# A Meta-analysis of Forest Recreation Values in Europe

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*Hamburg, 31 August 2005*

**Working Paper FNU-86**

## Abstract

This paper presents a meta-analysis of forest recreation in Europe based on studies that have applied the travel cost method covering 25 studies in 9 countries since 1979. We conduct the meta-regression with an increasing number of variables where level I includes only data available from the studies, level II aggregate socio-economic variables and level III site specific characteristics such as diversity, fraction of open land, and location. Data shows that consumer surplus varies between USD0.72 per trip to USD122 with a median of USD4.90 per trip. Results of the model with the best overall summary indicate that forest recreation benefits are positively influenced by an increasing level of costs per kilometre, opportunity cost of time and average distance travelled. Also large and popular forests, monotone vegetation and diverse age classes influence benefits positively. GDP, however, appear to have a negative impact on benefits and population density does not contribute significantly to predicting recreation welfare.

**Keywords**

Travel Cost Method, Meta-analysis, Recreation, Forestry

# 1. Introduction

Recreation is one of numerous services provided by ecosystems. The value that users attach to nature recreation can be substantial although it is not reflected by market prices and is provided as a quasi-public good. On a practical level, taking these values into account can make a significant difference in the management, conservation and planning options for nature recreation. On a research level, gaining knowledge on the range of values attributed to ecosystems, dependent on population characteristics, quality and quantity of the natural resource as well as specification of demand models is essential when assessing general trends and impacts on the use of forests for recreation.

This paper focuses on forests as one particular type of ecosystem, producing a range of recreation opportunities. We use statistical meta-analysis to investigate a wide range of data on the value of recreation in forests. By restraining the analysis to the travel cost method (TCM), we ensure a comparable measure of value, as TCM only values the price of access to a site as opposed to changes in on-site quality attributes.

Meta-regression analysis is a statistical technique that originates from the health sciences. The first application was by Karl Pearson in 1904, evaluating data from many studies to conclude that vaccination against intestinal fever was ineffective (Mann, 1994). Although the majority of meta-analyses have been applied to psychology, education and medicine, the technique has become widely accepted in labour and transport economics and since the early 1990s also in environmental economics (van den Bergh et al., 1997). Meta-analyses in economics differ from the experimental data used in the health sciences by reporting on data from different model set-ups and interdependent panel nature of any sample for research results (Smith and Karou, 1990).

Meta-analyses carried out in the field of environmental valuation have been applied to a variety of fields, including the provision of wetland functions across North America and Europe (Brouwer et al., 1997), fresh water fishing (Sturtevant et al., 1995), air pollution (Smith and Huang, 1995) , benefits of endangered species (Loomis and White, 1996), visibility in national parks (Smith and Osborne, 1996), and general outdoor recreation (Smith and Karou, 1990; Walsh et al., 1992). Only two meta-analyses in Europe have focused specifically on recreation in forests as opposed to general outdoor recreation. These have been limited to studies carried out in the UK (Bateman, 1999 and 2003).

By systematically analysing the variation in data from different sources, we aim to identify the extent to which methods, design, and data affect reported forest recreation values. We limit our scope to studies conducted in Europe that have applied the travel cost method. The travel cost method is generally regarded as a robust methodology and theoretically well suited for transferring values from one site to another, despite indications that model assumptions do appear to have an influence on the results (Loomis, 1992; V.K. Smith & Y. Kaoru,1990). By limiting our analysis to the travel cost method, which measures the price of access, we expect to obtain a higher explanatory power of the meta-model than what is generally found in meta-analyses.

The paper is organised as follows: Section two describes the regression methods applied, Section three the data collected in the literature review, Section four presents results and discusses and Section five concludes.

## 2. Meta-model

Original valuation studies often test several model specifications and report more than one result of interest for the meta-analysis. Rather than averaging the source estimates to avoid one study dominating the results in the meta-model (Stanley, 2001), the meta-analysis regression should be able to handle the variation in estimates within one study. Also, averaging values of dependent and independent variables within one study may lead to aggregation bias in the meta-regression if a non-linear specification is applied (Stoker, 1993). This, in turn, produces a data set with a grouped structure with possible intra-group error correlation (Moulton, 1986)

A random group effects model is able to recognize the common origin for a given set of estimates and the resulting implications for the correlation structure of error terms in the meta-model. We assume that the set of welfare measures generated by a given study can by described with the following model (Greene, 2003):

$y_i = \beta x_i + \varepsilon_i$ with

$$\varepsilon_i = \mu_i + e_{it} \qquad (1)$$

where $y_i$ is a vector of observations on forest recreation values from study *i*, adjusted to USD2000 and $x_i$ is a matrix of explanatory variables including study methodology, site and user population characteristics. $\varepsilon_i$ is a vector of error terms associated with welfare measure $y_i$, which is decomposed into a study specific constant $\mu_i$ and a vector $e_{it}$ with $f_i$ iid observation-specific errors with mean zero and common variance $\sigma_e^2$. We assume that the distribution of $\mu_i$ is as follows:

$$E[\mu_i \mid \mathbf{X}] = 0,$$
$$E[\mu_i^2 \mid \mathbf{X}] = \sigma^2 \text{ if } i = j \quad \textbf{(2)}$$
$$E[\mu_i^2 \mid \mathbf{X}] = 0 \quad \text{if } i \neq j$$

where E denotes the expectation operator. Each contributing study 'draws' a study-specific constant term from a normal distribution with mean zero and variance $\sigma_\mu^2$. These deviations are assumed uncorrelated across studies. We also assume that $\mu_i$, $e_i$, and $x_i$ are uncorrelated within and across studies. By allowing for study-specific error terms, the meta-model can capture correlation across observations within a given study (Moulton, 1986).

If the hypothesis of random effects in the Breusch and Pagan Lagrangrian multiplier test is rejected, the fixed-effects model should be estimated more efficiently, which assumes homogenous effect sizes across studies within models. We also use a Hausman specification test. If our model is correctly specified and if $\mu_i$ is uncorrelated with $x_i$, the coefficients estimated by the fixed effects and the random effects estimators should not statistically differ.

# 3. Travel Cost Demand Model & Data

Our meta-analysis focuses on studies that apply the travel cost method where recreation in forests is the main attraction (as opposed to eg. studies valuing fishing resources). It includes studies, where recreation is directly linked to services provided by forests but excludes those, where other non-forest ecosystems such as water, grassland etc. are the main reasons for visiting a site.

The travel cost recreation demand model can be seen as "a derived demand for a recreation site that contributes to each individual's production of a recreational activity providing utility" (Smith, 1990). A simple utility function U, specified in terms of the activities $A_i$ that a person wants to consume and other goods, $Z_i$, could look like this:

$$U = U(A_1, A_2 ..., A_k, Z_i), \quad \textbf{(3)}$$

where the production of each A is a combination of market goods, $x_{jt}$, necessary to consume in order to undertake activity A (e.g. vehicle and petrol to travel to reach a recreation site, fishing equipment for fishing trips etc.), the amount of time, $t_i$, to consume activity A, and non-market commodities, $y_{ki}$ such as the characteristics and availability of a recreation site and substitute sites:

$$A_i = f_i(x_{1i},...,x_{ni},t_i,y_{1i},...,y_{ni}), \quad \textbf{(4)}$$

The specification of budget and time constraints, necessary to formally derive the travel cost demand model, depends on the assumptions that the researcher applies, for instance whether or not to include an opportunity cost of time of travel and/or of time spent on site, and evaluated at which fraction of the wage rate. Demand for recreation is in travel cost studies measured by the number of trips to the site (v):

$$v = g(P, P_S, Y, d), \quad \textbf{(5)}$$

where $P$ is the implicit price of a trip, $P_S$ the travel costs to substitute sites, Y is income and $d$ are demographic characteristics, which describe the differences in taste, determining heterogeneous responses to the components in the recreation production function.

In our meta-analysis we use the normalised consumer surplus, $(CS)$ per trip $(v)$, to reflect differences in the condition of access across studies, as the dependent variable:

$$\begin{aligned} CS/v &= L(P_0, P_c, P_s, Y, d) \\ &= \int_{P_0}^{P_c} [g(p, P_S, Y, d)/g(P_0, P_S, Y, d)]dp, \end{aligned} \quad \textbf{(6)}$$

where $P_0$ is the current price and $P_c$ is the choke price. In order to estimate $(CS/v)$ we make assumptions on which variables in L(.) influence the welfare measure, based on available information in the studies and relevant exogenous data. The consumer surplus is the integral behind the demand function in (5).

In addition to the components of the travel cost demand model in (6), also features of each recreation site, specifications of the estimated demand function, and underlying assumptions in the behavioural model (e.g. treatment of substitute sites) influence estimates of $(CS/v)$ across studies. Our basic form of the estimating meta-regression model is therefore a combination of travel cost demand parameters and modelling specifications, such that $\beta x_i$ of (1) is decomposed into:

$$CS / v_i = \beta_A X_{Ai} + \gamma Z_i + \varepsilon_i , \qquad \textbf{(7)}$$

where $X_{Ai}$ is a vector of parameters estimated in (6) and $Z_i$ is a vector of variables describing modelling decisions.

We have identified a total of 25 studies from 9 European countries, totalling 251 observations. 11 of the studies reported only on one welfare estimate whereas the remaining studies include up to 77 estimates of consumer surplus. This is partly because of disaggregated multi-site studies, partly due to different model specifications and changes in independent variables, e.g. looking at the effects of including and excluding opportunity cost of time. Particularly researchers in the UK and Italy have conducted many travel cost studies (8 and 6 respectively) with 145 observations in the UK alone.

Estimates of consumer surplus per trip were converted to US dollars, adjusted for purchasing power, per person and referenced to a common date (2000) using the US consumer price index. The consumer surplus per trip varies significantly across studies, ranging from USD0.72 per trip to USD122 with a standard deviation of 30.53USD. The average welfare per trip across the studies is therefore far greater (USD19.30) than the median (USD4.90), whereas the within study difference between mean and median is less pronounced. An exception is the study by Elsasser (1993) where two very different groups of sites (one is predominantly holiday and one clearly for daytrip recreation) produce large difference in per trip values and hence a large variation in value estimates. Table 1 lists the studies and welfare estimates included.

The majority of gathered valuation studies report on size for forest site and annual number of visits to recreation sites, but exclude more detailed information on the physical site characteristics such as phenology, diversity and density of vegetation, type of site management, and provision of visitor facilities, which is believed to be of importance for the choice and length of recreation visits (e.g. Hanley and Ruffell, 1993). This is understandable for an individual study where these characteristics are constant, but makes post-comparisons across sites problematic. To the extent possible, we have included site relevant information as exogenous data provided by the relevant forest management authorities. These include density of forests in terms of fraction of open land, such as roads, pathways and clearances within the forest area, fraction of coniferous trees and trees older than 60 years, Shannon indices of diversity for species and age classes as well as longitude and latitude of forest sites. The Shannon indices of diversity take into account richness and evenness of species distribution (Shannon and Weaver 1949). The higher the index, the more rich and evenly distributed the age and species classes.

In terms of socio-economic characteristics, the extent to which data such as sex, age, income and group size is included varies considerably across studies. We have therefore added averages of national data on per capita income level and population density around the sites, measured in a 1x1 degree grid cell. Although aggregate data have no direct link to the study sites, the exogenous additions are directly comparable across studies and countries and may capture differences, especially across countries.

Dummy variables were generated on authorship and nationality for the most dominant studies in terms of number of observations. Registered variables dealing with methodological issues include model specification, i.e. whether the left hand side and right hand side specification were linear or not, and estimation, i.e. whether an OLS regression was used or not. Also the type of TCM (individual or zonal) and number of zones, if applicable, were coded. Not all studies calculate the value of time travelling to a site. We have therefore included a dummy variable for the inclusion of opportunity cost of income in addition to a continuous variable on the percentage of the value of time used, if applicable. Travel cost per kilometre was included as well as the level of expenditure, where relevant. The latter cover other costs of the travel such as lodging, food, and equipment. Finally, we coded the inclusion of substitute sites and whether visits were registered as holiday or day-trips. All regressors are listed in Table 2.

# 4. Meta-analysis Results & Discussion

Table 3 and Table 4 report the results of two meta-models based on different dependent variables: the log of consumer surplus, which proved superior to a linear specification and the consumer surplus normalised for size of forest. We introduced the normalised consumer surplus to compare whether the object (i.e. a value of a site) or the quantity (i.e. a per hectare value) of recreation services provided by forests provide a better fit of the meta-model to the data at hand. Each of the two models are run with a stepwise increasing number of variables, reflecting the level of data used. The first level (I) includes only information available from the studies; the second level (II) adds two aggregate variables on socio-economics, GDP per capita and population density in a 1X1 Degree grid cell around the forest site studies; the third and final level (III) introduces site attributes such as fraction of open land, age and species diversity indices as well as latitude and longitude of the forest site locations. In total, we report on six regressions, three for each of the two meta-models.

The appropriateness of including a study-specific error term was accepted in all regressions by the Breusch-Pagan Lagrange Multiplier test for the constraint $\sigma_{\mu} = 0$ as the $H_0$ of no intra-panel error can be rejected in all cases. Also, the Hausman test confirms in five out of six regressions that the model specification is correct, i.e. that differences between the coefficients estimated by the fixed-effects estimator and the random-effects estimator are systematic across studies. Looking at the model using the log of the consumer surplus as dependent variable, we find that we can reject the Hausmann $H_0$ in level II and III when decomposing the variable cost per kilometre into within and between effects, i.e. into the average and the deviation from the average, respectively. This reflects that the average cost of travelling may have one effect while transitional costs may have a different effect on forest visitation rates and hence consumer surplus. However, we find no evidence of systematic differences in coefficients between the fixed- and random-effects estimators in level I. The regressions using the consumer surplus per hectare all show evidence of systematic differences in coefficients.

The scale, significance level and sign of coefficients clearly differ between the two meta-models, regardless of the level applied. The model using the log of consumer surplus appears to have a superior explanatory power (overall $R^2$: 74% - 87%) than the normalised consumer surplus model (overall $R^2$: 33% - 41%). Especially the former produce a high explanatory power compared to other meta-analyses of non-market good valuation studies with $R^2$ ranging from 15% and 68% (Smith and Kaoru, 1990; Walsh et al., 1992; Mrozek and Taylor, 2002; Shresta and Loomis, 2003;).

Looking at the year in which the studies were carried out, we find a positive and significant relationship at the 20% level or better in the normalised regression but non-significant in the semi-log model in level I and II. The trend signifies that benefit estimates generally have been increasing at a greater rate than inflation over time. This trend is also found in Rosenberger and Loomis (2001), Smith and Huang (1995), and Woodward and Wui (2001).

Although the effect of the author dummy variable 'Willis' on consumer surplus is significant in both models in level I, the signs change from positive in the semi-log model to negative in the normalised model. The reason for the difference lies partly in the specification of the dependent variable. When applying the consumer surplus per hectare, data shows that the normalised welfare measures estimated in the Willis studies are on average 48% lower than the overall level of the European studies, leading to a negative coefficient. This effect is not outweighed by the smaller average size of sites investigated by Willis, which inflates the dependent variable of these studies compared to other studies. Using the semi-log specification, the difference in level of consumer surplus between the Willis studies and the other studies is negligible and the positive impact on overall welfare must be attributable to other aspects. Due to multicollinearity with the variable GDP in level II and III, we removed Willis from the regression.

The coefficient for the country dummy variable, Italy, is positive and significant in both models, apart from level I of the semi-log model. Our data indicates that forest recreation values estimated in Italy are on average 79% higher than the overall average of forest recreation values found in European studies using the travel cost approach. The high values in the Italian studies are not caused by an above average distance travelled (this is among the lowest in the studies collected) but rather by using the highest cost per kilometre (1USD on average for the Italian studies compared to 0.40 USD in average over all studies).

Cost used per kilometre, size of site and average costs per kilometre are overall positive and significant in the semi-log model and generally negative and significant in the normalised model. The reason for the opposing signs lies again with the normalisation of the welfare measure by size. Sites that are larger than the average have lower normalised values than sites with smaller than average size. This reverts the positive relationship between benefits and size of site as visitors normally tend to travel further to a larger site than to a smaller site, found also in other studies (Zandersen et al. 2005; Scarpa et al., 2000). Due to the longer distance travelled to larger sites, the average distance travelled and the average costs per kilometre positively influence the level of consumer surplus. The normalised model reverts this trend such that smaller sites have comparably higher normalised benefits, causing the coefficients of costs of travelling, distance and size of site to decrease benefits. Related to this is the coefficient of log of number of yearly visits per site, which is positive and highly significant in the semi-log model, but appear to have no influence on the normalised benefit measure.

Both models agree that the individual travel cost approach has a positive and highly significant influence on benefits. This is supported by Shrestha and Loomis (2003) who find in their meta-analysis on outdoor recreation in the USA that the individual travel cost method leads to increased welfare measure. The fraction of wage used as a proxy for the opportunity cost of time is also positive and significant in both models, a relationship also found in Smith and Kaoru (1990).

Introducing aggregate socio-economic data in Level II indicates that 'GDP' is significant at the 1% level or better in both level I and II in the semi-log model and at the 10% level or better in the normalised model, but only at the level II. The negative relationship in the semi-log model between aggregate GDP and site level benefits is surprising. The reason may be the relatively small and thin spread of the sample on several countries, with outliers such as the study of Oyazun (1994) which estimated the highest mean consumer surplus per person and where the aggregate GDP measure ranks as the second lowest among the studies investigated. The coefficient of the population density variable is non-significant in both cases, which may be attributable to the aggregate level of the variable.

Adding site attributes in level III shows again very different results in terms of scale, significance and sign between the two models. Shannon indices of species diversity and age are highly significant in the semi-log model, where species monotone rather than diverse forests and forests with diverse and evenly distributed age classes seem to enhance welfare. In the normalised model, diversity plays no significant role but fraction of open land appears to increase consumer surplus; forest recreation in the southern parts of Europe, according to the data collected, is more valuable than in the northern parts of Europe.

Due to multicollinearity and bivariate correlation, several variables were removed from the models presented, of which the most important included longitude, functional form of the demand function, type of regression, other author and country dummies. Also, variables for individual TCM and the country dummy for Italy dropped out in level III due to multicollinearity.

Table 5 lists observations that are clearly outliers with respect to consumer surplus. In the semi-log model, three studies from Germany and Spain produced estimated consumer surplus up to 10 times higher than the average over studies. The sites are far greater than the average size (between 3 and 14 times larger) and average distance (283km – 890km) clearly not based on day-trip recreation. One further outlier from the UK can be identified with a very low consumer surplus (0.03USD). The cost per kilometre used in the study is very low and the forest site relatively small (7 times smaller than the average).

In the normalised model, two observations from Germany and one from Italy differ substantially from the remaining data set by having very small forest sites (149ha-159ha) and very low distance travelled in the German study (no information was available for the Italian study on travel distance).

## 5. Concluding Comments

Our literature review of forest recreation studies in Europe focused on studies that have applied the travel cost method between 1979 and 2001. The data indicates that there is a substantial variance in forest recreation values across studies, ranging from USD0.72 to USD122 per trip with a median of USD4.90. The confinement to travel cost studies ensures a consistent economic concept (Marshallian willingness to pay) with value of access representing an identical change in service provision across studies.  By selecting the same type of recreation activity, typology of sites and valuation methodology, our aim has been to reduce the differences across studies and countries as much as possible whilst ensuring a minimum number of studies and observations. This has resulted in a higher explanatory power of variance in the data than seen in meta-analysis studies that include different valuation methodologies (Walsh et al., 1992; Woodward and Wui, 2001; Rosenberger and Loomis, 2000).

Despite the similarities in approach and service provisions surveyed in this meta-analysis, the summarised benefit estimates reflect being carried out in different geographical locations in different studies and across long time periods. Meta-analyses in the past (Shresta and Loomis, 2003,  Walsh et al., 1992, Rosenberger and Loomis, 2000; Smith and Kaoru, 1990) and this study to some extent have shown that values are influenced by the measurement of value (e.g. value per trip, per day or per season), by the travel cost approach (i.e. zonal versus individual travel cost method), by the definition of costs (i.e. inclusion and level of opportunity cost of time, composition of car-borne travel costs) and other methodological issues (e.g. inclusion of substitute sites, postal or face to face interviews, or specification of functional form of the meta-analysis). This study adds to the growing evidence from the meta-analysis literature by finding that number of visits to recreational sites and costs of travel have significant influence on the level of consumer surplus. Also, the inclusion of exogenous data on site characteristics reveals that site specific characteristics such as size, species and age diversity have distinctive effects on benefits summarised in a meta-analysis. These site attributes have previously shown to have significant influences on welfare in original valuation studies (Zandersen et al., 2005, Scarpa et al., 2000, Termansen et al., 2004), but have to date not been included in meta-analyses. However, site specific characteristics are rarely available in valuation studies as they are treated as constants for the purpose of the original study. Similarly, well-known problems exist in obtaining information about socio-economic values of samples not to mention socio-psychological and cultural characteristics (Brouwer et al.,1999; Woodward and Wui, 2001). There have been numerous calls in the past for additional explanatory data to be made readily available from original studies for use in value transfers and meta-analyses (e.g. David, 1992; Rosenberger and Phipps, 2001). Also, meta-analyses, including the present one, would significantly improve if more observations for each type of survey design were available, for instance made available through an outlet that focus on publications that repeat published survey designs to different settings. This would to a large degree eliminate the variation in point estimates due to different survey designs and focus the analysis on variation due to site attributes, population characteristics etc.

***Acknowledgements***

We would like to thank the authors of original studies summarised in this paper who took time and efforts to clarify and provide additional information, e.g. Eija Pouta, Jens B. Christensen and Peter Elsasser, as well as forest agencies and national park authorities who were very helpful in providing data on site attributes, e.g. Steve Smith, Arnold Bijlsma and Timothy Samuels from the Forestry Commission, UK; Thorsten Spät and Rainer Köpsell from the Forest Planning Agency of Lower Saxony, Germany; Axel Röder and Wolgang Koch from the Forest Agency in Rhineland-Palatinate, Germany; Folkhard Spangenberg, Hamburg Forest Agency as well as forest mangers in the Hamburg forests, Germany; Paola Berto from the Regional Agricultural Agency of Veneto, Italy; Christina Oddgaard from the Nature and Forest Agency and Thorkild Krogh from Copenhagen Forest Department, Denmark. We are also grateful for the use of library and helpful comments on earlier versions of this paper by Peter Elsasser as well as for the valuable guidance by David Maddison in the inception phase of this project. The VW Foundation provided welcome financial support.

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**Table 1 Forest Recreation Studies using the Travel Cost Method & Welfare Measures**

| Study | Country | Type of Publication | Obser-vations | Mean Consumer Surplus (USD2000) | Median Consumer Surplus (USD2000) | Standard Deviation |
|---|---|---|---|---|---|---|
| Bateman et al. (1996) | UK | Journal | 2 | 3.17 | 3.17 | 0.30 |
| Boatto et al. (1984) | Italy | Journal | 1 | 6.46 | 6.46 | . |
| Bojö (1985) | Sweden | Report | 1 | 35.12 | 35.12 | . |
| Christensen (1988) | Denmark | Dissertation | 47 | 0.87 | 0.56 | 0.86 |
| Elsasser (1996) | Germany | Dissertation | 26 | 10.71 | 7.71 | 20.68 |
| Everett (1979) | UK | Journal | 1 | 4.90 | 4.90 | . |
| Gatto (1988) | Italy | Journal | 1 | 3.38 | 3.38 | . |
| Glück (1977) | Austria | Journal | 1 | 0.72 | 0.72 | . |
| Hanley (1989) | UK | Journal | 1 | 4.58 | 4.58 | . |
| Hanley and Ruffel (1993) | UK | Book | 1 | 4.54 | 4.54 | . |
| INRA (1979) | France | Report | 3 | 11.02 | 12.70 | 3.57 |
| Löwenstein (1991) | Germany | Proceedings | 1 | 56.30 | 56.30 | . |
| Luttmann and Schröder (1995) | Germany | MSc thesis | 2 | 122.21 | 122.21 | 102.27 |
| Marangon and Gottardo (2001) | Italy | Report | 2 | 18.19 | 18.19 | 6.70 |
| Marinelli et al. (1990) | Italy | Journal | 2 | 25.47 | 25.47 | 28.94 |
| Marinelli and Romano (1986) | Italy | Book | 1 | 1.81 | 1.81 | . |
| Merlo (1986) | Italy | Journal | 1 | 2.74 | 2.74 | . |
| Merlo and Signorello (1991) | Italy | Proceedings | 7 | 16.62 | 14.71 | 7.22 |
| Moons et al. (2001) | Belgium | Journal | 6 | 5.27 | 4.88 | 1.56 |
| Ovaskainenet al. (2001) | Finland | Journal | 1 | 38.80 | 38.80 | . |
| Oyarzun (1994) | Spain | Journal | 2 | 95.52 | 95.52 | 94.84 |
| Willis (1991) | UK | Journal | 77 | 3.94 | 3.97 | 2.07 |
| Willis and Benson (1988) | UK | Journal | 3 | 3.95 | 3.82 | 2.12 |
| Willis and Benson (1989) | UK | Journal | 24 | 4.27 | 4.62 | 1.87 |
| Willis and Garrod (1991) | UK | Journal | 36 | 1.98 | 1.22 | 1.96 |
| Total Observations | | | 251 | | | |
| Total mean by study | | | 10.04 | 18.77 | 18.77 | 21.01 |
| Total median by study | | | 2 | 4.90 | 4.88 | 2.85 |
| Total standard deviation by study | | | 18.60 | 30.53 | 30.59 | 35.48 |

**Table 2 Explanatory Variables, means and ranges**

| Variable | Observations | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| **Authorship Dummy Variables** | | | | | |
| Willis (=1, 0 otherwise) | 251 | 0.56 | 0.50 | 0 | 1 |
| Christensen (=1, 0 otherwise) | 251 | 0.19 | 0.39 | 0 | 1 |
| Elsasser (=1, 0 otherwise) | 251 | 0.10 | 0.31 | 0 | 1 |
| **National Dummy variables** | | | | | |
| UK (=1, 0 otherwise) | 251 | 0.59 | 0.49 | 0 | 1 |
| Denmark (=1, 0 otherwise) | 251 | 0.18 | 0.39 | 0 | 1 |
| Germany (=1, 0 otherwise) | 251 | 0.12 | 0.32 | 0 | 1 |
| Italy (=1, 0 otherwise) | 251 | 0.06 | 0.24 | 0 | 1 |
| **Site Characteristic** | | | | | |
| longitude | 251 | 2.72 | 6.75 | -5 | 24 |
| latitude | 251 | 52.92 | 3.30 | 40 | 63 |
| size (ha) | 250 | 10,164.17 | 32,872.05 | 47.2 | 334,000 |
| yearly number of visits | 230 | 990,553.70 | 3,116,546 | 1,426 | 2.16E+07 |
| Fraction coniferous (%) | 223 | 0.64 | 0.29 | 0 | 1 |
| Shannon age diversity index | 217 | 1.40 | 0.40 | 0 | 2.29 |
| Shannon species index | 213 | 1.23 | 0.34 | 0.572 | 1.97 |
| density of forest (%) | 216 | 0.96 | 0.20 | 0 | 1 |
| fraction of trees older than 60 yrs (%) | 214 | 0.41 | 0.24 | 0 | 1 |
| fraction open land (%) | 212 | 0.25 | 0.15 | 0.00714 | 0.86 |
| **Methodology Issues** | | | | | |
| opportunity cost of income used (=1, 0 otherwise) | 248 | 0.69 | 0.46 | 0 | 1 |
| expenditure (USD 2000 PPP) | 247 | 0.20 | 0.40 | 0 | 1 |
| opportunity cost of time (% of salary) | 246 | 0.25 | 0.29 | 0 | 1 |
| cost per km (USD 2000 PPP) | 245 | 0.27 | 0.49 | 0.02 | 7.1 |
| OLS regression (=1, 0 otherwise) | 243 | 0.95 | 0.21 | 0 | 1 |
| left hand side linear (=1, 0 otherwise) | 243 | 0.39 | 0.49 | 0 | 1 |
| right hand side linear (=1, 0 otherwise) | 243 | 0.92 | 0.28 | 0 | 1 |
| regional study (=1, 0 otherwise) | 251 | 0.89 | 0.31 | 0 | 1 |
| multi-site (=1, 0 otherwise) | 251 | 0.24 | 0.42 | 0 | 1 |
| individual TCM (=1, 0 otherwise) | 251 | 0.16 | 0.37 | 0 | 1 |
| trip value used (=1, 0 otherwise) | 251 | 0.98 | 0.15 | 0 | 1 |
| holiday visits (=1, 0 otherwise) | 242 | 0.23 | 0.42 | 0 | 1 |
| substitute sites (=1, 0 otherwise) | 238 | 0.51 | 0.50 | 0 | 1 |
| number of zones | 204 | 22.92 | 57.64 | 0 | 767 |

| Variable | Observations | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| **Socio-economic Characteristics** | | | | | |
| population density (1X1 Degree grid cell) | 251 | 272,416.90 | 234,992.30 | 2601 | 829,285 |
| GDP PPP per capita (national level) | 251 | 21,088.22 | 2,434.72 | 15,280.08 | 28,084.03 |
| **Study Characteristics** | | | | | |
| publication date (yr) | 251 | 0.02 | 0.13 | 0 | 1 |
| sample size | 235 | 1,037.33 | 2,369.61 | 21 | 16,512 |
| travel time (hrs) | 201 | 0.11 | 0.32 | 0 | 1 |
| average distance (km) | 191 | 73.72 | 106.20 | 2.5 | 890 |
| average time on site (mn) | 182 | 8.96 | 23.29 | 0 | 112.44 |
| maximum distance travelled (km) | 158 | 154.23 | 182.89 | 35 | 1330 |

**Table 3 Robust Random-effects GLS meta-regression results with log of consumer surplus as dependent variable**

| Random-effects GLS regression<br>Random effects u_i ~ Gaussian | | Group variable (i): ref<br>corr(u_i, X) = 0 (assumed) | |
|---|---|---|---|
| **Dep: Variable** | **Log of consumer surplus** | | |
| **Model Specification** | I | II | III |
| Species diversity index | | | -0.2963935*** |
| Age diversity index | | | 0.5964462*** |
| Open land | | | 0.3068394 |
| Latitude | | | -0.0017737 |
| Gdp per capita | | -0.0001191**** | -0.0001655**** |
| Population density | | -1.29e-08 | -8.48e-08 |
| Year of study | 0.0089173 | 0.0204087* | 0.0269273 |
| Willis | 0.7623154**** | | |
| Italy | 0.4652399 | 0.7807605**** | |
| Size | -6.21e-06 | 0.0000884**** | 0.000068*** |
| Size$^2$ | | -3.66e-09**** | -2.91e-09*** |
| Cost/km | 0.1833045 | | |
| Avgerage cost/km | | -0.1923367**** | 0.0425521 |
| Deviation cost/km | | 3.122538**** | 3.179742**** |
| Expenditures | -0.1938821* | 0.1788032* | 0.2220307 |
| Holiday | 0.1004711 | 0.0620681 | 0.1076862 |
| Opportunity cost of time | 1.740182**** | 1.335449**** | 1.309819**** |
| Individual tcm | 3.389947**** | 3.843062**** | |
| Log of number of visits | 0.1102791**** | 0.1279282**** | 0.1575362*** |
| Avgerage distance | 0.0053105**** | 0.0048779**** | 0.0042511**** |
| constant | -15.28549 | -35.39993* | -48.12467 |
| *sigma_u* | | | |
| *Sigma_e* | 0.45815897 | 0.44364181 | 0.40287574 |
| *Rho* | | | |
| R-sq: within | 0.3020 | 0.6015 | 0.6834 |
| between | 0.8523 | 0.9762 | 0.9997 |
| overall | 0.7369 | 0.8592 | 0.8739 |
| Wald chi2 | 5003.46 | 45419.73 | 1610.03 |
| Prob>chi2 | 0.000 | 0.000 | 0.000 |
| Number of obs | 168 | 168 | 151 |
| Number of studies | 10 | 10 | 5 |
| Average obs per study | 16.8 | 16.8 | 30.2 |
| **Breusch-Pagan Lagrange Multiplier Test** | | | |
| Chi2(1) | 0.96 | 1.44 | 1.49 |
| Prob > chi2 | 0.3261 | 0.2294 | 0.2215 |
| **Hausman Test** | | | |
| Chi2() | 25.59 (6) | 9.70 (7) | 12.41(11) |
| Prob > chi2 | 0.0003 | 0.2062 | 0.3336 |

**** Significant at 1% level or better ** Significant at 10% level or better
*** Significant at 5% level or better * Significant at 20% level or better

**Table 4 Robust Random-effects GLS meta-regression results with consumer surplus per hectare as dependent variable**

| | | | |
|---|---|---|---|
| Random-effects GLS regression<br>Random effects u_i ~ Gaussian | Group variable (i): ref<br>corr(u_i, X) = 0 (assumed) | | |
| **Dep: Variable** | **Consumer surplus per hectare** | | |
| **Model Specification** | I | II | III |
| Species diversity index | | | 0.0006585 |
| Age diversity index | | | 0.0038225 |
| Open land | | | 0.0105276* |
| Latitude | | | -0.0006483*** |
| Gdp per capita | | 1.13e-06** | 6.95e-07 |
| Population density | | -1.95e-09 | -1.59e-10 |
| Year of study | 0.0005337* | 0.0003977* | 0.0005829* |
| Willis | -0.0066312** | | |
| Italy | 0.0065043**** | 0.0133209**** | |
| Size | -1.49e-07**** | -8.78e-07**** | -1.08e-06*** |
| $Size^2$ | | 2.79e-11**** | 3.65e-11** |
| Cost/km | -0.0014398**** | -0.0012814**** | 0.0017609 |
| Expenditures | -0.0003297 | -0.0010679 | -0.003602 |
| Holiday | -0.0009425** | -0.0003895 | -0.000314 |
| Opportunity cost of time | 0.0090306*** | 0.011229 | 0.0121871*** |
| Individual tcm | 0.0094182*** | 0.0070441 | |
| Log of number of visits | -0.0002687 | -0.0001172 | -0.0011652 |
| Avgerage distance | -5.54e-06 | -1.33e-06 | -0.000131* |
| constant | -1.048798* | -0.8070323* | -1.127099* |
| *sigma_u* | | | |
| *Sigma_e* | 0.00616029 | 0.00609477 | 0.00615046 |
| *Rho* | | | |
| R-sq: within | 0.1622 | 0.1980 | 0.2474 |
| between | 0.8430 | 0.9281 | 0.9993 |
| overall | 0.3383 | 0.3840 | 0.4090 |
| Wald chi2 | 6288.98 | 3287.81 | 76.50 |
| Prob>chi2 | 0.00 | 0.00 | 0.00 |
| Number of obs | 168 | 168 | 151 |
| Number of studies | 10 | 10 | 5 |
| Average obs per study | 16.8 | 16.8 | 30.2 |
| **Breusch-Pagan Lagrange Multiplier Test** | | | |
| Chi2(1)= | 1.17 | 1.60 | 1.47 |
| Prob > chi2 = | 0.2789 | 0.2053 | 0.2261 |
| Hausman Test | | | |
| Chi2() = | 5.15(7) | 2.45(7) | 2(11) |
| Prob > chi2 = | 0.6421 | 0.9308 | 0.9985 |

**** Significant at 1% level or better ** Significant at 10% level or better
*** Significant at 5% level or better * Significant at 20% level or better

**Table 5 Outliers in Normalised and Semi-log Models**

| Average/Outliers | Author | Site | Cs | Log(1+cs) | Cs/ha | Avg. dist | Cost/km | size |
|---|---|---|---|---|---|---|---|---|
| **Average, All Studies** | | | 19.93 | 5.79 | 0.00267 | 73.72 | 0.27 | 7,457.39 |
| | Elsasser,P.(1996) | Niendorf, Hamburg, Germany | 9 | 6.20 | 0.06338 | 7.5 | 0.13 | 149 |
| **Outlier, normalised model** | Elsasser,P.(1996) | Bergedorf, Hamburg, Germany | 8.6 | 6.15 | 0.05772 | 7.5 | 0.13 | 149 |
| | Merlo,M.& Signorello,G. (1991) | Abetina Reale, Italy | 8.87 | 6.18 | 0.05579 | . | 0.25 | 159 |
| | Luttmann,V.& Schröder,H. (1995) | Lüneburger Heide, Germany | 194.53 | 9.27 | 0.00905 | 890 | 0.17 | 21,500 |
| | Elsasser,P.(1996) | Pfälzerwald (aggregate), Germany | 106.66 | 8.67 | 0.00101 | 283 | 0.13 | 106,108.2 |
| **Outlier, semi-log model** | Oyarzun,D.A.(1994) | La Pedriza, Manzanares, Spain | 162.58 | 9.09 | 0.00348 | . | 0.28 | 46,728 |
| | Willis, K.G.& Garrod,G.D.(1991) | Cheshire (delamere forest), UK | 0.03 | 0.49 | 0.00003 | . | 0.07 | 957.13 |

**Table 6 Average Consumer Surplus of European Forest Recreation and Main Influences**

| Main Influences | Semi-log Model (log of consumer surplus) | Normalised Model (cs/ha) |
|---|---|---|
| Species Diversity | - | |
| Age diversity | + | |
| Fraction Open Land | | + |
| Cost per km | + | - |
| Willis | + | - |
| Italy | + | + |
| Opportunity cost of time | + | + |
| Individual tcm | + | + |
| Number of Visits | + | |
| Size | + | - |
| Average distance | + | |
| **Average Consumer Surplus (USD 2000)** | **5.79** | **0.0042** |

Note: Total Average Consumer Surplus across studies is USD18.77

**Working Papers**

**Research Unit Sustainability and Global Change**

**Hamburg University and Centre for Marine and Atmospheric Science**

Zandersen, M. and R.S.J. Tol (2005), *A Meta-analysis of Forest Recreation Values in Europe,* **FNU-86** (submitted)

Heinzow, T., R.S.J. Tol and B. Brümmer (2005), *Offshore-Windstromerzeugung in der Nordsee - eine ökonomische und ökologische Sackgasse?* **FNU-85** (submitted)

Röckmann, C., U.A. Schneider, M.A. St.John, and R.S.J. Tol (2005), *Rebuilding the Eastern Baltic cod stock under environmental change - a preliminary approach using stock, environmental, and management constraints,* **FNU-84** (submitted)

Tol, R.S.J. and G.W. Yohe (2005), *Infinite uncertainty, forgotten feedbacks, and cost-benefit analysis of climate policy,* **FNU-83** (submitted)

Osmani, D. and R.S.J. Tol (2005), The case of two self-enforcing international agreements for environmental protection, **FNU-82** (submitted)

Schneider, U.A. and Bruce A. McCarl, (2005), *Appraising Agricultural Greenhouse Gas Mitigation Potentials: Effects of Alternative Assumptions*, **FNU-81** (submitted)

Zandersen, M., M. Termansen, and F.S. Jensen, (2005), *Valuing new forest sites over time: the case of afforestation and recreation in Denmark,* **FNU-80** (submitted)

Guillerminet, M.-L. and R.S.J. Tol (2005), *Decision making under catastrophic risk and learning: the case of the possible collapse of the West Antarctic Ice Sheet*, **FNU-79** (submitted)

Nicholls, R.J., R.S.J. Tol and A.T. Vafeidis (2005), *Global estimates of the impact of a collapse of the West Antarctic Ice Sheet: An application of FUND,* **FNU-78** (submitted)

Lonsdale, K., T.E. Downing, R.J. Nicholls, D. Parker, A.T. Vafeidis, R. Dawson and J.W. Hall (2005), *Plausible responses to the threat of rapid sea-level rise for the Thames Estuary,* **FNU-77** (submitted)

Poumadère, M., C. Mays, G. Pfeifle with A.T. Vafeidis (2005), *Worst Case Scenario and Stakeholder Group Decision: A 5-6 Meter Sea Level Rise in the Rhone Delta, France,* **FNU-76** (submitted)

Olsthoorn, A.A., P.E. van der Werff, L.M. Bouwer and D. Huitema (2005), *Neo-Atlantis: Dutch Responses to Five Meter Sea Level Rise,* **FNU-75** (submitted)

Toth, F.L. and E. Hizsnyik (2005), *Managing the inconceivable: Participatory assessments of impacts and responses to extreme climate change*, **FNU-74** (submitted)

Kasperson, R.E. M.T. Bohn and R. Goble (2005), *Assessing the risks of a future rapid large sea level rise: A review,* **FNU-73** (submitted)

Schleupner, C. (2005), *Evaluation of coastal squeeze and beach reduction and its consequences for the Caribbean island Martinique,* **FNU-72**

Schleupner, C. (2005), *Spatial Analysis As Tool for Sensitivity Assessment of Sea Level Rise Impacts on Martinique,* **FNU-71**

Sesabo, J.K. and R.S.J. Tol (2005), *Factor affecting Income Strategies among households in Tanzanian Coastal Villages: Implication for Development-Conservation Initiatives,* **FNU-70** (submitted)

Fisher, B.S., G. Jakeman, H.M. Pant, M. Schwoon. and R.S.J. Tol (2005), *CHIMP: A Simple Population Model for Use in Integrated Assessment of Global Environmental Change*, **FNU-69** (submitted)

Rehdanz, K. and R.S.J. Tol (2005), *A No Cap But Trade Proposal for Greenhouse Gas Emission Reduction Targets for Brazil, China and India*, **FNU-68** (submitted)

Zhou, Y. and R.S.J. Tol (2005), *Water Use in China's Domestic, Industrial and Agricultural Sectors: An Empirical Analysis*, **FNU-67** (submitted)

Rehdanz, K. (2005), *Determinants of residential space heating demand in Germany*, **FNU-66** (submitted)

Ronneberger, K., R.S.J. Tol and U.A. Schneider (2005), *KLUM: A simple model of global agricultural land use as a coupling tool of economy and vegetation,* **FNU-65** (submitted)

Tol, R.S.J. (2005), *The Benefits of Greenhouse Gas Emission Reduction: An Application of* FUND, **FNU-64** (submitted)

Röckmann, C., M.A. St.John, F.W. Köster, F.W. and R.S.J. Tol (2005), *Testing the implications of a marine reserve on the population dynamics of Eastern Baltic cod under varying environmental conditions,* **FNU-63** (submitted)

Letsoalo, A., J. Blignaut, T. de Wet, M. de Wit, S. Hess, R.S.J. Tol and J. van Heerden (2005), *Triple Dividends of Water Consumption Charges in South Africa*, **FNU-62** (submitted)

Zandersen, M., Termansen, M., Jensen,F.S. (2005), *Benefit Transfer over Time of Ecosystem Values: the Case of Forest Recreation,* **FNU-61** (submitted)

Rehdanz, K., Jung, M., Tol, R.S.J. and Wetzel, P. (2005), *Ocean Carbon Sinks and International Climate Policy*, **FNU-60** (forthcoming, *Energy Policy*)

Schwoon, M. (2005), *Simulating The Adoption of Fuel Cell Vehicles*, **FNU-59** (submitted)

Bigano, A., J.M. Hamilton and R.S.J. Tol (2005), *The Impact of Climate Change on Domestic and International Tourism: A Simulation Study*, **FNU-58** (forthcoming, *Climate Research*)

Bosello, F., R. Roson and R.S.J. Tol (2004), *Economy-wide estimates of the implications of climate change: Human health*, **FNU-57** (forthcoming, *Ecological Economics*)

Hamilton, J.M. and M.A. Lau (2004) *The role of climate information in tourist destination choice decision-making,* **FNU-56** (forthcoming, Gössling, S. and C.M. Hall (eds.), Tourism and Global Environmental Change. London: Routledge)

Bigano, A., J.M. Hamilton and R.S.J. Tol (2004), *The impact of climate on holiday destination choice*, **FNU-55** (forthcoming, *Climatic Change*)

Bigano, A., J.M. Hamilton, M. Lau, R.S.J. Tol and Y. Zhou (2004), *A global database of domestic and international tourist numbers at national and subnational level*, **FNU-54** (submitted)

Susandi, A. and R.S.J. Tol (2004), *Impact of international emission reduction on energy and forestry sector of Indonesia*, **FNU-53** (submitted)

Hamilton, J.M. and R.S.J. Tol (2004), *The Impact of Climate Change on Tourism and Recreation*, **FNU-52** (forthcoming, Schlesinger et al. (eds.), Cambridge University Press)

Schneider, U.A. (2004), *Land Use Decision Modelling with Soil Status Dependent Emission Rates*, **FNU-51** (submitted)

Link, P.M., U.A. Schneider and R.S.J. Tol (2004), *Economic impacts of changes in fish population dynamics: the role of the fishermen's harvesting strategies*, **FNU-50** (submitted)

Berritella, M., A. Bigano, R. Roson and R.S.J. Tol (2004), *A General Equilibrium Analysis of Climate Change Impacts on Tourism*, **FNU-49** (forthcoming, *Tourism Management*)

Tol, R.S.J. (2004), *The Double Trade-Off between Adaptation and Mitigation for Sea Level Rise: An Application of* FUND, **FNU-48** (submitted, *Mitigation and Adaptation Strategies for Global Change*)

Erdil, Erkan and Yetkiner, I. Hakan (2004), *A Panel Data Approach for Income-Health Causality,* **FNU-47**

Tol, R.S.J. (2004), *Multi-Gas Emission Reduction for Climate Change Policy: An Application of* FUND, **FNU-46** (forthcoming, *Energy Journal*)

Tol, R.S.J. (2004), *Exchange Rates and Climate Change: An Application of* FUND*,* **FNU-45** (forthcoming, *Climatic Change*)

Gaitan, B., Tol, R.S.J, and Yetkiner, I. Hakan (2004), *The Hotelling's Rule Revisited in a Dynamic General Equilibrium Model*, **FNU-44** (submitted)

Rehdanz, K. and Tol, R.S.J (2004), *On Multi-Period Allocation of Tradable Emission Permits*, **FNU-43** (submitted)

Link, P.M. and Tol, R.S.J. (2004), *Possible Economic Impacts of a Shutdown of the Thermohaline Circulation: An Application of* FUND, **FNU-42** (*Portuguese Economic Journal*, **3**, 99-114)

Zhou, Y. and Tol, R.S.J. (2004), *Evaluating the costs of desalination and water transport,* **FNU-41** (f*Water Resources Research,* **41** (3), W03003)

Lau, M. (2004), *Küstenzonenmanagement in der Volksrepublik China und Anpassungsstrategien an den Meeresspiegelanstieg,***FNU-40** (submitted, *Coastline Reports*)

Rehdanz, K. and Maddison, D. (2004), *The Amenity Value of Climate to German Households*, **FNU-39** (submitted)

Bosello, F., Lazzarin, M., Roson, R. and Tol, R.S.J. (2004), *Economy-wide Estimates of the Implications of Climate Change: Sea Level Rise*, **FNU-38** (submitted, *Environmental and Resource Economics*)

Schwoon, M. and Tol, R.S.J. (2004), *Optimal* $CO_2$*-abatement with socio-economic inertia and induced technological change*, **FNU-37** (submitted, *Energy Journal*)

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