Benefit Transfer over Time of Ecosystem Values: the Case of Forest Recreation

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Abstract

We conduct a functional benefit transfer over 20 years of total willingness to pay based on car-borne forest recreation in 52 forests, using a mixed specification of a random utility model and geographic information systems to allow heterogeneous preferences across the population and for heterogeneity over space. Results show that some preferences of forest attributes, such as species diversity and age, as well as transport mode have changed significantly over the period. Updating the transfer model with present demand for recreation improves the error margins by an average of 182%. However, average errors of the best transfer model remain 145%.

Keywords

random utility model, value transfer over time, recreation, GIS.

JEL classification

Q230, Q510

1. Introduction

Value transfer of non-market environmental goods and services can be a cost and time-saving means of valuing sites for which there is little or no information (Boyle 1992, Rosenberger et al. 2000). Benefit transfers are based on sites where monetary valuation has already been carried out (policy-sites), and transferred to new, unstudied sites (study-sites), either in the form of single benefit values or entire value transfer functions. They are useful in a wide range of different contexts including cost benefit analyses of new projects and policy initiatives (e.g. Hanley et al., 1999), in general equilibrium models (e.g. Dessus and O'Connor 1999), environmental regulation (e.g. WATECO 2003), and for calculating the adequate compensation payments in pollution accident cases (e.g. 1980-CERCLA).

In environmental economics, benefit transfers have traditionally been carried out over space from one geographical location to another. Relatively few of these spatial transfers have tested the accuracy of transferring values and functions across sites, and those who have, found transfer errors up to 475% of the original site value (Brouwer 2000, Loomis et al. 1995, Kirchhoff et al., 1997, Scarpa et al., 2002). Even fewer studies explicitly test the reliability of transfers over time even though most spatial benefit transfers are estimated on historic data. Downing and Ozuna (1995) investigate the reliability of function and welfare transfers over a short period of time (3 years). Although they come to the conclusion that many transfer functions are statistically equivalent to the original functions, they conclude that transferring values over time is not reliable. Loomis (1989), on the other hand, finds evidence that willingness to pay is relatively stable over short periods of time (9 months) when the determinants of willingness-to-pay stay constant. To our knowledge, there have not previously been any attempts to validate benefit transfers over periods longer than 3 years. In this paper, we test the accuracy of benefit transfers of recreational values over a period of 20 years for 52 forests in Denmark.

The time aspect is important in environmental value transfers when planning long term projects e.g. afforestation or wilderness preservation where maximum welfare may only be reached 40 to 80 years after project start. The same also applies when comparing benefits to costs of long-term impacts of climate change or planning large investments in e.g. water quality from sewage treatment plants and river restoration projects. Extrapolations of estimated benefit measures are often made over periods of 10 to 50 years without knowledge about the reliability of the transfer functions, the welfare estimates or the determinants of welfare (Loomis 1989).

Non-similarity across sites in value transfers often poses another practical difficulty in benefit transfers. Basic criteria of transferring values between a policy- and study-site suggest that population characteristics, non-market commodity, change in provision level and sites in which the environmental resource is found should be similar (Boyle and Bergstrom,1992). However, the provision level and quality of an environmental resource may often differ significantly between new policy and study-sites, which seriously limits the application of previous study results (Brouwer, 2000). Random utility models (RUMs) and choice experiments, which are based on the same theoretical premise, are among the few tools available that may provide a solution to this problem.

RUMs are based on the principle that the consumer makes a choice among a set of available recreation sites, given a variety of site characteristics, where the choice is between a finite number of mutually exclusive alternatives. The method can be used to value changes in specific site characteristics, value the benefits of introducing a new site or the losses from eliminating a site. Because of the inclusion of multiple site characteristics, a RUM can adjust for differences across sites in benefit transfers. Combining a RUM with Geographical Information System (GIS) further improves the adjustment for site heterogeneity in a benefit transfer. It also limits the aggregation bias in random utility models which causes the loss of essential information on individual site characteristics and consequently a loss in estimation accuracy (Parson and Needelman, 1992; Haener et al., 2004).

In this article, we test the accuracy of value function transfers over a 20-year time period at the individual site level by using a multi-site model with a mixed logit specification, which allows for heterogeneity in preferences across the population. We combine the model with the use of GIS, following the approach of Termansen et al. (2004a), to capture a larger proportion of site heterogeneity with a disaggregated representation of forest sites. Furthermore, it allows us to account for the spatial pattern of population density and other demographic characteristics.

Our logit models are based on data from two identical national visitor surveys in forests from 1976/77 and 1996/97 (Koch, 1980; Jensen, 2003). We focus on the regions of Copenhagen and Frederiksborg in Northern Zealand in Denmark. The two surveys were carried out by the Danish Centre for Forest, Landscape and Planning and are directly comparable using identical questions and identical sampling sites and schedules. To our knowledge, this is the first set of large-scale recreation surveys that allow a direct comparison of the outdoor use of forests over a time span as large as 20 years.

The purpose of this paper is four-fold: to (a) evaluate the random utility models from 1977 and 1997, which allows us to assess changes in preference towards forest characteristics and travel over 20 years; (b) combine the 1997 random utility model with a count data model to determine total demand of each forest site in 1997; (c) conduct a value transfer from 1977 to 1997 with and without correction for changes in trip demand, which allows us to assess the efficiency of repeating a data-intensive random utility exercise versus transferring values over time ; and (d) test the statistical equivalence of the models and the estimated transfers.

The remainder of the paper is organised as follows: Section 2 describes the data used to estimate the count and choice models. Section 3 specifies the theory and econometric estimation of the choice models. Section 4 outlines the benefit transfer approach, tests of reliability and results; and Section 5 discusses the findings of our analysis and concludes.

2. Data

2.1. On-site Survey Data

We focus on 52 state owned forests in Northern Zealand in 1977 and 1997 in order to study in detail how the changes in forest characteristics and visitor behaviour impact forest recreation over time. Forests in this region are primarily state owned forests, and attributes such as species, age and infrastructure are available in a comparable format across sites. The 52 forests are located in the forest districts of Tisvilde, Frederiksborg, Kronborg, Jægersborg and Copenhagen and represent 93% of forest area in the region.

The surveys pertain only to day trips and were carried out during one year from April 1976 to March 1977 and December 1996 to November 1997 on 22 random days. Questionnaires were distributed simultaneously on 321 locations within the 52 forests. The same routes within the forests were used at each sampling time and were designed to ensure that all cars visiting the forest during one ½ hour received the questionnaires. Only car-borne visits are included. The identical sampling effort in each on-site survey implies a proportional random sampling where the population probabilities visiting individual sites can be assumed identical to the sample probabilities (Haab and McConnell, 2002).

The response rate was 53.7% out of a total of 16,518 questionnaires in the 52 forests in 1977 and 48% out of 18,394 questionnaires in 1997. For ease of computation and to ensure a relevant choice set of the sample population, we excluded visitors to the 52 forests who came from outside the regions of Copenhagen and Frederiksborg. Also visitors, where the address could not be identified or where the recreational trips could not be identified were excluded. The final samples retained for analysis are 6,580 questionnaires in 1977 and 6,987 questionnaires in 1997.

Origins of the trips were digitised through postal addresses using the "Befordringbidrag" software (Carl Bro, 1997) that assigns the postal addresses to the nearest node in the road network. The travel distances were calculated using a 1:200,000 scale vector road map (Kort & Matrikelstyrelsen, 1995). We calculated the actual observed distance that people had travelled from their origin of trip to one of the 52 forests. By choosing the most centrally located survey distribution point as the representative location in each forest, we also calculated a distance matrix between trip origin and each of the 51 other forests, which they could have visited. We assume all along that people used the shortest route possible. Average variable costs of travelling by car in 1977 and 1997 were applied to the return distance. Variable costs including taxes but excluding car depreciation amount to €0.22 per km in 1977 (1997 prices) and €0.187 per km in 1997 (1997 prices) (Truelsen, 1977; Vejdirektoratet, 2001).

2.2. Household Survey and Socio-economic Data

For the 1997 forest valuation model, we use a national household survey dataset from 1994 to estimate visit frequency (Jensen and Koch,1997). 2,916 people between 15 and 76 years were randomly sampled from the national register during one year from November 1993 to October 1994 with a response rate of 83.7%. We retained only questionnaires of people living in the regions of Copenhagen and Frederiksborg with complete questionnaires, totalling 283 people. Potential variables, which we tested for influencing visit frequency, included income, age, distance to the nearest of the 52 forests, and ownership of car. We assume that the frequency of visits and underlying demand determinants in 1994, which we derive from the 1994 household survey, are not significantly different from 1997, where no such survey was carried out. Table 1 lists the measurements and sources.

For the 1977 forest valuation model, we calculated an average frequency of annual 18.25 car-borne trips per year per person, based on an average of 33 visits per person to forests per year and 55.3% of people travelling by car to forests in 1977 (Koch 1978). We use a fixed average, as the original data were not available.

1997 demographic data for the two regions are derived from a national digital dataset of 2,116 parishes with information on male and female population divided into 6 age classes. Population segments distributed on nodes in the road network were available from the Danish Centre for Forest, Landscape and Planning using an urban land use map (100x100m resolution). Data on average household income and car ownership were available from Danish Statistics on parish and local authority level, respectively.

2.3. Forest Data

A list of potentially important site attributes from 1977 and 1997 were added to the distance matrixes. To ensure comparability across forests and years, we use official forest data of the Danish Forest and Nature Agency from 1977 and 1997. Based on the forest inventories, we calculated Shannon indices as measures of species and age diversity. This takes into account species richness and evenness of species distribution (Shannon and Weaver 1949). Fraction of broadleaf and conifer vegetation, size of forest, fraction of trees older than 60 years and water bodies within the forests were also extracted from the forest inventories. Certain attributes that have not changed over the 20-year period, such as topography and distance to coast were available from Skov-Petersen (2002) and the land cover map "area information system, AIS" (Miljø & Energiministeriet / Danmarks Miljøundersøgelse, 2000). Table 2 lists the site attributes tested in the logit models.

Table 3 lists mean and standard deviation of forest attributes in 1977 and 1997, averaged over the 52 forests. Two-sample t-tests for equal means indicate than none of the attributes are significantly different across the two time periods.

3. Theory and Econometric Estimation of the Choice Models

3.1. Trip Demand Model

The prediction of total demand of recreational trips to forests is based on a zero-inflated count model to account for the large number of recreational trips not undertaken by car. The frequency of car-borne trips is modelled in two stages. The first stage is the inflation function which models the decision of mode of transport between a latent group A of individuals who never use the car for recreational trips, i.e. a zero trip frequency has a probability of 1, and a group B of individuals who sometimes uses a car, i.e. a positive trip frequency has a non-zero probability (Long, 1997). The second stage is the decision on the number of annual recreational trips given that the individuals belong to group B. As we find evidence of over dispersion, we specify the second stage as a negative binomial, allowing the variance to exceed the mean.

The probability of individual *n* not choosing the car as mode of transport is given by:

$$\Pr(y_n = 0 \mid x_n) = \Psi_n + (1-\Psi_n)\left(\frac{\alpha^{-1}}{\alpha^{-1}+\mu_n}\right)^{\alpha^{-1}} \quad (1)$$

where Ψ is the cumulative normal density function of the inflation model results, specified as a function of characteristics of an individual *n*, $F(z_n\gamma)$, where z_n is a vector of socio-economic values of individual *n* and γ a vector of parameters. μ_n is specified as a linear exponential , $\exp(\boldsymbol{x}_n\beta)$, of the negative binomial model where $\boldsymbol{x}_n$ is a vector of socio-economic values, not necessarily the same as in the inflation function, and β a vector of parameters. α is the dispersion factor.

The conditional probability of individual *n* undertaking a given annual number of car-borne visits y, given a vector of socio-economic values, x_n, is:

$$\Pr(y_n \mid x_n) = (1-\Psi_n)\frac{\Gamma(y_n+\alpha^{-1})}{y!\Gamma(\alpha^{-1})}\left(\frac{\alpha^{-1}}{\alpha^{-1}+\mu_n}\right)^{\alpha^{-1}}\left(\frac{\mu_n}{\alpha^{-1}+\mu_n}\right)^{y} \quad (2)$$

where $\Gamma(\ )$ is the gamma function from which δ_i, the mean of the error term, is drawn (See Long, 1997).

3.2. Trip Allocation Models

The allocation of trips between several sites in a given choice set is based on a Random Utility Model (RUM). These are discrete choice models based on utility maximising behaviour, where the decision maker chooses the alternative which provides the greatest utility, which in our case is one forest site with the highest level of utility out of a choice set of several forests. As researchers, we can only observe some attributes of the alternatives *j* faced by the decision maker *n*, labelled x_{nj}. These are the components of the representative utility function $V_{nj} = V(x_{nj})\ \forall j$ which relates the observed factors to the decision marker's utility. Since we cannot observe all parts of utility, the 'true' utility U_{nj} can be decomposed as:

$$U_{nj} = V_{nj} + \mu_{nj} \quad \forall j, \quad (3)$$

where μ_{nj} captures the difference between the observed and 'true' utility. μ_{nj} is treated as random. Based on the joint density of the vector parameter μ_{nj}, it is possible to make probabilistic statements of the choices of the decision makers (Train, 2003).

Our first specifications of standard conditional logit models clearly showed a violation of the "independence from irrelevant alternatives" (IIA) property in more than half the sites of the choice sets in 1977 and 1997. As the unobserved portion of utility is correlated over alternatives, we specified mixed logit models that allow for the correlation of errors by introducing error components and preference variation over the population by specifying a distribution for the coefficients (Train, 2003).

The representative utility function in the mixed logit specification is specified as:

$$V_{nj} = \boldsymbol{\beta}'\mathbf{x}_{nj}, \qquad (4)$$

where $\mathbf{x}_{nj}$ is a vector of observed variables relating to alternative *j*, $\boldsymbol{\beta}$ is a non-observed preference parameter vector specified according to a preference distribution function with density $f(\boldsymbol{\beta}\,|\,\boldsymbol{\theta})$, where $\boldsymbol{\theta}$ are the parameters of this distribution, such as the mean and variance.

The stochastic part of the indirect utility function is denoted:

$$\mu_{nj} = \boldsymbol{\eta}' z_{nj} + \varepsilon_{nj}, \qquad (5)$$

where $\boldsymbol{\eta}$ is a vector of random, non-observed terms with zero mean that varies over alternatives by σ_{ec} and has density $g(\boldsymbol{\eta}\,|\,\boldsymbol{\delta}_{ec})$. z_{nj} is the error component that allows for heteroskedasticity and correlation in utility over alternatives and ε_{nj} is iid extreme value.

The probability for individual *n* of choosing site *i* out of *J* sites in a mixed logit is the integral of standard logit probabilities over a density of parameters, namely the density functions of the random vector parameters $\boldsymbol{\eta}$ and $\boldsymbol{\beta}$, given below:

$$P_{ni} = \int_{\beta}\int_{\eta}\left(\frac{e^{\boldsymbol{\beta}'\mathbf{x}_{ni}+\boldsymbol{\eta}'\mathbf{z}_{ni}}}{\sum_{i\in J} e^{\boldsymbol{\beta}'\mathbf{x}_{ni}+\boldsymbol{\eta}'\mathbf{z}_{ni}}}\right) g(\boldsymbol{\eta}\,|\,\boldsymbol{\delta}_{ec}) f(\boldsymbol{\beta}\,|\,\boldsymbol{\theta})\, d\boldsymbol{\eta}\, d\boldsymbol{\beta} \qquad (6)$$

P_{ni} is called a mixed function where the logit formula is the weighted average evaluated at different values of $\boldsymbol{\eta}$ and $\boldsymbol{\beta}$ with the weights given by the density functions $g(\boldsymbol{\eta}\,|\,\boldsymbol{\delta}_{ec})$ and $f(\boldsymbol{\beta}\,|\,\boldsymbol{\theta})$, also called the mixing distributions (Train,2003). A mixed logit model with an error-component structure is fully general (Train, 2003; McFadden and Train, 2000). In a standard logit model, the z_{nj} term is zero preventing any correlation over alternatives and the term β is considered known by the researcher and specified with a fixed coefficient; and the mixing distribution is limited to fixed parameters $f(\beta)$=1 for $\beta = b$ and 0 for $\beta \neq b$.

The mixed logit is based on an identical choice set in 1977 and 1997 of 52 forests and using identical measures for attributes in 1977 and 1997. Coefficients of variables, which can logically take either sign and which are of particular policy relevance in this study, such as fraction of conifer trees, or fraction of open land in forests, were given an independent normal distribution with mean and standard deviation that are estimated. Other preference parameters for attributes, which remain largely constant over time such as size, slope, presence of water and distance to coast, were given fixed specifications across the population. We gave the coefficient for travel costs an independent log normal distribution as costs are expected to have the same negative sign for all visitors, with only the magnitude differing over the sample population. The random utility models were estimated using GAUSS, adopting the routine developed by Kenneth E. Train[1].

3.3. Value of Access in Random Utility Models

The indirect utility function is the basis for welfare calculations in random utility models and provides a direct means of estimating welfare impacts of changes in site characteristics or access. The expected maximum utility that we seek to estimate is given by:

$$E\{max(U)\}=\ln\left(\sum_{j\in J}\exp(\mathbf{v}_{\mathrm{nj}})\right) \tag{7}$$

where the indirect utility function of individual *n* choosing site j is $v_{nj}=v(y-c_{nj},\mathbf{q}_j)$, y is income, c_{nj} is the cost for individual *n* to visit site *j* and **q** is a vector of site attributes

$$WTP_n=\frac{\ln\left(\sum_{j\in J}\exp(v_{nj}\,*)-\ln(\sum_{j\in J}\exp(v_{nj})\right)}{\beta_c} \tag{8}$$

The value of access to a site is calculated by increasing the cost of travel to infinity which drives the probability of visiting a site to zero. Simulation was performed using 500 random draws for each node in the road network. The difference in welfare measures between 500 draws and 1000 draws was non-significant.

3.4. Parameter Estimates of Trip Allocation Models 1977 and 1997

Variables and parameter estimates of the two mixed logit models, listed in Table 4, are similar in both sign and magnitude. Interesting results are the differences in whether the sample populations in 1977 and 1997 show preference variation in site attributes or not. Whereas preferences towards species diversity and fraction of open land in forests diverge in the 1997 model, the fixed parameter model seems to be adequate for modelling the preferences of species diversity and fraction open land for the 1977 data. The opposite is the case regarding trees older than 60 years, where the fixed parameter model does not appear to be significantly worse than a mixed model over the 1997 sample while the opposite is the case for the 1977 sample.

Preferences for species diversity and degree of openness in forests vary in 1997 with 62%[2] preferring a species diverse and 38% a non-diverse forest and 76.2% a dense forest and 23.8% open forests. The 1977 data set has no significant preference variation for these two attributes but agrees with the 1997 sample on finding species diverse and dense forests more attractive. Preferences on fraction of trees older than 60 years vary in the 1977 model with 81.6% preferring older trees and 18.4% younger forests, but stays fixed in the 1997 model with a clear preference towards forests with older trees.

Commonalities in preference between the two sample populations show that more than 60% of the sample populations in Northern Zealand appear to prefer coniferous forests to broadleaf forests with a slight increase over the period from 62% to 66% preferring forests dominated by needle leaf treas. Sloped terrain and presence of water bodies also increase the likelihood of a forest being selected in both 1977 and 1997. As expected, larger forests appear to be more popular than smaller forests, however with a declining marginal effect. Also sites close to the coast are more attractive than inland forests as the coefficient on the distance from coast is negative. The error term on distance to coast indicates a common substitutability between forests close to the coast and a difference in the substitutability with other forests.

3.5. Parameter Estimates of Trip Frequency Model 1994

The parameter estimates and z-values of the zero inflated negative binomial model are given in Table 5. The inflation function, which estimates the probability of a zero count, confirms that owning a car and increased distance to the forests in the choice set also increases the probability of travelling by car to forests. The negative binomial shows that the amount of car-borne trips taken in a year decreases with distance to the nearest forest in the choice set and increases for people older than 39 years. Income has no significant influence on choice of transport mode or number of car-borne trips to forests in the region.

4. Benefit Transfer Approach

We use a benefit transfer approach to assess the reliability of transfer over time, keeping the spatial dimension constant. We conduct two different transfers of value of access and compare these to the "true" value of access in 1997, estimated using the 1997 model over the 1997 sample:

- Transfer "A" includes an updated demand for forest recreation, derived from a repeated national household survey in 1994 that repeats the national household survey from 1977, but allocates trips to the individual forests based on site preferences from the 1977 onsite survey. Only the preference structure is not held constant;

- Transfer "B" uses both preferences for forest attributes and demand for car-borne recreational trips from 1977 to calculate the transfer WTP. Trip demand in this model

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is measured as a fixed average number of trips based on the national household survey in 1977. Both the preference structure and demand for forest recreation are transferred to 1997.

We update site attributes and per unit travel cost to 1997 values in both cases.

Transfer "A" allows us to determine the error margin when transferring preferences 20 years over time, holding the trip demand constant at 1994 values compared to the "true" model.

Transfer "B" reveals the error margin when both preferences and a fixed average trip frequency are transferred over time compared to the "true" model results. The difference in error margin between the two transfers indicates the efficiency of repeating a household survey or not.

The 1997 "true" values of access are estimated by combining the trip demand and trip allocation models. For each node in the road network, we predict the total demand for car-borne trips to forests using the estimates from the trip allocation model and the socio-economic regional data. Subsequently, we predict the probabilistic allocation of the total number of trips from each node in the road network to each of the forests in the choice set using the random utility model results of the 1997 on-site survey. We combine the total demand of trips and the allocation of trips to individual forests, P_{ni}, to all forests from all nodes in order to calculate the total, yearly willingness to pay of access (Equation 8).

The same procedure is repeated in the two transfers, where the probabilistic allocation of trips are based on the random utility model results of the 1977 on-site survey in both transfers. The 1994 trip allocation model is used in transfer "A" and a fixed average number of trips from 1977 in transfer "B".

4.1. Tests of Transferability

We test whether the set of coefficients of the 1977 and 1997 mixed logit models are statistically equivalent. The test is based on a null-hypothesis that the set of random utility model coefficients of the original 1997 model are the same as the set of the transfer 1977 model. We make this test in both directions: a) we compute a standard log likelihood ratio between the log likelihood of the 1977 model coefficient estimates, computed over the 1997 sample, and the log likelihood of the 1997 model coefficient estimates, computed over the 1997 sample; b) we compute a standard log likelihood ratio between the log likelihood of the 1997 model coefficient estimates, computed over the 1977 sample, and the log likelihood of the 1977 model coefficient estimates, computed over the 1977 sample. This ensures identical sample sizes in each log likelihood ratio.

The log-likelihood ratio tests on statistical equivalence between the 1977 and 1997 coefficients show significant differences in models. The results of the 1997 sample based log likelihood ratio in 1997 prices are 2X(-16097.506+16199.48)=203.948 . With a χ^2 (10) distribution, the probability of exceeding this ratio is less than 1 and we strongly reject the null hypothesis that the sets of coefficients are the same. Similar, the 1977 sample based log likelihood ratio in 1997 prices is 2X (-16869.27+ 17590.43)=1442.34 and we also strongly reject the H_0 hypothesis.

In addition to the statistical equivalence test of the sets of coefficients, we test for the statistical equivalence of the welfare results by constructing confidence intervals for the mean per choice benefit for each of the three models. The intervals are obtained using the Krinsky-Robb draw procedure (Krinsky and Robb, 1986), where we draw 1,000 parameter vectors from a asymptotic normal multivariate distribution with means and variance-covariance matrix estimated in the random utility models. We use these to calculate and rank 1,000 WTP per site per model. Results show that the 95% confidence intervals of WTP for five forests, transferred by model "A", overlap those of the "true" model. Transfer model "B", however, only produces two forests with confidence intervals overlapping the "true" model confidence intervals.

5. Benefit Transfer Results

The "true" 1997 model and the two transfer models show similar spatial patterns in terms of ranking of site values (Figure 1). However, the transfer models tend to overestimate the value of access. Transfer "A", which includes an updated demand for forest recreation, performs better than transfer type B, as expected. However, the error margin of total WTP per site lies between –40% and +393% with an average of 145%. Transfer type B, which uses preferences and demand from 1977 to calculate the transfer WTP for 1997, produces error margins between 9% and +758% with an average of +327% per site.

Values of access of the "true" 1997 model range between €5,800 and €12.8million and in terms of visits between 2,426 to 3.3 million per site per year. In accordance with estimated preferences, the most valuable forests are large, close to the coast with predominantly coniferous vegetation and dominated by old and species rich forests.

The results of transfer type A, which uses the 1977 on-site survey but repeats the household survey, show an increase in minimum and maximum values of access to €28,000 and €15.2million as well as a doubling of the number of visitors choosing the least favoured forests. However, the transfer doesn't predict an increase in the number of visits to the most favoured forest sites compared to the "true" 1997 model. Using both the on-site survey and the average trip frequency from 1977 (transfer type B) further increases the access values to range between €36,000 and €24.4 million and number of visits to range between 6,859 and 4.1 million. Table 6 presents the predicted number of visits and values and Figure 1 illustrates the spatial differences in total yearly WTP between the three models. The level and spatial distribution of the error margins at individual site level, measured as the difference in willingness to pay of access between the "true" model and each of the two transfer models, are shown in Figure 2, which ranks error margins of WTP of access. It is clear that for each individual forest, model "B" systematically over-predicts the willingness to pay compared to model "A". Also, the spatial distribution of the transfer errors appear to be linked to the value of forests, where the most valuable are better predicted than the less valuable forests.

In the case of model "B", forests closer to Copenhagen are better predicted than forests further away from the metropolitan centre.

6. Discussion

In this paper, we compared the efficiency of transferring benefits over 20 years between a functional transfer model that updates car-borne forest recreation demand to recent years (Transfer type A) and a functional transfer model that does not update the demand function to recent years (Transfer type B). The latter keeps the underlying preferences and demand structures constant over 20 years. By comparing the transferred model results with the "true" model from 1997, we gained information about when a benefit transfer over time using discrete choice modelling is likely to be subject to least error. The different abilities of the two transfer models in predicting the "true" values over time show clearly that updating a functional transfer model substantially reduces prediction error. In our case, the update of trip demand in the transfer model type A reduced the error margin by up to 379% and on average by 182%, compared to using the transfer model type B.

The log likelihood ratio test of the set of coefficients and the development of confidence intervals of welfare estimates in the three models allowed a more rigorous comparison of the models and the WTP estimates. Despite the transfer models not being statistically equivalent to the "true" model, transfer "A" produced five forests and transfer "B" two forests where the 95% confidence intervals of the mean benefit measures overlap those of the "true" model. These forests are not necessarily those with the best prediction success in terms of error margin.

Rather than expecting a successful transfer to be one that predicts results identical to an original study, it may be helpful to agree upon an acceptable level of transfer error, depending on the purpose and use of the transfer. In this study, the best performing transfer model predicted the willingness to pay of access of 22 forests that were within an error margin of ±100% of the "true" benefit and ten forests that were within an error margin of ±50%. The less well-performing transfer model could predict six forests within an error margin of ±100% and three forests within an error margin of ±50%. These results are based on a transfer over time alone, where the transferred individual site values are compared to the "true" values of the same sites. Introducing transfer over time *and* space would most probably further reduce the reliability of the transfers.

From a policy perspective, it is interesting to weigh these transfer errors against the costs of undertaking additional original surveys. The costs of the national household survey that was repeated in 1994 amounted to approx. €13,000 for the sample in our study region and ca. €200,000 for the on-site survey in the 52 forests that was repeated in 1997. The relatively low costs of a household survey combined with the significant improvements offered by updating the transfer model with new recreation demand, as shown in model "A", makes it an obvious choice when choosing to carry out a benefit transfer.

Looking at the reasons behind the differences in benefit measures between models, the study has shown that both demand for forest recreation and preferences for forest attributes have changed significantly between 1977 and 1997. Determinants of WTP, as described by Loomis (1989), have clearly changed between the two periods. We see two sources of this change, which cause the transfer errors: a shift in transport mode, illustrated by the differences in error margin between transfer model "A" and model "B", and a change in preferences towards forest attributes, illustrated by the differences between the "true" model and transfer model "A".

The shift in transport mode shows up clearly in the data, where the average number of trips by car to forests fell from 18.25 in 1977 to 14.6 in 1994. At the national level, however, average yearly number of visits to forests increased by 25%, and 15% when accounting for population growth. This is primarily due to more people travelling by bike and foot to forests (Koch, 1978; Jensen and Koch, 1997). As a consequence, the use of cars have dropped from approx. 55% of visits to forests in 1977 to approx. 49% by 1994. Related to the reduced use of cars, average distances travelled have dropped from 10.5km to 8.5km. The relative decrease in car-borne recreational value of forests over the period can be explained on the basis that, although people as a whole visit forests more frequently in 1994 than in 1977, the change away from the use of cars outweighs the increased visit frequency. This necessarily plays an important role when using methods that are based on the use of cars. The discrepancy between transferred and originally estimated frequency of car-borne forest visits leads to a significant overestimation of transferred benefit values due to the shift in transport mode, as illustrated in transfer model "A". Understanding the choice of mode of transport and how this changes over time is therefore central in non-market valuation methods based on the travel cost method.

A change in preferences towards forest attributes over the 20-year period explains the differences in welfare estimates between the "true" model and transfer model "A", as the only difference between these two models is the trip allocation models. Also, attributes of the forests as a whole have not changed significantly over the period. The parameter estimates of the trip allocation models indicate that people have developed a heterogeneous preference in relation to species diversity, measured by the Shannon diversity index, and openness of forests, measured by percentage of forest as open space. In 1997, 62% of the population appear to prefer a species rich forest and 76,2% a dense forest whereas the 1977 model does not show significant evidence of heterogeneity of these preferences. Preferences for forests with trees older than 60 years vary over the population in 1977 with 81.6% finding older trees more attractive, but showed no significant evidence of variance in preference across the population in the 1997 model. By specifying a mixed logit we have been able to assess the changes and the level of heterogeneity in preferences across the population in 1977 and 1997. Relatively few studies in the environmental economics literature have used the random utility model or the discrete choice approach in benefit transfer (Parsons and Kealy, 1994; Feather and Hellerstein, 1997; Scarpa et al., 2002; Haener et al., 2001) but none to our knowledge have included heterogeneity of preferences.

Comparing the results of attitudes towards forest attributes with other studies, species composition has been shown to have a positive impact on the recreational choice of forests by increasing the popularity in forests with a higher diversity of species compared to forests with lower diversity (Hanley et al., 2002; Scarpa, 2000; Jensen and Koch, 1997; Boxall et al., 1996). Contrary to the findings in this study, Hanley and Ruffel (1993) found the Shannon species diversity index to be insignificant and percentage of forest as open space to be positive and highly significant. This illustrates that some attributes may be subject to large variation in cross-cultural preferences.

In terms of commonalities within this study between 1977 and 1997, we have shown that 60% to 64% of people prefer coniferous forests to broadleaf forests. This is different from research on the national data set by Termansen (2004b) who shows that, on a national level, only 40% of the population prefer coniferous forests. Also, two national forest preference studies based on evaluation of black and white photographs reveal a general preference for broadleaved forest environments compared to coniferous (Koch and Jensen, 1988; Jensen and Koch, 1997). A reason for the apparent contradiction in results could be the preponderance of broadleaf in the 52 forests which makes conifer appear more attractive in this region. The 52 forests in the study have a broadleaf cover of 72% in 1977 and 74% in 1997 respectively (Danish Forest and Nature Agency, 1977; 1997) compared to a national average of 37% broadleaved forest in 1997 (Statistics Denmark, 2001).

Other commonalities include the preference for large rather than small forests, with declining marginal effect, which also other studies confirm (Scarpa et al., 2000). The nationwide valuation study of forests in Denmark (Termansen, 2004b) also confirms the stable preference towards sloped terrain and coastal proximity. These types of preferences seem to hold over space and time.

Comparing the travel cost parameter estimates over time, the higher mean in the 1977 trip allocation model indicates that people went further than in 1997 despite the fact that petrol was relatively more expensive in 1977 (€0.22 , 1997 prices) than in 1997 (€0.187). This is also confirmed by the national surveys in 1977 and 1994 where the average distance travelled in 1977 was 14.9km compared to 12.6km in 1994 (Koch, 1978; Jensen and Koch, 1997). The decrease in car-borne travel to forests despite reduced travel costs is due to a markedly shift in transport mode as found in the national household surveys (Koch, 1978; Jensen and Koch, 1997). Again, this confirms the need to understand the use of modes of transport and how this may influence the choice of recreation site, at least in the Danish population.

The present paper has given an indication of the order of magnitudes one can experience when the determinants of willingness to pay change significantly over almost two decades, even when using state-of-the art transfer models combined with GIS. Loomis (1989), looking at the stability of willingness to pay, finds that welfare measures are relatively stable over a short period (9 months) where the determinants of willingness to pay have not changed. However, his results did not show an unambiguous one-to-one relationship between the willingness to pay in period 1 and 2. Also, Downing and Ozuna (1995) find that while benefit functions are transferable over 3 years in at least 50% of the time, practically no transfer produced statistically similar benefit estimates.

This paper has also shown the importance of updating a transfer model, in this case with the demand for forest recreation, which decreases errors by an average of 182%. Given the relatively low costs of repeating a household survey compared to an on-site survey, policy makers could advantageously only repeat the household survey, but would still need to accept an average of 145% transfer errors when conducting a transfer for these forests over 20 years. However, the question as to which level of error one is willing to accept in order to avoid costly on-site surveys, if this information is available at all, remains a political one.

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[1] The GAUSS routine for mixed logit is available from K. Train's website.

[2] The area under the standard normal curve for values between zero and the relative z-score, where the z-score is the mean divided by its standard deviation.

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8. Tables

Table 1. Count Model Variables

VARIABLE	MEASUREMENT
Income[1]	Yearly gross income at parish level
Age[2]	Year of birth
Car ownership[1]	Dummy variable. 1= owing at least one car in the household; 0 otherwise
Distance[3]	Shortest Euclidian distance through road network from home address of respondents to the nearest of the 52 forests in the choice set.
Visit frequency[4]	Total number of car-borne forest visits per year

Source:
[1] Statistics Denmark (2004)
[2] Jensen and Koch (1997)
[3] Kort & Matrikelstyrelsen (1995)
[4] Own calculations, based on Jensen and Koch (1997)

Table 2. Site Attributes.

VARIABLE	MEASUREMENT	Data Source
Travel distance	Shortest distance through road network from the origin of the trip given by the respondents to the sites. The travelled distance is measured to the visited site and back to trip origin. The distance to the alternative sites are measured to the representative survey location.	Koch, N.E. (1980); Jensen, F.S. (2003) Kort & Matrikelstyrelsen (1995)
Forest area	Size of the forest	Danish Forest and Nature Agency (1977/1997)
Distance to coast	Euclidian distance from aggregate site to nearest coastline	Miljø & Energiministeriet and Danmarks Miljøundersøgelse (2000)
Slope	The average slope index of the 1 km by 1 km area around the aggregated sites.	Skov-Petersen (2002)
Distance to View point	Euclidian distance from aggregate site to nearest view point	Kort & Matrikelstyrelsen, (1995)
Planting Year	Shannon diversity index; % trees older than 60 years	Danish Forest and Nature Agency (1977/1997)
Species (family level)	Shannon diversity index; % broadleaf; % coniferous	Danish Forest and Nature Agency (1977/1997)
Water presence	Continuous variable. Fraction water within forest area	Danish Forest and Nature Agency (1977/1997)
Open Space (landscape type)	% afforested area within forest	Danish Forest and Nature Agency (1977/1997)

Table 3. Differences in Site Attributes.

Attribute	*Year*	*Mean*	*Std. Dev.*	*Min*	*Max*
Shannon Species Index	1977	1.228	.230	.572	1.695
	1997	1.279	.191	.808	1.747
Fraction broadleaf	1977	.718	.180	.2	1
	1997	.744	.177	.194	1
Fraction conifer	1977	.282	.180	0	.8
	1997	.256	.177	0	.806
Fraction open land	1977	.158	.175	.027	.864
	1997	.164	.183	0	.756
Shannon Age Index	1977	1.707	.425	.163	3.639
	1997	1.731	.286	.636	2.124
Fraction older than 60 years	1977	.378	.141	.005	.72
	1997	.416	.146	.002	.803
Distance to coast	1977	5.884	4.433	.05	14.99
	1997	5.884	4.433	.051	14.99
Slope index	1977	1.151	.575	0	2.83
	1997	1.150	.575	0	2.83
Distance to viewpoint	1977	11.120	5.794	2.02	26.04
	1997	11.120	5.795	2.024	26.04
Fraction water bodies	1977	.031	.074	0	0.47
	1997	.030	.073	0	0.47
Size (ha)	1977	446.287	1023.222	34.9	7329.5
	1997	450.122	1020.911	34.9	7315.4

Table 4. Mixed Logit Models of Car-borne Forest Recreation in 1977 and 1997 (1997 prices, DKR)

		Mixed Logit 1977		**Mixed Logit 1997**	
VARIABLES		Estimates	asymptotic z-value	Estimates	asymptotic z-value
Travel cost	Mean of ln(coefficient)	-2,967	129.0	-2.476	106.579
	Std. Dev. of ln(coefficient)	1.092	35.226	1.020	37.449
Shannon species index	Mean of coefficient	2.461	16.085	1.116	6.409
	Std. Dev. Of coefficient			3.639	12.951
Fraction of open land	Mean of coefficient	-1.692	8.096	-4.192	12.012
	Std. Dev. Of coefficient			5.880	13.665
Fraction of trees > Age60	Mean of coefficient	3.279	15.689	3.902	16.040
	Std. Dev. Of coefficient	3.641	10.709		
Fraction coniferous	Mean of coefficient	0.538	3.611	0.831	4.737
	Std. Dev. Of coefficient	1.833	5.120	2.000	3.569
Log(size)	Mean of coefficient	0.915	48.158	1.295	38.684
Log (coast)	Mean of coefficient	-0.565	17.656	-0.539	10.789
Slope	Mean of coefficient	0.158	3.762	0.279	6.725
Fraction of water bodies	Mean of coefficient	2.316	6.598	2.752	9.998
Coast Error component	Std. Dev. Of coefficient	1.288	7.951	1.360	5.329
Mean Log-likelihood		-2.563		-2.304	
Sample size		6580		6987	
Choice set size		52		52	

Table 5. Count Data Model Results

Inflation model = normal
Number of observations = 283
Log likelihood (Zinb) = -649.23
Nonzero obs = 122
Log likelihood (Poisson) = -7822.4
Zero obs = 161

	Variable	**Coefficient**	**Asymptotic-z**
Negative binomial	Constant	4.576	16.275
	distance	-0.191E-03	-5.031
	Age 17-39	-1.242	-3.764
Dispersion parameter	Alpha	2.773	8.128
Inflation Function	Constant	2.596	4.756
	Car owner	-1.851	-4.542
	distance	-0.308E-03	-4.796
Vuong Test of Zinb vs. Neg. Bin: Std. Normal		5.2534	

Table 6. Predicted Number of Car-borne Visits and Values of Site Access

Economic Measure	*True Model*	*Transfer Model A*	*Transfer Model B*
Numbers of car-borne visits			
Minimum	$2.4 * 10^3$	4.8×10^3	6.9×10^3
Maximum	$3.3 * 10^6$	2.7×10^6	4.1×10^6
Average	2.6×10^5	2.6×10^5	4.4×10^5
Total Value of Car-Access per site			
Minimum (€/year/site)	$5.7 * 10^3$	28×10^3	36×10^3
Maximum (€/year/site)	$12.8 * 10^6$	15.3×10^6	$24.4 X 10^6$
Average (€/year/site)	$9.5 * 10^5$	1.4×10^6	2.3×10^6
Total Value of Car-Access per ha			
Minimum (€/year/ha)	121	587	756
Maximum (€/year/ha)	24,547	35,292	45,814
Average (€/year/ha)	2,191	3,707	6,554

9. Figures

Figure 1. WTP of Car Access (I), Transferred WTP of Car Access using transfer type A (II) and transfer type B(III) [Euro/site/year]

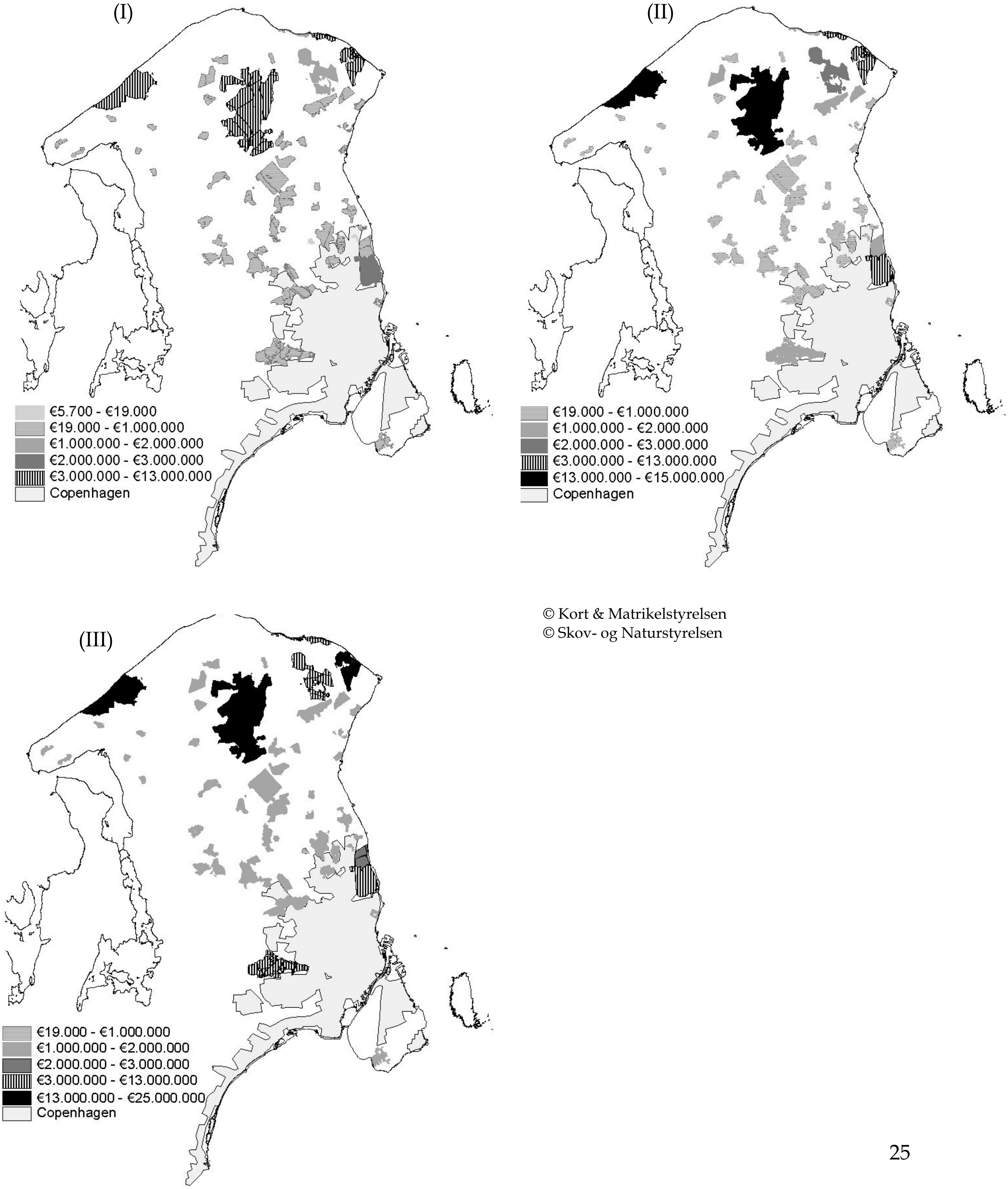

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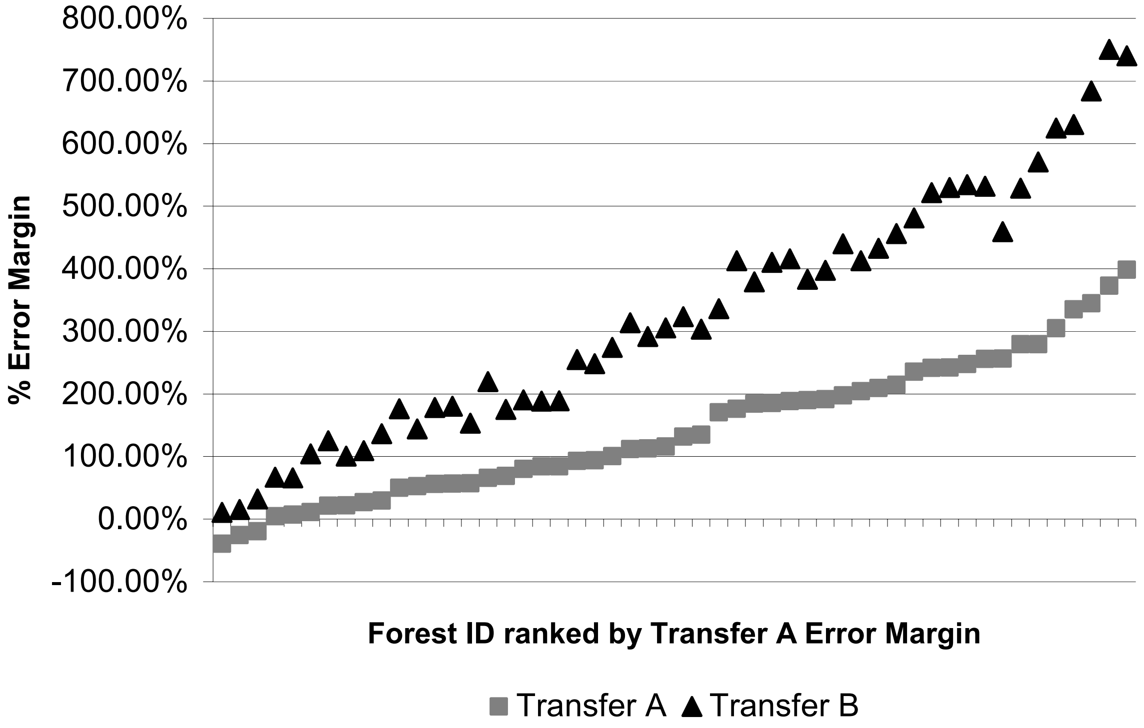
Figure 2. Error Margins of total WTP per Forest (car-borne visits).



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