will be identical[11] (Bockstael and McConnell, 1993).

However, Willig (1978) has shown that under certain conditions, the marginal value of quality is the quality derivative of the ordinary demand function. The most important of these conditions is that the average incremental consumer's surplus, i.e. the average over all units of the good consumed, should be independent of income. If these ”Willig conditions” hold, then Bockstael and McConnell (1993) claim that the change in consumer's surplus for a quality change will be bounded by CV and EV.

The fact that consumer's surplus is bounded by CV and EV does not imply that the three measures must be close in size. As Hanemann (1991) has shown, CV and EV for a change in a public good (quality) can diverge considerably even when income effects are small, if no private good is a close substitute for the public good. In fact, he shows that in the limiting case where there is zero substitutability between the public good and all private goods that can be purchased on the market, EV for an increase in quality can be infinite, even when CV for the same change would be finite.[12]

We would perhaps not expect to find zero substitutability between a public good and all private goods all that often. However, for many environmental amenities, private goods are likely to be poor substitutes, and the divergence between CV and EV could thus be large. This may be of some relevance in the present case, especially if we consider a quality change that affects a major portion of the Swedish coast.

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[10]Boadway and Bruce (1984, p. 216f) give a nice intuitive explanation of the Willig bounds.

[11]If quality increases, and if quality matters, we can reduce the individual's income without reducing his utility. Thus if the good in question is normal, compensated demand at the fixed price level will be less than ordinary demand. Hence the two curves will cross at a higher price.

[12] In this case, the public good would thus be an essential good, in the sense that the condition in (5) does not hold.

2.4 The household production function approach

Another way of viewing the consumer, in order to get additional insight into the travel cost method, is the household production function (HPF) approach. This approach also offers some illuminating interpretations of the concept of weak complementarity. The question of how time should be valued is most easily understood within the HPF framework. In this paper, a cost function for recreational trips is estimated, and the resulting equation is used to calculate the cost of travel to the different destinations. The HPF model can be seen as a justification for this approach.

In the HPF approach, first presented by Becker (1965) to analyze the household's time allocation behavior, the household consumes some commodities[13] which it produces by combining goods, bought in a market, with time, by way of a household production function. In their capacity as producers of commodities, the members of the household minimize cost, given available household production technologies.

The household's decision problem in an HPF model could be specified as follows:[14]

$$\max_{\mathbf{x},\mathbf{t},t_w} u(\mathbf{z})$$

$$s.t. \begin{cases} \mathbf{z} = \mathbf{f}(\mathbf{x},\mathbf{t},b) \\ \mathbf{px} = y \\ \sum_{\forall i} t_i = T \end{cases} \tag{8}$$

The row vector **z** denotes the commodities on which the household places a positive or negative value. It is produced by means of a household production technology, which is described by the vector valued function **f**. The inputs used are a vector, **x**, of market goods, and a vector, **t**, of time allocated to different activities. The production possibilities are influenced by a non-market good, b (e.g. a public good) which is not part of the household's decision set. An alternative specification would be to let the non-market good enter the utility function directly.[15]

Two constraints bind the household. The first one is the usual budget constraint. The second constraint, the time constraint, simply states that time allocated to various activities has to equal the total time available, T.

In the HPF framework, the marginal cost of production of a commodity is the analogue of prices of goods in the usual consumer choice model. A major complication is that there is usually no reason to assume that marginal cost is constant. A reformulation of the HPF model illustrates this problem. Let us ignore the time constraint, and the non-market good, and write the household's problem:[16]

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[13] In the following, final goods, i.e. goods that enter the utility function, will be called commodities, and the word "goods" will denote inputs in the household production function. This appears to be common usage in the field.

[14] This formulation of a HPF model is adopted from Bockstael, Hanemann and Strand (1987) with some alterations.

[15] Again, we could equally well have defined b to be a vector, **b**, of non-market goods.

[16] This is adopted from Bockstael and McConnell (1983), but the notation has been slightly altered.

(9) $\max u(\mathbf{z}),\ \text{s.t. } c(\mathbf{z},\mathbf{p}) = y$

where $c(\mathbf{z},\mathbf{p}) = \min_x [\mathbf{px} | \mathbf{f}(\mathbf{x}) = \mathbf{z}]$ is the minimum cost of producing the bundle **z**, given available household production technologies, at prices **p**. The function c(**z**,**p**) will usually not be linear in **z**. Thus the powerful insights from consumer theory that build on the linearity of the budget restriction do not necessarily hold in the HPF setting.

Bockstael and McConnell (1983) show that ordinary demands for commodities as a function of their marginal costs are not even uniquely defined in the HPF approach. In other words, we cannot say what demand response will follow from a given change in the marginal price, without additional information on the cost function. However, compensated demand for commodities as functions of marginal cost can still be defined, and it is possible to define Hicksian welfare measures in commodity space for changes in price or quality. In fact, Bockstael and McConnell (1983) show that CV for a change in quality is the change in the area between the marginal value and marginal cost curves if weak complementarity holds. In other words, no additional assumption is needed to extend the validity of our CV measure to an HPF model.

Empirical estimation of CV in commodity space, as outlined above, would still be difficult, as no Marshallian demand functions exist by which we would be able to approximate the corresponding Hicksian functions. However, Bockstael and McConnell (1983) demonstrate how, under certain conditions, an equivalent measure can be derived from the demand functions on the goods market.

To see this, we first need to define the expenditure function. Depending on whether we think of the quality factor, b, as an element in the utility function, or as a factor in the household production function, we will get two different definitions of the expenditure function.

(10a) $m(\mathbf{p}, b, u^0) = \min_x \{\mathbf{px} | u^0 = u(\mathbf{z}, b), \mathbf{f}(\mathbf{x}) = \mathbf{z}\}$

(10b) $m(\mathbf{p}, b, u^0) = \min_x \{\mathbf{px} | u^0 = u(\mathbf{z}), \mathbf{f}(\mathbf{x}, b) = \mathbf{z}\}$

Regardless of which approach we choose, the expenditure function will have the same properties. However, as discussed below, the interpretation of the conditions under which the resulting welfare measure is valid will be slightly different in the two cases. Since expenditure is linear in **x**, compensated demand will be the price derivative of the expenditure function, just as in the ordinary consumer choice model. The compensated demand for x_1 will thus be:

(11) $\partial m(\mathbf{p}, b, u^0) / \partial p_1 = x_1(\mathbf{p}, b, u^0)$

Evaluating the integral in (3) will thus give (4) in an HPF model also, and will yield CV according to definition (2) if:

(12) $m(\bar{p}_1, \hat{\mathbf{p}}, b^0, u^0) = m(\bar{p}_1, \hat{\mathbf{p}}, b^1, u^0)$

The condition under which the change in the area under the compensated demand curve induced by a change in b provides a measure of CV is the same in the HPF approach as in the ordinary consumer choice model. However, the interpretations and implications are slightly different.

Bockstael and McConnell (1983) give three conditions that together are sufficient for the equality in (12) to hold. Firstly, let b be complementary to some subset of commodities, say $\mathbf{z}_A \in \mathbf{z}$, in such a way that $\partial u/\partial b=0$ if $z_i=0$, $\forall i \in A$. Secondly, let x_1 be essential for the production of all $z_i \in \mathbf{z}_A$. In other words, if we can write $\mathbf{z}=(\mathbf{z}_A,\mathbf{z}_B)$, where $\mathbf{z}_B$ is the vector of all commodities not belonging to the subset $\mathbf{z}_A$, and $\mathbf{x}=(x_1, \hat{\mathbf{x}})$, where $\hat{\mathbf{x}}$ is the vector of all goods except x_1, we should have, $\mathbf{f}(0,\hat{\mathbf{x}}) = (\mathbf{0},\mathbf{z}_\mathbf{B})$. Thirdly, the subset of commodities, $\mathbf{z}_A$ must be non-essential to the household.

The first condition is the weak complementarity condition with which we are by now familiar. In the model where b enters the utility function directly, (10a) above, the first of these conditions implies that the household's preferences are such that b is weakly complementary in the utility function to each $z_i \in \mathbf{z}_A$. If b instead enters the household production function, (10b) above, for the commodities belonging to the subset $\mathbf{z}_A$ but not for any of the other commodities, the condition will hold trivially.

Another sufficient condition for (12) to hold is to assume that b is weakly complementary in the production function with x_1, and that x_1 is not essential in the production of any $z_i \in \mathbf{z}$. (We assume that b does not enter the utility function directly.) If we denote all inputs except x_1 by $\hat{\mathbf{x}}$, sufficient conditions for (12) to hold would thus be:

$$(13) \qquad \frac{\partial \mathbf{f}(0,\hat{\mathbf{x}},b)}{\partial b} = \mathbf{0} \quad \wedge$$

$$(14) \qquad \{\exists[(x_1,\hat{\mathbf{x}}):\mathbf{f}(x_1,\hat{\mathbf{x}},b) = \mathbf{z}] \Leftrightarrow \exists[(0,\hat{\mathbf{x}}'):\mathbf{f}(0,\hat{\mathbf{x}}',b) = \mathbf{z}]\}$$

In other words, we assume that b does not affect production if x_1 is not used, and that if it is possible to produce a certain level of $\mathbf{z}$ using x_1 it will be possible to produce the same level without the use of x_1.[17] The essential points for these two alternative sets of sufficient conditions for (12) to hold are, firstly, that they ensure that it will be possible to compensate the household for the complete loss of x_1 and secondly, that if x_1 is not used, then the level of b should have no effect on utility, either directly through the utility function, or indirectly through the production function.

The advantage with this use of the HPF approach is, in the words of Bockstael and McConnell (1983, p813), that ”by focusing on goods rather than commodities, it avoids the ill-defined Marshallian commodity demands.” Also, ”all information about technology necessary to derive the value of a public input is embodied in the derived demand functions for goods.” In addition, we may often have a rather vague idea of how we should define the commodity in which we are interested. A visit to a seaside resort: Is that a commodity? Or is the commodity relaxation? Swimming? To experience the outdoors? Or perhaps all of the above? The Bockstael and McConnell approach to the problem really does not require us to specify exactly how we define the commodity. Instead, we need to find some input into the household production function which 1) is non-essential to the individual, either by beeing an input only into non-essential commodities, or by not beeing essential in the production of any

[17] Note that in this setting, we do not need to assume that $\mathbf{z}$ is non-essential to the individual. Even if $\mathbf{z}$ is essential, x_1 can be non-essential if there are alternative ways of producing $\mathbf{z}$. See Johansson (1996) for a discussion of this issue.

commodity and 2) is weakly complementary with the quality characteristic we are interested in, either in the utility function, or in the production function.

Putting the travel cost method into the HPF framework, we interpret a recreational trip as a commodity, or a bundle of commodities, which is produced with several inputs. In producing such a trip, the household may use as inputs transportation to any of a number of sites. Quality of the site, which can be a vector of characteristics, is assumed to be weakly complementary to the visit to the site in the utility function or in the production function.[18] In estimating the cost function for recreational trips, this paper assumes a specific form of the household production technology. This is necessary in order to calculate the cost to the household of visiting the alternative sites, as we only have data on the cost of visiting the site which is actually chosen.

2.5 Time in an HPF framework

It has long been acknowledged that account needs to be taken of travel time when performing a travel cost study. As Cesario (1976) and others have pointed out, ignoring the cost of time would lead to an underestimation of recreational benefits. If time cost is not added to the monetary cost of traveling to a site, the total cost of the trip is underestimated. The absolute value of the demand response for a given change in price will thus be overestimated, and as a result benefits will be underestimated. Cesario proposes a crude way of incorporating the time used for traveling to the recreational site. On the basis of a number of empirical studies, he suggests that non-work travel time should be valued at between one fourth and one half of the after-tax wage rate.

The HPF approach, which was originally conceived to study the allocation of time, lends itself to a somewhat more elaborate treatment of this issue. In Becker’s (1965) original formulation, a fixed amount of time is needed to ”produce” each commodity (or alternatively, to consume it). Only the commodities, but not time, enter the utility function. DeSerpa (1971) extends the model to allow time also in the utility function. Thus utility is a function not only of commodities but also of the time allocated to consuming them. The consumption of a commodity requires a minimum amount of time, but the individual may elect to spend more than that amount of time in its consumption.

We now ignore non-market goods, and assume that all household production involves combining only one of N marketed goods with time. The decision problem can then be stated as:[19]

[18] For all practical purposes, the question of whether the quality aspect affects utility directly or through the production function is of no consequence.

[19] This formulation, which is due to DeSerpa (1971), is used by Johansson and Mortazavi (1995). The notation is slightly altered.

$$\max_{\mathbf{x},\mathbf{t}} u(\mathbf{x},\mathbf{t})$$

(15) $$s.t.\begin{cases}\mathbf{px} = y \\ \sum_{\forall i} t_i = T \\ t_i \geq \alpha_i x_i, \forall i\end{cases}$$

The coefficients α_i can be seen as technological constants, determining the minimum amount of time needed to consume the x_i:s. DeSerpa refers to the inequality constraints as time consumption constraints, as opposed to the other time constraint which he denotes the time resource constraint. The budget constraint is the usual one.[20,21]

This problem yields the first-order conditions, with regard to the time arguments:

(16) $$\partial u / \partial t_i = \mu - \kappa_i, \forall i$$

where μ and κ_i are the Lagrangian multipliers associated with the time resource and the time consumption constraints respectively. We have $\mu>0$ and $\kappa_i \geq 0$, with $\kappa_i=0$ when the consumption constraint is not binding.

Dividing condition i by the marginal utility of income, termed λ, yields a money measure of the marginal value of time allocated to activity i. DeSerpa terms this the value of time as a commodity:

(17) $$\frac{\partial u / \partial t_i}{\lambda} = \frac{\mu}{\lambda} - \frac{\kappa_i}{\lambda}$$

The value of time in different activities will thus, in general, be different as soon as the time consumption constraint is binding. As Johansson and Mortazavi (1995) point out, we cannot a priori say whether the value of time in a given activity should be more or less than the wage rate.

From an economist's point of view, the time resource constraint is irrevocably exogenous. We cannot acquire more time. The first term on the right-hand side of

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[20] In DeSerpa's model, the labor-leisure decision is not explicitly dealt with. Money income, y, is fixed. The interpretation of this can be either that work hours are institutionally fixed, or that one of the commodities, the price of which is negative, is work.

[21] Note that this formulation of the HPF model can be seen as a special case of the formulation used in (8). The problem could equivalently be formulated as:

$$\max_{\mathbf{x},\mathbf{t}} u(\mathbf{z})$$

(15') $$s.t.\begin{cases} z_j = \min\left(x_j, t_j / \alpha_j\right), j = 1, \ldots, N \\ z_j = t_j, j = (N+1, \ldots, 2N)\end{cases}$$

where the t_j, j=N+1,...,2N, are defined to be the time spent on consumption of commodity j-N, and the resource constraints are the same as in the original problem.

(17), the value of time as a resource, is perhaps of little significance. However, the second term, in DeSerpa's vocabulary the value of saving time in a given activity, has an empirical content, and can be estimated. The HPF framework thus provides us with a means of empirically determining the value placed by the household on time spent traveling to a recreation site.

In this paper, the time cost estimates by Johansson and Mortazavi (1995) will be added to the monetary cost of making a trip, to obtain the total travel cost. These authors use DeSerpa's approach, and obtain a per hour cost of recreational travel time.

2.6 Welfare measures and discrete choice

The nature of recreational behavior forces us to deal explicitly with the non-negativity constraints on consumption. Especially when dealing with multi-site models, we can expect a majority of the consumers to make zero visits to one or several of the sites, i.e. they will choose corner solutions to their utility maximization problem. Therefore discrete choice models are often used to describe recreational behavior. Discrete choices complicate analysis, either by causing discontinuous demand, or by leading to points of non-differentiability in the indirect utility function, and in the expenditure function. However, Small and Rosen (1981) show that under very general conditions, the usual compensated variation measure is valid also in the presence of discreteness, with the same restrictions as in the continuous case. Below, their model is set in an HPF framework, but the argument is basically the same.

Suppose the consumer decision problem can be formulated as:

(18) $$\max_{\mathbf{x}} u(z, x_n)$$

where the z, which can be a vector or a scalar, is produced with household production technology:[22]

(19) $$f(x_1, x_2, \hat{\mathbf{x}}, b) = z$$

The vector $\hat{\mathbf{x}}$ denotes all inputs into the production of z, other than x_1 and x_2, which are discrete, mutually exclusive goods, i.e. we must have $x_1 x_2 = 0$. The quality factor, b, is assumed to be weakly complementary to x_1 in the production function.[23] The budget restriction becomes:

(20) $$p_1 x_1 + p_2 x_2 + \hat{\mathbf{p}}\hat{\mathbf{x}} + x_n = y$$

As long as x_n is perfectly divisible, u is strictly increasing in x_n, u is non-decreasing in z, and f is non-decreasing in all its arguments, the indirect utility function will exist and be strictly increasing in income. Thus it can be inverted to obtain the expenditure function.[24]

[22] Naturally, if we define z to be a vector, we will need to define the function f to be vector valued.

[23] We could equally well make b weakly complementary in the utility function. For example, the quality factor, b, could be weakly complementary to a commodity in the production of which x_1 is a necessary input. The important requirement is, as earlier, that the consumer do not care about b if no x_1 is purchased.

[24] This is almost exactly the same argument as that used by Small and Rosen (1981).

Now write the conditional expenditure function for good i∈ {1,2}, i.e. the minimum expenditure needed to obtain a certain level of utility, given that the individual consumes good i:

(21) $$\tilde{m}_1(p_1, \hat{\mathbf{p}}, b, u) \text{ and } \tilde{m}_2(p_2, \hat{\mathbf{p}}, u)$$

These two functions can be seen as the result of solving two sub-problems: cost minimization conditional on the consumption of each of the two goods. Formally, each sub-problem will be identical to a usual continuous problem. The conditional expenditure functions will thus be continuous, and the price derivative of the two functions will be the conditional compensated demand for x_1 and x_2, respectively. The reasoning is the same as that behind equation (11) above.

Naturally, the unconditional expenditure function will be the minimum of these two functions, as this will be the minimum income needed to put the individual on the reference level of utility.[25] In other words, the unconditional expenditure function will be:

(22) $$m(p_1, p_2, \hat{\mathbf{p}}, b, u) = \min\{\tilde{m}_1(p_1, \hat{\mathbf{p}}, b, u), \tilde{m}_2(p_2, \hat{\mathbf{p}}, u)\}$$

For prices p_1 and p_2 where x_1 (x_2) is consumed, the unconditional expenditure function will thus coincide with the conditional expenditure function for x_1 (x_2). At the switching point, e.g. at the prices at which the consumer is indifferent between the two goods, the two conditional expenditure functions will be equal. The conditional expenditure function will thus be continuous everywhere and differentiable everywhere except at the switching points where it will be right and left differentiable. In fact, the negative of the derivative of the unconditional expenditure function with regard to p_1 (p_2) will be equal to x_1^h (x_2^h) when x_1 (x_2) is consumed, and zero otherwise.

From this it follows that we can write the compensating variation for a price change so that it can still be measured as the area to the left of the compensated demand curve between the initial and final prices, just as in the continuous case. In other words:

(23) $$m(p_1^0, p_2, \hat{\mathbf{p}}, b, u^0) - m(p_1^1, p_2, \hat{\mathbf{p}}, b, u^0) = \int_{p_1^0}^{p_1^1} x_1^h(p_1, p_2, \hat{\mathbf{p}}, b, u^0)\,dp_1$$

where p_1^0 is the initial price, p_1^1 is the final price and u^0 is the initial utility. Following Small and Rosen (1981), we differentiate this expression with respect to b and let p_1^1 go to infinity. Keeping expression (7) in mind, i.e. the assumption that the quality derivative of the expenditure function goes to zero as the price goes to infinity, we get:

(24) $$\frac{\partial m(p_1^0, p_2, \hat{\mathbf{p}}, b, u^0)}{\partial b} = \int_{p_1^0}^{\infty} \frac{\partial x_1^h(p_1, p_2, \hat{\mathbf{p}}, b, u^0)}{\partial b}\,dp_1$$

Integrating this expression from b^0 to b^1 yields an expression for the compensating variation for a change in quality:

[25] For the sake of expositional clarity, we do not consider the case where none of the discrete goods are consumed. The reasoning is easily extended to include that case also.

$$CV(b^1,b^0) = m(p_1^0,p_2,\hat{\mathbf{p}},b^0,u^0) - m(p_1^1,p_2,\hat{\mathbf{p}},b^0,u^0) = \tag{25}$$
$$= \int_{p_1^0}^{\infty}[x_1^h(p_1,p_2,\hat{\mathbf{p}},b^1,u^0) - x_1^h(p_1,p_2,\hat{\mathbf{p}},b^0,u^0)]dp_1$$

This integral is obviously equal to the one in (3) above. In other words, we can define CV for a change in quality in the same way in a discrete setting as in a continuous setting.

2.6.1 The random utility maximization model

A model commonly used in discrete choice analysis is the random utility maximization (RUM) model. A RUM model can be described as follows.[26] The individual is assumed to choose between a finite number, say N, of mutually exclusive alternatives. The alternatives are such that either the individual consumes a fixed quantity of an alternative, or he does not consume it at all. Leaving the HPF framework for the moment, the model can thus be written:

$$\max_{x_n,\mathbf{x}} u(x_n,\mathbf{x},\mathbf{b},\varepsilon) \tag{26}$$
$$s.t.\begin{cases} x_n + \mathbf{px} = y \\ x_j \in \{0,1\},\ j = (1,2,\ldots,N) \\ x_j x_k = 0, \forall[j,k = (1,2,\ldots,N) \wedge j \neq k] \end{cases}$$

As before, x_n is our numeraire good. The vector **x** is the N-dimensional vector of discrete goods, and **p** is the associated price vector. The vector, $\varepsilon=\{\varepsilon_1,\varepsilon_2,...,\varepsilon_j,..,\varepsilon_N\}$, is an N-dimensional vector of stochastic terms. Each ε_j is associated with alternative j, and affects the individual's utility from choosing that alternative, but not the utility from the other alternatives. The N-dimensional vector $\mathbf{b}=\{b_1,b_2,...,b_j,...,b_N\}$ is a vector of quality characteristics of each alternative, and enters the utility function so that each b_j is weakly complementary with the consumption of alternative x_j for j=(1,2,...,N).[27]

As Smith (1989) points out, the RUM model implies a time horizon short enough to make appropriate the assumption that choices are mutually exclusive. Very few choices are mutually exclusive in the long run. Even though it is usually reasonable to assume that an individual only buys one home to live in, over a longer time period, of say a few decades, we would no longer expect residential alternatives to be mutually exclusive. Conversely, if the time horizon is short enough, almost all consumption will take the form of choices between mutually exclusive alternatives. The choice of time horizon is thus crucial in discrete choice analysis. In the case of a travel cost analysis, this implies that we focus on the separate choice occasion, and not on a whole season.

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[26] For discussions of the RUM model, see e.g. Smith (1989), Bockstael, McConnell and Strand (1991), Small and Rosen (1981), Maddala (1983) or McFadden(1976).

[27] We could instead have a vector, $\mathbf{b_j}$, of characteristics associated with each alternative, in which case we would have a matrix $\mathbf{B}=\{\mathbf{b}_1,\mathbf{b}_2,...,\mathbf{b}_N\}$ instead of the vector **b**. Again, for the sake of expositional clarity, I will let the quality factor be one dimensional.

Further, the RUM model implies that decisions are independent across choice occasions. In other words, when making a recreational decision, the individual is not influenced by past decisions of the same nature. The fact that a certain site has been visited in the past makes it neither more nor less likely that it will be visited again.

From (26), we can write the conditional direct utility, i.e. the utility if the individual chooses alternative j:

(27) $$\tilde{u}(x_n, x_j, b_j, \varepsilon_j)$$

where it follows from the constraints on the initial problem, that

(28) $$x_n + p_j = y,\ x_j = 1$$

Substitution yields the conditional indirect utility function:

(29) $$\tilde{w}(y - p_j, 1, b_j, \varepsilon_j) = \tilde{v}(y - p_j, b_j, \varepsilon_j)$$

This is the result of Hanemann (1982), that in a pure discrete choice model, price and income must enter the utility function as y-p. The individual chooses the alternative that yields the highest utility. His unconditional indirect utility function can thus be written:

(30) $$v(y - p_1, y - p_2, \ldots, y - p_N, \mathbf{b}, \varepsilon) = \max[\tilde{v}_1, \tilde{v}_2, \ldots, \tilde{v}_N]$$

where $\tilde{v}_j = \tilde{v}(y - p_j, b_j, \varepsilon_j)$

If this convenient form of the indirect utility function is to hold also in the HPF framework, we must preserve the problem's characteristic as one of pure discrete choice. We could then assume that each discrete input good is a necessary input into a discrete commodity. The price would then be the total price for producing the commodity in question. For all practical purposes, the HPF model would then be identical to the ordinary consumer choice model.

Alternatively, we could assume that regardless of what discrete good the individual chooses, he incurs a fixed cost in producing the resulting commodity, or bundle of commodities. This latter assumption is natural in the context of a travel cost model. Suppose the cost of a trip consists of two parts, the travel cost and on-site costs. Further, suppose that the discrete goods which we are considering are defined as travel alternatives to N available sites. The travel cost would then correspond to the price of the discrete goods. If we assume that on-site costs are fixed for each individual, regardless of which site he chooses, and redefine y to be income minus on-site costs, the properties of the indirect utility function above are preserved. With these assumptions, we get the same results as with the ordinary consumer choice model, and do not need to complicate the analysis by specifically referring to the HPF model. The arguments in the utility function are just interpreted slightly differently. (For a specification of a RUM model in the HPF framework, see Appendix B.)

Since utility from a given alternative is stochastic, we can write the probability that the individual will choose alternative j as:

(31) $$\pi_j = prob[\max\{\tilde{v}_1, \tilde{v}_2, \ldots, \tilde{v}_N\} = \tilde{v}_j] = prob[\tilde{v}_j \geq \tilde{v}_k, \forall k = (1,2,\ldots,N)]$$

The probability that j will be chosen is thus the probability that the utility from consuming j will be higher than the utility from consuming any other alternative.

Now, suppose that individuals in the population differ with regard to a vector of observable characteristics, $\mathbf{s}^i$, where super-index denotes individual, and that the indirect utility for individual i, conditional on the choice of alternative j, can be written:

(32) $$\tilde{V}_j^i = V_j^i + \varepsilon_j^i \text{ where } V_j^i = V(y^i - p_j^i, b_j; \mathbf{s^i})$$

This implies that we assume that the conditional indirect utility function is additively separable into a deterministic part, $V(y^i\text{-}p_j^i,b_j;\mathbf{s^i})$, and a stochastic part, ε_j^i. The stochastic term is specific both to the individual and to the site. In other words, all individuals will face different realizations of the random vector ε, where each term is associated with exactly one alternative. We also allow different individuals to face different prices for the same alternative. This is natural in the travel cost context, as the cost of travel to a given site will be different for different individuals. The function V is assumed to be the same function of individual specific and site specific terms for all individuals and sites.

The probability that individual i will choose site j can then be written:

(33) $$\pi_j^i = prob[V_j^i + \varepsilon_j^i > V_k^i + \varepsilon_k^i, \forall k \neq j]$$

Thus, individual i will choose alternative j if the sum of deterministic utility and the stochastic term is higher for alternative j than for any other alternative. Given a joint probability distribution of the ε_j^i:s, the probability will be a function only of the deterministic part of utility. This means that we can write $\pi_j^i = \pi_j^i(\mathbf{V}^i)$, where $\mathbf{V}^i=\{V_1^i, V_2^i,..., V_N^i\}$. If we assume a functional form for the conditional indirect utility function, i.e. the function V, then the probabilities can be estimated empirically.

Now, define the cumulative distribution function of $\varepsilon_j^i \in \boldsymbol{\varepsilon}^\mathbf{i}$:

(34) $$F(\varepsilon) = \Pr(\varepsilon_j^i < \varepsilon)$$

In other words, $F(\varepsilon)$ is the probability that the realization of the random variable ε_j^i will be less than ε. Assume that this function is everywhere differentiable, and define the probability density function:

(35) $$f(\varepsilon) = \partial F(\varepsilon) / \partial \varepsilon$$

Subsuming the super index for an individual, we can then write (33) as:

(36) $$\pi_j = prob[\varepsilon_k < \varepsilon_j + V_j - V_k, \forall k \neq j] = \int_{-\infty}^{\infty} \prod_{k \neq j} F(\varepsilon_j + V_j - V_k) f(\varepsilon_j) d\varepsilon_j$$

A commonly used distribution in RUM models is the type I extreme value distribution. (See e.g. McFadden, 1973, Maddala, 1983 or Anderson, de Palma and Thisse, 1992.) If ε follows this distribution then the cumulative distribution function and probability density function of $\varepsilon_j \in \varepsilon$ are defined to be:

(37) $$F(\varepsilon) = \exp(-e^{-\varepsilon})$$

(38) $$f(\varepsilon) = \exp(-\varepsilon - e^{-\varepsilon})$$

It can then be shown that the probability that alternative j will be chosen can be written:

(39) $$\pi_j = \frac{e^{V_j}}{\sum_{k=1}^{N} e^{V_k}}$$

(See e.g. Maddala, 1983. The derivation is presented in Appendix A.) We thus get a very simple closed form solution for the choice probabilities. In empirical applications, the function V is usually assumed to be linear. It is then obvious from (39) that factors which are constant over alternatives will cancel out of the choice probabilities. Individual specific characteristics will thus have no influence on the probabilities of choosing a certain alternative insofar as they do not interact with choice-specific variables.

If we can write $V_j=\beta \mathbf{Z}_j$ where $\mathbf{Z}_j$ is a vector of site-specific characteristics, and β is the associated parameter vector, then (39) can be written:

(40) $$\pi_j = \frac{e^{\beta \mathbf{Z}_j}}{\sum_{k=1}^{N} e^{\beta \mathbf{Z}_k}}$$

The model resulting from this distributional assumption on ε, usually termed the conditional logit model,[28] was originally developed by McFadden (1973). Apart from the assumptions underlying the RUM model, the conditional logit model implies that the choice probabilities have the property which is called independence of irrelevant alternatives. This means that the ratio of the probabilities of choosing two alternatives is independent of the characteristics of all other choice possibilities. This is obvious from (39), since the denominator cancels out if we take the ratio of the probabilities for two alternatives. This is econometrically convenient, but not always theoretically appealing.[29]

Two main paths have been followed in attempts to soften the assumption of independence of irrelevant alternatives. One way is to assume that ε is distributed according to the multivariate normal distribution. However, the resulting multinomial probit model does not give us the nice closed-form solution for the probabilities of the conditional logit model. If we have N choice alternatives, the probabilities will be N-1 variate integrals. If we have more than a few alternatives and parameters, the

[28] The conditional logit model is sometimes called the multinomial logit model. Following Greene (1993) and Maddala (1983), this latter term is reserved for models where the probabilities of the individual making a certain choice are functions of the characteristics of the individual, while the term conditional logit model is used when the choice probabilities are functions of characteristics of the choice alternatives. The way the problems are set up is different in these two models. However, the likelihood functions will be the same.

[29] The property of independence of irrelevant alternatives is often illustrated by the ”red bus-blue bus problem”. Suppose an individual can choose between two alternatives for getting to work: car or a blue bus. Suppose a new alternative is introduced: a red bus. Independence of irrelevant alternatives implies that the probability ratio between car and blue bus should remain the same, i.e. the probability that someone who, in the old setting, would have gone by car will switch to the red bus should be the same as the probability that someone who formerly went by blue bus will switch to the red bus. This does not appear reasonable. (See e.g. Train, 1986).

estimation of a multinomial probit model is problematic even with small samples (Greene, 1993).

The other attempt at relaxing the assumption of independence of irrelevant alternatives is to assume that ε follows a generalized extreme value distribution. (For a definition of the generalized extreme value distribution, and a discussion of the resulting choice probabilities, see Appendix A.) The resulting model, developed by McFadden (1976), is usually termed the nested multinomial logit (NMNL) model. In the NMNL model, we can allow choices within a group of alternatives to be more closely correlated with each other than with alternatives which are not part of the group.

The NMNL model takes its name from the decision structure which we imagine gives rise to the model. Suppose the N alternatives can be divided into S subgroups, such that each alternative belongs to exactly one subgroup. Denote the set of choices, j, belonging to subgroup s, by Σ_s, for s=(1,2,...,S). The individual is then seen as choosing first between the subgroups, and then between the alternatives belonging to the chosen subgroup. The decisions are assumed to be independent over decision levels, i.e. different factors affect the decision at the two levels.[30]

Assume that the deterministic part of the conditional indirect utility is a linear function, such that the utility from visiting site j, $j\in\Sigma_s$, can be written:

(41) $$V_{j,s}=\beta_a\mathbf{X}_s+\beta_b\mathbf{Y}_{j,s}$$

where $V_{j,s}$ is deterministic utility from visiting site j in subgroup s. $\mathbf{X}_s$ is a vector of characteristics of the subgroup s, which are assumed to be constant over alternatives belonging to subgroup s, and β_a is the associated parameter vector. In a travel cost analysis, we would interpret $\mathbf{X}_s$ as regional variables, such as average rainfall, expected days with sunshine, etc. The vector $\mathbf{Y}_{j,s}$ is a vector of choice specific attributes, and β_b is the associated parameter vector. In a travel-cost analysis, $\mathbf{Y}_{j,s}$ would be site-specific factors.

Write the probability that alternative $j\in\Sigma_s$ will be chosen as:

(42) $$\pi_j=\pi_{j|s}\cdot\pi_s$$

where π_j is the probability that j will be chosen, $\pi_{j|s}$ is the probability that j will be chosen conditional on the choice of s, and π_s is the probability that subgroup s is chosen. If we assume that ε follows a generalized extreme value distribution, and put some restrictions on the parameters of the distribution (see Appendix 1), it can be shown that the probability that the individual will choose subgroup s can be written (see e.g. Anderson, de Palma and Thisse, 1992 or McFadden):

(43) $$\pi_s=\frac{e^{\beta_a X_s+(1-\sigma)I_s}}{\sum_{t=1}^{S}e^{\beta_a X_t+(1-\sigma)I_t}}$$

where

[30] We will confine the discussion to the two-level nested model. The reasoning is easily extended to any number of nesting levels.

(44) $$I_t = \ln\left(\sum_{j\in\Sigma_t} e^{\beta_b Y_{j,t}/(1-\sigma)}\right), \text{ for t=(1,2,...S)}$$

I_t is termed an inclusive value and can be seen as a measure of the attractiveness of region t. The higher the inclusive value, the more attractive the region. In fact, the inclusive value for group t can be shown to be the expected value of the maximum of the utilities from alternatives in group t (Verboven, 1996). As the individual is assumed always to choose the best alternative, the inclusive value is thus his expected utility, conditional on the choice of an alternative in group t.

The coefficient on the inclusive value, 1-σ, is often called the dissimilarity parameter, as it can be seen as a measure of the degree of similarity of alternatives belonging to each group. McFadden (1981) has shown that this coefficient must lie in the unit interval for the model to be consistent with stochastic utility maximization. A value close to zero implies great similarity between the alternatives in the subgroup, and a value close to one denotes little similarity. If the value is exactly one, we are back to the ordinary conditional logit model.

Given that the individual has chosen subgroup s, the probability that he will choose alternative $j\in\Sigma_s$ can be written:

(45) $$\pi_{j|s} = \frac{e^{\beta_b \mathbf{Y}_{j,s}/(1-\sigma)}}{e^{I_s}} = \frac{e^{\beta_b \mathbf{Y}_{j,s}/(1-\sigma)}}{\sum_{k\in\Sigma_s} e^{\beta_b \mathbf{Y}_{k,s}/(1-\sigma)}}$$

Notice that expressions (43) and (45) have the same form as (40). In fact, expression (45) defines a conditional logit model. This is easy to see if we assume for a moment that we are only dealing with alternatives belonging to subgroup s and define $\beta_b' = [1/(1-\sigma)]\beta_b$. Expression (45) will then be of precisely the same form as (40). A similar exercise can be performed for equation (43), if we define $\mathbf{X}_t' = \{\mathbf{X}_t, I_t\}$ and $\beta_a' = \{\beta_a, (1-\sigma)\}$. We then treat each subgroup as a separate alternative. The NMNL model can thus be seen as a "nesting" of simple conditional logit models. The NMNL model can then be estimated by first estimating the lowest nesting level, then calculating the inclusive value for each subset, and finally using the inclusive value as an independent variable in estimating the higher nesting level.

2.6.2 Welfare measures in the RUM model

Small and Rosen (1982) derive a convenient expression for the compensating variation in a RUM model, for a change in quality or prices which changes the vector of values of the conditional indirect utility function, $\mathbf{V^m}=\{V(y-p_1^m,\mathbf{b}_1^m), V(y-p_2^m,\mathbf{b}_2^m),..., V(y-p_N^m,\mathbf{b}_N^m)\}$[31], where m=(0,1) from $\mathbf{V}^0$ to $\mathbf{V}^1$:

(46) $$CV(\mathbf{V}^1,\mathbf{V}^0) = \frac{1}{\lambda}\int_{\mathbf{V}^0}^{\mathbf{V}^1}\sum_{j=1}^{N}\pi_j(\mathbf{V})d\mathbf{V}$$

[31] We thus allow for multi-dimensional quality at each site, and subsume individual characteristic factors.

where λ is the (constant) marginal utility of income.[32] If we interpret the π_j:s as the probabilistic demand for alternative j, this expression can be interpreted as the change in the area to the left of these curves, caused by a change in quality.

For the conditional logit and NMNL models, i.e. with probabilities as defined by (40) and (43)-(45) respectively, Small and Rosen (1982) show that a closed-form solution can be obtained for (46). For a change in the vector of values of the conditional indirect utility from $\mathbf{V}^0$ to $\mathbf{V}^1$, we will have:

(47) $$CV(\mathbf{V}^1, \mathbf{V}^0) = \frac{1}{\lambda}\left[\ln\left(\sum_{j=1}^{N} e^{V_j}\right)\right]_{\mathbf{V^0}}^{\mathbf{V}^1}$$

where V_j is defined as in (41) in the case of an NMNL model, and as $V_j=\beta\mathbf{Z}_j$ in the conditional logit model. Note that expression (47) is very similar to expression (44). In fact, the term within square brackets in (47) defines an inclusive value. While the inclusive value in (44) is the expected utility given that an alternative in subgroup t is chosen, this term is the unconditional expected utility, i.e. expected utility when the individual is allowed to choose between all alternatives. Thus (47) is the change in expected utility induced by the change in prices and quality, and weighted by the inverse of the marginal utility of income, λ, to produce a monetary measure of the change in utility. Income will be constant over alternatives in the linear specification of the indirect utility function, and cannot be obtained directly. However, from (29) it follows that the marginal utility of income will be the negative of the price coefficient in a linear model.

If we obtain estimates of the coefficients, β or (β_a,β_b), expression (47) can be used to obtain estimates of CV for each individual for actual or hypothetical changes in the quality of one or several of the alternatives. To obtain aggregate CV, we need to summarize over individuals. If we assume that marginal utility of income is also constant over individuals, this is done by calculating (47) for each individual in the sample, summing over all individuals, and multiplying by the inverse of the sampling ratio.

One additional point needs to be noted. As the RUM model focuses on the choice of recreation site given that a trip is undertaken, the total number of trips is exogenous. Two groups of solutions to this problem have been proposed. One alternative is to introduce a zero trip alternative as a top nesting level of an NMNL model (Morey, Rowe and Watson, 1993). An alternative is to estimate an NMNL model, conditional on participation, and then estimate a count data model for the participation decision. Usually, an inclusive value for all alternatives such as the value within square brackets in (47) is calculated, based on the estimated coefficients from the NMNL model, and this value is then used as an independent variable in the participation model. (See e.g. Bockstael, Hanemann and Kling, 1984, Hausman, Leonard and McFadden, 1993 or Creel and Loomis, 1992).

[32] To arrive at this expression, Small and Rosen (1981) assume that the marginal utility of income is approximately independent of prices and quality, that income effects are negligible, i.e. that the goods in question consume a sufficiently small part of the individual's budget, and that non-essentiality and weak complementarity hold. Silberberg (1972) has shown that if the Jacobian matrix $(\partial\pi_i/\partial V_j)$ is symmetric, this line integral will be path-independent.

Both these approaches will always predict an increased number of trips undertaken if quality increases. This need not be a plausible assumption. Suppose the quality at a distant site increases. In this case it is entirely likely that the individual will substitutes a visit to this high-quality site for more than one visit to closer, lower-quality sites, thus reducing the total number of trips. To relax this assumption, it has recently been proposed that expected values of prices and quality (based on the estimated probabilities from the NMNL model) should instead be used as independent variables in the participation model (Feather, Hellerstein and Tomasi, 1995). As the expected price can then rise, when the quality of a distant site increases as the probability of visiting that site increases, the expected total number of trips can than either fall or rise.

In this study, however, the participation decision will be taken to be exogenous, for reasons explained in Section 3.3 below. The CV measure defined above in (47) will thus be CV conditional on the initial number of trips. Morey (1991) has shown that this can be interpreted as a Laspeyres index that will bound CV from below. However, he also shows that this measure can diverge substantially from true CV. How much it diverges is determined by the marginal rate of substitution between recreational trips and staying at home. The higher the marginal rate of substitution, the larger the disparity between our CV measure and true CV. In other words, if staying at home is a close substitute to making a trip, we can expect the change in the total number of trips to be large, and consequently the divergence between true CV and our Laspeyres index will also be large.

Let us summarize what the formula in (47) claims to measure, and what it can never measure. We have assumed weak complementarity. Thus, if our quality characteristic enters the utility function directly, and independently of the consumption of any marketed good, i.e. involving non-use values, then such values will not be captured. The same will be true of values that accrue to other goods which enter the utility function as complementary to the quality factor. We have also made some other rather strong assumptions about the form of the utility function, implying among other things that the marginal utility of income is constant. However, if we are prepared to live with the assumptions behind this model, we have a tool which can easily be used to calculate the change in welfare from proposed or actual changes in quality characteristics.

3. Model specification and empirical issues

In this paper, the household is assumed to choose between N sites. It will visit exactly one site. To visit a given site, it will have to use transportation to that site as an input good. The cost of this transportation consists of monetary travel cost, plus the cost of travel time. The sum of these two elements is termed the total travel cost. Regardless of which site is visited, fixed amounts of other goods and of time will be used. The cost incurred for these resources is termed on-site cost. The total cost of a trip will thus consist of a fixed element, the on-site cost, and a term which depends on which site is visited, the total travel cost. The value which the household derives from a trip will depend on a vector of quality characteristics of the site chosen and a random term which is interpreted as in Section 2.6.1. The quality characteristics are thus weakly complementary to transportation to that site. A formal specification of the model is provided in Appendix B.

The part of the cost of a trip that is independent of the site visited will not influence the decision about which site the household should visit, as it has no variation over alternatives. Thus if we have measures of, or make assumptions about, the kilometer cost of travel, the average speed of travel, and the cost of travel time, we can calculate the total travel cost to sites at different distances from the household's place of residence.

The usual way to calculate monetary travel cost is simply to multiply the travel distance by some calculated kilometer price, such as the vehicle operating cost. In this paper, a cost function will instead be estimated, based on the stated total trip cost.[33] This goes some way towards meeting the criticism expressed by Randall (1994) about the travel cost method. He claims that a fundamental problem with the travel cost method is that travel cost is unobservable.[34] Using the stated cost, and the detailed data available from the tourism and travel database (TDB), may hopefully help us to come closer to a true measure of travel cost.[35] The TDB is described in Section 3.1, and the cost function is described in Section 3.2.

A measure of the monetary kilometer cost of travel is obtained from the cost function. The total travel cost is obtained by adding the estimated time cost of recreational travel, taken from a study by Johansson and Mortazavi (1995). This variable is then used as an explanatory variable in the actual travel cost model. This model is described in Section 3.3.

A crucial issue in estimating environmental benefits is how we measure quality, and how policy affects this measure. Bockstael, Hanemann and Strand (1987) cite Vaughan, Russell and Gianessi (1982) as proposing that five links should be captured to estimate the benefits from policies intended to improve water quality. Firstly, we need to know how policy affects emissions. Secondly, we need to know how this change in emissions translates into changes in ”ambient environmental conditions”. Thirdly, we need to know how this change in ”ambient environmental conditions” translates into some quality characteristic that is perceived by recreationists. Fourthly, we need to know how the change in this perceivable quality characteristic affects recreational behavior. Finally, we need to value this change.

Thus far, we have only dealt with the last two of these points. Estimating the costs of a policy deals implicitly or explicitly with the first point. Some studies have been made of the effects of policy on emissions of nutrients in connection with estimates of the cost of reducing emissions (primarily Green, Elofsson and Jannke, 1995 and Johannesson and Randås, 1995). It can be argued that points two and three are outside

[33] This approach is basically the same as that of Boonstra (1993).

[34] The problem pointed out by Randall is in no way unique to the travel cost method. All consumption involves subjective factors that affect the ”true” cost of the good in question. To consume a good, usually we first need to buy it. However, shopping can itself be a commodity that should enter the utility function, on which the individual may place a positive or negative value. Thus, the price of a consumption good does not measure the cost of the good exactly. It may overstate or understate the true cost.

[35] An econometrically more sophisticated approach is presented in Englin and Shonkwiler (1995). They use a latent variable model to include the effect on the unmeasurable total travel cost of out-of-pocket costs, travel time and the opportunity cost of time (measured by the wage rate).

the realm of economists. However, without any knowledge of these two links, policy evaluation will be impossible.

In order to make policy simulations, we will make two alternative, crude assumptions concerning point two. In the simulation on a trans-Baltic reduction of emissions, we will assume that a reduction in the nutrient load would result in a uniform reduction of the concentration of nutrients along the Swedish coastline. In the policy experiment on a local reduction of nutrient emissions, the assumption will be that this reduction will only affect the immediately surrounding area.

In the present study, the quality variable that is related to the nutrient load is sight depth. The link corresponding to point three above would thus be the link between the concentration of nutrients and sight depth. To establish this link, a simple regression is run with sight depth as the dependent variable, and nitrogen concentration, phosphorus concentration and water temperature as explanatory variables. This model, and a discussion of the chosen quality index, based on sight depth, is presented in Section 3.4. The results of this regression are used for the policy simulations presented in Section 5.

3.1 The Tourism and Travel Data Base (TDB)[36]

The source for the data on travel behavior used in this study is the tourism and travel data base (TDB). The TDB is based on information collected through telephone interviews. Telephone numbers are selected at random by the so-called random digital dialing method. If the number, when called, turns out to belong to a private household, a member of the household is randomly selected and interviewed. If the person selected is under the age of 15 one of the parents is interviewed. If contact is not made, the same number is called up to eight times. If still no contact is made, a new number is selected. Around 2000 interviews are performed each month, except for June and July, when 4000 interviews are performed each month.

TDB contains socio-economic variables, and information on trips made by the interviewee during the month of interest. The TDB distinguishes between eight types of trip, two of which are of interest for the present study: recreational travel within Sweden with overnight stays away from home, and the same without overnight stays.[37] A serious limitation is that day-trips are only reported if they are undertaken to a destination that lies 100 km or more away from home. However, it could be argued that the trips thus excluded constitute a quite different commodity - ”close-to-home” tourism. The two most recent trips in each category made by the interviewee are followed up. Information is acquired on the number of nights away from home, number of nights in each of several categories of accommodation, objective(s) of the trip, main mode of transportation, destination(s), money spent for different purposes, etc. The month during which the trip was made is recorded.

A main point of criticism of the TDB is that non-responses are not reported satisfactorily. The non-responses are given as accounting for between 15 and 25

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[36] This section mainly relies on Christianson (1990), Cassel, Burke Marknadsinformation AB (1993) and Swedline (1994).

[37] The other kinds of trips are on-the-job travel, within Sweden and abroad, with or without overnight stays away from home, and recreational travel abroad with and without overnight stays.

percent, but this includes only cases when the interviewee refuses to participate, or is reported not to be available by other members of the household. However, the replacement procedure used means that the total number of non-responses is probably considerably larger. Further, it is not unlikely that non-respondents would systematically differ from the respondents with regard to their travel patterns. A frequent traveler is naturally less likely to be reached by the interviewer (Christianson, 1990 and Cassel).

An effect working in the opposite direction is examined by Nordström. He finds evidence of over-reporting of the number of trips in the TDB. This is due to the so-called telescoping effects, which often cause respondents to place an event more recently in time than it in fact occurred. In the case of the TDB, we could thus expect people to report that trips, which in fact were made before the month covered by the interview, had occurred during that month. Comparing TDB data with accommodation statistics from Statistics Sweden (SCB), both for 1992, Nordström concludes that the telescoping effect for leisure tourists caused an over-reporting of about 15 percent. It could, however, be argued that this effect is likely to be smaller for the trips used in this study, as they are mainly undertaken during the summer vacation. People are thus more likely to remember when the trip was undertaken.

In the present study, only a small fraction of the TDB is used. Trips with ”sunbathing and swimming”, ”fishing”, ”other outdoor activity” or ”to experience the outdoors” as a stated objective of the trip were selected.[38] Also, only non-business travel to coastal areas was included. Only data for the summer months of June, July and August were used, since a preliminary analysis of the data indicated that almost all seaside recreation takes place during these months. Data were available for the years 1990 through 1994.

The total sample includes 3169 trips. Of these, 771 were undertaken in June, 1929 in July, and 469 in August.[39] The most common of the four purposes selected was ”sunbathing and swimming”, which was stated as an objective for 2098 of the trips. 276 interviewees stated that one purpose of the trip was to go fishing, and 1063 gave ”other outdoor activity” or ”to experience the outdoors” as an objective.[40]

Of Sweden’s 286 municipalities (kommuner), 84 are situated by the coast, representing 15 counties (län). Over 60 percent of all trips were made to four of these counties, namely Göteborgs och Bohus län and Hallands län on the west coast, and Kalmar län and Stockholms län on the east coast.[41]

[38] Respondents are asked to state the principal objective of the trip, and are also allowed to give three other objectives of the trip.

[39] Note that only half as many interviews are undertaken for August as for June and July.

[40] Note that the figures do not sum to the total sample size, as respondents are allowed to give more than one purpose for the trip. Of the respondents, 262 quoted two of the purposes included as objectives of the trip, and three respondents stated three of them.

[41] These counties account for 20.8 percent, 17.4 percent, 13.2 percent and 13.1 percent of the total number of trips respectively. The fifth most frequent destination, the island of Gotland, has less than half the number of trips compared to number four, Stockholms län.

The sample used to estimate the cost function and that used for the travel cost model were slightly different. The reasons for this, and the selection criteria, will be dealt with in connection with the respective models.

3.2 The cost function

We assume here that the cost function is linear in distance traveled, given the mode of transport. The cost per day away from home, given the choice of accommodation, is allowed to be different for trips of different duration, as is the cost per participating household member. Cost will thus be a linear function of a combination of dummy variables for mode of transport and distance traveled, dummy variables for choice of accommodation, and trip duration and the number of participating household members. Further, we assume that the cost for all non-measured inputs in the production of a trip can be treated as an independently distributed random term.

Dummy variables were defined for trips of three days or more, i.e. trips over more than a weekend, for trips of longer duration than a week, and for trips of over two weeks' duration. The dummy variables were multiplied by the total number of nights away from home, by nights spent in different forms of accommodation, and by the number of household members on the trip, thus allowing different costs per day and per person. In addition, a dummy variable for day-trips was included in the regression. Trips of more than four weeks were excluded from the sample. Such trips are likely to be very different from the rest of the sample, but are too few to be distinguished as a separate subgroup.

The cost variable has only been recorded since 1992. Thus the cost function is estimated using data from 1992 through 1994. The TDB distinguishes between 12 modes of travel. Travelers stating ”by air”, ”by ship”, ”by bicycle” or ”other” as their main mode of transport were excluded, since too few respondents used these modes of transport for it to be meaningful to distinguish them as separate groups.

Two categories were merged with the ”car” category, namely those traveling by motorcycle or with a mobile home. These included too few observations to be allowed to constitute separate groups, but it was felt that they were sufficiently similar to travel by car so that they should not be excluded. Three of the remaining categories, namely travel by train, coach or bus, were merged into a single group, travel by public means of transport. Those who stated private boat as their main mode of transportation were considered to be a separate category.[42] Thus the cost per kilometer of travel was allowed to differ between travel by car, travel using public transport and travel by private boat.

The TDB distinguishes between 17 different forms of accommodation. Some of these categories were merged, as they are obviously very similar. For example, the TDB has one category for houses rented through a booking agency, and another for those who booked directly through the owner. A simplified version of the cost function was run after this initial restructuring, to test which forms of accommodation appeared to imply a cost per day that was significantly different from the ”base case”, which was defined as people using their own private vacation homes. On the basis of this result,

[42] The observant reader will notice that only 11 categories are accounted for. This is because no respondent gave ”by air (charter)” as their main mode of transport.

four categories were distinguished from the base case in the final cost function, namely living in a caravan, staying with family and friends, living in a hotel, and renting a house.

Both the total number of participants on the trip and the number of persons from the household are reported. However, only household members are included in the model. To check if the number of non-household members participating on the trip had any effect on the cost of the trip, the difference between the two figures was included in one regression; however, it was not significant. The exclusion of this variable thus seems justified.

The distance variable was obtained from a distance matrix from the Swedish Road Authority (Vägverket). Some municipalities were absent from this matrix, and these were replaced by figures from neighboring municipalities. A few observations had invalid codes for the origin of the trip, and had thus to be excluded. In addition, respondents with a missing cost variable or stating zero as the cost of the trip, were excluded. In the TDB interviews, respondents are asked how many nights they were away from home, as well as how many nights they spent in the different forms of accommodation. The latter should sum to the former. In some cases it does not. These observations were also excluded. The total number of observations for the years used for the cost function is 2164. The sample used to estimate the cost function, i.e. after excluding observations as described above, consists of 1770 trips.

The cost function estimated can thus be described as follows:[43]

(48)
$$\begin{aligned} COST &= \gamma_0 + \gamma_{1,0} PERS + \sum_{k\in K} \gamma_{1,k} D_k PERS + \gamma_{2,0} DIST + \sum_{m \in M} \gamma_{2,m} T_m DIST + \\ &+ \gamma_{3,0} TNIGHTS + \sum_{n\in N} \gamma_{3,n} NIGHTS_n + \gamma_{4,0,0} DAYTRIP + \\ &+ \sum_{k\in K} \left(\gamma_{4,k,0} D_k TNIGHTS + \sum_{n\in N} \gamma_{4,k,n} D_k NIGHTS_n \right) + \eta \end{aligned}$$

where COST is the total stated monetary cost of the trip, PERS is the number of persons participating, DIST is distance traveled, TNIGHTS the total number of trips away from home, $NIGHTS_n$ the number of nights spent in accommodation category n and DAYTRIP is a dummy variable equal to one if the trip is a day-trip, zero otherwise. The D_k:s are dummy variables equal to one if the length of the stay away from home falls in the range $k\in K$, K={3-28,8-28,15-28}, and zero otherwise. The T_m:s are dummy variables equal to one if the mode of transport $m\in M$, M={public transport, private boat} is chosen, and zero otherwise. The γ:s are parameters and η is a random term.

The most interesting elements in this model are, naturally, the coefficients for distance traveled. These coefficients are interpreted as kilometer prices for the different travel modes, and are used in the conditional logit and NMNL models to calculate the cost of travel to each destination.

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[43] This equation can be seen as a specification of Equation (B5) from Appendix B, if we view the variables in (48) as proxy variables for goods needed to produce a trip.

One important additional input is needed in order to produce a recreational trip: time. We assume that the value of a unit of travel time is constant. To obtain the full cost of a trip, we will need to add the value of time multiplied by the time needed to make the trip. However, for trips by private boat no time cost is added, as the travel itself is probably part of the recreational experience. In terms of the model in (15), the time consumption constraint for this commodity is not binding.

The cost of time for traveling by car and by public transport for recreational purposes was obtained from a study by Johansson and Mortazavi (1995). They estimated a model based on DeSerpa's version of the HPF approach described above, on the TDB. They used a RUM model of the choice between different modes of transport for people making recreational trips to Stockholm, from different origins, and they obtained estimates of the value of time saved, i.e. for κ_i/λ in equation (17).

Johansson and Mortazavi also checked for seasonal variation, and found that the value of time saved for travelers was considerably lower during the summer months than during the rest of the year. The value of time for car travelers was estimated to be 68 SEK per hour during the summer and 220 SEK per hour during the rest of the year, while the corresponding figures for train travelers were 76 SEK per hour and 203 SEK per hour, respectively. These authors also tested to see whether there were any differences in the estimated time cost for different income groups. They found no significant differences.

In this work, when constructing the total travel cost variable, the values estimated for the summer months are used. We assume that households traveling by car travel at an average speed of 75 kilometers per hour, and have a one-hour break every four hours. For recreational travel by public transport, Johansson and Mortazavi's estimated time cost for train travel is used. It is assumed that travel by public transport takes place at an average speed of 60 kilometers per hour, and that one additional hour is needed to get to and from the station at each end of the trip.

3.3 The travel cost model

For the actual travel cost model, data from all available years, i.e. 1990 through 1994, were used. Trips with a duration of more than four weeks were excluded, as were day trips to destinations further away than 250 km. In addition, trips to a total of 18 coastal municipalities in the north of Sweden were excluded. The destinations thus excluded are those lying in the four northern coastal counties of Gävleborgs, Västernorrlands, Västerbottens and Norrbottens län, and there are two reasons for omitting them from the model. First, a very small fraction of all seaside recreation in Sweden takes place in this area. Secondly, the large rivers of northern Sweden often make the water of the northern Baltic Sea muddy. Thus sight depth may not be such a good measure of quality in this region of the Baltic as it is in the other parts. The island of Gotland also had to be excluded, due to lack of data on sight depth. This is unfortunate, since Gotland is a major recreation location. The size of the final sample was 2425 trips, of which 217 were by private boat.

Each site was defined as a single coastal municipality. This choice was dictated by the data, as destinations are specified by municipality in the TDB. Three models were estimated: a conditional logit model on boat travelers, a nested multinomial logit model on car travelers and those traveling by public transport, and an ”un-nested” conditional logit model, also on car travelers and those traveling by public transport. For the nested model, a two-stage decision process was assumed. Recreationists were seen as first choosing which region to visit, and then which site to visit within that region.

Four regions were defined: a) The Stockholm region, consisting of Stockholms län (county) and the two neighboring counties, Södermanlands län and Uppsala län, b) the rest of the east coast, consisting of three counties, Östergötlands län, Kalmar län and Blekinge län, c) Skåne, which consists of the two southernmost counties of Sweden, Malmöhus län and Kristianstads län, and d) the two counties on the west coast, Hallands län and Göteborgs och Bohus län.

In the two models for car travelers and users of public transport, the choice sets for recreationists going on day trips were restricted to sites within a range of 250 kilometers from the households' place of residence; for the other trips, all sites were seen as part of the choice sets. For recreationists traveling by private boat, the choice sets were defined so that people could choose between sites in their own county of residence, and the counties bordering on this one. In addition, people living in the counties on the east coast were allowed to choose between all sites on the east coast. This definition of the choice set corresponds to observed travel behavior for this group of recreationists.

The indirect utility from visiting a given site, i.e. V_j from equation (32) is a function of the total travel cost and a vector of quality characteristics of the site, and is assumed to take the following form:

$$V_j=\beta_1 TTC_j+\beta_2 LNSIGHT_j+\beta_3 BEACH_j+\beta_4 LICENCE_j+\beta_5 SUN_j \tag{49}$$

The β:s are coefficients. TTC_j is the total travel cost to site j, calculated on the basis of the results from the cost function regression, and the Johansson and Mortazavi time cost coefficients, as described in Section 3.2. $LNSIGHT_j$ is the natural logarithm of sight depth at the site. The reason for taking the logarithm of this variable is that it is reasonable to assume that the marginal value of sight depth is decreasing.[44] Data sources and problems with this variable are discussed below, in Section 3.4.

The variable $BEACH_j$ is the number of beaches in the municipality. This variable was obtained from a regular road map, and was included to take account of the varying size of the municipalities, and to account for the general attractiveness of the site. $LICENCE_j$ is the number of alcohol-serving licenses per thousand inhabitants in the municipality. This variable was included because it was felt that account needed to be taken of the ”night-life factor”, which may be an important determinant of travel behavior. Data on the number of alcohol-serving licenses per municipality were obtained from the Swedish Alcohol Inspection Board (Alkoholinspektionen), and population statistics were obtained from the Swedish Federation of Municipal Councils (Svenska Kommunförbundet).

SUN_j denotes the average hours of sunshine per month. These data, which are calculated as an average over the years 1961-1990, were obtained from the Swedish

[44] The value of an increase in sight depth from 1 to 2 meters is probably greater than that of an increase from 11 to 12 meters. (Probably, the increase from 11 to 12 meters is not even detectable by purely visual inspection.)

Institute for Meteorology and Hydrology, SMHI (1994). This variable is a regional variable, i.e. it has the same value for all municipalities belonging to a given region.

In the nested model, all variables except SUN were seen as affecting the decision at the lowest nesting level. Thus the lowest level was estimated, and the inclusive values were calculated. The top nesting level was then estimated, treating the inclusive value (IV) and SUN as independent variables. Descriptive statistics on the quality variables are provided in Table 1. We have quite a large variation in all the quality variables.

As mentioned earlier, the RUM model cannot by itself explain the total number of trips undertaken by the individual during a season. The usual way of solving this problem is to append a count data model to the conditional logit or NMNL model. However, the data in the TDB are not well suited to this approach as no data are available on the total number of trips undertaken by an individual during a season. Only the number of trips during the month in question is recorded, within each of the TDB categories, i.e. business, non-business, overnight stays, day trips, domestic or abroad.

In the present study, this question is therefore left aside. However, it is not unreasonable to assume that a relatively small fraction of the benefit from an improvement in water quality will accrue to an increase in the number of trips, i.e. that the total number of trips is not likely to change much as a result of changing water quality. In terms of the Morey (1991) result cited above in Section 2.6.2, we can expect the marginal rate of substitution between a trip and staying at home to be relatively small. Barring exceptional changes, it is more likely that changing quality leads to a re-allocation of trips between different sites, and an increase in the utility from each visit, rather than a large increase in the total number of trips.

Hausman, Leonard and McFadden (1995), in their study of the Exxon Valdez oil spill, estimated that the total loss in recreational consumer surplus caused by the accident for 1989, the year of the spill, was USD 3.8 million. Of this sum, USD 3.1 million were due to substitution between sites, or reduced utility from each visit, while the remainder was due to a reduced number of trips undertaken. Thus even for such a major quality change, the latter effect was relatively small.

Table 1 - Descriptive statistics on quality variables

Variable	Mean	Stand. dev.	Minimum	Maximum
SIGHT (meters)	4.95	2.14	0.83	12.3
BEACH (number)	9.02	6.63	0	30
LICENCE (number per thousand)	1.33	0.71	0.51	4.67
SUN (hours per month)	250	23.5	221	292

3.4 Sight depth, and the link to the nutrient load

The crucial variable in the travel cost model is the sight depth variable,[45] as it provides the link with nutrient load. In other words, it is the link between the environmental variable that can be influenced by policy, the concentration of phosphorus and nitrogen in the water, and recreational behavior. If this link does not hold, the whole valuation exercise will be meaningless.

Data on sight depth had to be acquired from a number of sources, but turned out to be available for most stretches of the coast.[46] However, while data are available from several observation points in some municipalities, there are others where no data are available. Also, for some observation points data are lacking for some months and several observations are made during other months.

To construct a quality index with exactly one figure for each municipality and month, the average of all observations made in a municipality each month was taken. In cases where no observation was made during a month, the average over all observations in that municipality were inserted. Finally, for municipalities where data were lacking completely, the average of the values for neighboring municipalities was used.

Another possible quality measure is chlorophyllic concentration. This measure would perhaps be more closely related to primary production, and thus to nutrient concentration. However, the link with the recreationist's perception of quality is likely to be weaker. Also, while sight depth is a one-dimensional concept, chlorophyllic concentration can be measured at different depths, and is thus more complicated to use. At any rate, the simple correlation between sight depth and chlorophyllic concentration (in the surface water) is high. The absolute value is almost 0.4. The correlation between sight depth and the natural logarithm of chlorophyllic concentration is even higher, with an absolute value of over 0.55, and the Spearman rank correlation coefficient is -0.59.

As pointed out above, it is really not a task for an economist to try and establish the link between pollutants, in the present case nitrogen and phosphorus, and observable quality characteristics.[47] Rather, it is a task for natural scientists to research this link. There is little doubt that such a link does exist between nutrient load and sight depth. An increase in inflow of nutrients increases primary production, i.e. the content of organic material in the water, which reduces the transparency of the water (Rosenberg, Larsson and Edler, 1986). We are, however, far from any quantifiable measure of how a change in the content of nutrients would translate into a change in sight depth.

In an attempt to quantify this connection, a very simple regression was run. Data on sight depth, water temperature and concentration of phosphorus and nitrogen from nine observation points in the municipalities of Norrköping, Söderköping and Valdemarsvik (Östergötlands län) for the years 1975-1993 were obtained from Motala

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[45] Sight depth is everywhere in this paper defined as Secchi depth, which is measured as follows: A white metal square of a fixed size is lowered in the water. Secchi depth is defined to be the depth at which the square can no longer be seen.

[46] For a list of sources of sight depth data, see the list after the references.

[47] Economists are sometimes accused of intellectual imperialism. Do not, I pray, interpret this and the following sections as a colonizing adventure. Rather, see it as a challenge to the natural scientists to come up with something better.

Ströms Vattenvårdsförbund. The natural logarithm of sight depth was regressed on the natural logarithms of total phosphorus (TP) content and total nitrogen content (TN). Water temperature (WTEMP) was also included as an explanatory variable, to allow for seasonal variations. Thus we assume the following model:

(50) $$LNSIGHT=\alpha_0+\alpha_1*WTEMP+\alpha_3*\ln(TN)+\alpha_4*\ln(TP)$$

Estimation yielded the following results. The t-values are estimated from White's consistent covariance matrix.

Table 2 - Estimation results for the sight depth model

Variable	**Coefficient**	**t-value** (two tail test)
Constant	5.62	18.8
WTEMP	-0.0156	-4.47
ln(TN)	-0.625	-12.7
ln(TP)	-0.177	-3.37

The coefficients are significant at more than 99 percent significance levels. The coefficients for total nitrogen and total phosphorus are negative, as expected. In other words, the higher the concentration of nutrients, the smaller is the sight depth. An R^2 of 0.35 must be deemed as most satisfactory, given the primitive and ad hoc nature of the model. It is also important to note that water temperature has a negative sign, i.e. the warmer the water, the smaller the sight depth. Had water temperature and sight depth been positively correlated, this could have been the source of a nonsense relationship between sight depth and travel frequency, as people are likely to prefer warm water to cold water.

Available evidence thus validates the link between the quality index chosen for this study, and the physical entities which can be affected by environmental policy measures.

4. Estimation results

4.1 The cost function

Two different estimates of the cost function were made. The first is an OLS. White's consistent covariance matrix is used to calculate the t-values, in order to take account of heteroskedasticity. (See any econometrics textbook, e.g. Greene, 1993.)

The OLS regression takes no account of the non-negativity constraint on the dependent variable, total travel cost. An alternative suggested by Greene (1991), for cases when the dependent variable is non-negative, is to assume that the error term is distributed log-normally. The regression was also run using this assumption.[48] The results from the two regressions are presented in Appendix C.

The estimates from the two different estimation methods are almost identical. However, the t-values differ. The important coefficients are naturally those for distance, which will be used to calculate the travel cost variable for the discrete choice model. The estimated cost per kilometer of car travel is 2 SEK and for public transport around 0.40 SEK per kilometer. Travel by boat is estimated to cost around 2.70 SEK per kilometer. However, this coefficient is significant only in the log-normal regression.

A number of alternative specifications were estimated. Alternative specifications of the ranges of duration of the trip, dummy variables for different stated objectives of the trip, and non-household members participating in the trip were examined. The coefficient estimates appear robust to specification.

4.2 The discrete choice model

The results of the nested multinomial logit, and the conditional logit models for car travelers and travelers by public means of transport, as well as the model for boat travelers, are presented below. Figures within parenthesis are the asymptotic standard errors of the coefficients. In the top level of the NMNL model, the inclusive value is a random variable. The standard errors are adjusted to take account of this. Naturally, no inclusive value coefficient is estimated in the conditional logit models.

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[48] A variable, Y, is said to be log-normally distributed if there exists a number, θ, such that $Z=\ln(Y-\theta)$ is normally distributed. $\theta=0$ gives us the two-parameter log-normal distribution, $Y\sim\Lambda(\mu,\varphi^2)$, where the parameters are the mean and variance, respectively, of $Z=\ln(Y)$. A theoretical justification for using the log-normal distribution is offered by Hart. If negative and positive random shocks affect a variable, Y, it is a well known consequence of the Central Limit Theorems that Y will tend to become normal as the number of shocks increase, so long as the shocks have finite variance. However, if the shocks are instead multiplicative, so that the value of Y acquires the form of randomly distributed proportions, smaller or larger than unity, then the CLT will instead apply to $Z=\ln(Y)$, and Y will thus be log-normally distributed. In the two-parameter log-normal model included as a standard model in Limdep, Y is our dependent variable, which is assumed to be positive, with the expected value $E(Y)=\beta'X$, where β is a vector of parameters, and X is the vector of explanatory variables. The variance of Y is $Var(Y)=\sigma^2(\beta'X)^2$, where σ is a constant. We will also have $Z=\ln(Y)\sim N[\ln(\beta'X)-1/2\sigma^2,\sigma^2]$. Thus the log-normal model assumes a specific form of heteroskedasticity. (For details of the log-normal distribution, see Amemiya, 1973.)

Table 3 - Estimation results for the travel cost model[49]

Variable	NMNL	Conditional logit	Conditional logit (boat)
Top decision level (X_s):			
IV	0.997 (0.0632)	-	-
SUN	0.283 (0.0420)	0.299 (0.0444)	0.612 (0.424)
Lower decision level (Y_{js}):			
TTC	-0.00108 (0.0000639)	-0.00101 (0.0000309)	-0.00213 (0.000201)
LNSIGHT	0.269 (0.0702)	0.575 (0.0627)	-0.172 (0.163)
BEACH	0.0164 (0.00229)	0.0207 (0.00199)	0.0420 (0.0116)
LICENCE	0.583 (0.0205)	0.544 (0.0186)	0.478 (0.0704)

All coefficients in the models for non-boat travel are significant at least at the 99 percent level of significance, and have expected signs. The inclusive value coefficient is almost exactly one, so that we would expect the conditional logit and NMNL models to be identical. All coefficients are indeed quite close, as would be expected, with the exception of the sight depth coefficient. The results suggest that the sight depth has an effect on recreational behavior. However, the magnitude of this effect is rather uncertain.

In the boat model, the coefficients for TTC, BEACH and LICENCE are significant at least at the 99 percent level of significance, while LNSIGHT and SUN are not even significant at the 10 percent level. The coefficient for LNSIGHT also has the wrong sign. This may be due in part to the small sample size. However, it is also likely that boat travelers are less affected by water quality. In addition, boat recreation often implies travel through several different municipalities. It is therefore doubtful whether the data on this category of recreationists are reliable in this respect.

5. Policy experiments

Our models of the households' recreational behavior, and the sight depth model, make it possible to estimate the benefits from policy measures that change the nutrient levels in water around the Swedish coast. Below, two different experiments are performed. The first is an attempt to calculate the results of a uniform change in

[49] The SUN variable had to be standardized in order to make estimation of the top level of the NMNL model converge.

quality along the entire Swedish coast. The second deals with a change in quality in just one small region, the Laholm Bay.

The Laholm Bay has been pinpointed in discussions of eutrophication. It is situated on the west coast in one of the main agricultural regions of Sweden. Two of the largest rivers of southern Sweden, Nissan and Lagan, as well as three smaller rivers discharge into the Laholm Bay. The bay is thus a major recipient of nutrients.

Rosenberg, Larsson and Edler (1986) reports an increasing frequency of algal blooms due to nutrient enrichment and a marked decrease in catches of fish due to oxygen deficiencies. Wennberg (1987) reports that in August 1980 a huge number of mussels were killed by oxygen deficiency and washed ashore. He also reports a long-term change in the composition of the macroalgal flora, beginning in the 1970s, which he claims is due to the increased nutrient load.

The area is also one of the most popular seaside recreation areas in Sweden. Of the 2208 trips made to all sites (boat recreationists excluded), 238 were made to the three municipalities around the Laholm Bay, i.e. over 10 percent.

5.1 Assessment of change in the quality index

The convenient form of the sight depth equation implies that the change in sight depth for a given proportional change in nutrients will be easily calculated. We will only deal with the case where both nutrients are reduced by the same proportion. It is obvious from the estimation results that if nutrients, i.e. TP+TN, change to t*(TP+TN), where t>0, then sight depth will change to about $t^{-0.8}$*(sight). Naturally, a reduction in nutrients will increase the sight depth and an increase in nutrients will reduce the sight depth. For example, if the nutrients are reduced by half, as in the HELCOM agreement, then in this model it would result in an increase in sight depth of about three quarters.

For purposes of simulation, we assume that this connection between the concentration of nitrogen and phosphorus in the water and sight depth holds around the entire Swedish coast. In the trans-Baltic policy simulation, we also assume that a change in the level of emissions will have a uniform effect on the nutrient concentration throughout the Sea. In the policy simulation on a change in the emissions of nutrients into the Laholm Bay, we assume that only the Bay area is affected.

5.2 Calculation of change in consumer surplus

After constructing a quality index on these simulated changes, a welfare change is easily estimated, using the estimated travel cost model and equation (47). The value within square brackets, the inclusive value, is calculated for the actual and simulated levels of quality. The difference between these two values is then summed over all observations, multiplied by the inverse of the sampling ratio[50], and divided by the

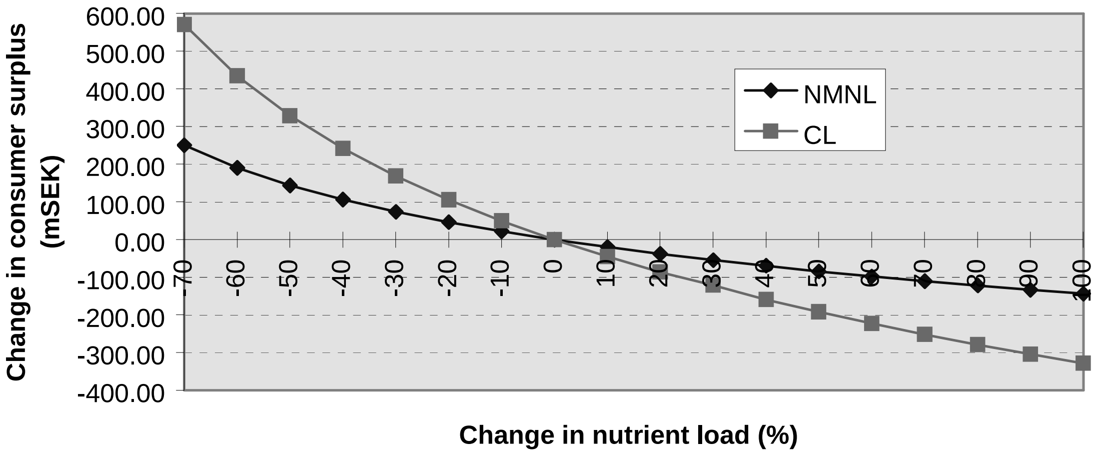
[50] 4000 interviews are carried out in June and July each year, and 2000 in August. In my sample, 14.8 percent of the visits are made in August, and the remaining 85.2 percent in June or July. Using these proportions to calculate a weighted average of the number of interviews per month produces a value of 3704. The population of Sweden is 8,745,109. The inverse of the sampling proportion is then 2361. However, we have to divide that figure by five, as we have data from five years, yielding a figure of 472.2.

estimated marginal utility of income, i.e. the negative of the coefficient for travel cost, to obtain an estimate of the change in consumer surplus for the entire population. If instead of multiplying by the inverse of the sampling ratio, we divide by the sample size, we obtain an estimate of the change in consumer surplus per trip.

5.3 Trans-Baltic emissions reduction

In Diagram 1 below, the results of simulations of a uniform change in nutrient concentration throughout the Baltic are presented. Simulations were carried out for changes ranging from a reduction by 70 percent to an increase by 100 percent.

Diagram 1 - Policy experiment, entire Swedish coast



The difference in the estimates between the NMNL and conditional logit models is due to the different coefficients for the sight depth variable.

The total change in consumer surplus for a 50 percent reduction of the nutrient load, i.e. the reduction agreed to by the countries around the Baltic Sea, is around 140 mSEK per year in the NMNL model, and around 330 mSEK per year in the conditional logit model. This is considerably lower than the benefit estimates arrived at by Söderqvist (reported in Gren et al, 1995). On the basis of a dichotomous choice contingent valuation survey, he estimates the total national willingness to pay for a reduction of the eutrophication of the Baltic Sea to be over 7 billion SEK per year.

Several differences between this study and the present one must be kept in mind when comparing these figures. Firstly, some limitations on the data used for the travel cost study are likely to bias the benefit estimates downwards. Of the 3169 trips that are made to coastal municipalities with some form of seaside recreation as the stated purpose, 744 are excluded from the sample for various reasons, as described above. Further, as only the first two trips in each category are reported in detail in the TDB interviews, more trips are undoubtedly undertaken. The total number of domestic recreation trips undertaken during the months and years covered is 47 676. Of these, 37 961 are followed up.

If we assume that all these excluded trips are ”average trips”, just like those on which the model is estimated, we can adjust for this by multiplying the benefit estimates by

1.64.[51] The benefit estimates for the 50 percent reduction in nutrients would then be 240 mSEK per year for the NMNL model, and 540 mSEK per year for the conditional logit. However, the difference between the contingent valuation study and the travel cost study is still large.

Secondly, in Söderqvist's contingent valuation study, the respondents are asked to evaluate a comprehensive international action plan against eutrophication. It is not obvious that this scenario is consistent with the 75 percent increase in sight depth postulated in the present policy experiment. Also, the action plan is described as a set of measures over a 20 year period that would reduce the load of nutrients to a sustainable level. It is quite possible that the alternative to the proposed plan is not seen to be the status quo, but rather a deterioration of the quality of the Baltic Sea. This is probably also a realistic assessment of the prospects, if nothing is done.

The total consumer surplus, estimated from the travel cost model, and adjusted for seaside trips not included in the data set, is 6.3 billion SEK per year for the NMNL model, and 7.6 billion SEK for the conditional logit. It is hardly likely that the scenario of the contingent valuation study would induce the respondents to see a total elimination of all seaside recreation as the alternative to the action plan. Thus this factor alone cannot explain the difference between the two studies, unless we assume very large non-use values. However, it is likely to be one important reason for the divergence between the estimates.

Thirdly, the travel cost method does not measure non-use values. Whether such values do exist, and should be included in a cost-benefit analysis, is a matter of debate. The issue will not be addressed in this paper. (See Portney, 1994, Hanemann, 1994 and Diamond and Hausman, 1994 for a summary of the controversy over the contingent valuation method.) We will only note that if positive non-use values do exist, the contingent valuation method should yield higher benefit estimates.

A second study by Söderqvist (in progress) does indicate that non-use values can be of considerable magnitude. In this open- ended contingent valuation survey, respondents are asked for their use values only. The results need to be interpreted carefully since they are only preliminary. Also, it is well known that open-ended contingent valuation surveys tend to produce lower willingness-to-pay estimates than dichotomous choice surveys. However, the average willingness to pay over the 20 years considered in the scenario is 750 SEK per year. The present value for Sweden, discounted at 7 percent and averaged over 20 years, would then be around 2.6 billion SEK per year. If it is assumed that non-respondents have zero willingness to pay, the corresponding figures would be 390 SEK and 1.4 billion SEK.

A comparison between Söderqvist's figures for willingness to pay per person, and the consumer surplus per trip obtained from the travel cost model, indicates the fourth, and possibly most important, source of the divergence between the two valuation studies. For the NMNL model, the consumer surplus per trip is estimated to be 140 SEK for the 50 percent nutrient reduction. The figure for the conditional logit model

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[51] [3169/(3169-744)]*[47 676/37 961]≈1.64. The first term within square brackets is the adjustment for observations excluded from the sample. The second term is the adjustment for trips not followed up in the TDB.

is 315 SEK. Thus the last of these estimates, at least, is thus quite close to the contingent valuation study.

It should be emphasized that this refers to consumer surplus per trip, while the figures from the contingent valuation study are per person. Given that a person makes at least one trip, he will on average make more than one trip. The consumer surplus per trip will thus be less than the consumer surplus per person.

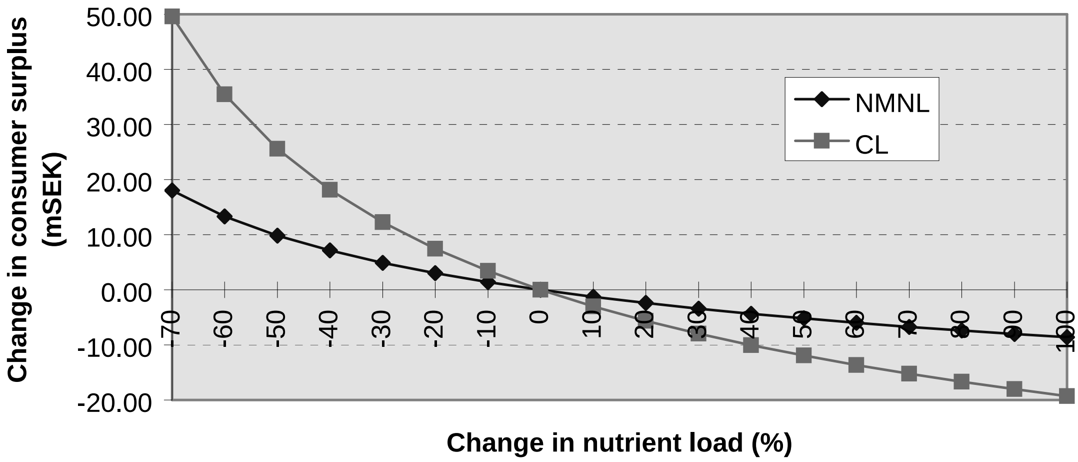
The number of trips reported in the TDB is probably a major source of error in the estimates. Obviously, the exclusion of day-trips to destinations closer than 100 km from home biases the estimates downwards. Sweden’s three largest cities, Stockholm, Göteborg and Malmö are all situated by the sea. Thus a major fraction of the population live close to the coast, and they will most probably undertake a large number of day-trips to sites close to their place of residence. The value which they place on a potential change in quality is not accounted for in the present study. The replacement procedure used for the TDB interviews also has this effect, as discussed above.

We can thus be fairly confident that the estimates obtained in this study are biased downwards. However, the benefit estimates obtained from this study are still considerably lower than available estimates of the cost of a clean-up. Gren, Elofsson and Jannke (1995) arrive at a cost for Sweden of around 7 billion SEK per year to achieve a cost-efficient reduction of nutrients by half. It should be noted that this requires all the other countries around the Baltic to ”do their share” of the reduction.

5.4 Nutrient reduction in the Laholm Bay

The quality variables for the policy simulation of the Laholm Bay were constructed in an analogous manner to the trans-Baltic experiment, but the values of all other sites except the three municipalities on the Laholm Bay were kept unchanged. Simulations were carried out for changes ranging from a reduction by 70 percent to an increase by 100 percent. The results are plotted in Diagram 2 below.

Diagram 2 - Policy experiment, Laholm Bay



The benefit from a 50 percent reduction of the nutrient load to the Laholm Bay is estimated to be around 9.8 mSEK per year from the NMNL model, and 26 mSEK per year from the conditional logit model. If the estimated benefits are adjusted for trips not reported in the TDB[52] we arrive at 12 mSEK per year and 32 mSEK per year, respectively.

The highest of these figures, 32 mSEK, comes close to the cost of a 50 percent reduction of the nutrient load in the Laholm Bay. Gren and Zylicz (1993) estimate that the cost of an efficient reduction by this proportion would be around 45 mSEK per year.

6. Final remarks

This study is, to my knowledge, the first RUM travel cost model applied to European data. Previous European travel cost studies have either been single-site models (e.g. Bojö, 1985 and Strand, 1981), or have treated visits to all sites as a single good (e.g. Boonstra, 1993).

Perhaps the most important result in this paper is that the sight depth variable performs so well as a quality index. Also, instead of just assuming a relation between the quality variable and pollution, it has been shown that the link between this quality index and nutrient concentration can be established with standard econometric methods. Naturally, a much more elaborate model could be developed.

Instead of constructing the travel cost variable by using some assessment of the operating cost of vehicles, a cost function has been estimated, based on the stated cost for the trip. This approach goes some way towards solving the problem of defining the ”true” cost of traveling to a site.

It should be possible to apply the methodology proposed in this paper, for using the TDB in environmental benefit studies, to problems other than the eutrophication of the seas around Sweden. The inclusion of other quality variables may make it possible to value other aspects of the environmental degradation of the coastal areas.

In addition, recreational values from programs to clean up lakes could easily be evaluated in this fashion. Substitutes could be identified by using the TDB, and a model similar to the one used in this paper could then be formulated. Several applications of the travel cost model have dealt with the evaluation of recreational fishing. Policy proposals which affect this kind of activity also fit easily into this framework. Most probably, the main problem in any such study would be to find suitable data to use as a measure of quality.

Some issues remain, however. Perhaps the main drawback with the TDB is that short day-trips are not reported. The seriousness of this problem naturally depends on the issue under analysis. If the recreational sites are mainly situated in sparsely populated areas, while most visitors are from other parts of the country, welfare estimates will be reasonably correct. In the present study the bias is likely to be larger. Studies to

[52] By contrast with the trans-Baltic estimate, it would not be correct to adjust for trips excluded from the sample, since most such trips are excluded because they are made to the island of Gotland or to northern Sweden. However, we can adjust for trips not followed up in the TDB, i.e. by 47 676/37 961≈1.26. The adjusted figures are thus the original figures multiplied by 1.26.

quantify this bias are warranted. In addition, a model to incorporate the total number of trips into this framework is also needed.

It is not surprising that WTP estimates from contingent valuation studies diverge from the consumer surplus measures obtained from a travel cost model. However, the difference seems to be disturbingly large. More research is certainly needed to attempt to explain this fact.

Appendix A - Type I and generalized extreme value distributions[53]

The expression for the probabilities, if the ε_j:s follow the type I extreme value distribution can, be derived as follows:

We have:

(36)

$$\pi_j = prob[\varepsilon_k < \varepsilon_j + V_j - V_k, \forall k \neq j] = \int_{-\infty}^{\infty} \prod_{k \neq j} F(\varepsilon_j + V_j - V_k) f(\varepsilon_j) d\varepsilon_j$$

For the type I extreme value distribution we get:

(A1)
$$\prod_{k \neq j} F(\varepsilon_j + V_j - V_k) f(\varepsilon_j) = \prod_{k \neq j} \exp(-e^{-\varepsilon_j - V_j + V_k}) \exp(-\varepsilon_j - e^{-V_j})$$
$$= \exp\left[-\varepsilon_j - e^{-\varepsilon_j} \left(1 + \sum_{k \neq j} \frac{e^{V_k}}{e^{V_j}} \right) \right]$$

Define:

(A2)
$$\xi_j = \ln\left(1 + \sum_{k \neq j} \frac{e^{V_k}}{e^{V_j}} \right) = \ln \sum_{j=1}^{N} \frac{e^{V_k}}{e^{V_j}}$$

Then (36) can be written:

$$\int_{-\infty}^{\infty} \exp(-\varepsilon_j - e^{-(\varepsilon_j - \xi_j)}) d\varepsilon_j$$

$$= \exp(-\xi_j) \int_{-\infty}^{\infty} \exp(-\varepsilon_j^* - e^{-\varepsilon_j^*}) d\varepsilon_j^*, \text{ where } \varepsilon_j^* = \varepsilon_j - \xi_j$$

$$= \exp(-\xi_j)$$

(39)
$$= \frac{e^{V_j}}{\sum_{k=1}^{N} e^{V_k}}$$

Note that:

(A3)
$$\frac{\partial \pi_j}{\partial V_m} = -\frac{e^{V_j} e^{V_m}}{\left(\sum_{k=1}^{N} e^{V_k} \right)^2} = \frac{\partial \pi_m}{\partial V_j}$$

[53] This appendix is based on Maddala (1983) and Anderson, de Palma and Thisse (1992).

The Jacobian matrix of equation (34) is thus symmetric, and the line integral is path independent.

Note also that:

(A4) $$\frac{\pi_j}{\pi_m} = \frac{e^{V_j}}{\sum_{k=1}^{N} e^{V_k}} \Bigg/ \frac{e^{V_m}}{\sum_{k=1}^{N} e^{V_k}} = \frac{e^{V_j}}{e^{V_m}}$$

The ratio of the probabilities of choosing j and m are thus a function of V_j and V_m only. This is the property of independence of irrelevant alternatives.

The generalized extreme value distribution is defined so that if ε follows the generalized extreme value distribution, it has cdf (Anderson, de Palma and Thisse, 1992):

(A5) $$F(\mathbf{e}) = \exp[-G(e^{-\varepsilon_1}, e^{-\varepsilon_2}, \ldots, e^{-\varepsilon_N})]$$

where $G(K_1,K_2,...,K_N)$ is a non-negative homogenous function of $(K_1,K_2,...,K_N)\geq 0$. G is also assumed to have the following properties:

(A6) $$\lim_{K_j \to \infty} G(K_1, K_2, \ldots, K_N) = \infty,\ j = 1, \ldots, N$$

For any given $(j_1,j_2,...,j_k)$, $\partial^k G / \partial K_{j1} \partial K_{j2} \ldots \partial K_{jk}$ exists and is non-negative for k odd and non-positive for k even.

Assuming ε follows the generalized extreme value distribution, and that G is homogenous of degree 1, implies that the choice probabilities can be written:

(A7) $$\pi_j = e^{V_j} G_j(e^{V1}, e^{V_2}, \ldots, e^{V_N}) \Big/ G(e^{V1}, e^{V_2}, \ldots, e^{V_N})$$

where

$$G_j(e^{V1}, e^{V_2}, \ldots, e^{V_N}) = \partial G(e^{V1}, e^{V_2}, \ldots, e^{V_N}) / \partial(e^{V_j})$$

McFadden (1978) shows that choice probabilities that conform to this structure are consistent with stochastic utility maximization.

The ratio of the probabilities of choosing alternatives j and m will thus be:

(A8) $$\frac{\pi_j}{\pi_m} = e^{V_j} G_j(e^{V1}, e^{V_2}, \ldots, e^{V_N}) \Big/ e^{V_m} G_m(e^{V1}, e^{V_2}, \ldots, e^{V_N})$$

This ratio will not necessarily be independent of the V_k:s, k≠j,m, as G_j and G_m will generally also be functions of the V_k:s. Thus, the independence of irrelevant alternatives is relaxed.

Notice that we have:

(A9) $$\partial\pi_j / \partial V_m = e^{V_j} e^{V_m} \left[\frac{G_{jm}G - G_j G_m}{G^2}\right] = \partial\pi_m / \partial V_j\ ,$$

where the arguments of the function G have been left out and $G_{jm}=\partial^2 G / \partial(e^{V_j})\partial(e^{V_m})$. If these partial derivatives are assumed to be continuous everywhere, by Young's theorem we have $G_{jm}=G_{mj}$. In other words, the generalized extreme value distribution also fulfills the condition for the line integral in (32) to be path independent.

Divide the N alternatives into S subgroups, such that each alternative belongs to exactly one subgroup. Call the set of choices, j, belonging to subgroup s, Σ_s, for s=(1,2,...,S), and define:

(A10) $$G(K_1, K_2, \ldots, K_j, \ldots, K_N) = \sum_{s=1}^{S} \left(\sum_{j\in\Sigma_s} K_j^{\,1/(1-\sigma)} \right)^{(1-\sigma)}$$

where $0 \le \sigma < 1$, and K_j is the argument of G associated with the j:th alternative.

This is the specification of G used in this paper. If we have $\sigma=0$ we would be back to the type I extreme value distribution, which is thus a special case of the generalized extreme value distribution. With this generalized extreme value distribution, the probability that the individual will choose alternative j in the subset s, given that he has chosen s can be written:

(A11) $$\pi_{j|s} = \frac{e^{V_j/(1-\sigma)}}{\sum_{k\in\Sigma_s} e^{V_k/(1-\sigma)}}$$

V_j is the value of the deterministic part of the utility from visiting site j. The probability that sub-group s will be chosen can be written:

(A12) $$\pi_s = \left(\sum_{j\in\Sigma_s} e^{V_j/(1-\sigma)} \right)^{(1-\sigma)} \Bigg/ \sum_{t=1}^{S} \left(\sum_{j\in\Sigma_s} e^{Vj/(1-\sigma)} \right)^{(1-\sigma)}$$

Of course, $\pi_j=\pi j_{|s}\cdot\pi_s$.

Assuming:

(41) $$V_{j,s}=\beta_a \mathbf{X}_s+\beta_b \mathbf{Y}_{j,s}$$

yields:

(43) $$\pi_s = \frac{e^{\beta_a X_s+(1-\sigma)I_s}}{\sum_{t=1}^{S} e^{\beta_a X_t+(1-\sigma)I_t}}$$

and:

(45) $$\pi_{j|s} = \frac{e^{\beta_b \mathbf{Y}_{j,s}/(1-\sigma)}}{e^{I_s}} = \frac{e^{\beta_b \mathbf{Y}_{j,s}/(1-\sigma)}}{\sum_{k\in\Sigma_s} e^{\beta_b \mathbf{Y}_{k,s}/(1-\sigma)}}$$

where the inclusive value for group t, I_t is defined as:

(44) $$I_t = \ln\left(\sum_{j\in\Sigma_t} e^{\beta_b Y_{j,t}/(1-\sigma)} \right)$$

Appendix B - A RUM model in the HPF framework

To set the RUM model in a household production framework, we can view the household as maximizing a utility function of the form:

(B1) $$\max_{\mathbf{x},\mathbf{t}} u(z_n, t_n, \mathbf{z})$$

where z_n is a ”numeraire commodity” produced at constant marginal cost using as inputs the M dimensional vector **x** of market goods, **z** is a vector of commodities associated with making a recreational trip, and t_n is ”numeraire time” - time left over after production of commodities. The marginal cost of producing z_n is normalized to one. The household’s decision variables are **x**, the vector of market goods used to produce commodities and **t**, the M-dimensional vector of time used in various household production activities. The utility function, u, is assumed to be strictly increasing in z_n and t_n and non-decreasing in all $z_j \in \mathbf{z}$.

The vector **x** can be partitioned into the N-dimensional vector $\mathbf{x}_A=(x_1,x_2,...,x_N)$ and the (M-N)-dimensional vector $\mathbf{x}_B=(x_{N+1},x_{N+2},...,x_M)$. The former consists of mutually exclusive goods that are either used in a fixed amount or not used at all, while the latter subset can be used in any proportion or combination. We thus have:

(B2) $$x_j \in \{0,1\}, \forall j = (1,2,\ldots,N) \wedge x_j x_k = 0, \forall [j,k = (1,2,\ldots,N) \wedge j \neq k]$$

Similarly, the vector **t** can be partitioned into an N-dimensional vector $\mathbf{t}_A$ of time devoted to activities associated with $\mathbf{x}_A$, and an (M-N)-dimensional vector $\mathbf{t}_B$ of activities associated with $\mathbf{x}_B$. While $\mathbf{x}_B$ can be used in the production of both z_n and **z**, $\mathbf{x}_A$ is only used in the production of **z**. The household production function for **z** can be written:

(B3) $$\mathbf{z} = \mathbf{f}(\mathbf{x},\mathbf{t},\mathbf{B},\varepsilon) = \begin{cases} \mathbf{g}(\mathbf{x}_A,\mathbf{t}_A,\mathbf{B},\varepsilon) \text{ if } [\mathbf{x}_B \geq \bar{\mathbf{x}}_B \wedge \mathbf{t}_B \geq \bar{\mathbf{t}}_B] \\ \mathbf{0} \text{ otherwise} \end{cases}$$

Thus, regardless of which $x_j \in \mathbf{x}_A$ is used in the production of **z**, a fixed cost is incurred. We interpret $\mathbf{x}_B$ as inputs needed to produce a trip, regardless of the destination, and $\mathbf{t}_B$ as the time needed in the production. The inputs could for example be accommodation, food, sporting equipment, etc. $\mathbf{B}=(\mathbf{b}_1,\mathbf{b}_2,...,\mathbf{b}_N)$ is a K×N dimensional vector of K non-market goods associated with each discrete input, and $\varepsilon=(\varepsilon_1,\varepsilon_2,...,\varepsilon_N)$ is a vector of stochastic terms associated with each discrete input. These are interpreted in the same fashion as in Section 2.6.1. We interpret $\mathbf{b}_j$ as public goods affecting the amount of **z** produced if site j is visited.

Assume further that the amount of **z** produced is entirely determined by $\mathbf{b}_j$ and ε_j if input j is chosen, and that a fixed amount of time needed in production is associated with alternative j. Thus we can write the function **g**:

(B4) $$\mathbf{g}(\mathbf{x}_A,\mathbf{t}_A,\mathbf{B},\varepsilon) = \mathbf{h}(\mathbf{b}_j,\varepsilon_j) \text{ if } [x_j = 1 \wedge t_j \geq \bar{t}_j] \text{ for j=(1,2,...,N)}$$

If x_j, j=(1,2,...,N), is interpreted as transportation to site j, this implies that no utility is derived from the travel itself, but only from the characteristics of the site, and from the random term. This assumption also implies that $\mathbf{b}_j$ is weakly complementary with x_j. If we define the price vector $\mathbf{p}_B$ associated with $\mathbf{x}_B$ and the prices p_j associated with goods x_j, j=(1,2,...,N), then the total monetary cost of making a trip to site j will be:

(B5) $$c_j = \mathbf{p}_B \bar{\mathbf{x}}_B + p_j$$

where the first term on the right-hand side will be the same for all alternatives. If we define $\mathbf{p}=(p_1,p_2,...,p_N,\mathbf{p}_B)$, the budget constraint can be written:

(B6) $$z_n+\mathbf{px}=y$$

where y is exogenous income. If alternative j is chosen, we will get:

(B7) $$z_n = y - \mathbf{p}\bar{\mathbf{x}}_B - p_j$$

The first two terms on the right-hand side will be the same regardless of which alternative is chosen.

The time constraint can be written:

(B8) $$\sum_{j=1}^{M} t_j + t_n = T$$

where T is total time available. As the time needed to produce **z** if alternative j is chosen does not enter the utility function, the time constraint in production will always be binding. The same is the case for the time vector associated with $\mathbf{x}_B$. Thus if alternative j is chosen, we will get:

(B9) $$t_n = T - \sum_{k=N+1}^{M} \bar{t}_k - \bar{t}_j$$

where the $\bar{t}_k$:s, k=(N+1,N+2,...,M) are the elements of the vector $\bar{\mathbf{t}}_B$. The first two terms on the right-hand side will be the same regardless of which alternative is chosen.

Substituting (B4), (B7) and (B9) into the utility function, we can write the conditional utility, if alternative j is chosen:

(B10) $$\tilde{\omega}\left(y - \mathbf{p}\bar{\mathbf{x}}_B - p_j , T - \sum_{k=N+1}^{M} \bar{t}_k - \bar{t}_j , \mathbf{b}_j , \varepsilon_j \right)$$

Assume that the utility function is such that we can write:

(B11) $$\tilde{\omega}\left(y - \mathbf{p}\bar{\mathbf{x}}_B - p_j , T - \sum_{k=N+1}^{M} \bar{t}_k - \bar{t}_j , \mathbf{b}_j , \varepsilon_j \right) =$$
$$\tilde{w}\left[y - \mathbf{p}\bar{\mathbf{x}}_B - p_j + \alpha\left(T - \sum_{k=N+1}^{M} \bar{t}_k - \bar{t}_j \right), \mathbf{b}_j , \varepsilon_j \right]$$

where α is a constant. In effect, we assume that t_n and z_n are perfect substitutes. Define income less fixed costs for a trip:

(B12) $$\hat{y} = y - \mathbf{p}\bar{\mathbf{x}}_B + \alpha\left(T - \sum_{k=N+1}^{M} \bar{t}_k \right)$$

and total travel cost for a trip to site j:

(B13) $\hat{p} = p_j + \alpha \bar{t}_j$

and write:

(B14) $$\tilde{w}\left[y - \mathbf{p}\bar{\mathbf{x}}_B - p_j + \alpha\left(T - \sum_{k=N+1}^{M} \bar{t}_k - \bar{t}_j\right), \mathbf{b}_j, \varepsilon_j\right] = \tilde{v}(\hat{y} - \hat{p}_j, \mathbf{b}_j, \varepsilon_j)$$

Unconditional indirect utility will be:

(B16) $$v(\hat{y} - \hat{p}_1, \hat{y} - \hat{p}_2, \ldots, \hat{y} - \hat{p}_N, \mathbf{B}, \varepsilon) = \max\{\tilde{v}_1, \tilde{v}_2, \ldots, \tilde{v}_N\}$$

where $\tilde{v}(\hat{y} - \hat{p}_j, \mathbf{b}_j, \varepsilon_j)$

It should be obvious that this expression is, for all practical purposes, the same as expression (28) in Section 2.6.1.

Appendix C: Results from estimation of the cost function

	OLS		Lognormal	
Variable	**Coefficient**	**t-value**	**Coefficient**	**t-value**
Constant	-795.65^{***}	(-4.097)	-795.65^{***}	(-27.336)
PERS	115.29^{***}	(6.049)	115.29^{***}	(27.219)
$D_{3\text{-}28}$*PERS	294.63^{***}	(5.411)	294.63^{***}	(3.805)
$D_{8\text{-}28}$*PERS	258.13^{*}	(1.759)	258.13	(1.365)
$D_{15\text{-}28}$*PERS	-119.40	(-0.477)	-119.40	(-0.162)
$DIST_j$	2.0031^{***}	(9.082)	2.0031^{***}	(27.341)
T_P* $DIST_j$	-1.6639^{***}	(-3.293)	-1.6640^{***}	(-27.414)
T_B* $DIST_j$	0.74100	(0.944)	0.74101^{**}	(2.489)
TNIGHTS	495.44^{***}	(4.986)	495.44^{***}	(23.991)
$NIGHTS_H$	516.94^{***}	(2.879)	516.94^{**}	(2.016)
$NIGHTS_F$	-135.26^{***}	(-2.814)	-135.26^{***}	(-25.256)
$NIGHTS_C$	-56.255	(-1.129)	-56.255^{***}	(-20.996)
$NIGHTS_R$	412.04^{***}	(2.899)	412.04^{***}	(4.320)
DAYTRIP	530.88^{***}	(2.960)	530.88^{***}	(24.540)
$D_{3\text{-}28}$*TNIGHTS	-260.21^{***}	(-3.215)	-260.21^{***}	(-7.492)
$D_{3\text{-}28}$*$NIGHTS_H$	41.902	(0.205)	41.902	(0.117)
$D_{3\text{-}28}$*$NIGHTS_F$	85.885	(1.434)	85.885^{**}	(2.253)
$D_{3\text{-}28}$*$NIGHTS_C$	158.95^{**}	(2.410)	158.95^{***}	(2.616)
$D_{3\text{-}28}$*$NIGHTS_R$	-98.684	(-0.676)	-98.684	(-0.843)
$D_{8\text{-}28}$*TNIGHTS	-100.10^{*}	(-1.922)	-100.10^{**}	(-2.019)
$D_{8\text{-}28}$*$NIGHTS_H$	28.027	(0.117)	28.027	(0.042)
$D_{8\text{-}28}$*$NIGHTS_F$	-39.016	(-0.742)	-39.016	(-0.775)
$D_{8\text{-}28}$*$NIGHTS_C$	0.35732	(0.006)	0.35732	(0.003)
$D_{8\text{-}28}$*$NIGHTS_R$	-41.421	(-0.696)	-41.421	(-0.342)
$D_{15\text{-}28}$*TNIGHTS	57.405	(1.026)	57.405	(0.543)
$D_{15\text{-}28}$*$NIGHTS_H$	-765.43^{***}	(-2.702)	-765.43	(-0.614)
$D_{15\text{-}28}$*$NIGHTS_F$	93.500	(0.922)	93.500	(0.976)
$D_{15\text{-}28}$*$NIGHTS_C$	-56.559	(-0.976)	-56.559	(-0.274)
$D_{15\text{-}28}$*$NIGHTS_R$	-175.26^{**}	(-2.188)	-175.26	(-0.709)
σ	-	-	1.3377^{***}	(82.135)

Sub-indices H, F, C and R denote hotel, family and friends, caravan and rented house, respectively. The sub-indices on the D variables indicate the range of duration of the trips. P and B indicate travel by public means of transportation and private boat, respectively. The asterisks indicate significance at the 99 percent, 95 percent and 90 percent levels of significance, in a two tail t-test.

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