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Measurement and benefit transfer of amenity values from afforestation projects – A spatial economic valuation approach using GIS technology

PhD Thesis

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Abstract: Urban forests provide substantial non-market benefits to residents and out-of-town visitors in the form of amenity and recreational values. This has been confirmed by a number of non-market valuation studies in Denmark, Sweden and other European countries. Using these monetary estimates in benefit transfer applications, however, can involve substantial uncertainties. In this PhD thesis benefit transfer has been applied in three cases including one based on original empirical research. The results are presented in four articles included in the appendix of this report. Results from the empirical research confirm the positive effect of proximity to forested areas on housing prices found in earlier studies in Denmark. However, they also illustrate the problems involved in the implementation of the hedonic pricing method caused by omitted variable bias. Testing for accuracy of benefit transfer using both the classical test of assuming equality and equivalence testing show high transfer errors even in cases where the null hypothesis of equality of estimates between sites could not be rejected. For none of the equivalence tests the null hypothesis of inequality could be rejected with error margins of 50 %. Only for transfers between two areas with rather similar willingness-to-pay results, the majority of transferred values are accepted to be equivalent within error ranges of 75 %.

Keywords: Benefit transfer, hedonic pricing method, omitted variable bias, equivalence testing

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Preface

I would like to thank my main Ph.D. advisor, Research Director Alex Dubgaard, Environmental Economics and Rural Development Division, Institute of Food and Resource Economics for his support and comments. A special thanks goes also to my two other Ph.D. advisors, Senior Researcher Flemming Møller from the Department of Policy Analysis at the Danish National Environmental Research Institute (NERI-SYS) and Bo Martin Bibby, Associate Professor at the Department of Biostatistics, University of Aarhus, for their willingness to read and comment on the numerous working papers and article drafts produced at various stages of my Ph.D. Likewise I am extremely grateful to my other colleagues at NERI-SYS, Berit Hasler and Jesper S. Schou for their comments on the final draft of the Ph.D. thesis and for co-authoring two articles included in this dissertation.

While most of my Ph.D. years were spent at the National Environmental Research Institute (NERI), Department of Policy Analysis, I was also able to participate in the research community at the Institute of Food and Resource Economics, KVL, for a six month period and get some experience with teaching. My thanks go also to Associate Professor Laura O. Taylor and her colleagues at Georgia State University, Department of Economics, Andrew Young School of Policy Studies, Atlanta, USA, where I was able to stay for four weeks in September/October 2005 and discuss my empirical work, both at individual discussions and at a guest lecture and presentation at the institute. In addition, I had the opportunity to present my work at the European Society of Ecological Economics (ESEE) conference 2005 in Lisbon and the Colorado University Environmental Economics Workshop in Vail, Colorado, USA in September 2005.

During my "Ph.D-journey" I have encountered and learned the basic skills of using a total of three different Geographical Information System (GIS)- programs, ArcView 3.2, ArcGIS 9 and MapInfo Thereby I have gained insight into a fascinating array of tools from another discipline and their potential in contributing to non-market valuation. In that respect I would like to thank my GIS colleagues from NERI-SYS, Henning Steen Hansen, Morten Tranekjær Jensen, Gregor Levin, Uffe Kousgaard and especially Bernd Münier for support in GIS calculations and their untiring willingness to answer all of my questions.

Last but not least special thanks go to the Danish Social Science Research Council (FSE) for funding my Ph.D. research.

Summary

Urban forests provide substantial non-market benefits to residents and out-of-town visitors in the form of amenity and recreational values. Newly planted forest areas can create amenity values to people living close to them less than 10 years after planting started. This has been confirmed by a number of non-market valuation studies in Denmark, Sweden and other European countries. Estimates of these values in monetary terms are an invaluable input in cost-effectiveness and cost –benefit analyses, both as primary benefits of the creation of new forest areas but also as secondary benefits in determining the net-costs of environmental protection measures that involve afforestation measures.

This kind of benefit transfer, i.e. the transfer of monetary estimates for environmental goods from a study site to a policy site, is a cost and time saving solution compared to conducting an original study. How uncertain such benefit transfers can be has been shown in several studies testing for accuracy of benefit transfer. Most of these benefit transfer testing studies are based on contingent valuation and travel cost models, only one is based on the hedonic pricing method, although this method is heavily applied in non-market valuation exercises.

In this Ph.D. thesis benefit transfer has been applied in three cases including one based on original empirical research. The results are presented in four articles included in the appendix of this report. In the first case of benefit transfer the implications for policy decisions of including monetary values for secondary effects have been demonstrated while the second benefit transfer application used values from Danish and Swedish forest valuation studies to determine the amenity and recreational values of forest in the urban fringe areas in Scania, South-western Sweden. In both cases results indicate substantial values for forest areas close to residential areas, but illustrate also the substantial uncertainty attached to this valuation methodology.

As an original empirical contribution this Ph.D. study has analysed three afforestation areas in Denmark using the hedonic pricing method in combination with Geographical Information Systems (GIS). Results confirm the positive effect of proximity to forested areas on housing prices found in earlier studies in Denmark. However, housing values are also impacted by other location-related attributes, natural or man-made, and their omission in estimating the hedonic price function can lead to omitted variable bias in determining the parameter for distance to afforestation areas and thus the marginal price for forest proximity.

For each case study area two different types of models were constructed, a “simple” model that only contained structural variables of the house and the “distance to the new forest” measure as ex-

planatory variables and an "advanced" model that in addition to the variables of the simple model did include a range of other location-related variables, typical for Danish housing markets. Results show a mixed evidence of the importance of including other location-related characteristics in model estimation. For three models including other spatial variables resulted in substantial changes in the parameter estimated for the distance to new forest variable, changing the significance level of this coefficient from insignificant to significant and vice versa. Other models were relatively robust to the inclusion of other spatial variables.

This analysis shows the uncertainty involved in applying the hedonic pricing method to value non-market goods. Although based on real money transactions, i.e. the purchase of a house with certain characteristics, the likelihood of missing out on relevant variables is high, either because these are not easily accessible or too expensive to obtain. This can lead to omitted variable bias in the estimation of the parameter of interest and thus misleading information about marginal and non-marginal benefits to policy makers.

Based on the empirical results this Ph.D. study did test for accuracy of benefit transfer of amenity values from afforestation projects in Denmark using both the classical test of assuming equality and equivalence testing, where inequality is assumed in the null hypothesis. Amenity values were estimated by applying the first stage of the hedonic pricing method and then calculating the percent differences in housing prices for different distance intervals. While tests for statistical equality of WTP estimates could not reject the null hypothesis of equality between WTP estimates for different distances in the majority of cases it would be inadequate to interpret these results in favour of validity of benefit transfer. Transfer errors can be substantial also for those transfers where equality of WTP estimates could not be rejected.

A cautious approach to benefit transfer is also warranted given the results from the equivalence tests. For none of the transfers the null hypothesis of inequality could be rejected with error margins of 50 %. Only for transfers between two areas with rather similar WTP results, the majority of transferred values are accepted to be equivalent within error ranges of 75 %.

Sammenfatning

Bynære skovområder skaber betydelige ikke-markedsværdier for indbyggerne og udefrakommende besøgende i form af herligheds- og rekreative værdier. Skovrejsningsområder bidrager med herlighedsværdier allerede indenfor 10 år efter plantning. Det er blevet bekræftet gennem resultater fra en række værdisætningsstudier gennemført i Danmark, Sverige og andre europæiske lande. Disse monetære værdier er et uvurderligt input i omkostningseffektivitetsanalyser og cost-benefit analyser, både som primære gevinster ved skabelsen af nye skovområder. Men også som sekundære gevinster i bestemmelsen af netto-omkostningerne ved miljøbeskyttelsestiltag som indeholder skovrejsning.

Denne form for gevinstoverførsel, dvs. overførsel af monetære værdier for miljøgoder fra et studiested til et policy sted, sparer omkostninger og tid i forhold til gennemførselen af et originalt studie. Flere studier har dog vist, hvor usikker sådan en benefit transfer kan være. Flertallet af disse studier er baseret på metoder som betinget værdisætning og rejseomkostningsmetoden, kun en er baseret på hedonisk prissætning, selvom denne metode er meget anvendt i værdisætning af ikke-markeds goder.

Benefit transfer er blevet anvendt i tre studier i denne Ph.d. afhandling inklusive et studie baseret på original empirisk forskning. Resultaterne er sammenfattet i fire artikler vedlagt som bilag til denne rapport. Den første anvendelse af benefit transfer viser de konsekvenser, som medtagelsen af sekundære gevinster kan have for politiske beslutninger. Mens den anden benefit transfer anvendelse bruger værdier fra danske og svenske værdisætningsstudier af skovområder til bestemmelsen af herligheds- og rekreative værdier for bynære skove i Skåne, Sydsverige. I begge studier viser resultaterne at bynære skove har store værdier for befolkning, men illustrerer også den betydelige usikkerhed forbundet med anvendelsen af benefit transfer.

Dette Ph.d. studie har som original empirisk bidrag analyseret tre forskellige skovrejsningsområder i Danmark ved hjælp af husprismetoden kombineret med anvendelsen af Geografiske Informationssystemer (GIS). Resultaterne bekræfter den positive effekt af skovnærheden på huspriser fundet i tidligere undersøgelser i Danmark. Men huspriser er også påvirket af andre områderelaterede variabler og en undladelse af dem i estimering af den hedoniske prisfunktion, kan føre til såkaldt "omitted variable bias" i beregning af den marginale pris for skovnærhed.

To forskellige modeller er blevet estimeret for hvert skovrejsningsområde, en "simpel" model som kun indeholder strukturelle variabler og selve afstanden til skoven og en "avanceret" model som ud over variablerne i den simple model også indeholder andre områderelaterede karakteristika. Resultaterne viser at for nogle modeller fører medtagelsen af andre områdevariabler til betydelige ændringer i signifikansniveauet af koefficienten for skovnærheden, mens andre modeller er mere robuste.

Denne analyse viser usikkerheden i anvendelsen af husprismetoden til værdisætning af ikke-markeds goder. Selvom metoden er baseret på faktiske betalinger, nemlig køb at et hus med bestemte karakteristika, er der stor sandsynlighed for at relevante variabler ikke medtages i analysen, enten fordi variablerne ikke er tilgængelige eller for dyre at skaffe. Dette kan medføre "omitted variable bias" og dermed føre til fejlagtige konklusioner angående marginale og ikke-marginale værdier.

Baseret på de empiriske resultater har dette Ph.d. studie testet nøjagtigheden af benefit transfer af herlighedsværdier ved anvendelsen af både den klassiske test af lighed mellem resultaterne og såkaldte "ækvivalenstests" som antager ulighed i nullhypotesen. Herlighedsværdier er blevet estimeret ved anvendelsen af første trin af husprismetoden og beregnet som procentuelle forskelle i huspriser for forskellig afstandsintervaller. Selvom den klassiske test for lighed mellem værdierne ikke kunne afvise nullhypotesen i et flertal af tests, ville det være forkert at interpretere dette som validitet af benefit transfer. Transfer fejl er betydelig også i det tilfælde, hvor lighed ikke kan afvises. Også resultaterne fra ækvivalens test viser, at for ingen af overførslerne kunne hypotesen af ulighed afvises med fejlmargin af 50 %. Kun for overførsler mellem to områder med lignende resultater kunne benefit transfer accepteres med en fejlmargin af 75 %.

1 Introduction

Denmark has made an ambitious decision in 1989 to double the nation's forest cover within one tree generation from 10 % to about 20 % within the next 100 years. This has resulted in more than 100 public afforestation projects[1] and about 1000 ongoing projects in private regi (Miljøministeriet and Skov- og Naturstyrelsen (2003)) in the last 17 years. Forest cover as of June 2006 is about 14 %[2] and about 18,000 ha new forest was planted since 1990. Tree types planted are mainly native trees, such as oak, beech and ash and some coniferous treetypes for variation.

While the main aim with afforestation in 1990 was to find alternative usage for agricultural areas, today's aims include to the same extend or even more the protection of drinking water and biodiversity, CO_2 sequestration and enhancement of recreational opportunities. Especially for national afforestation projects recreational opportunities and groundwater protections are the main goals. Therefore the majority of national afforestation projects are planted in the vicinity of residential areas. But also more and more municipalities engange in afforestation activities, where one of the positive side-effects can be increased tax income from house owners (Anthon et al. (2005)).

1.1 Non-market valuation methods and the valuation of forests

Amenity and recreational values resulting from existing and newly planted forests are so-called non-market values where no market prices exist for their valuation. Obtaining reliable monetary estimates for these non-market benefits is, however, essential for choosing the optimal spatial allocation of future forest areas with the aim of maximising welfare to society. There has been an increased focus on the development and improvement of non-market valuation methods in the last 20 years.

Non-market valuation methods are divided up into two groups, one called "stated preference" methods that consists of contingent valuation and choice experiments. Data collection in both these methods is based on questionnaires sent to a population sample. Here respondents are asked to state their willingness-to-pay (WTP) for a specific environmental good in a hypothetical market created by the researcher.

The other group of non-market valuation methods is called "revealed preference" methods. Data collection for implementation of

1 See information on the Dansh Nature Protection Agency at http://www.skovognatur.dk/Emne/Skov/Skovrejsning/Statslig/Indsatsomraader_skovrejsning.htm.

2 Skov & Landskab Nyt 4/2006

these methods is based on peoples' real action in existing markets. Thus the respondent "reveals" his or her willingness-to-pay for the particular environmental good of interest by e.g. choosing a house or travelling to a specific recreational site. It is then the researcher's task to recover these preferences from the market data using different statistical methods and assumptions. Both the hedonic pricing method and travel cost method fall into this category. Hedonic pricing is based on housing market data while travel cost analysis is based on information about number of trips, trip length and travel mode to recreational sites. A detailed description of the different non-market valuation methods can be found in Garrod and Willis (1999), Freeman III (2003), Champ et al. (2003) and Haab and McConnell (2002).

A summary of non-market valuation studies of forest values from Denmark and Sweden is included in Article 2: Birr-Pedersen, K. and B. Hasler: "The value of forestation in urban fringe areas in the Øresundsregion" in this thesis. Since the finalisation of this paper two more studies have been finalised in Denmark, Nielsen et al. (in press) focusing on the extra value for forest visitors from converting to nature-based forest management practices and Termansen et al. (2004) who apply a random utility model to forest recreation trips of the Danish population. In both Denmark and Sweden, results from these studies indicate that people place a high value on forests, both old forests and the planting of new ones. Values exist for recreational purposes, berry picking and amenity values (as reflected in house prices). People also seem to have substantial non-use values attached to forests. Generally distance to the nearest forest has a disproportional effect on the size of forest values, i.e. people prefer forests to be close to their residence and the closer the distance the higher the total amount of visits per person and year.

These results can be confirmed or are similar to those obtained from similar studies in other European countries, i.e. Finland and Great Britain. In Finland both the hedonic pricing method (Tyrväinen (1997)) and the contingent valuation method (Tyrväinen (1998)) resulted in positive WTP estimates from the population, either expressed in higher housing prices for residents located in close proximity to forest areas or in WTP to avoid a decrease in urban forest cover because of construction activities.

In Great Britain Willis and Garrod (1992) used the hedonic pricing method and showed that house price premiums varied by differences in the age and type of forests and woodlands. By comparing WTP for establishing woodlands to the farmers willingness-to-accept (WTA) compensation Bateman et al. (1996) showed that WTP was almost twice the compensation amount required by farmers for conversion of farm land to forests.

1.2 Application of GIS in non-market valuation

Many environmental valuation methods involve spatial aspects and their variations in their application, the most obvious examples being the two revealed preference methods hedonic pricing and travel cost method. In the past the inclusion of these spatial aspects often involved a range of simplifications, e.g. the assumption of constant travel times, use of centroids as departure points in travel cost analyses or time consuming individual measurement of distances on the household level in hedonic pricing studies. The use of Geographical Information Systems (GIS)[3] in connection with valuation studies allows a more realistic data collection, e.g. by including road network and travel speed or substitute availability. In addition GIS offers the possibility to automate distance calculation and to create indices for the characterisation of landscapes surrounding built-up areas and thus likely to influence housing prices.

Geographical Information Systems (GIS) have recently gained attention as a tool that potentially can improve the accuracy of benefit transfer applications as many valuation exercises have a spatial dimension (i.e. distance to recreational area, substitute availability, proximity to disamenities like hazardous waste sites etc.). Bateman et al. (2000) conclude that the application of GIS can assist benefit function transfer due to the system's easy and systematised data access to, for example, information on the availability of substitutes and road networks (including road speeds). Among the new opportunities created by GIS applications are enhanced variable specification, larger sample sizes and greater replicability of analysis (Lovett and Bateman (2001)). In addition, GIS offers new possibilities of the spatial representation of the environmental impacts of policy decisions (see Bateman et al. (2003) for an example of GIS application in cost-benefit analysis).

In one of the earlier studies, Eade and Moran (1996) applied GIS technology to construct an 'economic value map' including non-market values of environmental assets in a conservation area in Belize. Lately GIS has been employed in the transfer of consumer demand curves for woodland recreation obtained through travel cost analysis in Great Britain. All studies are based on one and the same travel cost survey of open-access woodland recreation values implemented at a site in eastern England in 1993. Visitor data from this study is then used to estimate visitor demand functions or arrival functions with differing degree of complexity and investigate their applicability to different benefit transfer aspects, e.g. by comparing the estimated amount of visitors to actual visitor counts from the GB Forestry Commission (Brainard et al. (1999), Bateman et al. (1999) and Lovett et al. (1997)).

Geographic Information Systems have also been combined with the hedonic pricing method in order to estimate the amenity benefits of access to woodland by local residents (Powe et al. (1997)) or

3 Geographic Information Systems (GIS) are computer programs that enable the capture, storage, management, analysis and visualisation of digital geo-referenced data.

to explain the value individuals attach to the diversity and fragmentation of land uses surrounding their homes (Geoghegan et al. (1997)). In both these studies the authors benefited from the detailed data processing abilities of the GIS in order to construct indices that could be useful in explaining variations in housing prices. Powe et al. (1997) calculated a forest access index for each property consisting of the sum of the different forest areas divided by the squared traveling distance to them.[4] The marginal price calculated for a unit increase or decrease of this forest access index was then applied to asses the costs or benefits associated with hypothetical tree falling and planting activities in the study region. Geoghegan et al. (1997) on the other hand, included two landscapes indices in their analysis, one for diversity and one for fragmentation of habitat, developed by landscape ecologists. Their results suggest that the nature and pattern of the surrounding landscape influences housing prices, however, the marginal prices will vary depending on whether the property is located in a highly developed, suburban or relatively rural area.

1.3 Objectives of this Ph.D. study

The Danish Nature and Forest Agency is responsible for more than 100 afforestation projects in Denmark, both finalised and still ongoing, which together with private re-forestation initiatives shall contribute to the realisation of the ambitious afforestation goal of doubling the nation's forest cover. Fulfilling this ambitious goal will require the initiation of an additional amount of afforestation projects in the future. Therefore one of the usages of valuation studies is their application in benefit transfer exercises.

Benefit transfer refers to the transfer of estimates of non-market values from original studies (normally referred to as "study sites") to new policy –relevant applications, the so-called "policy sites". There exist different forms of benefit transfer that vary by their "theoretical" potential for correcting for variations in markets and consumer attributes between study and policy site. In this Ph.D. thesis benefit transfer has been applied in three cases including one based on original empirical research. The results are presented in four articles included in the appendix of this report.

The first two articles have introductory character to the issue of benefit transfer and describe two applications of the benefit transfer methodology. One where benefits from afforestation measures are included as secondary benefits in reducing nitrogen reduction measures in agriculture (Article 1: Birr-Pedersen, K. and J. S. Schou: "The inclusion of secondary benefits in the cost-effectiveness analysis of nitrogen reduction measures in agriculture") and one where benefits from forest areas estimated for Denmark are used to place a monetary value on forests in the Scania region in Sweden (Article 2: Birr-Pedersen, K. and B. Hasler: "The value of forestation in urban fringe areas in the Øresundsre-

4 The forest access index had the following form: forest access index = $\Sigma_{i}(\text{area}_i/\text{distance}_i^2)$, see Powe et al. (1997).

gion"). Both articles are based on project work undertaken in the years 2003 – 2004, i.e. in a period where final results from the hedonic pricing analysis of this Ph.D-study were not yet available. Benefit transfer in these articles is thus based on other forest valuation studies than the one implemented in this Ph.D. project.

For the empirical part of this Ph.D. project the hedonic pricing method was chosen to estimate amenity values from afforestation projects in Denmark. Data on housing characteristics is easily available in Denmark because information on these characteristics plus the sales prices are kept for taxing purposes in the Danish housing registers. In these housing registers all buildings are spatially referenced which allows the incorporation of spatial measures using the technology of Geographical Information Systems (GIS).

The introduction of GIS into hedonic pricing studies (e.g. Hite et al. (2001)) has lately allowed relatively easy incorporation of spatial /location-related characteristics in estimating the hedonic price equation for one housing market, from simple straight distance measures to the construction of complicated indexes (Geoghegan et al. (1997)). In theory there is no limit to finding spatial characteristics with potential influence on housing prices, in reality the inclusion of these measures is often restricted by what is available in terms of existing maps.

Earlier studies have often used simpler models, which besides the classical structural housing characteristics did only include the distance measure of interest. However, this might lead to omitted variable bias in estimation. In this study both simple models consisting of the classical structural housing characteristics and advanced models incorporating also a range of other location-related independent variables are estimated and their results compared to each other to test the sensitivity of omitted variable bias for implicit price estimates. The results from the hedonic pricing analyses of the three afforestation areas and the test and discussion of omitted variable bias are summarized in Article 3: Birr-Pedersen, K.: "Omitted variable bias in estimating amenity values from afforestation areas in Denmark".

In order to be able to apply the results of the hedonic pricing analysis in benefit transfer exercises it is necessary to estimate the price differentials for houses for different distances from the forest edge. The price gradients for the distance to new forest measures are presented as percentage differences for 100m intervals from the forest edge up to the largest distance measured in the respective datasets. The uncertainty attached to such benefit transfer approaches is examined by calculating the transfer errors of fictive transfers between areas and by testing for the accuracy of transfers using both classical equality tests and equivalence testing. The results from this testing for accuracy of benefit transfer are summarized in Article 4: Birr-Pedersen, K. :"Testing the transferability of amenity values from afforestation areas in Denmark".

This introduction and the material and methods section below are enlarged versions of the material and methods sections included in the four articles. Thus some repetitions are unavoidable and the reader will hopefully bear with me. Chapter 2 contains a description of the hedonic pricing theory and the specific problems and issues associated with the first and second stage estimation of the hedonic pricing method which were not covered in the same amount of detail in the articles, e.g. the estimation of flexible Box-Cox function forms and the problems involved in estimating the underlying demand functions for different characteristics. Chapter 3 summarizes the different benefit transfer approaches with a special emphasis on meta-analysis, an issue not covered in the four articles and the description of benefit transfer guidelines. In chapter 4 the main results from the empirical work of this Ph.D. project are summarised, while the last chapter contains a summary of the conclusions and an outlook for further research issues.

2 The hedonic pricing method

The hedonic[5] pricing method (HPM) is part of the group of valuation methods called revealed preference methods. The HPM assumes complementarity between a market good and an associated public (or non-market) good. The basic idea here being that if the quantity of a public good increases (e.g. amount of recreational area available or air quality improvements) this leads also to increasing demand of the connected market good. Classic examples are the housing market, where real estate prices are influenced by area attributes like air-quality, green space and quality of public schools, or employment market, where it is assumed that risks to life and health will affect the workers' wage rate.

A substantial amount of hedonic pricing studies have examined the relationship between property values and environmental quality. Ridker and Henning (1967) was probably the earliest hedonic pricing study. A summary of hedonic pricing studies by subject area can be found in Boyle and Kiel (2001), while for example Smith and Huang (1995) have conducted a meta-analysis of hedonic pricing studies of the specific subject of air pollution. The theory of hedonic pricing is explained in detail in Freeman III (2003), while Taylor (2003) and Haab and McConnell (2002) also focus on the practical estimation problems related to empirical application of the method. Palmquist (2004) provides a more recent review of property value models in general.

In the hedonic approach a good is assumed to consist of a set of attributes (so-called differentiated good) and the good's value or price thus can be considered a function of each attribute. Lancaster (1966) was the first to formulate a the theory that utility derived from consumption of a good is derived from the consumption of the good's characteristics rather than from the good as such. Described in its simplest form:

Value of a good = (value of attribute 1) (quantity of attribute 1) + (value of attribute 2) (quantity of attribute 2).

If environmental quality (q) is one characteristic of a differentiated market good, individuals can choose the consumption of q by choosing a specific private good consumption bundle. The market for that particular differentiated good can thus serve as a market for q. In theory it should therefore be possible to estimate the demand for q from the price differentials (i.e. differences in prices for composite goods with varying amounts of the attribute q) revealed in private markets.

5 According to Hidano (2002) the origin of the word can be traced back to "hedonism", a Greek school of philosophy. Here hedonism is a synonym for the word "pleasure". In that sense the "hedonic method" tries to value the pleasure associated with (the different attributes of) a good.

The estimation strategy for a complete hedonic model consists of two steps. In the first stage the hedonic price equation is estimated using information about prices and attributes of houses. This is done by using regression analysis and includes among other essential issues the choice of functional form and the choice of explanatory variables. This hedonic price equation can be used to infer marginal willingness-to-pay of the house owners for small changes in attributes. The first stage does not allow the direct identification of uncompensated or compensated demand function.

The second stage uses the estimated marginal prices from the first stage supplemented with information about income and other socio-economic characteristics of the individual house owners to estimate the uncompensated demands for the different characteristics. By using duality the exact welfare changes in terms of compensating/equivalent surplus or compensating/equivalent variation can be calculated based on these uncompensated demand functions.

The following chapters contain a summary of the most essential elements of the first and second stage hedonic pricing analysis respectively.

2.1 The property market and its functions

While the basic idea behind hedonic pricing is derived from consumer theory (Lancaster (1966)), a formal theory of hedonic prices was developed by Rosen (1974) and further elaborated by for example Bartik (1988) and Palmquist (1988).

We assume that the price of a differentiated product can be explained by the vector of its characteristics z:

$$P = P(z) \qquad (1)$$

In the case of the housing market the characteristics z can be divided up into three subgroups:

(1) structural characteristics S_i of the individual houses, e.g. lot size, size of living space, number of rooms and bathrooms, roof material etc.;

(2) neighbourhood characteristics N_i, e.g. location, social qualities, socio-economic characteristics of population; and

(3) environmental characteristics Q_i, e.g. noise, recreational opportunities, air quality.

One of the major assumptions behind the hedonic pricing method is that characteristics can be varied continuously. This distinguishes the method from discrete choice methods, e.g. the random utility method, where – if the method is applied to the housing market – choices are assumed to be based on discrete bundles of characteristics.

In the hedonic model households are assumed to select a specific housing type, *z*, while maximising their utility given their available budget or income, *y*, and the hedonic price function *p(z)* (1):

$$\max_{z,x} U(z,x;D) \text{ subject to } p(z)+x<y$$

D is a vector of household characteristics that explains differences in preferences across individuals, while *x* is a composite non-housing commodity with a price of unity.

The suppliers of housing on the other hand choose a vector of characteristics, *z*, and the number of units to offer, *M*, in order to maximise profits according to

$$\max_{z,M} M(p(z))-C(M,z;S).$$

C(.) is the supplier's cost function and S is a vector of supplier attributes that explains the existence of different supplier cost functions, e.g. factor prices, technology etc.

Rosen (1974) described the consumers' and producers' action in the form of bid and offer functions. Consumer's actions or willingness to pay can be represented in a bid function of the form

$$\theta(z,u,y;\alpha)$$

where *z* is again a vector of housing attributes, *u* represents utility of the consumer, *y* income and *a* represents a consumer specific set of other socio-economics characteristics. For each bid function it is assumed that income and utility remain constant. The marginal bid for z_i, θ_{zi}, equals the marginal rate of substitution, U_{zi}/U_x. Thus, optimization requires that the marginal bid be equated to the marginal price in the market. Different consumers will choose different products because of differences in *a*. The hedonic price schedule is taken as exogenous.

On the other side of the market are producers that want to maximise profits *π*. Producers' or firms' behaviour can be described by an offer function:

$$\phi(z,\pi;\beta)$$

where ϕ represents the unit price a producer can accept for a product with characteristics *z* and make profits *π* given producer attributes β. Optimum for each producer is again the point where marginal (acceptable) price is equal to marginal costs of production. The hedonic equilibrium price schedule is determined by the interaction of consumers and producers in the market. Figure 2.1 shows the equilibrium price schedule in a housing market. Consumers would like the lowest possible bid to win in order to maximise their utility, while producers would like their highest possible offer to be accepted in order to maximise their profits. The resulting observable winning bids (i.e. house sales) are assumed to be part of an underlying continuous equilibrium hedonic price schedule (Palmquist (2004)).

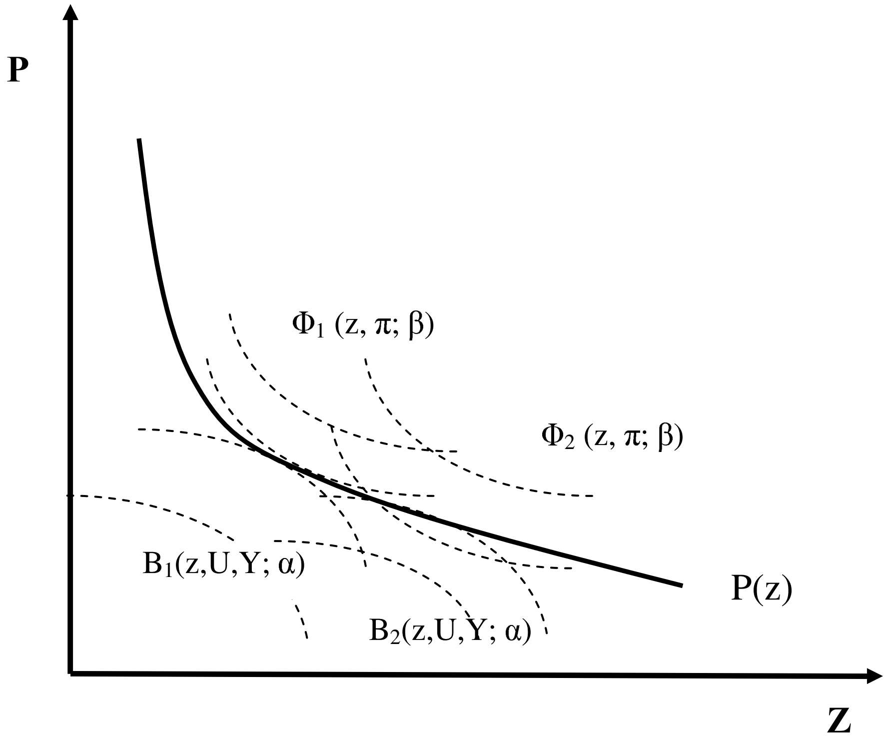

Figure 2.1 Equilibrium price schedule
Source Palmquist (1991), p. 81, adapted to environmental good where increasing distance provides decreasing prices

In the case of housing, the equilibrium price schedule is completely demand determined as the specific characteristics of a house are predetermined (at least in the short run) and generally costly to change. For the hedonic model of the housing market thus only the hedonic price equation and the behavioural equations of the consumers are relevant (Palmquist (1999)).

Following Rosen (1974) the partial derivative of the hedonic price function (1) with respect to any characteristic gives its marginal implicit price:

$$\frac{\partial P}{\partial z_i} = p_{z_i} \qquad (2)$$

The marginal implicit price, p_z, (also called the hedonic slope) is equal to the additional expenditure required to purchase a unit of the differentiated product with a marginally larger quantity of that characteristic.

In a housing market equilibrium the marginal implicit price will be equal to the marginal willingness to pay of the consumer and the marginal offer price of the supplier for the particular characteristic, i.e.

$$\frac{\partial P}{\partial z_i} = \frac{\partial U / \partial z_i}{\partial U / \partial x} \qquad (3)$$

The two sides of equation (3) represent the marginal hedonic price function and the marginal bid function (which at this equilibrium point is equal to the marginal rate of substitution between the attribute z_j and the set of all non-housing goods, x). As can be seen in Figure 2.1 the equilibrium points that make up the hedonic price schedule each represent a point of differing marginal bid functions, i.e. of consumers with differing income and utility functions. As only one point on these individual marginal bid functions is identified when the hedonic price function is estimated the bid functions can not be obtained from the hedonic price schedule. Likewise it becomes clear from Figure 2.1 that individual socio-economic characteristics do in general not influence the hedonic price schedule. Information about for example income will only be included as an average characteristic of specific areas or market segments of a housing market, e.g. in order to capture the positive effect of higher income neighbourhoods on housing prices.

2.2 Estimation of the first stage

Estimating the hedonic price equation (1) empirically requires the choice of a dependent variable and the explanatory variables. The dependent variable is normally the sales price of the houses in the dataset. The sales price is generally preferred to other alternative measures of house prices if the market is in equilibrium. However, other possibilities include rental values (e.g. for apartments) if the housing market is free for any form of rent control measures or official appraisal figures, e.g. for taxing purposes. What should be remembered in any case is that sales price and official valuation reflect the discounted present value of all future rents to be expected from the property, i.e. the price equal to the present values PV

$$PV = \sum_{t=1}^{T} \frac{R_t}{(1+r)^t} \qquad (4)$$

where R_t reflects the rent in time t and r is the discount rate.

Thus the marginal prices calculated according to equation (2) represent the discounted value of future benefit flows from the respective characteristics. When transferring these present values into annual values, e.g. when they are used in a cost-benefit analysis, it is necessary to assume a time horizon T and discount rate r.

Palmquist (1992) has shown that in the case of localised externalities the hedonic price equation is also sufficient to determine WTP for non-marginal changes, as long as only a relative small number of properties are affected. Examples here are the construction of a highway or the siting of a hazardous waste facility but also the afforestation of an area, where the general equilibrium price equation of the property market will not be affected by the change and price of one of its characteristics.

But also if estimation is restricted to the first stage, the hedonic price schedule, a number of important estimation issues need to be considered (Palmquist (2004)). For example should all observations come from a single market, i.e. consumers in that market should consider all sub-areas in the chosen area as viable substitutes. The contribution of the various characteristics of a house should remain stable over time, i.e. consumers' tastes are assumed to remain unchanged in that period.

Not always are the objective measurements of the environmental variable and the subjective perceptions of the same environmental good or disamenity of the residents in an area identical. Although the price of an individual house will not depend on the specific perceptions of the resident, a survey investigating the average perception of environmental changes could provide useful information.

Typical statistical issues that need to be investigated are multicollinearity, heteroskedasticity and autocorrelation. Multicollinearity refers to situations where interrelationships between independent variables exist and thus the parameter estimates of those variables become unreliable (Maddala (1977)). This will nearly always be the case for some of the structural variables in house price models, e.g. are number of rooms and bathrooms correlated with the number of square meters of living space. In estimating the demand for environmental goods multicollinearity first becomes an issue when the environmental variable of interest is correlated with other variables (Garrod and Willis (1999)). Heteroskedasticity exists when residuals do not have a common variance, instead the variance can for example vary with income or other explanatory variables of the regression model. Solutions to heteroskedasticity are either deflation or log transformation (Maddala (1977)). Autocorrelation exists if covariance between error terms is different from zero. In the case of hedonic models spatial autocorrelation can exist, i.e. the price of house can be influenced by the price of houses nearby.

Another very essential issue of the estimation of the first stage is the choice of functional form for equation (1). Theory does not proscribe a specific functional form for the hedonic price function, with the exception that it is monotonically increasing in desirable characteristics (Palmquist (1999)). Thus the first part of Rosen's two-step procedure consists of specifying a particular functional form and estimating the parameters it contains.

Practical applications of the hedonic pricing method have determined the functional form empirically, most (or many) of them are using the general quadratic Box-Cox function suggested by Halvorson and Pollakowski (1981). Parametrically this flexible functional form describes the hedonic price function for the i^{th} house as:

$$p_i(\mu) = \alpha_0 + \sum_{c=1}^{C} \alpha_c z_{ic}(\lambda) + 0.5 \sum_{c=1}^{C} \sum_{g=1}^{C} \beta_{cg} z_{ic}(\lambda) z_{ig}(\lambda) + \varepsilon_i \qquad (5)$$

where ε_i is a random error term which is assumed to be normally and independently distributed with zero mean and constant variance. The *a's* and *β's* are parameters for the transformed attributes i.e. the independent variables *z*. The Box-Cox transformation of a variable *x* (which might be the dependent variable *p* or the independent variables z_i) is typically

$x(\theta) = (x^{\theta} - 1)/\ \theta$ for $\theta \neq 0$

$= \ln(x)$ for $\theta = 0$ (6)

This transformation is only possible for variables with positive values. Figure 2.2 shows the different restricted functional forms that can be derived from the flexible quadratic Box-Cox functional form by restricting the transformation parameters μ and λ to the values 0, 1 or 0.5 and by setting the vector of coefficient *β* to zero.

Flexible functional forms like the quadratic Box-Cox suggested by Halvorson and Pollakowski (1981) can provide more accuracy in predicting the dependent variable. However, more complicated functional forms also increase the problem of collinearity between covariates. Experimental studies like the one done by Cropper et al. (1993) have been able to compare the true marginal values with the estimated ones. Results here suggests that a simple functional form specification like the linear function or the linear Box-Cox function results in the smallest absolute error, when attributes are measured with errors.

Cassel and Mendelsohn (1985) argue that the huge amount of parameter estimates reduces the accurateness of individual parameter estimates for the independent variables in the dataset because of unavoidable collinearity between variables. Thus the "best functional form" is not necessary the one that explains the effect of a specific independent variable best. Box-Cox parameter estimates are influenced by the most influential variables on house prices, i.e. living area, lot size, age etc. Transformation parameters estimated for these variables may not be adequate for the environmental variables.

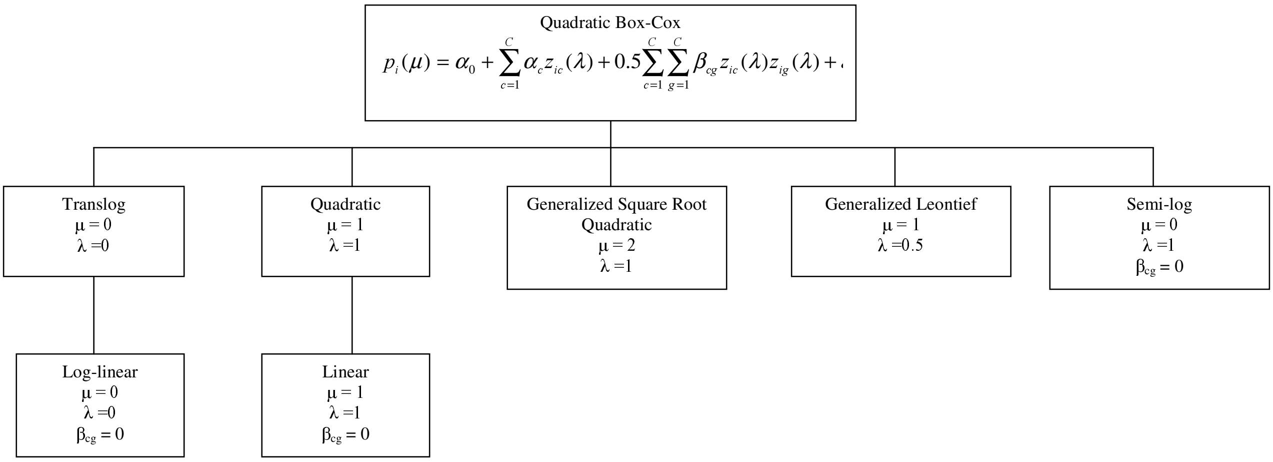

Figure 2.2 The quadratic Box-Cox and related functional forms
Source Halvorson and Pollakowski (1981), p.47, simplified version of Table 1.

The optimal values for the Box-Cox transformation parameters can be determined by either using pre-defined computer packages (available in STATA and LIMDEP) or using a grid search.

For the analyses presented in this Ph.D. thesis functional form specification was based on graphical tools like scatter-plots and residual analysis (plots of residuals and studentized residuals versus predicted values) and calculation of Cook's index. Simple linear regressions of the inflated house price vs. the various continuous explanatory variables were conducted in order to determine the optimal transformation of the predictors and response. Four combinations, linear, semi-log, inverse semi-log and double-log transformations are tested. Table 2.1 provides an overview over the different diagnostic statistics available. Based on the complete model added variable plots are drawn for each continuous variable in order to check the model fit and if the transformation is accurate. This procedure resulted in the choice of a double-log functional form for Drastrup and Kirkendrup datasets. Also for Sperrestrup the basic functional form was double-log though with the exemption of the three continuous variables "age at the time of sale" and "distance to old forest areas" and "distance to childcare institutions" where graphical analyses suggested no transformation.

Table 2.1 Overview over diagnostic statistics

Outliers		
Scatter plot	Response vs. predictor	Compare observation points to estimated line: Are points distributed equally on both sides of the line? Are there outliers that seem to have a strong influence on the estimated line? Does the distribution of points indicate a polynomial form for the model?
Studentized residuals, r	Residuals, $\hat{e}_i$, are scaled by an estimate of their standard error	If the model is correct Studentized residuals should have a common and constant variance equal to 1. Studentized residuals with high values (>3.5) could indicate outliers.
Residuals vs. predicted values		Check for systematic deviation, i.e. residuals are positive for small and large values and negative in the middle. This indicates that a squared term should be added to the model.
Non-constant variance		
Studentized residuals vs. predicted values		If model correct then: Null plot: swarm of points without pattern around zero and with zero slope. Right or left opening megaphone indicates non-constant variance. Isolated points far from zero might indicate outliers (only 5 % should exceed 2, only 1 % should exceed 3)
Added variable plot	Scatter plot of residuals from regression on all variables with the exemption of the last one added vs. residuals from regression of the added variable vs. all other explanatory variables in the model	"Modelling the part of the response variable that is not explained by the already included variables vs. the part of the new variable that is not explained by the variables already included in the model."
Influential observations		
Cook's distance D_i		Cases for which D is large have substantial influence on ^β and fitted values.

In addition to the graphical tests, Box-Cox functional forms have been estimated using the box-cox routine in STATA for the full dataset of sales in the period 1996-2005. Box-Cox models are estimated for two different sets of variables. One for the "simple" version, i.e. a model only containing the classical structural variables, distance to the new forest and a dummy variable for sub-markets if necessary. And another model for the "advanced" model, which in addition to the variables of the simple model also includes various other location-related variables. Results from an estimation procedure allowing transformation of both sides with dummy variables untransformed are reported in Table 2.2 for the three case study areas.

Table 2.2 Box-cox estimation results for parameter values μ and λ

Afforestation area	Type of model	Box-cox parameter	Coef.	Std. Err.	z	P>z	[95 % Conf.	Interval]
Drastrup	Advanced model	λ	0.433	0.294	1.470	0.141	-0.144	1.010
		μ	0.199	0.175	1.140	0.256	-0.144	0.542
	Simple model	λ	0.183	0.229	0.800	0.424	-0.266	0.633
		μ	0.179	0.174	1.030	0.304	-0.162	0.520
Kirkendrup	Advanced model	λ	0.372	0.079	4.720	0.000	0.218	0.527
		μ	0.300	0.106	2.830	0.005	0.092	0.507
	Simple model	λ	0.410	0.076	5.370	0.000	0.260	0.559
		μ	0.280	0.106	2.650	0.008	0.073	0.487
Sperrestrup	Advanced model	λ	0.333	0.064	5.240	0.000	0.208	0.457
		μ	1.175	0.191	6.140	0.000	0.800	1.550
	Simple model	λ	0.317	0.062	5.100	0.000	0.195	0.439
		μ	1.134	0.190	5.980	0.000	0.762	1.506

Table 7 and Table 8 in the appendix contain the detailed estimation results based on the flexible Box-Cox functional form. With the exemption of the advanced model for Sperrestrup none of the parameter estimates for the distance to new forest measure is significant at the 10 % level. For the Drastrup area estimates for λ and μ are not significantly different from zero, both for the simple and the advanced model. This suggests a double-log functional form, the same that was also selected based on residual analyses. For the Kirkendrup area the coefficient estimates for λ and μ are still close to zero while for the Sperrestrup models the estimated Box-Cox parameters suggest functional forms that are substantially different from the ones chosen based on residual analyses. Keeping the limitations of the Box-Cox procedure described above in mind it was decided to base transformations and thus choice of functional form on the graphical analyses.

2.3 Estimation of the second stage

While estimation of the first stage of a hedonic pricing analysis yields information about the marginal prices of the different attributes and in the case of localised externalities also of the willingness-to-pay for a non-marginal change in an attribute to house owners, an estimation of a demand function or willingness-to-pay function is only possible when also the second stage is applied. Given the time constraints in this Ph.D. project second stage estimation was unfortunately not possible. However, in order to provide the reader with necessary background information to the method and the outlook section of this thesis, a short introduction to the second stage and its potential problems in empirical applications are outlined below.

For a simple private market good, demand functions can be estimated by simultaneously observing the price, the amount and the socio-economic characteristics of the consumers. With differentiated goods as for example housing, this is not possible as the individual prices for the different characteristics cannot be observed, only the price for the house as such. The estimation strategy for a complete hedonic model thus needs to proceed in two steps.

First, the hedonic price equation (1) is estimated and the marginal prices for the different characteristics (2) are calculated. This enables us to identify *points of intersections* of the marginal price and the marginal bid functions. However, only the marginal price function is known. Therefore, in a second step, marginal prices are combined with the socio-economic attributes of consumers including some measure for wealth or expenditure on non-housing goods, to estimate the behavioural equations for the consumers, the bid-functions or demand functions (see Palmquist (1999), Palmquist (2004) and Taylor (2003) for a detailed description of second stage estimation).

The second stage estimation process involves extensive data requirements and some rather complex econometric issues. The most important ones are the identification problem and the problem caused by endogeneity of prices and quantities. The identification problem exists because it can be difficult for the researcher to distinguish between the already estimated hedonic equation and the demand equation (or bid function) in the second stage estimation process. As a solution data from a number of different markets can be used that are spatially or temporally separated or the researcher needs to assume a specific form for the underlying utility function, which is different from the functional form chosen for the hedonic price equation. The endogeneity problem is caused by the simultaneous determination of marginal price and quantities consumed when the consumer chooses a particular house (Palmquist (1999)).

2.3.1 Identification problem: Using multiple markets

If data on multiple markets can be acquired, it is possible to estimate uncompensated demand functions by combining data across markets. By doing so one assumes that individuals with the same socio-economic profile have the same preferences independently of the location they are living in. Because different markets result in different marginal prices for the characteristic of interest, the individuals' choices will vary across markets.

The first step in this approach consists of estimating separate hedonic price functions for each market with the same functional form specification and use them to calculate marginal prices. In a second step the estimated marginal prices can than be regressed on the quantities consumed and the socio-economic characteristics in order to obtain the uncompensated demand function for the particular characteristic of interest. By integrating vertically under the inverse uncompensated demand function consumer surplus estimates can be computed (Taylor (2003)).

However, rather than consumer surplus one would like to have estimates of one of the theoretically correct welfare change measures based on Hicksian compensated demand functions. In the case where it is assumed that house owners will not move when an exogenous change of quantity in one of the characteristics occurs, because moving costs are prohibitively large, the relevant welfare measures would be the compensating or equivalent surplus. In cases where moving is possible, i.e. the house owner rather faces a price change than a quantity change the relevant welfare measures would be the compensating and equivalent variations. Taylor (2003) explains two approaches were duality[6] can be used to recover the correct welfare measures when uncompensated demands are estimated.

Former application of the multiple market method to environmental characteristics of housing are Boyle et al. (1999) for measuring the demand for protecting fresh water lakes from eutrophication and Zabel and Kiel (2000) and Palmquist and Israngkura (1999) which estimated demand for improvements in air quality.

2.3.2 Identification problem: Using functional form restrictions

If multiple market data is not available identification of bid functions can be achieved by simply choosing a functional form for the utility function and then estimate the marginal bid and the parameters of the utility function (Taylor (2003)). Chattopadhyay (1999) and Cropper et al. (1993) provide two examples where they estimate the equilibrium conditions of equation (3), where the left hand side is calculated based on the estimated hedonic price equation and the right hand side form is given by the assumed form of the utility function and information about the chosen levels of the particular characteristics and socio-demographic information about the house owner. Unfortunately these restrictions are assumed a priori to be correct and there is no way of testing their correctness based on the data. Given these limitations this approach is often considered to be less desirable. When the parameters of the utility function have been estimated, welfare measures can be directly computed based on the utility function.

2.3.3 Endogeneity

The problem of endogeneity arises because of the simultaneous determination of the marginal price and the level of attributes in the case of non-linear specifications of the hedonic price function. In that case prices are non-constant and by choosing a specific amount of amenity, e.g. by choosing the distance to the forest, the consumer also determines the price of this housing attribute. Thus, when estimating inverse demands by regressing marginal prices against quantities and socio-economic characteristics, both the price as the dependent variable and the quantity consumed are

[6] See Flores (2003) and Freeman III (2003) for detailed description of the concept of duality. In short duality refers to the relationship between the ordinary (Marshallian) demand functions and the compensated Hicksian demand functions. The relationship is termed "duality" as both demand functions describe the same choice process, one in terms of maximising utility given a budget constraint and one minimising expenditures subject to a given level of utility.

correlated with the error term. This makes least square estimation inconsistent. In addition adjusted income, calculated as the actual income minus housing expenses, also becomes endogenous if prices are non-linear.

Endogeneity can be approached by instrumental variable techniques (Maddala (2001)). To apply these techniques it is necessary to find instrumental variables that are uncorrelated with the error term, highly correlated with the explanatory endogenous variable and of full rank, i.e. add new information to the system of equations (Taylor (2003)). Examples of such instrumental variables include socio-economic characteristics, e.g. age, gender or number of children for adjusted income and local conditions, e.g. number of house sales per year or employment rates in an area for marginal prices. Earlier approaches also experiment with spatially-lagged variables involving spatial relationships between neighbouring houses (Cheshire and Sheppard (1998)). Endogenous prices and adjusted income are then regressed against these instrumental variables and predicted values for prices and adjusted income are calculated based on the estimated parameters. These predicted values are then included in the demand equations for further estimations.

3 Benefit transfer

As a less costly alternative to conducting an original non-market valuation study, policy analysts are applying more and more so-called benefit transfer (BT)[7], i.e. the transfer of monetary estimates of environmental values estimated at one site (study site) to another, so-called policy site. Examples here are the USA[8], where cost-benefit analyses are required by law for all new regulations. In addition, an increasing amount of litigation cases regarding environmental damages under CERCLA[9] has increased the demand for benefit (or better: damage) estimates to be extracted and transferred from earlier valuation studies.

While having been in use for decades in political decision making, benefit transfer as a research area started to gain attention about 12-15 years ago (Loomis (1992)). A broader scientific discussion of the subject started in 1992 with a special issue of the American journal "Water Resources Research".[10] As pointed out by Barton (1999) the issue is no longer "... *whether* benefit transfer can be done, but *when* it should be done and *how* to do it in a consistent manner given the requirements for reliability demanded by the policy-context and the decision-maker".

By how accurate are these transfers? What margin of uncertainty is acceptable for policy evaluation? Any recommendation for a systematic use of cost-benefit approaches in environmental projects requires an assessment of the transferability of benefit estimates. Research in the area of BT-testing has primarily focused on two avenues (Boyle and Bergstrom (1992)). One where benefit transfer experiments are based on original studies conducted in similar areas and comparable environmental goods and one where the results of comparable studies are analysed using a technique called meta-analyses. A summary of these tests for transferability and their results are provided in Article 4 of this thesis Birr-Pedersen, K.: "Testing the transferability of amenity benefits from afforestation areas in Denmark", while benefit transfer using meta-analysis is presented in more detail below.

7 Actually the term "Benefit" is slightly misleading as not only benefit estimates are subject to transfer exercises but also damage estimates. Therefore some authors prefer the term "environmental value transfer". In this paper, however, the term "benefit transfer" is used following the custom in the majority of publications about the issue.

8 See Desvousges et al. (1998), p.1-3, for a summary of the application of cost-benefit analysis and benefit transfer in the USA.

9 Comprehensive Environmental and Resource Compensation and Liability Act.

10 *Water Resources Research*, Vol. 28, No. 3, March 1992.

3.1 Benefit transfer approaches

Current methodological description of benefit transfer approaches divide the subject into four basic categories[11]:

1. Unit value transfer
   a) Simple unit value transfer
   b) Unit value transfer with adjustment, e.g. income
2. Function transfer
   a) Benefit function transfer
   b) Meta-analysis

The easiest way of transferring benefits consists of applying unadjusted mean or median measures from the study site at the policy site, e.g. recreational activity per time period (value per trip) or value per household. This simple unit value transfer basically assumes that the utility gain of an average individual at the study site is the same as that of an average individual at the policy site. This supposition will hardly hold in most circumstances for a variety of reasons:

1. People at study and policy sites might differ from each other in terms of income, education and other socio-economic characteristics that affect their preferences for e.g. recreation.
2. The good to be valued at study and policy site respectively might not be similar enough to be comparable, i.e. the good might differ with regard to its physical characteristics but also with regard to the proposed change in provision.
3. Market conditions applying to the sites might vary, e.g. with regard to the existence of substitutes. Actually one could think of situations where the policy site itself becomes a substitute of the study site, with resulting changes in demand functions for both sites.
4. Estimates might not be stable over time, i.e. WTP might change because of inflationary impacts, changes in the distribution of population, changes in taste and the availability of specific environmental assets. In fact, preferences are also likely to be affected by "hot" issues in the media and general shifting attention of the political agenda.

Despite the fact that the above-mentioned pitfalls are more likely to be present than not, transferring unadjusted unit values is actually quite common in analyses supposed to guide political decision making (see e.g. Dubgaard et al. (2001) for an example from Denmark).

11 One can find different categorisations of benefit transfer approaches in the literature. For example do Bateman et al. (2000) describe meta-analysis as a method for adjusting unit values. In most meta-analyses, however, unit values are recalculated using the "meta"-function, rather than simply adjusting them (see for example Schipper et al. (1998)).

3.1.1 Unit value transfer with adjustment

Instead of transferring unadjusted unit values the researcher or policy analyst can adjust the value estimates to better reflect differences between policy and study site. These differences could include (a) different socio-economic characteristics of the households, (b) differences in the change in environmental quality or quantity and (c) differences in the availability of substitutes for the environmental good in question.

A simple method of adjusting unit values when transferring them between countries is to correct for income differences (or differences in general price levels) by applying Purchase Power Parity (PPP) indexes or PPP adjusted exchange rates instead of using normal exchange rates. PPP adjusted exchange rates are exchange rates that keep the purchasing power constant between countries and thereby eliminate differences in price levels. These exchange rates are for example regularly published by the OECD and the World Bank.[12] PPP indexes do however, still not correct for differences in environmental conditions, cultural and institutional issues that have an impact on preferences. Often it will be necessary to use locally differentiated PPP indexes (e.g. for specific cities or regions in one country) as national wide PPP indexes might not be representative for the study site (Ready et al. (2004)).

Environmental values that are transferred over time should be adjusted for inflation, e.g. by using the consumer price index for the relevant years. Another form of unit value adjustment is that of using expert judgements. The term expert comprises here a wide range of people, from the researcher working with environmental valuation methods and benefit transfer to government officials and local expertise, e.g. real estate agents.

3.1.2 Unit value transfer and application of dose-response functions

A special form of unit value transfer that often combines the different adjustments discussed above is a transfer of values in connection with the application of so-called dose-response functions. For many forms of pollution (e.g. emissions to air and water) the related damages are not easily observed but need to be calculated or inferred from bio-physical functions, the respective amount of emission ("the dose") and its distribution in an area. This "chained-approach" is normally referred to as "dose-response" method or function.[13] Results from an application of this dose-response method are physical effects, e.g. in the form of number of asthma attacks, reduced activity days or number of deaths resulting from increases in air pollution. These physical effects are often "valued" by transferring values from other studies to the new policy context.

12 www.oecd.org/std/ppp and World Bank (1999).

13 In the ExternE project it is called "impact-pathway approach".

In the case of mortality the transfer unit will be Value of a Statistical Life (VSL) or Value of a Life Year (VOLY), while for morbidity cases different "symptom" units exists, e.g. for coughing, headache and itching eyes. These values can be calculated using different valuation methods, e.g. contingent valuation, hedonic wage-risk methods and avoidance costs. Often these values are transferred unadjusted, sometimes corrected for income or purchasing power parity differences between countries. While this would seem to be a straightforward application of unit value transfer a number of issues need to be considered here:

1. Different studies have tried to determine willingness-to-pay (WTP) for reduction in fatal risks from traffic accidents, while there do not exist many studies for risk reductions from air pollution. On average victims of air pollution are about 75 years old and thus substantially older than victims of traffic accidents, which have an average age of 40. It could therefore be argued that WTP for risk reductions decreases with growing age. In fact some studies of WTP for risk reductions of fatal traffic accidents show an inverted U-shaped form when plotted against the age of the survey respondents.[14] One form of expert adjustment of VSL estimates for traffic accidents consists therefore of reducing original values with 25-35 % so that VSL for air pollution victims is equal to 65-75 % of those for traffic accidents.
2. WTP for risk reduction measures might also vary depending on whether risks are faced voluntary (e.g. when driving a car) or involuntary (e.g. when inhaling polluted air in the streets). In addition WTP might differ if the risk is immediate (e.g. being injured while crossing a street) or latent (e.g. developing cancer from radioactivity). These risk characteristics are however hardly ever taken into account when transferring values, mainly because the direction and size of adjustment could not be agreed upon in the empirical literature.[15]
3. In the case of morbidity there is the problem that symptom and illness-units can vary from study to study in terms of severity and duration.

The combination of unit value transfer with results from dose-response method application can be used to calculated damage values per tonne emission of a certain substance. These "values per tonne" of different types of emissions represent again a form of unit value that could be transferred to different contexts. However, one needs to keep in mind that the physical damage effects of the same amount of pollution (and thus their total monetary value) can vary according to the area where they are emitted (e.g. rural or urban), i.e. the amount of people or crop affected, the specific

14 This means that WTP increases first with age, reaching its maximum around 50 years and than decreases again. See also WHO (1999), p.33 for a graphical presentation.

15 As cited in Holland et al. (1999), p. 242, some studies point to the fact that WTA for involuntary risks can be 10 or 100 times higher than WTA for voluntary risks.

weather and wind characteristics and other things that can have an impact on the final effect. Thus monetary estimates of air pollution damages cannot easily be transferred as costs per tonne emission without ensuring that the physical effects are the same at the policy site. Uncertainty regarding the end result of such a valuation chain is only partly associated with the monetary valuation of health effects. As much uncertainty or even more might stem from the estimation of exposure-response functions and exposure factors.

3.1.3 Benefit function transfer

When transferring the entire benefit function instead of per unit benefit estimates more information can in principle be transferred between study and policy site. Benefit function transfer can directly account for differences in user and site characteristics. This, however, requires access to an original study where WTP is described as a function of different explanatory variables. The coefficients of this function combined with the respective variables of the policy site can then be used to calculate new WTP values for the policy site. Expressed in its most general model benefit function transfer can be defined as (Barton (1999))

$$w^{p/s} = f^s(\beta^s, X^p) \qquad (7)$$

where

$w^{p/s}$ = WTP measure, recalculated at the policy site ("p") using the benefit function (i.e. coefficients) from the study site ("s"),

β^s = vector of coefficients from the study site

X^p = vector of explanatory variables from the policy site.

As pointed out by Barton (1999) what in fact is transferred here are the average effects of the different explanatory variables (β^s) from the study site.

Using a benefit transfer approach thus implies finding an original contingent valuation study with parameter estimates for β^s and collecting data for the independent variables X^p at the policy site. Data for X^p should be fast and easy to collect and at low costs (e.g. in the form of national statistics), otherwise the basic idea of benefit transfer, i.e. saving money and time, might get lost. By replacing parameter values and data for the independent variables in the model (7) household willingness-to-pay at the policy site can be calculated. Problems can occur if relevant variables have been excluded in the original study (because of lack of variation if only one or few sites are included) or if the study exhibits methodological flaws (Navrud (2000)).

Some of the independent variables, especially recreation quality and measure of cost and quality of substitutes are often very difficult to determine for both, study and policy site. Extreme caution need therefore be exercised when transferring functions when the proposed recreational area does not closely resemble the study area. The same is valid when the new site ends up being a substitute site for the study area. If both sites end up sharing the same catchment area, using the demand specification from the study site would overestimate recreational benefits from creating a new site.

3.1.4 Meta-analysis

The previous BT methods have focussed on finding the most suitable benefit estimate or function from a range of available studies valuing the same type of environmental good or disamenity. Instead of focusing on just one study and relying on the "search-for-identical-conditions" (Santos (1998)), it might be useful to extract information on benefit values from a range of available studies by conducting a so-called meta-analysis. Meta-analysis originated in medical and psychological research, where it is a common tool employed to summarise results of different tests of treatments and medicine in a quantitative way. As defined by Brouwer et al. (1999) –"... meta-analysis is the statistical evaluation of the summary findings of empirical studies, helping to extract information from large masses of data in order to quantify a more comprehensive assessment." In this sense meta-analysis differs from the simple pooling of multiple case studies to derive a pooled benefit function as it is based on independent studies from distinct research programs (Bal and Nijkamp (2001)).

A meta-analysis investigates the relationship between benefit estimates (i.e. WTP) of different studies and the specific features of the environmental good to be valued and assumptions of the models used. For the practical application this means employing regression analysis where different study WTP-results are treated as the dependent variable. WTP is then explained by independent variables that according to Schipper et al. (1998) can be broadly divided up into the two categories of (a) sample population and site-specific characteristics, which describe location and/or socio-economic characteristics of the original study and (b) study characteristics, i.e. number of variables, date of data collection or publication, country. Thus a a meta-regression model could be set up according to

$$WTP_{ij} = \beta_0 + \beta_1 METHOD_{ij} + \beta_2 SITE_{ij} + \beta_3 SOCECO_{ij} + \varepsilon_{ij} \qquad (8)$$

where

WTP_{ij} = WTP estimate i from study j

$\beta_0, \beta_1, \beta_2, \beta_3$ = coefficient vectors

METHOD, SITE, SOCECO = vector of method, site and socio-economic variables respectively.

Most original studies were not conducted and described with the idea in mind that the results could be applied in further empirical analysis at a later time. Therefore studies often lack information on the specific characteristics of the study site, the changes in environmental quality valued, income and other socio-economic characteristics of the sample population (Navrud (2000)). Thus especially information about the first category is often missing in publications. Another potential problem in using meta-analysis for BT-purposes is the existence of publication bias (also called selection bias or availability bias), i.e. the fact that only studies with significant results tend to be published in peer reviewed journals.

Generally there are huge differences in the number of studies included in the different meta-analyses. One study can include multiple surveys covering different population samples or employing different elicitation techniques, survey formats or tests for embedding and other problems encountered in contingent valuation studies. These different surveys might report their results or estimation with varying degrees of truncation resulting in multiple observations per survey implemented. Multiple results from the same study are often treated as independent observations and are included in the analysis in line with results from other studies without testing for intra-study correlation. This however, causes a problem as taking different WTP estimates from the same study introduces a panel structure (Santos (1998)) that causes correlation between residuals of individual observations, also called heteroskedasticity, which need to be controlled for using the appropriate techniques (Desvousges et al. (1998)).

Meta-analysis can be used to explain variations in results across studies. The calculated meta-function can than potentially be used to transfer values (i.e. recalculate them) for policy sites by substituting independent variables with policy site values. Alternatively single coefficients derived from meta-analysis can be used to adjust unit values or benefit functions from a single study. Advantages of meta-analysis over other types of benefit transfer are according to Rosenberger and Loomis (2000): (a) The potential for utilising information from a variety of different studies and (b) the possibility to control for methodological differences when using the meta-analysis function for benefit transfer purposes. Multi-activity, multi-site meta-analyses of for example recreational activities might according to Rosenberger and Loomis (2000) be used for projecting estimates for new or unstudied activities in regions where these particular activities have not been surveyed yet.

Meta-analyses have been conducted for a wide range of environmental goods and services, e.g. outdoor recreation, air pollution, rare and endangered species and wetland ecosystem functions, to name just a few. Table 3 provides a summary of meta-analyses published. Revealed and stated preference methods for valuation are equally represented. Meta-summaries of hedonic pricing studies actually bear a certain resemblance to the so-called second stage estimation, where multiple markets are combined in order to estimate a behavioral function (Smith and Huang (1995)). However, meta-analyses lack the necessary information about microlevel data on each home owner. Thus they only are able to reflect an average of marginal values estimated under varying conditions.

Table 3 Summary of meta-analyses

Topic	Study	Valuation technique
Agricultural landscape conservation	Santos (1998)	CV
Air pollution	Smith and Huang (1995)	HP
Aircraft noise	Schipper et al. (1998)	HP
Fresh water fishing	Sturtevant et al. (1995)	TC
Groundwater	Boyle et al. (1994)	CV
Groundwater quality	Poe et al. (2001)	CV
Mortality rates, short-term morbidity	Desvousges et al. (1998), chapter 4	Dose-response studies, CV
Outdoor recreation	Rosenberger and Loomis (2000)	CV/TC
Outdoor recreation	Smith and Kaoru (1990b); Smith and Kaoru (1990a)	TC
Outdoor recreation	Walsh et al. (1992)	CV/TC
Outdoor recreation use values	Shrestha and Loomis (2001), Shrestha and Loomis (2003)	CV/TC
Rare and endangered species	Loomis and White (1996)	CV
Recreation, environmental amenities, health risks	Carson et al. (1996)	HP/TC/CV/DE/market prices
Visibility at national parks	Smith and Osborne (1996)	CV
VSL based on labor-market studies	Mrozek and Taylor (2002)	HP
VSL for developing countries	Bowland and Beghin (2001)	HP
Wetland ecosystem functioning	Brouwer et al. (1999)	CV
Wetland services	Woodward and Wui (2001)	CV/TC/NFI/RC/HP
Woodland recreation	Bateman and Jones (2003)	
Woodland recreation	Bateman et al. (1999)	CV

Source: Brouwer (2000), p. 142, table 3 and newer studies added by the author.

[a] TC, travel costs; CV, contingent valuation; HP, hedonic pricing; DE, defensive expenditures; NFI, net-factor income; RC, replacement costs

3.2 Guidelines for benefit transfer

Although there does not exist a systematic process for conducting benefit transfer, some researchers and environmental agencies have suggested their own set of guidelines (e.g. EPA (2000), National Oceanic and Atmospheric Administration (1994), Boyle and Bergstrom (1992)). Official Danish guidelines for benefit transfer are under preparation (Navrud (forthcoming)). The essential steps can be summarised as follows:

Step 1. Description of the policy case[16]

The policy site or case should be described clearly, stating all characteristics and consequences, including the population impacted by the proposed policy. It is essential to clarify if a policy affects the general population or only subgroups, e.g. children, users of a recreational site) as this might be used to aggregate per person or per household estimates. According to Kask and Shogren (1994)

16 Kask and Shogren (1994) suggest a detailed transfer protocol for stage 1 covering three intermediate steps: commodity specification, sample and site characteristics and market and exchange mechanisms.

the description of the policy case should also include an indication of the level of precision that is needed for the estimate(s).

Step 2. Identification of existing studies/ conducting a literature search

The literature search should include published literature, e.g. survey articles, books and reports, but also if possible identify the so-called "gray" literature, i.e. unpublished research, works in progress and governmental publications. Helpful tools here are databases for valuation studies, e.g. Environmental Valuation Reference Inventory (EVRI), a Canadian web-based database (http://-ww.evri.ec.gc.ca/EVRI/), ENVALUE, an Australian based database (http://www.epa.nsw.gov.au/envalue/) and the UK Department for Environment, Food & Rural Affairs' Environmental Valuation Source List for the UK (http://www.defra.gov.uk/environment/evslist/05.htm.. Access to EVRI, however, is costly and the UK list is only sorted by author not subject. Recently a Swedish valuation study database has been assembled, called ValueBase^{SWE} (http://www.beijer.kva.se/valuebase.htm).

Step 3. Check for quality and applicability of available studies

Quality control is often difficult and dependent of the type of valuation method applied in the original study. Applicability will depend on whether available studies are comparable to the policy situation, i.e. whether the environmental assets to be valued are equivalent, baseline and change in environmental quality are similar and whether the affected populations are comparable. For recreational activities study and policy sites should obviously support similar recreational activities, similar quality of recreational experience and availability of substitutes (Kirchhoff et al. (1997)). If important differences exist between study and policy site it is essential to determine if adjustments can be made to the original results. It might even be possible in some cases to discuss the intended use with the author(s) of the original study.

Step 4. Transfer of benefit estimates

Transfer of benefit estimates following one of the methods outlined in the previous chapters, i.e. unit values transfer (with or without adjustments), benefit function transfer or conducting a meta-analysis and than applying the estimated meta-function to the policy site.

Step 5. Uncertainty description /assessment

All assumptions and judgements should be stated clearly and their potential impact on the final results analysed, if possible in the form of a sensitivity analysis. There exist specially designed computer programs for conducting sensitivity analysis that can be directly linked to spreadsheet programs, e.g. @RISK. In contrast to simple adhoc sensitivity analyses where single parameter are changed one at a time these programs allow the definition of distributions for the different parameters and can thus simulate the potential outcome taking the interrelationships between different uncertain cost and benefits into account.

4 Summary of main results

In this Ph.D. study the hedonic pricing method was applied to housing data from three different afforestation areas, Drastrup afforestation project, located close to Aalborg in the northern part of Jutland, Kirkendrup afforestation project located on the island of Fyn, north-west from Odense and Sperrestrup afforestation area in the northern part of Zealand. A detailed description of the study approach and results from this empirical analysis and the testing for accuracy of benefit transfer of these results between study areas are presented in the two main articles of this Ph.D. thesis, Article 3: Birr-Pedersen, K.: "Omitted variable bias in estimating amenity values from afforestation areas in Denmark" and Article 4: "Testing the transferability of amenity values from afforestation areas in Denmark". The following section provides a summary of the main findings.

Regression results are determined by applying the hedonic pricing method as described in Chapter 2. Two basic types of models were estimated for each case study area. A "simple" model, which only contained the classical structural housing variables, the distance to the new forest area and dummy variables for sub-markets where applicable and an "advanced" model, that in addition to the variables of the simple model did include a range of other location-related variables that might have a positive or negative effect on housing values.

For each of these two general model types three different transformations of the distance to new forest variable were tested, one where the variable remained untransformed, one where it was log-transformed and one where distance was entered as its reciprocal value. In all models the coefficient for distance to new forest had the expected negative sign for the un-transformed and log-transformed variables and positive sign for the reciprocal transformation (with the exemption of the simple model for Sperrestrup), thus indicating that house prices decrease with increasing distance from the forest edge. The reciprocal transformation was not statistically significant in any of the three areas, neither in the advanced nor in the simple models. The untransformed distance proved to be statistically significant in all models besides the simple model for the Drastrup area. The log-transformed distance to new forest areas was only significant in the simple model for the Sperrestrup area and in both the advanced and simple model for Kirkendrup afforestation area. Table 4 provides a summary of parameter results for the distance to new forest measure for those models where the estimated coefficient for distance to new forest was significant at the 10 % level (or close to significant as in the Drastrup simple model).

Table 4 Summary of parameter results and calculated marginal prices for the models with significant parameter of distance to new forest[17]

Forest	Drastrup		Kirkendrup				Sperrestrup	
Transformation of distance to new forest areas	No transformation (semi-log)		No transformation (semi-log)		Log transformation (double-log)		No transformation (semi-log)	Log transformation (double-log)
Model type	Simple	Advanced	Simple	Advanced	Simple	Advanced	Simple/Advanced	Simple
N Obs	185	185	476	476	476	476	259	259
Size of forest area (ha)	232	232	75	75	75	75	115	115
Parameter value	-0.000089	-0.000312	-0.000053	-0.000075	-0.034	-0.040	-0.000053	-0.024
P-value	0.159	0.005	0.004	0.001	0.005	0.003	0.000	0.005
Standard error	0.000063	0.000109	0.000019	0.000023	0.012	0.013	0.000014	0.008
95 % CI up	0.000035	-0.000096	-0.000017	-0.000031	-0.010	-0.014	-0.000025	-0.007
95 % CI low	-0.000213	-0.000527	-0.000090	-0.000120	-0.057	-0.066	-0.000081	-0.040
Average house price (DKK)	1,479,584	1,479,584	1,370,993	1,370,993	1,370,993	1,370,993	1,756,401	1,756,401
Average distance to forest (m)	402	402	977	977	977	977	1236	1236
Implicit price at average distance (DKK)	-132	-462	-73	-103	-47	-56	-93	-34
Implicit price 95 % CI up (DKK)	52	-142	-23	-42	-14	-19	-44	-10
Implicit price 95 % CI low (DKK)	-315	-780	-123	-164	-80	-92	-142	-57
R^2	0.684	0.686	0.574	0.610	0.573	0.609	0.692	0.686
Adj R^2	0.674	0.673	0.569	0.603	0.569	0.601	0.682	0.675
AIC	-133.2	-132.2	-296.0	-330.9	-295.9	-329.0	-413.8	-408.6
BIC	-110.7	-106.5	-271.0	-289.3	-270.9	-287.4	-381.8	-376.5
Calculation of total value per afforestation area								
Maximum distance in dataset (m)	1000	1000	1700	1700	1700	1700	2000	2000
Total number of one-family houses within max distance	381	381	1,080	1,080	1,080	1,080	350	350
Average price increase per house (DKK)	58,963	222,911	26,855	37,740	16,063	18,850	67,155	25,518
Total value of afforestation area (million DKK)	22.5	84.9	51.4	72.3	30.8	36.1	23.5	8.9
Value per ha (DKK)	96,832	366,073	685,699	963,636	410,151	481,305	204,385	77,662

The results presented in Table 4 show the large variations of implicit prices per meter across models and datasets, ranging from -34 to -462 DKK/m. But also "within model" variation can be high, i.e. the uncertainty attached to the individual parameter estimates illustrated by the width of the confidence intervals. For example does the implicit price per meter based on the Drastrup advanced model range from -142 to -780 DKK/m.

17 The results for the simple Drastrup models are included here as the parameter estimate for the distance to new forest measure was nearly significant and in order to show the large variations in results for this area based on the inclusion of other location-related variables.

Results for Sperrestrup and Kirkendrup are surprisingly similar, while the effect of forest proximity in Drastrup seems to be unusually large in the advanced model. In both the Drastrup and Kirkendrup datasets advanced models produced a higher price-distance gradient for distances to new forest areas than the simple models.

Results partly confirm what earlier studies in Denmark have found (Hasler et al. (2002a), Anthon et al. (2005), Præstholm et al. (2002)), i.e. forest areas are perceived as an amenity for house owners and at least part of these benefits are already in place within few years after planting started. Other European studies with similar results are Tyrväinen (1997), Garrod and Willis (1992a) and Tyrväinen and Miettinen (2000), while Thorsnes (2002) shows a positive proximity effect for forest areas for areas in Michigan, USA.

All of the previous Danish studies of forest amenity values have used simple models without incorporating other spatial measures that might affect housing values. Tyrväinen (1997) and Tyrväinen and Miettinen (2000) included distance measures to small forest parks, watercourses, beaches as well as distance to schools, shopping centres etc., but did not explicitly analysis the effect an omission of these extra spatial variables would have on the distance to urban forest measure. As can be seen from the results from this study differences in terms of coefficient results for forest proximity between simple and advanced models for the same case study area indicate that omitted variable bias might have an effect on the estimation of marginal prices for this land category. However, the effect can work both ways. In Drastrup and Kirkendrup including other spatial measures increases the size and significance level of the coefficient for the untransformed distance to new forest measure, while it reduces the positive effect of forest proximity in the case of Sperrestrup for the log-transformed distance to new forest measure.

The sensitivity of the coefficient for distance to new forests to the inclusion of other spatial variables has been tested in two ways, first by using a "bottom-up" approach, i.e. starting with the simple model and incorporating one other spatial measure (in addition to the distance to new forest measure) and by using a "top-down" approach, where based on the advanced model one spatial measure was deleted (and all other spatial measures remain in the model if they prove to be significant).

Results from the sensitivity analyses indicate that partial inclusion or exclusion of other location-related variables can have substantial impact on the parameter estimate of the distance to new forest measure. The direction of omitted variable bias can go both ways, i.e. decrease or increase the significance level and size of parameter estimates. Because of the inherent multicollinearity between spatial variables it is basically impossible to postulate the direction of bias before conducting the analysis.

The parameter results from the advanced models were subsequently used to calculate price differences for houses located at varying distances from the forest edge. The results for the three areas are summarizes in Table 5. Detailed parameter results for all three areas are presented in Appendix 5. Results for the semi-log models for Sperrestrup and Kirkendrup are surprisingly similar with price differences of 10-12 % for houses located within 100m from the forest edge and going down to about 5 % for 1000m distance. Compared to these two areas percentage increases in Drastrup seem to be unusually large with average values between 32 % and 13 % for the first 100m – 600m distances. In general the uncertainty attached to the percentage increases in high, especially in the Drastrup area, where percentage increases for houses within 100m to the forest edge vary between 9 % and 60 %, with an average increase of 32 %.

Table 5 Price differences (in %) for houses located at different distances from forest edge compared to houses at maximum distance in dataset including confidence intervals (CI)

	Drastrup		Kirkendrup				Sperrestrup	
Distance to forest edge	No transf. (semi-log)	(CI low - CI up)	No transf. (semi-log)	(CI low - CI up)	Log transf. (double-log)	(CI low - CI up)	No transf. (semi-log)	(CI low - CI up)
100	32.4	(9.0 - 60.7)	12.8	(5.0 - 21.1)	12.0	(4.0 - 20.5)	10.5	(4.8 - 16.5)
200	28.4	(8.0 - 52.5)	12.0	(4.7 - 19.7)	8.9	(3.0 - 15.1)	10.0	(4.6 - 15.6)
300	24.4	(7.0 - 44.6)	11.1	(4.4 - 18.3)	7.2	(2.4 - 12.1)	9.4	(4.3 - 14.7)
400	20.6	(5.9 - 37.2)	10.3	(4.1 - 16.9)	5.9	(2.0 - 10.0)	8.8	(4.0 - 13.8)
500	16.9	(4.9 - 30.2)	9.5	(3.7 - 15.5)	5.0	(1.7 - 8.4)	8.2	(3.8 - 12.9)
600	13.3	(3.9 - 23.5)	8.6	(3.4 - 14.1)	4.2	(1.5 - 7.1)	7.7	(3.5 - 11.9)
700	9.8	(2.9 - 17.1)	7.8	(3.1 - 12.7)	3.6	(1.2 - 6.0)	7.1	(3.3 - 11.0)
800	6.4	(1.9 - 11.1)	7.0	(2.8 - 11.4)	3.0	(1.0 - 5.1)	6.5	(3.0 - 10.2)
900	3.2	(1.0 - 5.4)	6.2	(2.5 - 10.1)	2.6	(0.9 - 4.3)	6.0	(2.8 - 9.3)
1000	0.0	(0.0 - 0.0)	5.4	(2.2 - 8.8)	2.1	(0.7 - 3.6)	5.4	(2.5 - 8.4)
1100	-	-	4.6	(1.9 - 7.5)	1.8	(0.6 - 2.9)	4.9	(2.3 - 7.5)
1200	-	-	3.8	(1.5 - 6.2)	1.4	(0.5 - 2.3)	4.3	(2.0 - 6.7)
1300	-	-	3.1	(1.2 - 4.9)	1.1	(0.4 - 1.8)	3.8	(1.8 - 5.8)
1400	-	-	2.3	(0.9 - 3.7)	0.8	(0.3 - 1.3)	3.2	(1.5 - 5.0)
1500	-	-	1.5	(0.6 - 2.4)	0.5	(0.2 - 0.8)	2.7	(1.2 - 4.1)
1600	-	-	0.8	(0.3 - 1.2)	0.2	(0.1 - 0.4)	2.1	(1.0 - 3.3)
1700	-	-	0.0	(0.0 - 0.0)	0.0	(0.0 - 0.0)	1.6	(0.7 - 2.4)
1800	-	-	-	-	-	-	1.1	(0.5 - 1.6)
1900	-	-	-	-	-	-	0.5	(0.2 - 0.8)
2000	-	-	-	-	-	-	0.0	(0.0 - 0.0)

Table 6 shows the transfer errors for benefit transfer between sites, calculated in per cent as

$$\text{transfer error} = 100 * (WTP_S - WTP_P) / WTP_P \qquad (9)$$

where WTP_S represents the average non-marginal willingness to pay for forest proximity at the study site while WTP_P is equal to the average non-marginal willingness-to-pay at the policy site. For both sites willingness-to-pay is calculated in terms of percentage differences in house prices between the respective distance to the forest edge and the maximum distance in the respective dataset.

Table 6 Transfer errors for distances 100m – 600m and test results, true WTP_P assumed to be known with certainty

Study site	Policy site	100m	200m	300m	400m	500m	600m	Range of absolute transfer errors
		Transfer errors for 100m-distance intervals (in %) (Standard errors in parentheses)						
Drastrup dnewforest	Kirkendrup dnewforest	153	137	120	100	79	54	54 - 153
		(102)	(94)	(86)	(77)	(68)	(57)	
Drastrup dnewforest	Kirkendrup Innewforest	171	218 $	241 $	247 $	238 $	214 $	171 – 247
		(109)	(126)	(133)	(133)	(128)	(117)	
Drastrup dnewforest	Sperrestrup dnewforest	208 $	185	160	134	105	74	74 – 208
		(124)	(113)	(102)	(90)	(78)	(65)	
Kirkendrup dnewforest	Drastrup dnewforest	-61$ *	-58 $ *	-54 $ *	-50 $ *	-44 $ **	-35 $ **	35 – 61
		(13)	(13)	(14)	(16)	(18)	(20)	
Kirkendrup Innewforest	Drastrup dnewforest	-63 $ *	-69 $ *	-71 $ *	-71 $ *	-70 $ *	-68 $ *	63 – 71
		(13)	(11)	(10)	(10)	(10)	(11)	
Kirkendrup dnewforest	Sperrestrup dnewforest	22 *	20 *	19 *	17 *	15 **	13 **	13 – 22
		(39)	(38)	(38)	(37)	(36)	(35)	
Kirkendrup Innewforest	Sperrestrup dnewforest	14 *	-11 **	-24 **	-33 **	-39 $ **	-45 $ *	11 – 45
		(40)	(31)	(26)	(23)	(21)	(19)	
Sperrestrup dnewforest	Drastrup dnewforest	-68 $ *	-65 $ *	-62 $ *	-57 $ *	-51 $ **	-42 $ **	42 – 68
		(9)	(10)	(11)	(12)	(14)	(16)	
Sperrestrup dnewforest	Kirkendrup dnewforest	-18 **	-17 **	-16 **	-14 **	-13 **	-11 **	11 – 18
		(23)	(23)	(24)	(24)	(24)	(25)	
Sperrestrup dnewforest	Kirkendrup Innewforest	-12 **	12 **	31 *	48	65	81	12 – 81
		(25)	(31)	(37)	(41)	(46)	(50)	
	Range of absolute transfer errors	12 - 208	11 - 218	16 - 241	14 - 247	13 - 238	11 - 214	

$: Rejection of null hypothesis of equality H_0

Accept of alternative hypothesis H_1 with the following limits of tolerance: ***50 %, **75 %, *100 %

Transfer errors vary between an underestimation of benefits by 11 % and an overestimation of benefits by 247 %. As expected errors are largest for transfers between Drastrup and the two other afforestation areas. The comparison of willingness-to-pay estimates between Kirkendrup and Sperrestrup showed that absolute transfer errors between these two areas are within the range of 11-81 %. Using results from the semi-log models for these two areas reduces the error range to 13-22 % overestimation or 11 to 18 % underestimation. This allows a positive outlook towards their potential for application in future policy evaluation exercises. Results for these two areas are also similar to those obtained in earlier studies in Denmark, e.g. Hasler et al. (2002a) for old forest areas and Anthon et al. (2005) for afforestation areas. Applying WTP estimates from Drastrup to the other two areas results in average transfer errors well above 100 %, showing the high uncertainty involved in using benefit transfer. Given that estimates for this area are substantially different from the other two areas in this study and previous study results, their application in benefit transfer exercises is not recommended.

Testing for accuracy of benefit transfer based on these study results was done using two different tests, the classical test that assumes equality in the null-hypothesis and so-called equivalence testing, where null- and alternative hypothesis are reversed and inequality is assumed in the null-hypothesis. Test results are reported in Table 6 for the transfer situation where the true willingness-to-pay at the policy site is assumed to be known with certainty. As can be seen in Table 6 equality of transfers from Kirkendrup to Drastrup and from Sperrestrup to Drastrup are rejected at the 10 % level for all distance intervals. Transfers in the opposite direction, i.e. from Drastrup to the two other areas are only rejected for five out of six from Drastrup to Kirkendrup, where true WTP_P is based on the double-log model and one out of six for transfers from Drastrup to Sperrestrup. Thus in quite a lot of cases H_0 could not be rejected despite the fact that transfer errors are larger than 100 %.

Reason for the failure to reject H_0 is clearly the large uncertainty attached to the parameter estimates for forest proximity. Standard errors in all models are high because of the relatively few observations available for each area. Thus this case study illustrates the drawbacks associated with using the classical null hypothesis of equality as pointed out by Kristofersson and Navrud (2005), where increasing variances of parameter estimates actually increase the likelihood that the null hypothesis of equality will not be rejected.

The results of the equivalence tests are likewise incorporated into Table 6, where the transfers for which the null hypothesis can be rejected are marked with stars. None of the transfers can reject the null hypothesis of difference between values when the acceptable error margins are set to 50 %, despite the fact that the average transfer error between Kirkendrup and Sperrestrup (in both directions) in the majority of cases is below 50 %. 14 out of 24 transfers between these two areas can be accepted with error margins of 75 % in the case where WTP_P is assumed be known with certainty. Seven transfer are only acceptable with error margins of 100 % while for three transfers the null hypothesis of inequality can not be rejected even with 100 % acceptable transfer error.

All of the transfers from Kirkendrup and Sperrestrup to Drastrup are acceptable with errors of 100 %, which can be explained by the fact that an underestimation of more than 100 % could only occur in cases where negative WTP_S would have been transferred (see formel (9)). However, a few transfers are also acceptable with errors of 75 %.

5 Discussion and Conclusion

This Ph.D.-research project has contributed to the existing research and on-going debate on the issues of hedonic pricing and benefit transfer in two ways. Firstly results show the potential impact omitted variable bias can have on the implicit prices calculated for the non-market good of interest. The hedonic pricing models in this research project have been supplemented by a range of other spatial variables. In addition to the "classical" structural attributes of houses, i.e. size of living area, lot size, number of rooms and the distance to the new forest areas, the models include other landscape features, like distance to wetlands and lakes. Also other typical (sub-) urban location-related attributes are included, i.e. distance to industry areas, small urban recreational areas, distance to central station and distance to schools and childcare institutions. By comparing the results from these "advanced" models to the estimated parameters based on more "simple" models it was possible to test the sensitivity of the parameter results for the distance to new forest areas for omitted variable bias.

Secondly the results from the advanced models have been tested for accuracy in a potential benefit transfer exercise which illustrates the uncertainty attached to the application of results from the hedonic pricing method in policy evaluation. The price gradients for the distance to new forest measures are presented as percentage differences for 100m intervals from the forest edge up to the largest distance measured in the respective datasets. This simplifies the comparison of results between models that are based on separate markets, result in different parameter estimates for the attribute of interest and different marginal prices for the distance to new forest areas. It reflects also better the policy relevant situation where the placement of a new afforestation project should be evaluated.

By using the average pre-afforestation house price in an area it is possible to calculate the predicted price increase for 100m intervals up to the forest edge, using the amount of one-family houses located within each interval range. Given that all houses are spatially reference in the Danish housing registers it should be relatively straight forward to "count" these houses for each policy site. Many Danish municipalities have ambitious objectives with regard to the establishment of urban forest areas. Both Sperrestrup and Kirkendrup have shown amenities values that are not only similar to each other but also resemble earlier results from Danish forest studies using the hedonic pricing method. The percentage effects for these areas could be transferred to potential policy sites and thus be included in cost-benefit analyses and siting decisions.

However, benefit transfer should always be accompagnied by sensitivity analysis. The uncertainty attached to benefit transfer of unit values from the empirical studies in this Ph.D. project has been evaluated by calculating potential transfer errors for inter-area transfers of the three areas involved in this project and by testing for statistical equality and equivalency of percentage differences between areas. Results show that even in transfer cases between rather similar areas like Sperrestrup and Kirkendrup none of the transfers within the first 600m from the forest edge can be accepted as equivalent using equivalence testing with limits of tolerance of 50 % transfer error. Only at transfer errors of 75 % or more can the working hypothesis of equality between sites be accepted in all transfers between Sperrestrup and Kirkendrup and vice versa, although average transfer errors between these two sites are in the range of 11-22 %.

This might be an indication that deciding on margins for sensitivity analysis based on average transfer errors from studies testing for transferability is underestimating the uncertainty attached to benefit transfer exercises. Average transfer errors or even ranges of transfer errors calculated in those studies are based on comparison of mean values and do not account for the variance of individual willingness-to-pay estimates. The variance or uncertainty can better be captured by equivalence testing. Thus it would be interesting to see further applications of these tests such that at some point information about what limits of tolerance were generally achievable could serve as guidance for sensitivity analysis recommendations.

While the evaluation subject in this project was amenity values from afforestation areas, the experiences can directly be extrapolated to other potential applications of the hedonic pricing method in Denmark and elsewhere, e.g. disamenities from landfills and animal farming activities or noise disturbances from traffic in urban areas. The GIS-based benefit transfer methodology presented here can easily be adapted to also include for example the effect of wind directions for the transfer of house price decreases in these other HPM applications.

In general, GIS has proved to be a valuable tool in applying the hedonic pricing method at various stages of its implementation. In the data generation process GIS was necessary to measure the direct distances to various location-related characteristics. In the data analysis stage GIS was extremely useful in highlighting the placement of outlier observations, identifying sub-markets and selecting the observations belonging to them. Last but no least in the presentation of results GIS provided tools in the form of maps.

ArcGIS 9 includes tests for spatial autocorrelation or spatial heterogeneity, i.e. the fact that error terms in estimated models are related to those of neighboring dependent variables (see e.g. Taylor (2003)). The three "advanced" semi-log models (one for each case study area) were tested for spatial autocorrelation using the tool in ArcGIS 9. Based on the test results none of these models show signs of spatial autocorrelation, but further research in this area should clearly be conducted, e.g. by testing simple models and models with varying amounts of location-related characteristics in order to see if these extra variables reduce the potential for spatial autocorrelation in hedonic pricing models.

If time would not have been an issue lots of other research areas could have been investigated under this Ph.D. They are shortly described below and might serve as an inspiration for future work in this area.

Besides the effect of omitted variable bias estimation result are also sensitive to the size of the local market selected for analysis as shown in the case of Kirkendrup. Here the original radius of 2000m from the forest edge proved to be too large to allow the measurement of the proximity effect of the afforestation area. While in this particular case study area the explanation was obviously, i.e. the proximity of a larger urban area, Odense city, that at some point did overshadow the effect of the afforestation area, a more thorough analysis of the extend of the local market on the estimated implicit prices and the total value of the afforestation areas is certainly warranted. The selection of larger datasets from the start would have provided chance of investigating the maximum extend of localised externalities from forests. Other hedonic pricing studies, for example Ready and Abdalla (2005), have used different index constructions in their estimations that allow the determination of where exactly the impact of a (dis-)amenity expires. This is certainly one type of analysis that would be worthwhile exploring further.

Another subject that has not been examined further in this study is the question of what variables house owners actually consider in their choice of residence. The assumption that a particular set of characteristics affect housing values (and thus is part of the preference function of the house owner), could be verified by interviewing local real estate agents and house buyers, both those that have just started their search for a new residence and those that recently have found a new place to live.

The analyses in this Ph.D. project have been entirely based on the period after afforestation was started in the different areas. This allows the measurement of a price-distance gradient but does not capture the value from a positive effect for the entire local area surrounding the afforestation area, if such an effect did happen, as this basic area effect would have been present in all house prices. Hasler et al. (2002a) used dummies for different time periods, i.e. planning stage, planting stage and after planting stage in order to capture the area effect. Similar attempts to elicit the positive or negative area effects using the hedonic pricing method have been undertaken in studies by Hallstrom and Smith (2005) for market responses to hurricane risks, Murdoch et al. (1993) for earthquake risks and Loomis (2004) for the effect of forest fires on housing values in an area. The problem with these approaches is that one must be very certain that no other impact has happened at the same time.

Afforestation in Denmark takes place almost entirely on former agricultural land areas. It might well be possible that these former agricultural areas had a positive or negative effect on nearby residential areas, depending on their previous intensive or extensive farming practices. Further estimations based on the datasets for the three areas could thus include before afforestation house sales and interact their distance to the afforestation areas or former agricultural land area with a time dummy. Similar approaches have been done by Ihlanfeldt and Taylor (2004) who used two different distance measures with cross-reference to the time period, before and after a hazardous waste site was listed officially in order to capture the information effect on housing values.

Based on revealed preference data there are basically two types of models to value product attributes: The hedonic pricing model (HPM) developed by Rosen (1974) and the random utility model (RUM) developed by McFadden (1978). In the environmental valuation literature, the HPM is mostly applied to the housing market. RUMs have primarily been applied to recreational choices, despite the fact that one of the most influential articles in developing the methodology, McFadden (1978), actually discussed the application of RUM to housing choices.

It could be interesting to attempt to identify demand functions for amenity values based on revealed preference data from the housing market by applying two different estimation methods to the same data set: (1) the second stage of the hedonic pricing method and (2) a random utility model (RUM). Applying both methods to the same data set does allow (a) to compare results from RUM and hedonic pricing analysis and (b) use both methods in a benefit function transfer exercise in order to see if one of them yields more accurate results.

Evidence from former studies using the same approach is, however, rather mixed. While the simulation exercises from Quigley (1986) and Mason and Quigley (1990) show a better performance of the HPM compared to the RUM, results from Cropper et al. (1993) indicate that RUM has substantially lower absolute errors when estimating non-marginal WTP. Studies using real housing market data (Palmquist and Israngkura (1999) and Chattopadhyay (2000)) show equally diverging results.

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Appendix 1, Article 1
The inclusion of secondary benefits in the cost-effectiveness analysis of nitrogen reduction measures in agriculture

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Abstract

Over the past few years a large number of studies have explored cost-effective strategies for reducing nitrogen loads from agriculture. However, the majority of these studies focus alone on financial costs to agriculture in spite of the fact that a number of relevant measures, e.g. establishment of wetlands and reduced livestock hold, lead to significant secondary environmental benefits. Ignoring these benefits risks the pursuit of inefficient policy recommendations. In this paper we identify the relevant secondary effects of four measures to reduce nitrogen loads from agriculture using an example of cost-effectiveness analysis (CEA) based on financial and socio-economic cost estimates, and demonstrate the implications of including secondary benefits.

Keywords: Benefit transfer, Cost effectiveness analysis, Nitrogen loads, Secondary effects

Introduction

Over the last 30 years the detrimental environmental effects resulting from nitrate losses from agriculture and other sectors have been focussed on in the environmental policy in Northern Europe. Beside various national regulations, the problem is addressed by HELCOM (2005), in the EU Nitrate Directive, in the Water Framework Directive, and by other policy recommendations of the EU and OECD. This focus has also resulted in a number of economic studies analysing measures for reducing nitrogen losses from agriculture. These studies most often use cost-effectiveness analysis, where the aim is to appoint the cost-minimising strategies resulting in a pre-defined environmental target. Among the large empirical literature e.g. Söderqvist, T. (2002), Hart, R. and M. Brady (2002), Schou, J. S. et al. (2000), Gren, I. M. (1999), Pan, J. H. and I. Hodge (1994), a common feature is that all cost estimates represent solely financial costs to the agricultural sector.

Regulating nitrogen emissions from agriculture also influences other environmental pressures such as emissions of ammonia and climate gasses. In addition, regulations result in changes in land use, which directly influence the supply of goods related to biodiversity and landscape. From a socio-economic point of view these secondary costs and benefits should be reflected in the cost estimates.

As these secondary effects are closely related to the fulfilment of countries' obligations under the recently implemented Kyoto protocol and the EU Habitat Directive, governments are trying to include at least some of them in policy analyses. For example, when preparing the third Danish Aquatic Action Plan in 2003-04 an attempt was made to quantify the secondary environmental effects of air emissions and include these in the economic analysis using the shadow price approach. Secondary effects resulting from changes in biodiversity and landscape were, however, not considered.

In this paper we discuss previous cost-effectiveness analyses (CEA) and show how recreational and amenity benefits can be included using the benefit transfer approach, based on existing valuation studies from Denmark and other Scandinavian countries. The consequences of including these secondary benefits in policy analyses are demonstrated by presenting results from financial and socio-economic cost-efficiency analyses of four selected policy measures.

The paper describes the measures used in this cost-effectiveness analysis and presents the secondary environmental effects of the measures together with an outline of possible ways to include them in socio-economic analysis. The benefit transfer approaches used for market values, amenity and recreational values are outlined subsequently, while the next section focuses on the shadow price approach used for emission reductions. The results are presented therafter, while the last section – based on the results from this analysis - argues for a cautious approach to benefit transfer, especially in cases where policy options can only be described and evaluated at a general level.

Description of measures

The measures discussed and applied when regulating agricultural nitrogen loads lie within two groups; measures regulating input use, livestock production and crop rotation, and measures changing land use. This first type of measures reduces production intensity or gives incentives for implementing environmental friendly production technologies, but agricultural production is basically maintained. This group includes reduced nitrogen input, wintergreen fields, restrictions on manure application, etc. The second type of measures changes land use permanently e.g. by establishing wetlands, extensive grasslands, buffer strips or through afforestation.[18]

Four measures, all leading to various scales of secondary environmental effects, can be taken as representative of the two types: mandatory reduction in nitrogen fertiliser input on all farms, reduced livestock hold, establishment of wetlands, and afforestation. In our analysis, in order to compare consistently, the measures are scaled to result in a yearly reduction in N loads by 5,000 tonnes, as described in Table 1. All four measures were analysed as part of the preparation of the third Danish Aquatic Action Plan (Jacobsen, B. H. et al. (2004)) although this included only the secondary benefits to air emissions; see Grant, T. and J. Waagepetersen (2003) for an evaluation of the first two action plans.

Table 1 Description of the measures.

Measure	Description
Reduced N input	Reduction of total nitrogen input by 5 percent on all farms
Reduced livestock hold	Reduction of agricultural livestock hold by 12 percent
Wetlands	50 000 ha agricultural land converted into wetlands
Afforestation	135 000 ha agricultural land converted into forest

Source: Anon. (2003).

Costs estimates of policy measures should represent the change in welfare to society caused by implementing the measure. This welfare change is approximated by 'socio-economic rent', calculated as the difference between income (if any) and total costs from implementing the measure. Estimates for the economic value of effects on secondary benefits (e.g. reduction of climate gasses) are included as negative costs.

18 Note as this analysis focuses on secondary environmental effects the starting points are the actual changes in activities, and therefore policies leading to the changes (e.g. taxes, subsidies, quotas or command-and-control) are not considered.

Secondary environmental effects

When applying measures for reduced nitrogen loads from agriculture, a number of secondary environmental effects are likely to occur. These encompass changes in ammonia (NH_4) and climate gas emissions (CO_2, CH_4 and N_2O) and provision of goods related to biodiversity and landscape. The economic value from each type of effect relates to changes in various goods. Ammonia emissions lead to eutrophication of low-nutrient nature locations such as bogs, oligotrophic lakes, dry grasslands and inland heath lands. The effects of changes in ammonia emissions therefore primarily relate to changes in national biodiversity. With respect to climate gas emissions, the impacts are of a global scale and range from impacts on urban settlements and agriculture to biodiversity preservation (see for example ExternE (2003)).

For some measures the secondary benefits relate both to effects resulting from changes in emissions and from direct changes in the provision of different goods. This is the case for establishment of wetlands and afforestation, for which changes in the provision of recreational and biodiversity goods will occur as a direct result from changing land use. The provision of biodiversity and recreational goods at a given location are of course correlated, but not unambiguously. Thus, a location with high biodiversity value does not need to have a high recreational value, as the realisation of recreational values is conditional on accessibility. Conversely, an area with high recreational value need not possess high biodiversity value (e.g. a golf course).

When analysing the economic consequences of changes in land use it is useful to distinguish between use values and non-use values. Using this distinction recreational opportunity is strictly a use value whereas biodiversity leads to both use and non-use values. The types of goods related to biodiversity effects of changes in land use are outlined in Table 2.

For privately-owned wetlands and afforested areas, typically not subject to public access so far as they remain private property, secondary values related to changes in the provision of recreational goods are restricted to the owner, e.g. fishing and game shooting. Their recreational value to the public rises if (as will happen in Denmark) public access is legally guaranteed to all public forests and all privately owned forests larger than 5 hectares.

Table 2 Types of goods related to biodiversity effects

Type of goods	Value function
Use value (amenity and recreational value)	The range of the value depend on public access to the area and distribution of property rights (e.g. fishing and game shooting)
Existence value (non-use)	The value of knowing that a given nature location, nature type, or species exist to day
Bequest value (non-use)	The value of knowing that a given nature location, nature type, or species are preserved for the benefit of future generations

Converting agricultural land into wetlands or forest imposes significant effects on the biodiversity of an area. Whether these conversions have a positive or negative effect on non-use biodiversity values is unclear. For example afforestration will substitute habitats for typical farmland species such as partridge, hare and skylark that today are in decline, with habitats for forest species such as roe deer, which have experienced a steady increase in population over many years.

Although the valuation of non-use goods is a useful concept, it should reflect the net (marginal) change in value. This has not been done in the few Danish studies that exist, which have dealt with the total value of unique nature locations and not changes in "ordinary" biodiversity attributes. Therefore existing studies seem not useful for the purpose of benefit transfer in this case, as the substitution between nature types, i.e. the change in attributes, should be reflected explicitly in the study. Therefore non-use values are not included further in the calculations in this article.

Benefit transfer of use and non-use values

Benefit transfer refers to the practice of transferring non-market values for environmental goods and services from a "study" or "source" site (i.e. the site where an original valuation study was conducted) to the "policy" or "target" site (i.e. the site where benefit estimates are required for decision making). It began to gain attention as a research area about 12-15 years ago, and is now included in every book covering non-market valuation of the environment e.g. Freeman III, A. M. (2003), Champ, P. A. et al. (2003), Haab, T. C. and K. E. McConnell (2002). It has its own chapter in the US Environmental Protection Agency's manual for cost-benefit analysis (EPA (2000)), and a similar OECD handbook is currently under preparation. The different benefit transfer approaches found in the literature can be broadly divided into four categories (Navrud, S. (2004)): unit value transfer; unit value transfer with adjustment, e.g. for income, benefit function transfer and meta-analysis.

Unit value transfer, the simplest way of transferring benefits, consists of applying unadjusted mean or median benefit estimates from the study site at the policy site. Simple unit value transfer basically assumes that the utility gain of an average individual at the study site is the same as that of an average individual at the policy site. This supposition will hardly hold in most circumstances as people at study and policy sites can differ from each other in income, education and other socio-economic characteristics that affect their preferences for, e.g., recreation. Likewise the good to be valued at study and policy site respectively might not be similar enough to be comparable, and the supply of the good and of substitutes might not be stable over time and space. Instead of transferring unadjusted unit values the policy analyst can adjust the value estimates to better reflect differences in socio-economic characteristics between policy and study site, e.g. by use of Purchasing Power Parities.

By transferring the entire benefit function instead of per unit benefit estimates, more information can be transferred between study and policy site. Benefit function transfer can directly account for differences in user and site characteristics. This, however, requires access to an original study where benefits are described as a function of different explanatory variables. A related method is to extract information on benefit values from a range of available studies, so-called meta-analysis. Here the relationship between benefit estimates of a number of different studies is quantified by employing regression analysis where the different study results are treated as the dependent variable, while model characteristics, country, etc. are used as explanatory variables.

The assessment of non-market secondary benefits in this study is entirely based on benefit transfer from existing studies. Given the general character of the policy options analysed unit value transfer is used, albeit in the case of amenity values from afforestation in a form that allows to adjust for income differences between policy and study site. In order to reduce the uncertainty resulting from transferring values as much as possible, most original studies are taken from Denmark.

Market use values

Changes in use-values resulting from the establishment of wetlands and afforestration can be divided into market and non-market effects. The market use values relate to fishing and game shooting as markets exist for some of these activities. Given the typical Danish shallow wetlands, effects on fishing values are likely to be very modest, and can safely be assumed to be zero in this study.

The effect of wetlands on game shooting has been significant in Denmark, because increased wetlands provide extra forage and thereby stocks of waterfowl. The increased value to game shooting of establishing wetlands was estimated by Dubgaard, A. et al. (2001) at 25 - 50 € per hectare for the large nature restoration project "Skjern Å" (about 2,200 hectares). For smaller projects, the benefits are likely to be at the lower end because of the scale dependency of effects on bird stocks. To be conservative, an average value of 25 €/hectare is used in this paper.

Afforestation is also known to increase the value of game shooting rights. This is clear from the mass of empirical evidence collected by the Danish Forest and Nature Agency (FNA), which is responsible for a large number of public afforestation projects. Data from the FNA show an increase in the market value of game shooting permits resulting from afforestation on agricultural land of 25 to 63 €/hectare. Because various restrictions on game shooting are typical in public forests and the value of the permits is therefore expected to be higher in private forest, we expect the average to be in the higher range of the interval and a mean of 50 €/hectare is used in our analysis.

Amenity values from afforestation measures

Amenity[19] values belong to the group of non-market use benefits from afforestation projects. The amenity values from forests would include any extra premium house buyers are willing to pay (WTP) for forest proximity. For the current analysis these values are

19 Amenity values cover all positive (or negative) effects for those households located close to the forests and would normally include fast and easy access to a recreational area, clean air and greener environment, but also view over forest landscape and possible the absence of further urban development options on the forested area.

measured using average unit WTP values per house for different distance intervals to the forest edge, using data from two Danish hedonic pricing studies (Hasler, B. C. et al. (2002a)/Hasler, B. C. et al. (2002b), Anthon, S. et al. (2005)/Anthon, S. and B. J. Thorsen (2002)). Both studies found a positive effect of proximity to forest and afforestation areas, using distance to the forest edge as the explanatory variable.

Figure 1 shows the percentage of the average house price that can be attributed to forest proximity for the four areas. The assumption on which benefit transfer is based is thus that the value of proximity to forests in policy sites will fall within the range of values estimated for different study sites in Denmark. By using percentage, we are also able to account for income differences and supply conditions at the policy site, thus allowing for some form of adjusted value transfer.[20]

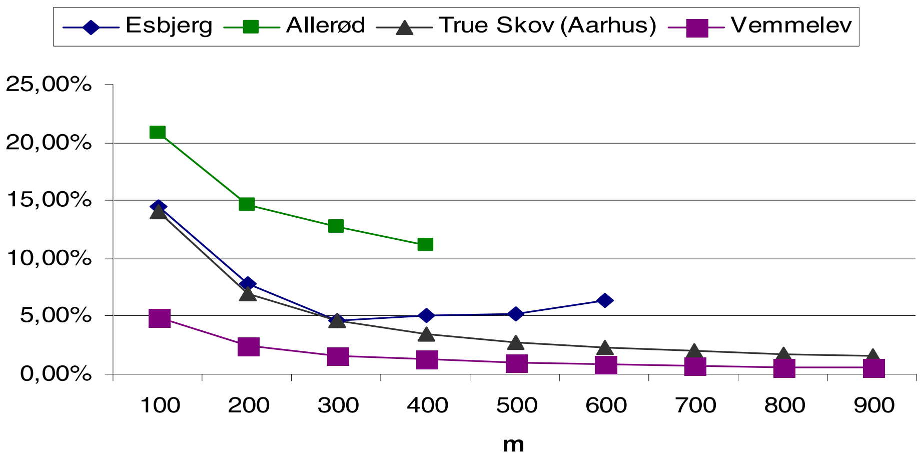

Figure 1 Percentage part of house price attributed to forest proximity
Source: Dummy variable estimates from Hasler, B. C. et al. (2002a) for Allerød and Esbjerg. Percentage effect for True Skov and Vemmelev based on results reported in Anthon, S. and B. J. Thorsen (2002).

Because of its national scope, this analysis handles the secondary benefits in a very general setting. Non-market use benefits from afforestation measures, amenity values and recreational values, will, however, depend on a range of spatial factors. These encompass placement in urban or rural areas, proximity to and total number of houses affected, substitute sites in the form of existing recreational and other amenity areas and other landscape features and last but not least the size of the afforestation area itself. Transferring unit values as "values per house" does therefore require the description of specific scenarios.

According to FNA (2003) the average size of a public afforestation area is 100 ha and of a private afforestation area 8 ha. As existing

20 There seems to be an indication that areas with higher average income and higher house prices (see e.g. Allerød and Aarhus) also have a higher absolute and relative willingness to pay for forest proximity. Given the limited number of study areas, however, this remains unproven.

studies in Denmark have focused on public afforestation areas with areas ranging from 60 to over 600 ha, we use the average size of 100 ha for the baseline scenario. For the current analysis two different scenarios are devised, one for urban areas and one for rural areas, which allow the calculation of "per ha" values for benefit transfer. Varying the different elements of the scenario, e.g. total size of area and form, can shed some light on the sensitivity of the estimated results.

For the urban scenario an afforestation project of 100 ha is placed in direct proximity to an urban area. A squared form for the forest area is assumed with one length of the square being 1000m long. Assuming an average (squared) lot size of 900 m^2, approximately 30 lots could be placed in one row and about 3 rows would be within 100m from the forest edge.[21] This results in approximately 90 houses located within each 100m interval.

Of course house prices vary substantially across Denmark, from an average of about € 340,000 in the greater Copenhagen area down to € 110,000 in mainly rural areas (Told- og Skattestyrelsen (2004)). For urban areas an average house price of € 200,000 is assumed. Using the percentage of house price for different distances shown in Figure 1 results in values per ha of forest, of € 25,033 – 106,668. By applying a social discount rate of 3 % and assuming an infinite time horizon, annual values per ha are equal to € 751 – 3,200.

The second scenario is placed in a predominantly rural area. The 100 ha of forest are assumed to be planted in a circular form. The average housing density is set to 0.1 houses per ha.[22] Based on this housing density, the total number of houses is calculated for 100m intervals. The value added to these houses is again calculated using the percentage effect on house prices shown in Figure 1. For the rural scenario an average house price of € 120,000 is assumed in the baseline scenario. As expected, amenity values per ha are substantially lower, amounting to € 873 - 3299 per ha of forest, or € 26 – 99 on an annual basis.

Recreational values from afforestation measures

Amenity values based on the hedonic pricing method only capture the value of a forest to those living close to it. Recreational use values from visitors travelling to the site need to be estimated using other methods. In Denmark the contingent valuation method has been applied in two different studies to measure the recreational value of forest. While one study (Dubgaard, A. (1994)) estimated willingness-to-pay (WTP) for access to a rather unique natural area in Denmark (Mols Bjerge), the other study (Dubgaard, A. (1998))

21 Allowance is made for streets separating the different rows.

22 Average housing density for detached houses (including farm houses) has been calculated for all counties in Denmark using information on the number of houses and total area (in ha) from Statistics Denmark. A housing density of 0.1 represents predominantly rural areas.

elicited WTP for access to all forests in Denmark by the entire Danish population. Neither study calculated the marginal WTP for increasing existing forest area.

Because the current study uses no particular policy scenario for afforestation, recreational values are transferred using average WTP values per forest visit from Dubgaard, A. (1998) and information about forest visitation patterns of the Danish population from Jensen, F. S. (2003).

Mean WTP for an annual pass to all forests in Denmark was 17 € (median = 13 €) in 1993 prices (Dubgaard, A. (1998)). Respondents visited forests on average 34 times per year thus resulting in an average WTP for a forest visit of 0.53 €.

Any transfer of values per visitor or per visit requires an estimate of the additional visits created by the new site. Total net recreational benefits from afforestation might well be zero if a new forest only acts as a substitute for other recreational areas. Some people also might be willing to increase their WTP for an annual pass because afforestation increases their recreational opportunities by giving them easier access to forest. Placing a forest in the vicinity of built-up areas is also likely to increase the total amount of visits to forests as Aakerlund, N. F. (2000) found a positive correlation between number of annual visits and distance to forest.

The most recent study of visiting patterns in Danish forests and other natural areas (Jensen, F. S. (2003)) is based on a nationwide count of cars parked close to forest and nature areas and was supplemented with a questionnaire distributed at selected parking facilities. Based on a relationship between car-borne and other transport modes depending on the distance to the forest which was estimated in an earlier study (Jensen, F. S. and N. E. Koch (1997)) the total number of visits to these forest areas could be estimated. Average number of visits per ha per year was 194 for all forest areas. However, visitation rates vary from a high of 4,460 visits per ha and year for Jægersborg Dyrehave located near the urban centre of Copenhagen to 14 visits per ha and year for forests located in rural areas.

For benefit transfer purposes an average visit frequency of 200 is assumed with a range of total visits per ha and year from 20 to 1000. Taking inflation into account, the average WTP per visit of € 0.53 for all forests in Denmark from Dubgaard, A. (1998) to 2003 prices becomes € 0.66 per visit. Using the mean value of 200 yearly visits per hectare this results in a mean annual WTP per ha of € 132. Depending on whether the new forest is placed in a rural isolated area or close to an urban area, annual WTP is likely to range from €13 to € 660 per ha.

Shadow prices for secondary benefits from emission reductions

Afforstation of current agricultural land will reduce emissions of climate gasses and ammonia. The extent to which afforestation and other measures would reduce the nitrogen load from agriculture was analysed as part of the preparation of the third Danish Aquatic Action Plan (Olesen, J.E. et al. (2004); and Anon. (2003)) and are reported in Table 3.

Ideally, the change in marginal damages resulting from the changes in emissions should be assessed based on emission-effect modelling and valuation studies. In the case of ammonia, this detailed emission-effect modelling is impossible given the general nature of the policy initiatives analysed. In addition, no valuation studies have been performed in Denmark revealing the WTP for improving the preservation status for different nature types, thus making it impossible to attach a reliable monetary value to avoided damages from reduced ammonia emissions.

With respect to climate gas emissions, extensive work has been done in the ExternE project in deriving estimates of the marginal damages resulting from energy related climate gas emissions (ExternE (2003)). In the ExternE analysis two different models are used to assess the damages resulting from global warming, resulting in a range of marginal damages from € 3.8 to € 139 per tonne CO_2-eqvivalents in 1995-prises. Within this interval, the suggested range for the aggregate marginal damages of climate gas emissions was € 18 to € 46 per tonnes CO_2-eqvivalent. No mean estimate is given, reflecting the significant uncertainty related to the climate scenarios and the resulting marginal damages.

Shadow-prices[23] offer an alternative way to value reduced emissions. The shadow price is calculated as the marginal abatement costs of a current or planned policy and thus holds the same characteristics as unit value transfer. In the optimal economic world marginal abatement costs and marginal damages would correspond, but in a more realistic second best policy the shadow price reflects societal (or the political/administrative) willingness to pay for reducing uncertain damages resulting from emissions. The approach can only include secondary benefits, and it requires an explicit target for reducing emissions and the existence of a cut-off price or that a marginal willingness to pay for reducing the emissions can be derived from existing policies.

23 The term “shadow price” refers to the method of assessing the height of a tree by measuring the length of its shadow.

Table 3 Secondary environmental effects of reduced air emissions. (The measured are scaled to resulting in a reduction in N loads of 5,000 tonnes.)

Measure	Ammonia (1,000 kg NH_4-N)	Climate gas emissions (Mill. kg. CO_2-eqvivalents)
Reduced N input	900	410
Reduced livestock hold	6,500	320
Wetlands	0	110
Afforestation	1,800	1,030

Source: Own calculations based on Olesen, J. E. et al. (2004); Anon. (2003); Jacobsen, B. H. et al. (2004).

In Denmark, the Ammonia Reduction Action Plan was implemented in 2001 as part of the compliance with the EU Emission Ceilings Directive and Gothenburg protocol. The shadow price for reducing ammonia emissions was estimated by Schou, J. S. and K. Birr-Pedersen (2000) as € 1 per kg NH_3-N and this price is used to assess the value of the secondary effects of ammonia emissions.

Denmark is one of the countries that have committed to reduce climate gas emissions by ratifying the Kyoto protocol, which sets an explicit emission reduction target for each country. This means that the effect of climate gas emissions can be valued using the shadow price method. Estimates of the future compliance costs for the European Union have been done by the European Commission under a number of policy constraints (European Commission (2003)). The scenarios range from no possibilities for applying the measures of Joint Implementation and Clean Development Mechanism in the Kyoto Protocol to allowing for the full use of these measures. The price estimates range from € 11 - € 26 per tonne CO_2-eqvivalent. For the EU countries, no restrictions were put on the use of Joint Implementation and Clean Development Mechanism, and therefore the cut off price of € 11 per tonne CO_2-eqvivalent can be used as the shadow price for reducing climate gasses.[24]

24 This is also the cut-off price indicated by the Danish Government.

CEA based on financial and socio-economic cost estimates

In Table 4, the units derived from the benefit transfer exercises are summarised for the different measures. Estimates for recreational and amenity values reflect differences in visit frequencies and housing prices between rural and urban areas. The range in estimates for climate gas values reflect estimates of the future compliance costs for the European Commission (2003) and ExternE (2003), and ranges for fishing and game shooting values are as described earlier.

Table 4 Benefit values

Secondary effect	Unit	Mean	Min	Max
Ammonia reduction	€/kg NH4-N	1.0	-	-
Climate gas reduction	€/tonne CO_2-eqv.	11	11	46
Game shooting, wetland	€/ha	25	25	50
Game shooting, afforestation	€/ha	50	25	63
Amenity value forest urban areas	€/ha	1 976	751	3 200
Amenity value forest rural areas	€/ha	63	26	99
Recreational value forests	€/ha	132	13	660

Secondary effects per kg N load reduction are derived by multiplying the unit values with the amount of emissions reduced or the scale of the land use change and then dividing the aggregate benefits by the estimated reductions in N loads of 5,000 tonnes. For afforestation, the secondary effects will vary substantially, depending on whether the newly forested area is in an urban or rural setting. See Tables 5 and 6, where the results (based on mean values) are shown for a rural and an urban scenario together with the estimated financial costs of the measures. These are expressed as loss of economic rent, using Jacobsen, B. H. et al. (2004).

The most significant secondary benefits for recreation and biodiversity are establishment of wetlands and afforestation as these result in significant changes in land use. The other two measures primarily result in reduced production intensity although reductions in livestock holding may also lead to reductions in grasslands and grassing potential if cattle stocks are reduced. Note also that because wetlands are typically private property without public access, no amenity or recreational values are attached to this measure.

Table 5 Rural scenario: Financial and socio-economic CEA, based on mean values (€/kg N)

Measure	Financial costs	Secondary effects			Socio-economic costs	Ranking based on	
		Emissions	Market use values	Non-market use values*		Financial costs	Socio-econ. cost
Reduced N input	2.1	0.6	0	0	1.5	1	1
Reduced livestock hold	6.9	2.4	0	0	4.5	4	4
Wetlands	4.4	0.6	0.3	0	3.5	2	3
Afforestation, amenity + recreational values	6.4	1.3	1.4	1.7 + 0.4	1.7	3	2

Tables 5 and 6 show that a policy of "reducing livestock hold" is always the most expensive, irrespective of the inclusion of secondary benefits. Because the need for reducing agricultural nitrogen loads typically originates in rural areas, "Reduced N input" remains the most cost-effective measure, even after the inclusion of secondary benefits (see Table 5). However where afforestation can be targeted to locations near urban areas, amenity and recreational values increase significantly, and costs per kg N reduction turn out to be negative when mean amenity values and the annual mean value of 132 € per ha for recreational benefits is applied (see Table 6).

Table 6 Urban scenario: Financial and socio-economic CEA, based on mean values (€/kg N)

Measure	Financial costs	Secondary effects			Socio-economic costs	Ranking based on	
		Emissions	Market use values	Non-market use values*		Financial costs	Socio-econ. cost
Reduced N input	2.1	0.6	0	0	1.5	1	2
Reduced livestock hold	6.9	2.4	0	0	4.5	4	4
Wetlands	4.4	0.6	0.3	0	3.5	2	3
Afforestation, amenity + recreational values	6.4	1.3	1.4	53.3 + 3.6	-53.2	3	1

The inclusion of the secondary environmental effects in the net cost estimates shows two significant consequences for cost-effectiveness analysis (CEA). First, the socio-economic abatement costs are significantly lower than those of pure financial analysis. This indicates that policies formulated based on financial economic analysis alone will overestimate the aggregate costs, and thus tend to lead to less ambitious policy goals than would an efficient, socio-economic solution. Secondly, the relative cost-efficiency of the possible measures changes. This is especially true for measures involving land use changes where amenity and recreational values are expected to rise. Thus, the cost-efficient mix of policy measures changes when shifting from financial to socio-economic cost-effectiveness analysis. This indicates that the secondary environmental effects may play an important role when formulating environmental policies.

It is important to note that this analysis is based on average values, and that real situations will have different outcomes. For example, if afforestation is implemented to a large extent, its marginal recreational value should be expected to fall and the increased demand for agricultural land to be used for afforestation will increase its financial cost. These two effects in combination will reduce the cost-efficiency performance of afforestation near urban areas, eventually causing socio-economic costs to be positive. Therefore when analysing the cost-efficient mix of policy measures on a larger scale it is important to include considerations of how demand functions and how the marginal values of the different goods will be affected in different policy settings.

Discussion and conclusions

In this analysis we demonstrate how non-market secondary effects can be included in cost-efficiency analysis using benefit transfer. A general feature of benefit transfer as well as of primary valuation studies is that the exactness of the estimates depends on how the project is described. If the analysis relates to a well described project at a designated location it usually should be possible to develop a detailed description of the changes in land use, effects on environmental quality and biodiversity, and the extent to which the project will change recreational possibilities. Such a description yields a good basis for deriving monetary estimates of the benefits. The uncertainty of benefit estimates mostly depends on the benefit functions used and can be subject to a reasonably noncomplex sensitivity analysis.

If the analysis deals with policy choices at the more aggregated level, as is the case in this example, decisions as to where the measures should be implemented and the scale of the measures are often implicit, and may (e.g. for political reasons) not be desirable to clarify. In this case benefit transfer may be difficult, especially when the effects and benefits hold site-specific elements. This uncertainty problem is not only related to benefit estimates but also to financial, economic and natural science evaluations. However, because of the relatively limited data on benefits and their variations with policy relevant parameters the issue becomes more explicit.

Given the limited number of studies available on Denmark (and internationally) we were unable to match values for changes in biodiversity (particularly non-use values) to changes in land use. Nevertheless, results indicate the substantial effect non-market values can have on policy initiatives. It is therefore suggested that future research should focus on eliciting these non-use values in order to provide policy makers with an indication of their potential size and variability.

Administrators tend to seek simplifications of decision-making processes. With regard to project and policy evaluation this can lead to an increasing focus on promoting and using so-called "approved unit values" in the form of € per measurement unit for benefit transfer. Such values are extremely context dependent and a cautious and qualified usage of these benefit estimates is therefore strongly suggested.

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Appendix 2, Article 2
The value of forestation – a benefit transfer study in urban fringe areas in the Oresund-region

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Abstract

Urban forests provide substantial non-market benefits to residents and out-of-town visitors in the form of amenity and recreational values. In Sweden this has been confirmed for the northern forests through the results from non-market valuation studies, primarily contingent valuation studies. No study has been undertaken for the south-western part of Sweden, despite the fact that forest cover here is substantially lower than in the rest of the country. Surveys of the Swedish population indicate that preferences for forest proximity are especially high in the southern part of the country which opens up for a discussion of the costs and benefits associated with afforestation projects in that region.

This study values the amenity and recreational values of forest in the urban fringe areas in Scania, South-western Sweden by using benefit transfer of unit values from a Danish hedonic pricing study and two contingent valuation studies, one from Sweden and one from Denmark. Results indicate substantial values for forest areas close to residential areas. The comparison of results from benefit transfer of per visit values shows the uncertainty attached to this valuation methodology.

The calculated non-market values can – despite their inherent uncertainty – provide some guidance to local decision makers regarding the planning of landscape scenarios in Southern Sweden. They also clearly show the necessity of conducting primary valuation studies for that region.

Introduction

By tradition the Swedish culture has a close connection to nature, especially forested areas. The right of common access is still considered essential and picking wild berries and mushrooms has a long standing tradition in Sweden. In a survey from 1997, however, Lindhagen and Hörnsten (2000) found evidence that preferences were changing from harvesting towards purely recreational activities, while visiting frequencies remained unchanged. Especially for people living in urban areas "urban forests", i.e. forested areas in the urban fringe, offer a range of benefits in the form of non-market values, e.g. opportunities for recreational activities, nature views and fresh air, as well as favourable conditions for biodiversity, representing both use and existence values for local residents and other users- and non-users of the forests.

While the northern part of Sweden has a high proportion of forest cover, Scania, the Swedish part of the Oresund region, is dominated by a mainly agricultural landscape. Although the county makes up only 2.6 % of Sweden it includes 17 % of Sweden's agricultural land area. With a forest cover of 31 % the county lies well below the average of 55 % for the whole of Sweden. On the other hand the agricultural area makes up about 47 % which is substantially above the average of 7 % for Sweden as a whole. Places with high population density in the county are Malmø (240,000 inhabitants) and Lund (74,000 inhabitants).

Gundersen et al. (2005) show that the area of forest and other wooded land in hectare per capita is approximately 0.1 in Denmark in general, also in the Copenhagen area. The same low ratio of 0.1 can be found in the vicinity to the city of Malmo in the south-western part of Scania while for all of Sweden this "area per capita" ratio is 3.41 on average. Thus this region resembles more the Danish counterpart Zealand, on the other side of the Oresund-bridge, than the rest of Sweden, which is heavily forested.

Non-market valuation of forest recreational values has primarily focused on the northern part of the country (Mattsson and Li (1993; Mattsson and Li (1994), Hörnsten and Fredman (2000) and Kriström (1990)). These studies indicate substantial values for recreational purposes, both for berry picking, walking, camping and visual effects. All these studies have used the contingent valuation method, while none to our knowledge has so far applied the hedonic pricing method to housing data in Sweden despite the fact that studies from other northern countries, e.g. Denmark (Hasler et al. (2002b)) and Finland (Tyrväinen (1997)) show that amenity values from urban forests, as reflected in price differences for houses close to the forest, can be substantial.

The aim of this article is to analyse and assess the amenity and recreational values of forest areas in the Swedish areas of the Sound region. Valuation of these amenity and recreational values can take place by both revealed and stated preference methods (cf. Price (2003); Mattsson and Li (1993; Tyrväinen et al. (2003)). But the implementation of both of these methodological approaches is very costly and time consuming, and is therefore not necessarily the first choice if the aim of the assessment is a preliminary judgement of the net benefits of a project. In such circumstances benefit transfer of the results from primary studies to comparable policy case sites can be an option, even though this method yields a lot of uncertainty.

Benefit transfer is used in the present study to assess and indicate the potential value of forests and forestation in the Swedish region Scania. Benefit transfer assessment of amenity benefits is based on former Danish valuation studies which where conducted with the use of the hedonic price method (Hasler et al. (2002a) and Præstholm et al. (2002)), while the potential recreational benefits are transferred from a Swedish contingent valuation (CV) study that was implemented in the Northern part of Sweden (Mattsson and Li (1993)). A Danish CV study (Dubgaard (1998)) is used to illustrate the sensitivity of total recreational values to the size of the transferred unit values.

The paper starts with a short introduction to the two non-market valuation methods, contingent valuation and hedonic pricing used for benefit transfer in this study and a description of the different benefit transfer approaches available. Likely candidates for primary studies in both Sweden and Denmark are described therafter followed by a section that contains the benefit transfer calculations for both amenity values reflected in house prices and recreational values based on the amount of annual visits to an area. The results and their implications for policy decisions are discussed in the last chapter.

The valuation of forest non-market goods and services

Methods for primary valuation

Benefit transfer in this study is based on studies that use the hedonic pricing method and the contingent valuation method, and in this section these two methods are explained in more detail before the benefit transfer method is outlined.

The family of s*tated preference methods* consist of several methodical approaches, with the common property that people are asked what economic value they attach on certain goods and services, e.g. services and goods connected to forests, other recreational areas or nature protections areas. The contingent valuation (CV) method is the most commonly used non-market valuation technique for environmental goods, internationally as well as in Denmark (Mitchell and Carson (1989); Carson et al. (2001); Dubgaard (1996), Dubgaard (1998); Bjørner et al. (2000)). The value estimates from a CV study are contingent on a hypothetical scenario for a change in a particular environmental good that is presented to the respondents for valuing. In other words, it relies on the analyst to create a hypothetical market for the good in question.

Basically, CV involves asking a sample of individuals for the highest amount of money they are willing to pay to obtain an improvement in their environment, described thorough to them as scenarios. The willingness to pay (WTP) can be elicited by three primary question formats: open-ended questions, dichotomous choice and payment cards, but the dichotomous choice and payment card methods are now most widely used. The open-ended format simply asks the respondents to state their maximum WTP for a particular scenario.

In the payment card method respondents are presented with a range of WTP values, called bids. The respondents can be asked directly to pay, or whether they would vote for a referendum on the environmental change, while they are informed on the costs of this policy to an individual or a household. Their maximum WTP to cover the costs can be chosen from the payment card. By the dichotomous choice method respondents are presented with one bid and asked if they are willing to pay this for the change in environmental quality, or to vote yes or no in a referendum. The amounts chosen for the survey are randomly assigned to the respondents, and the respondents are offered to say yes or no to the amount (or vote yes or no). In double bounded dichotomous choice the respondents is offered a second higher amount, and it has been argued that this improves the efficiency of the WTP results (cf Hanemann et al. (1991)).

The strength of the CV method as well as other stated preference methods is that the results can be used to assess the effects of projects ex-ante, as well as the results cover a representative set of respondents. Hence the method can be used to estimate the total value of a public good

Another group of valuation methods are the *revealed preference methods*, which the hedonic price method is a member of. The revealed preference methods assume complementarity between a market good, e.g. house prices, and an associated public (or non-market) good, e.g. amenty values of forests. Rosen (1974) was the first to develop a formal theory of hedonic pricing. In the hedonic approach a good is assumed to consist of a set of attributes (so-called differentiated good) and the good's value or price thus can be considered a function of each attribute.

Environmental valuation studies that use the hedonic pricing method are almost entirely based on the housing market, where it is assumed that real estate prices are influenced by area attributes like air-quality, green space and quality of public schools. Compared to CV the strength of this method is that the WTP is revealed from real market data and not hypothetical answers. The weakness is that only values for house owners are assessed, as house prices are used as the market data.

By collecting data on the sales prices of houses and housing attributes like structural characteristics (e.g. house and lot size, age), neighbourhood characteristics (e.g. distance to schools, shopping areas) and the environmental good one is interested in (e.g. distance to forest areas) a so-called hedonic price equation can be estimated. This hedonic price equation is simply a function that explains the price of a house by its different attributes. As shown by Rosen (1974) by taking the first derivative of this function with regard to the individual attributes the marginal effect of the particular attributes on the house price, i.e. their marginal implicit price, can be determined.

The marginal implicit price is equal to the additional expenditure required to purchase a unit of the differentiated product (i.e. a house) with a marginally larger quantity of that characteristic. Assuming that the market is in equilibrium, consumers will have maximised their utility by choosing a particular house. This implies that they have equated their marginal willingness-to-pay for its attributes to the attributes' marginal implicit prices, thus the marginal implicit price can be interpreted as the marginal willingness-to-pay of the house owner for a particular housing characteristic.

Palmquist (1992) has shown that in the case of localised externalities the hedonic price equation is also sufficient to determine WTP for non-marginal changes, as long as only a relative small number of properties are affected. For the current project it is assumed that in the case of afforestation the change in forest cover will only affect a small part of the housing market.

Methods for benefit transfer

Benefit transfer, i.e. the transfer of monetary estimates of environmental values estimated at one site (study site) to another, so-called policy site, offers a less costly alternative to conducting a primary valuation study. Despite the inherent uncertainty attached to this method benefit transfer is becoming a more and more common tool in policy and project appraisal in Denmark. As pointed out by Barton (1999) the issue is no longer "... whether benefit transfer can be done, but *when* it should be done and *how* to do it in a consistent manner given the requirements for reliability demanded by the policy-context and the decision-maker"[25].

The current literature broadly divides benefit transfer approaches into four categories (Navrud (2004)):

1. Unit value transfer
   a) Simple unit value transfer
   b) Unit value transfer with adjustment, e.g. income
2. Function transfer
   a) Benefit function transfer
   b) Meta-analysis

Simple unit value transfer is the easiest way of transferring benefits by applying unadjusted mean or median measures from the study site, e.g. willingness-to-pay per recreational activity or per area of environmental resource conserved, at the policy site. It is simply assumed that the utility gain of an average individual at the study site is the same as that of an average individual at the policy site. It is not difficult to imagine that this assumption will not hold in most circumstances. People at study and policy sites are more likely than not to differ from each other in terms of income, education and other socio-economic characteristics that affect their preferences for e.g. recreation. In addition market conditions at the policy site are likely to be different in terms of existence of substitute sites, physical characteristics of the good to be valued or its proposed change.

One way of overcoming the short-comings of simple unit value transfer is to adjust the value estimates to better reflect differences in socio-economic characteristics between policy and study site. Income differences between countries can be adjusted for by applying Purchase Power Parity (PPP) indexes or PPP adjusted exchange rates instead of using normal exchange rates. Environmental values that are transferred over time should be adjusted for inflation.

A benefit function describes people's preferences in terms of WTP for a particular attribute depending on its characteristics and the socio-economic characteristics of the individual. When transferring the entire benefit function instead of per unit benefit estimates more information can in principle be transferred between study

25 Barton (1999), p. 24.

and policy site. Benefit function transfer can directly account for differences in user and site characteristics. This, however, requires access to an original study where WTP is described as a function of different explanatory variables. The coefficients of this function combined with the respective variables of the policy site can then be used to calculate new WTP values for the policy site.

Instead of focusing on just one value it might be useful to extract information on benefit values from a range of available studies by conducting a so-called meta-analysis. Meta-analysis originated in medical and psychological research, where it is a common tool employed to summarise results of different tests of treatments and medicine in a quantitative way. A meta-analysis investigates the relationship between benefit estimates of different studies and the specific features of the environmental good to be valued and assumptions of the models used. Basically this means employing regression analysis where the different study results are treated as the dependent variable and various factors assumed to influence WTP-results are included as explanatory variables.

Meta-analyses have been conducted for a wide range of environmental goods and services, e.g. outdoor recreation, air pollution, rare and endangered species and wetland ecosystem functions, to name just a few. The only meta-analysis study focusing entirely on recreational values of woodland is Bateman and Jones (2003). The authors do only include UK studies (both CV and travel costs models) and their main focus is on testing different modelling techniques.

The main problems of meta-analyses are caused by the inadequate data provided by the original studies. Published studies often lack information on the specific characteristics of the study site, the changes in environmental quality valued, income and other socio-economic characteristics of the sample population. Publication bias (also called selection bias or availability bias), i.e. the fact that only studies with significant results tend to be published in peer-reviewed journals might cause additional bias.

Geographic Information Systems (GIS) are computer programs that enable the capture, storage, management, analysis and visualisation of digital geo-referenced data. Many environmental valuation methods need to incorporate spatial aspects and their variations in their application. In the past the inclusion of these spatial aspects often involved a range of simplifications, e.g. the assumption of constant travel times, use of centroids as departure points in travel cost analyses or time consuming individual measurement of distances on the household level in hedonic pricing studies. The use of Geographical Information Systems (GIS) in connection with valuation studies allows a more realistic data collection, e.g. by including road network and travel speed or substitute availability. In addition GIS offers the possibility to automate distance calculation and to create indices for the characterisation of landscapes surrounding built-up areas and thus likely to influence housing prices.

In the current study GIS is applied to create buffers of 100m intervals around the three case study areas selected in Svedala county in Scania. This allows the transfer of per household forest amenity values for different distances from a Danish study.

Identification of existing studies: Results from the literature search

Forest valuation studies from Sweden

In Sweden only few studies were performed regarding valuation of forests, and most of the studies were done 10 to 15 years ago. A review of these studies and a discussion of the social and policy relevance of them is made by Boman et al. (2000) who conclude that most of the studies are highly relevant for policy advice. However, all of the studies use the contingent valuation approach and no studies are performed using hedonic pricing.

Hörnsten and Fredman (2000) conducted a survey of the Swedish population regarding their preferences for forest proximity. Their results indicate that on average over 40 % of the Swedish population would prefer a shorter distance to forest areas, while the proportion wishing for closer proximity to forests was closer to 70 % in the south-western part of Sweden. However, the total number of responses from this part of Sweden was only 38 (out of 453) thus the answers should be treated with some caution. Part of the respondents to the questionnaire did also receive WTP questions regarding their WTP to avoid a doubling of their present distance to the nearest forest area. Results indicate mean WTP of 110 SEK (median 50 SEK)[26], however also here the sample size is rather small with 84 respondents, 34 of them being zero bids.

Kriström (1990) used CV to ask 1100 households about their willingness to pay to protect eleven sensitive forest areas. The areas were assumed to be valuable because of recreational and environmental reasons, and the particular sites were chosen because they are well known to most Swedes. The results indicated an aggregated willingness to pay of 3.8 billion SKK, (200 mill. annually) which was 0.4 billion more than the alternative costs, consisting of the lost income from harvesting the forests.

Mattsson and Li (1993) conducted a CV study of the non timber value of Northern Swedish forests and found that two third of the value of recreation was attributed to the value of picking berries, walking, camping etc. while the last third was attributed to the visual value. The latter could be enhanced by changes in the composition of trees from spruce to broad leaved (Mattsson and Li (1994)). Holgén et al. (2000) analysed the dataset from the CV study further and found that changes in harvest methods, e.g. mix rotation periods such as natural regeneration is established under old trees, could increase the recreational value of forests.

26 Respondents from the south-western part of Sweden have been excluded from the estimation as forest supply was deemed to be too different from the rest of the country.

Bostedt and Mattsson (1995) also implemented a CV study where they asked tourists visiting nature tourism areas in both Southern and Northern Sweden for their maximum WTP for a trip to that particular area and how much of that value was related to the respective tourist area and the particular forest characteristics.

Forest valuation studies from Denmark

Even though, or maybe because, forest is a more scarce resource in Denmark than in Sweden, there are more valuation studies on forests in Denmark compared to Sweden. A number of forest valuation studies have been conducted in Denmark using the hedonic pricing (Anthon et al. (2005), Hasler et al. (2002b)), contingent valuation (Dubgaard (1994); Dubgaard (1998)), Bjørner et al. (2000)) and contingent ranking method (Aakerlund (2000)). Results from part of these studies have subsequently been applied in benefit transfer exercises, e.g. Damgaard et al. (2001) and Schou (2003).

Hedonic pricing studies

Hasler et al. (2002a) conducted a hedonic pricing study to measure the amenity value of four different forest areas in Denmark (Selskov in Hillerød, Tokkekøb Hegn in Allerød, Haslev Orned in Haslev and Gjesing Plantage in Esbjerg) and one afforestation area (Drastrup Skov in Aalborg). Data for the analysis has been extracted from the public real estate, construction and housing registers, BBR and ESR, that cover all the essential housing characteristics including the sales price.

The absolute value of forest proximity for old forest areas was highest in Allerød and Hillerød, somewhat lower in Esbjerg, while there was no evidence of positive effects on real estate values in Haslev. The analysis shows that distance to forest has a significant value up to 600m from the edge of the wood. Values are basically zero for distances larger than 600m. Estimations are done by using models including distance to the forest edge as an explanatory variable and models with dummy variables for buffers of 100m intervals around the forest. Figure 1 shows the percentage effect on house prices for different distances based on the results from the dummy variable model.

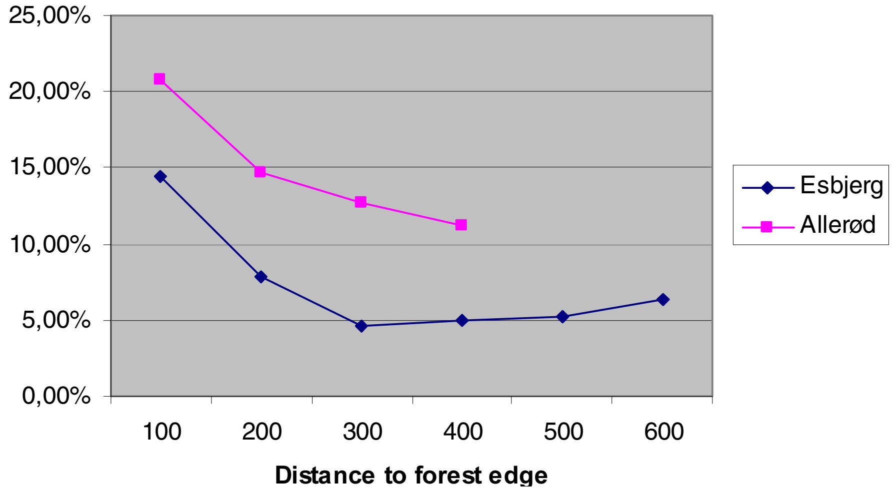

Figure 1 Percentage part of house price for different distance buffers
Source: Hasler et al. (2002a)

Anthon et al. (2005) conducted a similar hedonic pricing study using two afforestation areas as case study areas, Vemmelev Skov south of Vemmelev on Zealand and True Skov, situated in Jutland near the northwestern part of Århus. Data sampling is again based on the central housing registers, BBR and ESR including only owner-occupied, one-family houses used for habitation. Proximity to forest is measured in two ways, as a continuous variable and as a discrete binary variable "Forest" for all houses within 600 metres of the forest. The environmental value is assumed to be zero before afforestation activities started, i.e. no increase in the value in the planing period is assumed. Figure 2 summarises the results for different distances.

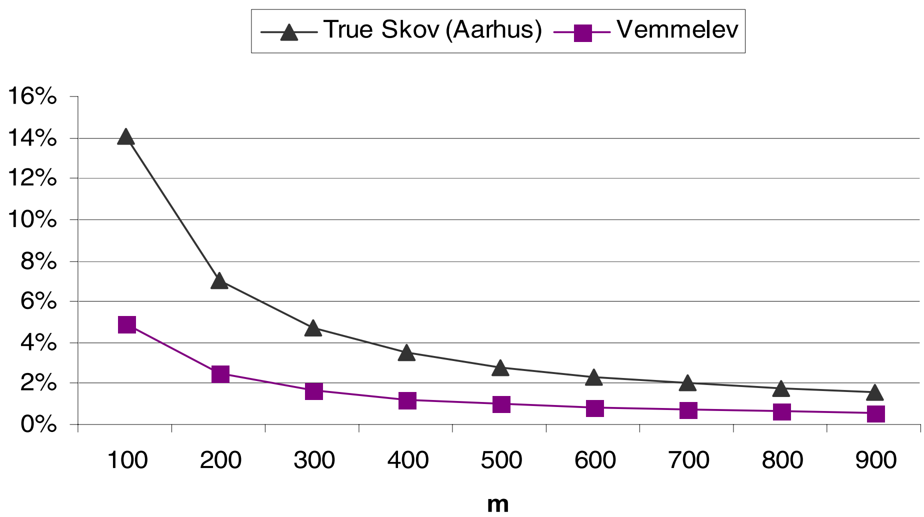

Figure 2 Percentage effect on house prices of proximity to an afforestation project
Source: Anthon et al. (2005)

Using the results from the continuous modelling of forest distance the total value of the respective afforestation project is calculated from the average house price by dividing the housing area into 50 metre intervals and calculating the value for each interval. Based on the dummy coefficient total forest value is calculated by multiplying the (constant) per house value within a radius of 600m with the total number of houses located within this radius. As in Hasler et al. (2002b) the total forest value is obviously dependent on the number of houses within each distance interval and the average housing price of the area. Table 1 summarises the results from the two studies discussed before. Obviously total amenity value depends strongly on the amount of houses located in the vicinity of the forest while amenity value per ha is determined by the total value and the size of the forest itself.

Table 1 Summary of results for different forest areas

Forest name/ City	No. of houses	Size (ha)	Amenity value MDKK/forest)	Amenity value DKK/ha	Amenity value DKK/ha/year
Gjesing Plantage/ Esbjerg (Hasler et al. (2002), p.102)	583	75	80.20	1,069,333	32,080
Tokkekøb Hegn/ Allerød (Hasler et al. (2002a), p. 103)	208	663	163.00	245,852	7,376
Drastrup Skov/ Aalborg Hasler et al. (2002a), p.120)	142	725	93.00	128,276	3,848
True Skov/ Skjoldhøjparken in Tilst (Anthon and Thorsen (2002), p.)	526	101	34.60	342,574	10,277
Vemmelev Skov/ Vemmelev (Anthon and Thorsen (2002), p.)	176	60	9.20	153,333	4,600

Contingent valuation studies

In Denmark the contingent valuation method has been applied in two different studies to measure the recreational value of forest areas. In the first study Dubgaard (1994) asked a selection of visitors to a rather unique natural area in Denmark, Mols Bjerge, about the willingness to pay for an annual pass that would grant them access to the area. The area includes both forest and pastoral areas. Based on the open ended format the mean WTP was 38 DKK for an annual pass, while it was 68 DKK based on the dichotomous choice (DC) sample. The study found that WTP was increasing with visit frequency but at a decreasing rate. WTP ranged from 34 DKK for one visit per year to 111 DKK for 13-36 visits per year resulting in mean WTP per visit per day of 34 – 4 DKK (58 – 6 DKK for DC question).

Total amount of visitors was estimated to be 106,000 per year based on counts distributed over a one-year period at different entrances of the area. Total WTP for access to the area was thus calculated to be 4.0 – 7.2 million DKK per year. Divided by the total amount of ha (2.500) this is equal to 1,600 – 2,900 DKK per ha per year.

In a later study Dubgaard (1998) used again the contingent valuation method, this time to elicit the WTP for access to all forest in Denmark by the Danish population. Mean WTP for an annual pass to all forests in Denmark was 128 DKK (median = 100 DKK). Multiplying mean WTP with the entire Danish population in the age cohort included (15-76 year old), equal to about 4 million people, provides estimated annual benefits of about 500 million DKK. Divided by the total forested area in Denmark of about 0.5 million ha the annual average WTP per ha is equal ca. 1,000 DKK. Respondents visited forests on average 34 times per year. This results in an average WTP for a forest visit of 4 DKK. The results from the two CV studies are summarised in Table 2 below.

Table 2 Summary of results from forest studies in Denmark

Forest	Size (ha)	Recreational value (MDKK)	Mean WTP per visitor (DKK)	Average number of visits	Annual visits	User population	Recreational use intensity (visits/ha)	WTP/ha/ year (DKK)
Mols Bjerge	2500	4,0 - 7,2	38-68	1,6*	165000	106000	66	1600-2900
All forests in DK	500000	500	128	34	136000000	4 000000	272	1000

*Average number of visits per visitor, not for population as a whole.

Do people construct their preferences while answering survey questions or do they have a set of pre-defined preferences, which can be called upon by framing the survey questions differently? While the first assumption is supported by the cognitive psychology literature, the latter is normally assumed by economists when designing and conducting valuation studies. Russel et al. (2003) and Bjørner et al. (2000) asked three questions designed to trigger (1) "private" preferences (self-interest of the respondent), (2) "sympathetic" (or "public") preferences (incl. other users) and (3) "committed" preferences (animals and plants) for the usage of a forest area and small lake in two countries, USA and Denmark. In Denmark the location was north of Copenhagen (Tokkekøb Hegn) while in the USA Radnore Lake natural area within Nashville, Tennessee was chosen.

Respondents were asked for their most and least preferred levels of use intensity for the area and for their willingness-to-pay (WTP) for access to the area by means of a hypothetical annual admission card. Results show that the differently framed questions were successful in triggering expressions of preferences for unspoilt nature (the "committed" version) as opposed to private preferences. However, respondents did not seem to have a statistically significant set of public preferences. One possible explanation here could be that the formulations used to elicit public concerns were not strong enough or because it generally is more difficult to stimulate concerns for others than for nature.

According to Bjørner et al. (2000), mean WTP for an annual admission card did not vary between frames and ranges from DKK 233 to 261 (respectively excluding/including high bids). As there is some evidence for a missing scope effect in the answers (some respondents noted that they were thinking of natural areas in general and not one specific area, which should have given rise to increasing WTP answers) the results should, however, be treated with caution.

Benefit transfer of forest amenity and recreational values to the Oresundsregion

Choice of policy sites

For the current analysis Svedala county (see Figure 3) has been chosen as case study area. In contrast to the Malmø region Svedala county has a substantially higher forest cover. Svedala county contains a large recreational area called ”Romeleås”. Especially the western part of it, a large forested area called ”Torup” is an attractive destination for recreational trips for inhabitants of Malmø. The Torup forest is located only 15 minutes by bicycle from the outskirts of Malmø. Total amount of annual visits is estimated to be 500,000.[27] Besides these recreational visits from the Malmø area an increasing amount of Malmø inhabitants take up residence in Svedala county, among other things to get easy access to green areas. Central Malmø is only a 20-minute car drive from Svedala city via highway E65.

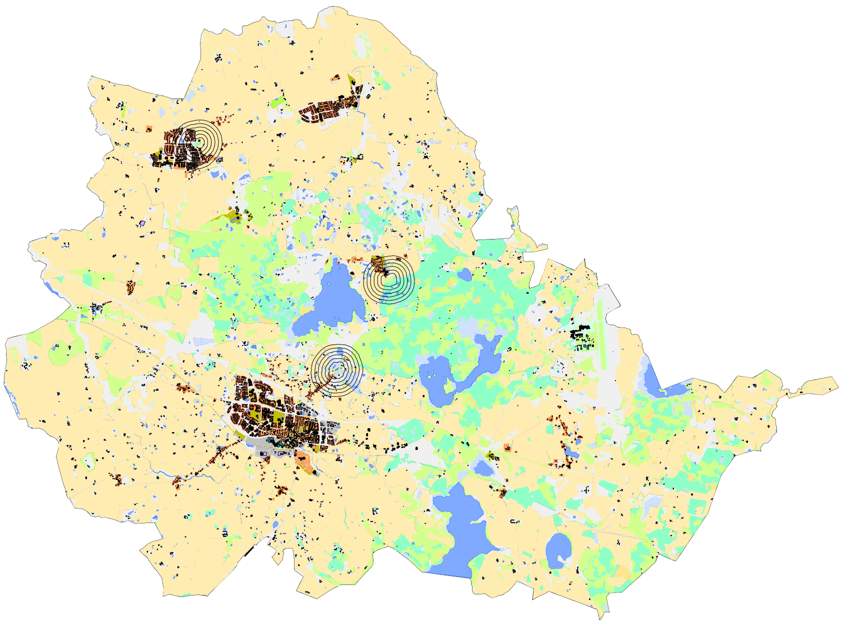

Figure 3 Svedala county, Scania, Sweden

27 Based on personal comunication with Christina Persson, Svedala County.

Svedala county does not have any current afforestation plans. Most of the farmland potentially available for conversion is either owned by private farmers or Malmø county. Any conversion would require the local communities to buy farming land in the first place. A policy, which does not receive much political support at the time. There are however, some other recreational projects in the planning phase, i.e. a golf course south of the city of Bara and a general improvement of bicycle lanes in the area.

Three policy sites have been selected for benefit transfer of amenity values (see Table 3), Bara, Holmeja and Sjødiken which is part of the city of Svedala. In the planning phase of the golf course in Bara about 15 local meetings were held. The discussion with locals indicated that they were particular font of the city's own forest despite its small size. This forest consists of pine on one site and willow on the other. According to the local estate agent in Svedala city (Eekenstam (2004)), all houses in Bara are positively affected by their proximity to Torup forest, which can easily be reached by bicycle.

Table 3 Description of case study areas

Name	Description
Sjødiken, Svedala city	Few and - according to the local real estate agent in Svedala city (Eekenstam (2004)) - very special houses that lie on both sides of a narrow street leading directly into the forest. The forest is a mixed beech forest, with some marsh areas at the forest edge.
Holmeja	Small rural town situated at the northern edge of Torup forest with houses located close to the forest edge.
Bara	Small forest area with small paths and a place for a bonfire that is situated on the east side of Bara.

All policy areas have been chosen because of the close position of built up areas to forest areas which usually start at less then 50 m from the forest edge. The developed areas consist mainly of one-family houses. The aim with these areas is to access the amenity value from existing forests to the local community, i.e. those citizens living close to the recreational forest area. Torup forest is used as a case study area for transfer of recreational values.

Benefit transfer of amenity values

Given that the policy sites in this project are existing forest areas benefit transfer will focus on results from Hasler et al. (2002a). Table 4 contains the results from the dummy variable estimation for Allerød and Esbjerg. As the dependent variable was log-transformed, the coefficient estimates for the different distance intervals represent the percentage effect on the price of the average house in the two areas, which is shown graphically in Figure 1.

Table 4 Dummy variable estimates for different distance buffer

Distance	Esbjerg	Allerød
0-100	0,144	0,2075
100-200	0,078	0,1462
200-300	0,046	0,1274
300-400	0,05	0,1115
400-500	0,052	NA
500-600	0,063	NA
View over forest	0,115	NA

Source: Hasler et al. (2002a)

Using the Geographical Information System (GIS) MapInfo buffers were created for distance intervals up to 600m around the three different forest areas. Figure 4, 5 and 6 show distance buffers for the three case study areas. The number of one-family houses within each distance buffer is calculated. According to Statistics Sweden[28] the average house price in Svedala county was SEK 1,400,000 in 2003. Unfortunately no site specific average house prices were available. Benefit transfer calculations for the city of Bara are summarised in Table 5, Table 6 and 7 summarise the calculations for the city of Holmeja and Sjødiken respectively.

Total present value of forest proximity is equal to about 50 Mio SEK for Bara and around 5.5 and 5 Mio SEK for Holmeja and Sjødiken respectively. Bara is the only larger connected built-up area in Svedala county that is situated in direct vicinity to a forest area. This is also reflected in the substantially larger amount of houses that are located within 600m from the forest edge.

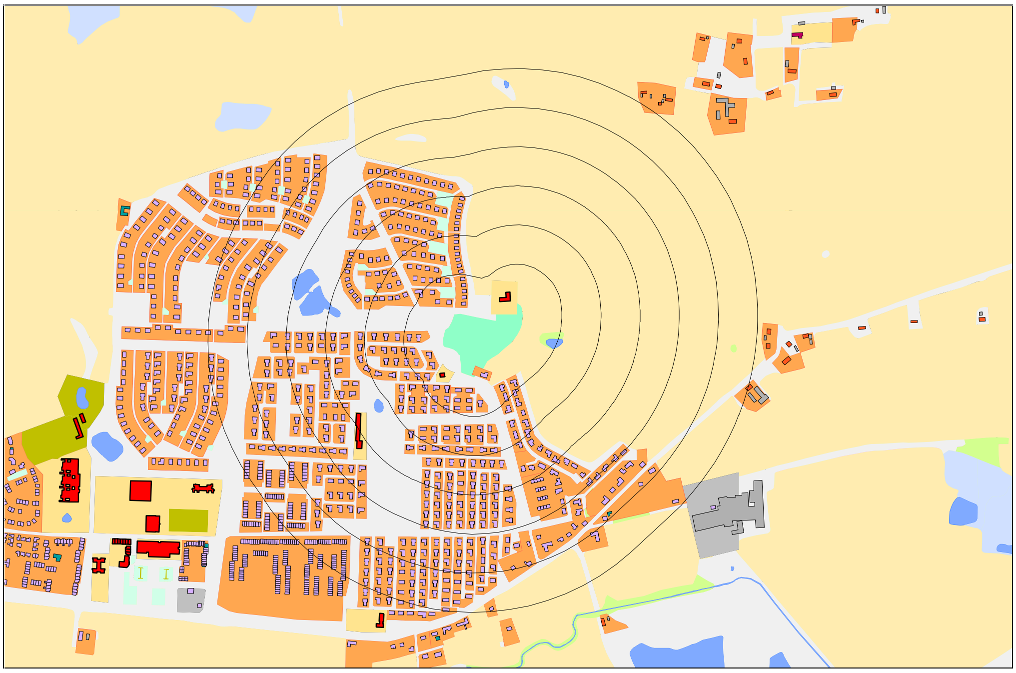

Figure 4 Distance buffers for forest in Bara city

[28] www.ssd.scb.se

Table 5 Benefit transfer calculations for the city of Bara

Distance buffer	Number of houses	Extra value per house (SEK) based on estimates from ...		Total value (SEK) based on estimates from...	
		Esbjerg	Allerød	Esbjerg	Allerød
0-100	26	201,600	290,500	5,241,600	7,553,000
100-200	68	109,200	204,680	7,425,600	13,918,240
200-300	88	64,400	178,360	5,667,200	15,695,680
300-400	99	70,000	156,100	6,930,000	15,453,900
400-500	109	72,800	NA	7,935,200	NA
500-600	111	88,200	NA	9,790,200	NA
View over forest	11	161,000	NA	1,771,000	NA
All houses	501		SUM	44,760,800	52,620,820

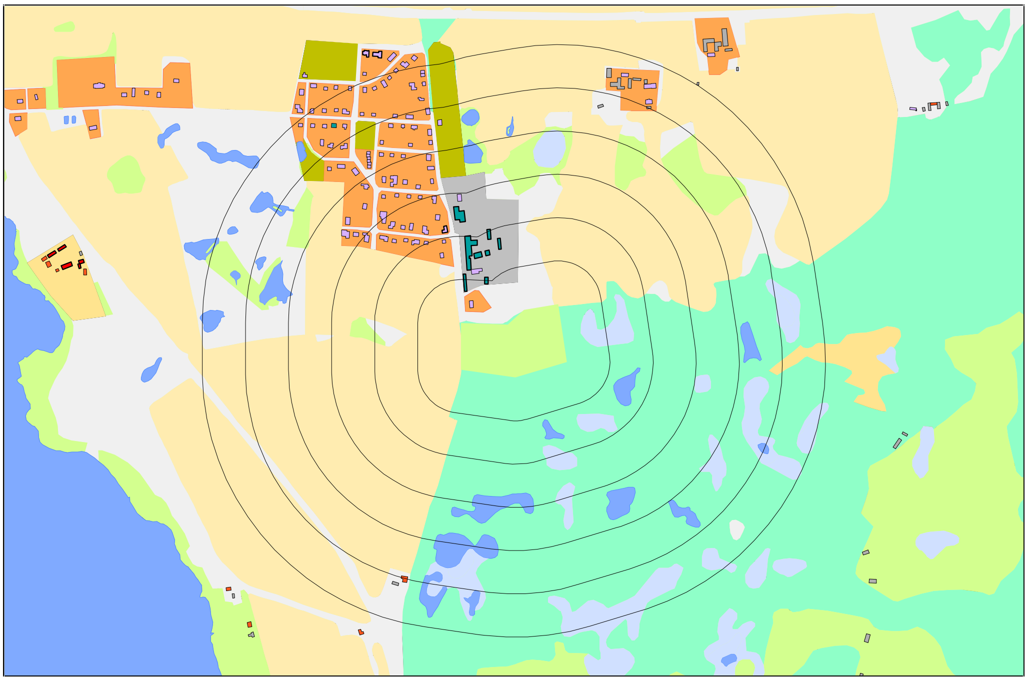

Figure 5 Distance buffers for forest in Holmeja

Table 6 Benefit transfer calculations for the city of Holmeja

Distance buffer	Number of houses	Extra value per house (SEK) based on estimates from ...		Total value (SEK) based on estimates from...	
		Esbjerg	Allerød	Esbjerg	Allerød
0-100	1	201,600	290,500	201,600	290,500
100-200	2	109,200	204,680	218,400	409,360
200-300	12	64,400	178,360	772,800	2,140,320
300-400	18	70,000	156,100	1,260,000	2,809,800
400-500	16	72,800	NA	1,164,800	NA
500-600	20	88,200	NA	1,764,000	NA
View over forest	1	161,000	NA	161,000	NA
All houses	69		SUM	5,542,600	5,649,980

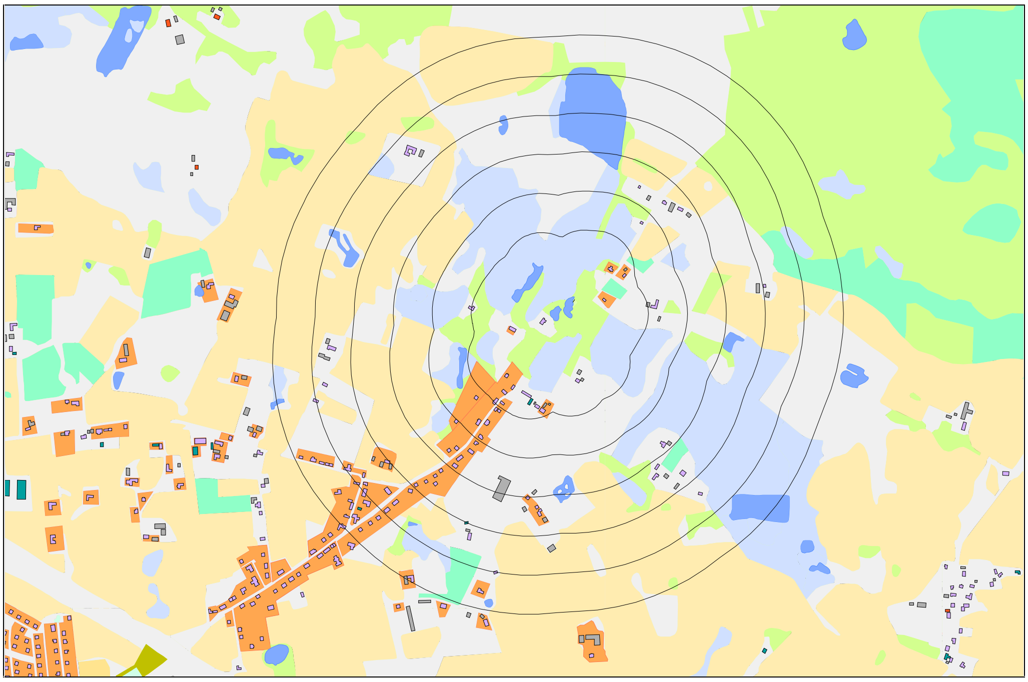

Figure 6 Distance buffers for forest in Sjødiken, Svedala city

Table 7 Benefit transfer calculations for Sjødiken, Svedala city

Distance buffer	Number of houses	Extra value per house (SEK) based on estimates from ...		Total value (SEK) based on estimates from...	
		Esbjerg	Allerød	Esbjerg	Allerød
0-100	6	201,600	290,500	1,209,600	1,743,000
100-200	6	109,200	204,680	655,200	1,228,080
200-300	7	64,400	178,360	450,800	1,248,520
300-400	5	70,000	156,100	350,000	780,500
400-500	9	72,800	NA	655,200	NA
500-600	15	88,200	NA	1,323,000	NA
View over forest	3	161,000	NA	483,000	NA
All houses	48		SUM	5,126,800	5,000,100

Of course the benefit transfer of income (or house price) adjusted unit values (in terms of percentage effect per house) involves a substantial amount of assumptions. First it is assumed that preferences for forest proximity are the same in Svedala county as in the two study areas in Denmark. Given the similarities between Scania, Sweden and Eastern Zealand, Denmark, this assumption might not be that unrealistic. As no hedonic pricing studies have been conducted in Sweden so far, there is unfortunately no possibility to verify this assumption. There are however, substantial differences regarding the size of the forest area in Bara and the forests examined in Allerød and Esbjerg. The size of the forest located in the city of Bara is only 2ha. The city itself is only located 1.5 km away from a large recreational forest area, Torup forest, which clearly will act as a substitute site. The results from benefit transfer for this policy site should therefore rather be regarded as an indication of the potential value an afforestation project of a more reasonable size can have for the local population if it is planted in direct proximity of a built-up area with no substitute sites in the vicinity.

Benefit transfer of recreational values

Torup forest has been chosen as the policy site for the benefit transfer of recreational values. Benefit transfer can be done using two different types of values, (a) WTP per forest visit or (b) WTP for general access to the forest, e.g. in the form of a (hypothetical) annual admission card. Both types of unit value transfer require a clear description of the market size. The annual amount of visits to Torup forest is approximately 500,000.[29] Svedala county has a total of 18,269 inhabitants, with 12,845 being in the age group between 17- 74 which is the one normally included in CV studies.

Benefit transfer of recreational values for the Torup forest in Swedala county is based on the study by Mattsson and Li (1993) who elicited willingness-to-pay values for forests in northern Sweden. Two value elicitation questions were asked in that CV survey, one open-ended and one dichotomous choice. Results were 2,234 (1991) SEK/ 2,725 (2003) SEK[30] per individual and year on average for the open-ended version and 5,856 (1991) SEK[31]/ 7,144 (2003) SEK per individual and year for the dichotomous choice question.

Mattsson and Li (1993) allowed the respondents to decompose their total WTP into different components which were on-site consumptive use (mushroom and berry-picking), on-site non-consumptive use (walks, hiking, camping, etc.) and off-site experience. They found that on-site non-consumptive use made up nearly 50 % of the total value while off-site experience and berry- and mushroom-picking amounted to 30 % and 20 % respectively. Respondents made on average 35 forest visits per year. Dividing the WTP per individual by the amount of forest visits results in 78 SEK or 205 SEK per visit depending on if the WTP from the continuous or DC-question is used. These are substantially larger WTP amounts than those estimated by Dubgaard (1998) for visits to all forests in Denmark. They are though closer to per visit values to Mols Bjerge (Dubgaard (1994)).

To indicate the sensitivity of the total recreational value depending on the size of the unit value transferred, also the per visit result from Dubgaard (1998) is applied here which is equal to 4 (1993) DKK or 6 (2003) SEK[32]. Table 8 summarises the total recreational value for the forest area using the different per visit values discussed above assuming a total amount of annual visits of 500,000.

29 Based on personal comunication with Christina Persson, Svedala County.

30 Inflationfactor of 1.22 from 1991 to 2003 using the consumer price index provided by Statistics Sweden (www.wcb.se).

31 The 90th percentile of the valuation distribution was used as a truncation point, i.e. the top 10% was eliminated (see Mattsson and Li (1993), p. 431 for detailed description).

32 Using a price inflation of 1.42 from 1993 to 2003 and an exchange rate of 1.22 SEK/DKK (Danish Nationalbank 21/01/05).

Using either the open-ended (OE) or the dichotomous choice (DC) format results annual recreational values are equal to 39 or 102 million SEK. When the substantially lower WTP results from the Danish study are applied total annual recreational values are only 3 million SEK.

As mentioned before Svedala county has 18,269 inhabitants, of which 12,845 are in the age group 17-74 years used in Mattsson and Li (1993). Multiplying these with the WTP per individual from the study results in total recreational or non-timber values of 35 or 92 million SEK, depending on if results from the OE or DC format are applied. If inhabitants of Svedala county have the same average forest visit frequency as the inhabitants of Västterbotten county in northern Sweden Torup forest would receive approximately 450,000 visits annually from Svedala county alone. This is only slightly lower than the official count of 500,000 visits reported above. WTP from those forest visitors coming from the Malmø region should thus be added to the total recreational values reported in the last column in Table 8.

Table 8 Recreational value for Torup forest, Svedala county

	Based on 500,000 visits per year		Based on population in Svedala county	
Source	WTP per visits (2003 SEK)	Annual recreational value (Million SEK)	WTP per person/year (2003 SEK)	Annual recreational value (Million SEK)
Mattsson and Li (1993), OE format	78	39	2,725	35
Mattsson and Li (1993), DC format	205	102.5	7,144	91.7
Dubgaard (1998)	6	3	NA	NA

Source: Own calculations based on results from Dubgaard (1998) and Mattsson and Li (1993).

Summary and conclusions

The purpose of this study is to illustrate the non-market values of forests for the southern part of Sweden, Scania region. The recreational values of Swedish forests have been estimated before but these studies have focused entirely on forests located in the northern part of Sweden, despite the fact that forest areas are more scarce in the southern part and thus could be assumed to be more valuable. There do not exist studies estimating the amenity value of forests by using the hedonic pricing method in Sweden. Results form hedonic pricing studies in Denmark, however, indicate substantial values of forest proximity captured in house prices.

Given the similarity of the Scania and Zealand regions on both sides of the Oresund-bridge with regard to relative forest cover it could be assumed that the housing markets on the Swedish side will exhibit similar values for forest proximity. This assumption is limited to the extent that open landscapes are regarded valuable in Scania. However, existing forests in the area are being regarded very attractive for recreation by the inhabitants of Malmoe.

The results from the benefit transfer exercise indicate considerable values for forest amenities and recreational usage of forests in Svedala county. It should be noted here that not all recreational areas in Svedala county were included in the benefit transfer exercise nor did we cover all built-up areas that are located close to the forest edge. The values presented here can however, be used as an indication of the substantial non-market value forests can have for society and which should be included in future policy decisions about afforestation in Southern Sweden.

Benefit transfer is always associated with uncertainty. The analysis here shows that annual recreational values for an area are very sensitive to the transferred per visit values if valuation is based on the annual number of visits or the size of the market if valuation is done in the form of WTP per person. WTP per visit and per person from the Swedish study are very high, which might be due to the fact that Swedes, in general, have higher preferences for forests and forest related recreational activities, e.g. berry and mushroom picking or that the Swedish study was done for one particular forest area, while the Danish study's aim was to elicit WTP for access to all forests in Denmark. Thus if the goal is to transfer average WTP for a recreational trip the Danish study might provide a more realistic and conservative unit value.

Recently, a number of research studies have tried to test for accuracy of benefit transfer in a more formal way (see Brouwer and Spaninks (1999) and Bateman et al. (2000) for a summary of these studies). In these "transfer experiments" benefit estimates for different sites are statistically compared to other on-site estimates and the resulting error ranges of unit value and benefit function transfer are compared. Results from benefit transfer testing indicate that benefit transfer also in the case of adjusted unit values or when transferring benefit functions easily involves errors of 20-50 % and more. Some studies (e.g. Ready et al. (2004)) indicate that the uncertainty increases when values are transferred across countries because of unexplainable differences in preferences. However, errors in that range could still be acceptable for certain types of policy decisions, e.g. for use in a cost-benefit analysis.

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Appendix 3, Article 3
Omitted variable bias in estimating amenity values from afforestation areas in Denmark

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Abstract

Newly planted forest areas can create amenity values to people living close to them less than 10 years after planting started. This was confirmed by the current study that analysed three afforestation areas in Denmark using the hedonic pricing method. However, housing values are also impacted by other location-related attributes, natural or man-made, and their omission in estimating the hedonic price function can lead to omitted variable bias in determining the parameter for distance to afforestation areas and thus the marginal price for forest proximity.

For each case study area two different types of models were constructed, a "simple" model that only contained structural variables of the house and the "distance to the new forest" measure as explanatory variables and an "advanced" model that in addition to the variables of the simple model did include a range of other location-related variables, typical for Danish housing markets. For each model type three different transformation of the distance to new forest variable were tested, resulting in a total of nine different models per model type.

Results show a mixed evidence of the importance of including other location-related variables in model estimation. For three models (out of a total of nine), including other spatial variables resulted in substantial changes in the parameter estimated for the distance to new forest variable, changing the significance level of this coefficient from insignificant to significant and vice versa. Other models were relatively robust to the inclusion of other spatial variables.

This analysis shows the uncertainty involved in applying the hedonic pricing method to value non-market goods. Although based on real money transactions, i.e. the purchase of a house with certain characteristics, the likelihood of missing out on relevant variables is high, either because these are not easily accessible or too expensive to obtain. This can lead to omitted variable bias in the estimation of the parameter of interest and thus misleading information about marginal and non-marginal benefits to policy makers.

Introduction

Denmark has made an ambitious decision to double the nation's forest cover within one tree generation reaching about 20 % within the next 100 years. In order to fill this gap the Danish Forest and Nature Agency has initiated more than 100 public afforestation projects across the country that supplement private reforestation initiatives supported by subsidies. Afforestation projects create multiple benefits, including a range of non-market benefits like groundwater protection, CO_2 sequestration, recreational and amenity benefits. Obtaining reliable monetary estimates for these non-market benefits is essential for supporting decision makers in choosing the optimal spatial allocation of future forest areas.

Forest valuation literature has focused on determining the recreational and amenity benefits resulting from existing forest areas using the travel cost, contingent valuation and hedonic pricing method. Amenity values[33] are normally best captured by applying the hedonic pricing method to data from housing markets. Recreational values from visitors from "outside of town" on the other hand are primarily measured through the application of contingent valuation, discrete choice, travel cost and random utility models. The hedonic pricing method does only capture the use value related to forest proximity of the house owners included in the analysis.

In Denmark the hedonic pricing method has been applied to existing forest areas (Hasler et al. (2002)) and afforestation areas (Anthon et al. (2005)). Both studies found a positive effect on house prices of proximity to forest and afforestation areas, using distance to the forest edge as the explanatory variable. Hasler et al. (2002) did also analyse the general effect of an afforestation project for houses located in the same neighbourhood, by including dummy variables for different time periods that coincided with the planning and planting periods of the project.

These previous hedonic pricing studies of forest and afforestation areas in Denmark have based their analyses on simple models consisting of structural housing characteristics and the distance to (new) forest measure. However, house prices are also likely to be influenced by other location-related characteristics than the one environmental variable of interest. Leaving out relevant explanatory variables can cause omitted variables bias in parameter estimation. Cheshire and Sheppard (1995) have shown that including a fully specified hedonic model, i.e. a model including all relevant

33 The concept of 'amenity value' as measured by the hedonic pricing method applied to housing market data includes all benefits to local users, which they obtain from living close to a certain facility, including active enjoyment of the site as well as more passive enjoyments, e.g. utility obtained from a pleasant view or fresh air.

land and location-specific characteristics, is essential in order to obtain stable and reliable parameter estimates of the structural characteristics of houses.

More essential than the effect on structural variables is however the effect of omitted variables on the parameter estimate for the environmental non-market good of interest. In an analysis of hazardous waste sites Deaton and Hoehn (2004) found that the presence of industrial areas can have a negative impact on house prices and that the omission of such a variable in estimating the effect of hazardous waste sites can lead to overestimation of the benefits associated with clean up efforts of such areas. In a hedonic pricing study of how water quality affects the value of waterfront residences, Leggett and Bockstael (2000) found that including the distance to emitters of water pollutants in the hedonic equation decreased the size and significance level for the parameter estimate for the fecal coliform variable which was measuring the level of water quality. Ready and Abdalla (2005) pointed out that including measures of surrounding land use in rural areas when estimating the negative impact from animal production activities increases the measured negative effect from those animal farms considerably.

This study tests for the influence of omitted variable bias on the estimated coefficients for proximity to new forest areas by estimating both a “simple” model, consisting of only structural housing characteristics and the distance to new forest areas and an “advanced” model, which in addition to the variables included in the simple model contains a range of other spatial variables assumed to have an impact, positive or negative, on housing prices.

The models are applied to three afforestation areas in Denmark, Drastrup, located in the northern part of Denmark, close to the city of Aalborg, Kirkendrup afforestation area, located on the island of Fyn, north-west from Odense and Sperrestrup afforestation area, located on Zealand, north-west from Copenhagen, close to the village of Oelstykke.

The paper starts with a general introduction to the hedonic pricing method, followed by a description of the case study area, dataset and the model selection process. Different datasets are tested with different transformations of the distance to forest variable. The estimation results based on these models are reported in the next chapter. The impact of adding and deleting other spatial measures on the parameter estimate for distance to new forest is examined subsequently, followed by a discussion of results and conclusions.

Hedonic pricing method

The hedonic pricing method (HPM) is part of the group of valuation methods called revealed preference methods. The hedonic pricing method assumes complementarity between a market good and an associated public (or non-market) good. Rosen (1974) was the first to develop a formal theory of hedonic pricing. In the hedonic approach a good is assumed to consist of a set of attributes (so-called differentiated good) and the good's value or price thus can be considered a function of each attribute.

Environmental valuation studies that use the hedonic pricing method are almost entirely based on the housing market, where it is assumed that real estate prices are influenced by area attributes like traffic noise, air-quality, green space or for example quality of public schools. The hedonic price equation for the price of a house can be described as a function of the different attributes of the house or in a more formal way as

$$P = P(s, l, q) \qquad (1)$$

where

s = structural characteristics, e.g. house and lot size, number of rooms, age etc.,

l = location-related characteristics, e.g. distance to the city centre, schools, etc.,

q = environmental good, e.g. distance to forest, noise level, air pollution.

By using the housing market as a substitute market for the non-market environmental good q it is possible to estimate the demand for q from the price differentials (i.e. differences in prices for houses with varying amounts of the attribute q) revealed in the private market.

The hedonic price equation (1) is determined by the supply and demand in the particular housing market. Following Rosen (1974) the partial derivative of the hedonic price function (1) with respect to any characteristic gives its marginal implicit price:

$$\frac{\partial P}{\partial z_i} = p_{z_i} \qquad (2)$$

The marginal implicit price, p_{z_i}, is equal to the additional expenditure required to purchase a unit of the differentiated product with a marginally larger quantity of that characteristic. Assuming that the market is in equilibrium, consumers will have maximised their utility by choosing a particular house. This implies that they have equated their marginal willingness-to-pay for the house's attributes to the attributes' marginal implicit prices. Thus the estimated coefficients for the different attributes can be used to calculate marginal WTP for the different characteristics of a house.

The formula for the calculation of marginal prices depends on the functional form chosen for the hedonic price function. Functional forms most often applied in hedonic pricing studies include the linear, semi-log, inverse semi-log and double log functional form. Attributes can also be entered in a reciprocal transformation, i.e. the inverse of their values. Table 1 shows how implicit prices for housing characteristics can be calculated based on different functional forms for the hedonic price function.

Table 1 Functional forms for the hedonic price function

Name	Equation	Implicit Prices
Linear	$P = \alpha_0 + \sum \beta_i z_i$	$\partial P / \partial z_i = \beta_i$
Inverse Semi-Log	$P = \alpha_0 + \sum \beta_i \ln z_i$	$\partial P / \partial z_i = \beta_i / z_i$
Semi-Log	$\ln P = \alpha_0 + \sum \beta_i z_i$	$\partial P / \partial z_i = \beta_i * P$
Double_log	$\ln P = \alpha_0 + \sum \beta_i \ln z_i$	$\partial P / \partial z_i = \beta_i / z_i * P$
Reciprocal transformation*	$\ln P = \alpha_0 + \sum \beta_i 1/z_i$	$\partial P / \partial z_i = -\beta_i / z_i^2 * P$

* Here with the dependent variable log-transformed.

Source: Taylor (2003), updated with reciprocal transformation.

Palmquist (1992) has shown that in the case of localised externalities the hedonic price equation is also sufficient to determine WTP for non-marginal changes, as long as only a relative small number of properties within one housing market are affected. For the current project it is assumed that in the case of afforestation the change in forest cover will only affect a small part of the respective housing market. This extra premium paid for forest proximity in the three study areas in terms of higher house prices the closer one gets to the afforestation area (assuming all other housing characteristics are kept at some constant value) represents the house owners' WTP for amenity values from forests for different distances.

Data and model selection

Description of case study areas

There are more than 100 afforestation projects in Denmark, ongoing or already finalized. However, in order to be able to apply the hedonic pricing method to determine amenity values from afforestation, case study areas needed to be found where the newly forested areas are situated in close proximity to built-up areas and where planting of trees had been done at least a couple of years ago in order to ensure enough house sales for the analyses. In an earlier Danish study, Anthon et al. (2005) had selected two areas and found significant positive effects of afforestation. For this study three other suitable areas were chosen, Drastrup, Kirkendrup and Sperrestrup, spread more or less equally across the country (see Figure 1).

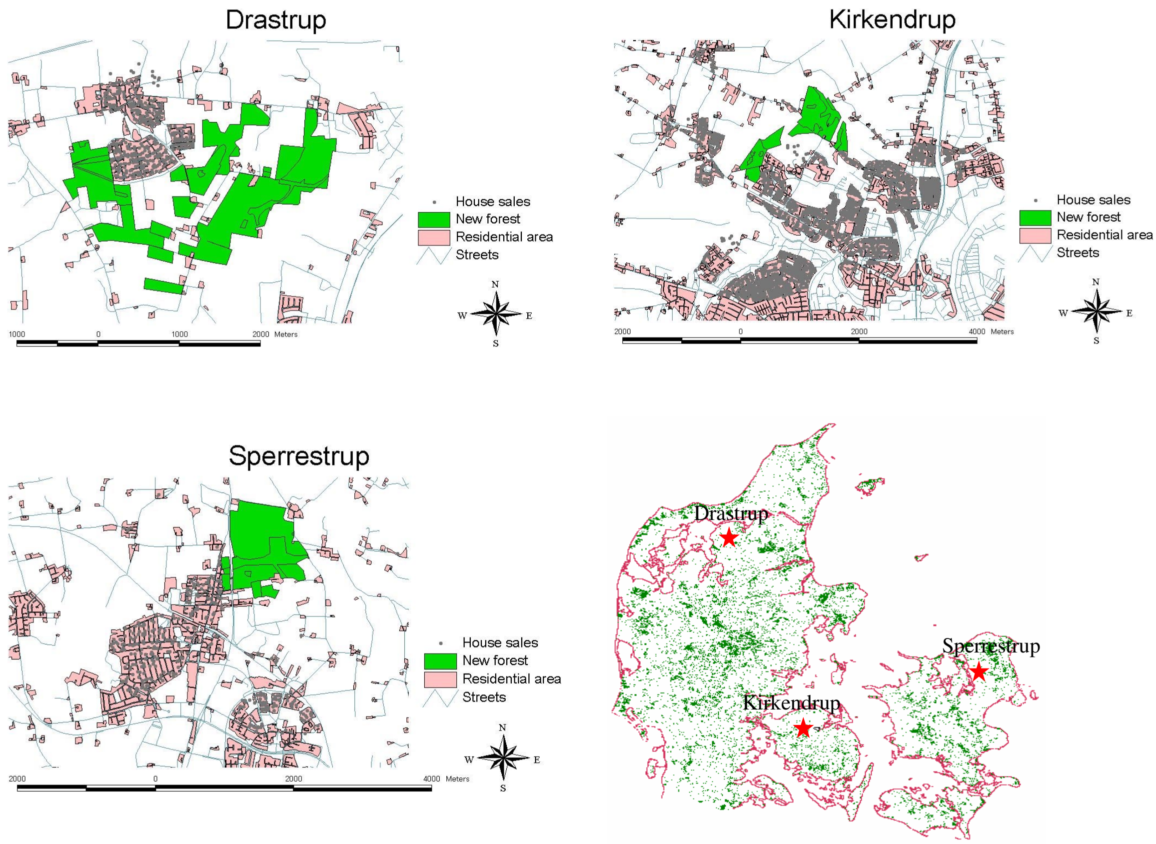

Figure 1 The three afforestation areas and their location

The Drastrup afforestation project is located close to Aalborg in the northern part of Jutland. Planting of trees started in 1996 and the total size of the afforestation area is about 200 ha. An earlier hedonic pricing study (Hasler et al. (2002)) has analysed this project by studying the development of house prices in the built-up area called Frejlev, which is located close to the afforestation project. They found a considerable positive effect of the period that coincided with the planting phase (from 1996 and on). According to their analysis house prices increased with 20 % over and above the general price increase during that period.

The Kirkendrup afforestation area is located on the island of Fyn, north-west from Odense, the third largest city of Denmark and has a total size of only 75 ha. Houses within the suburban area of Kirkendrup are within bicycling distance (2-7 km) to central Odense. The planting of trees started here in 1996.

The Sperrestrup afforestation area is located on the island of Zealand, north of the village of "Oelstykke" and consists of 115 ha. Planting of trees did start in 1997. Oelstykke is connected to the Greater Copenhagen area, the capital of Denmark, by S-train, which makes it an attractive area for people working in Copenhagen. The S-train tracks going from west to east divide the residential area in two parts and a main road, Roskildevej, that goes from north to south, separates the housing area from the afforestation area. A little pedestrian bridge connects the afforestation area with the housing area.

Data selection and preparation

Information about housing characteristics is collected from two different data sources. The official Danish Housing registers (BBR/ESR registers) contain information about the structural characteristics of houses, i.e. size of living area and lot, number of rooms, toilets and bathrooms, age and sales price to name just the most essential ones. Information about neighbourhood characteristics is collected using Geographical Information Systems (GIS), specifically ArcGIS and ArcView based mainly on TOP10DK, a topographic map system for all of Denmark (Kort & Matrikelstyrelsen (2001)).

Data selection started with including all houses sold within a 2 km radius of the afforestation projects. A radius of 2000m was chosen as former studies in Denmark have shown a substantial influence of forest proximity up to 600m from the forest edge and a 2000m radius thus would ensure sufficient variations in forest proximity and anticipated effect of forest. From this spatial selection all single family houses, detached and semi-detached, that are registered as residence all year round, are selected. Any houses containing commercial entities are discarded. The housing registers include the latest sales price of the property and the date of deed signature.

The house price index issued by the Danish Tax Authorities (Told- og Skattestyrelsen (2004)) is used to inflate sales prices to 2004 prices.[34]

Continuous variables for structural characteristics of individual houses in the dataset include the number of rooms, size of the lot, age at sale and the sales price inflated to 2004 prices and a weighted area measure. The BBR/ESR register contains detailed information about the size of the different floors of houses, the size of an eventual basement and attic and the existence and size of garage, outhouse, patio and carport. The Danish Ministry of Taxation uses a weighted measure of living space for the tax assessments (Told & Skat (2004)) and the same measure is used in the following analysis. This measure attributes different weights to the size of ground and other floors, attic and basement and also includes the size of garage, carport, outhouse and patio. Formulas to calculate this weighted measure differ with regard to the type of house (detached or semi-detached) and the size of the county the house is located in.

GIS tools (ArcView and ArcGIS) are used to measure the Euclidian distance, "as the crow flies", to the edge of the afforestation area. Public open land areas and private open land areas enrolled in conservation programs have been found to have a positive effect on housing prices by Irwin and Bockstael (2001). Vaughan (1981) and Morancho (2003) found positive premiums associated with locations close to urban parks and green areas, while Garrod and Willis (1992b) found a positive effect of proximity to rivers and negative effect of proximity to wetlands in their hedonic pricing study of selected countryside characteristics on housing values. Mahan et al. (2000) showed that proximity to wetlands exhibit a positive influence on housing prices. In addition, afforestation projects are often planted as continuations of already existing forest areas, thus also the effect of old forest areas should be accounted for in the hedonic price equation.

Based on information available in TOP10DK maps a number of other continuous variables for spatial characteristics are included in the dataset. These include the distance to the nearest industrial area, distance to the nearest lake, heath, wetland area and old forest. "Old forest" areas are defined as areas with tree planting with a minimum size of 0.25 ha, i.e. this category does also include smaller "forestry-like" areas in between houses. In addition another spatial characteristic called "recreational areas" is included in this analysis, which in TOP10DK (Kort & Matrikelstyrelsen (2001)) is defined as all areas that are used for recreational activities and includes areas as parks, public green areas, playgrounds and amusement parks etc. Other spatial measures included are distance to the nearest coastline, highway exit and direct distance

[34] The index varies by the population size of the county the house is located in and special indexes are issued for the northern part of Zealand and the Greater Copenhagen Area, where house prices have risen substantially more than in other parts of the country during the last decade.

to nearest highway. Also a variable measuring the distance to nearest high-rise buildings (defined as build-up areas with more than 2 levels) was included. Maps with train stations, elementary schools and childcare institutions in the area and the nearest larger town were constructed and the direct distances to these facilities from each observation were measured.

Dummy variables were added for semi-detached houses, fireplace and if the house had more than one toilet. In addition dummy variables were used to indicate the type of roof material (flat roof or tile) and if the outer wall construction material was not made up of brick stones (e.g. fibercement, wood, concrete, gas concrete and others).

In the two areas Drastrup and Sperrestrup semi-detached houses were included in the dataset used for estimation. In both areas the amount of house sales available after afforestation started was limited in the first place. In addition, semi-detached houses in these two areas are distributed more evenly across the areas, thus minimising the possibility of bias resulting from this housing category. In Kirkendrup the location of semi-detached houses is generally further away from the afforestation area, which might bias results. A comparison of coefficient results for the "distance to new forest" measure between models with and without semi-detached houses for this area showed that including semi-detached houses increased the size and significance level of the coefficient. In order to ensure a conservative approach the regression analyses for Kirkendrup were only based on the "detached" housing category.

Distance to highway and highway exit, high-rise buildings and distance to coast and heath area were generally longer than 2 km and thus could not be expected to produce either negative or positive effects on the housing prices in the three areas. In the Kirkendrup area distance to coast and high-rise buildings did coincide with distance to Odense central station. These five measures were therefore generally excluded from model estimation. A variable measuring the distance to the nearest larger city was also not included in the analyses of the three areas, either because it coincided with the distance to central station measure as in Kirkendrup or because the distance was too long and variation within one area too small in order to show an effect.

In the case of Drastrup afforestation areas also distance to central station was excluded as an explanatory variable as the distance was too long to show an effect. Distance to school was also excluded as there was only one school in the case study area.[35]

[35] The school is located in the far north-western corner of the village. The school distance measure proved to be highly correlated with distance to industry and the distance to new forest measure. Its inclusion in the model resulted in a large and highly significant positive coefficient for distance to school and a large and highly negative coefficient for distance to industry, thus indicating that schools are a disamenity while proximity to industrial areas is considered positive. The coefficient for distance to new forest

While a first data selection process was based on a radius of 2000m around the afforestation areas, in the Drastrup and Kirkendrup area this radius proved to be too large in order to capture the effect of localised externalities from afforestation. In the case of Drastrup the local housing market was therefore confined to the village of Frejlev, thus keeping observations within a maximum distance of 1000m from the forest edge.[36]

For the Kirkendrup afforestation area the maximum distance radius of 2000m did not show a significant effect of proximity to afforestation areas. In order to test the sensitivity of the coefficient results for distance to new forest (and in a sense, the extend of the localised externality from an afforestation project), estimations are repeated for different sub-datasets for distance intervals from 2000m down to 1000m from the forest edge. Decreasing the radius resulted in general in an increase in the size and significance level for the coefficient for distance to new forest up to about 1000m, then size and significance decreased again. While this exercise shows the sensitivity of coefficient estimates for the extend of the local market chosen for analysis, its effect can probably be explained by the increasing orientation towards Odense city with increasing distance from the newly planted forest area. A distance radius of 1700m was chosen for final model estimation as this was the largest distance were both the untransformed and log-transformed distance to new forest measure showed a significant effect.

For the Drastrup and Sperrestrup datasets it was necessary to create additional dummy variables that could capture the effects of local sub-markets in the areas. For Drastrup this resulted in a dummy variable for "Frejlev East", a residential area that consists of architect-designed houses, which because of the area's slope nearly all have view over "Limfjorden", a large saltwater inlet a couple of kilometres north from the village of Frejlev. In order to account for possible housing sub-markets within Oelstykke in the Sperrestrup dataset, house sales are divided further into three different sub-areas, the area north from the S-train line, called "Oelstykke North" in this analysis, the area south and east from the train tracks, "Oelstykke East" and the area south and west from it, called "Oelstykke south".[37]

areas was highly insignificant in a model including distance to school. The reliability of the results for the Drastrup area based on the sensitivity of the models to the inclusion of other variables is discussed in the last section of this article.

[36] A model including all houses within the 2km radius was tested where dummy variables have been created indicating which parish the house was located in. The forest distance measures were, however, still insignificant.

[37] Dummy variables for houses located directly adjacent to the main road running through Frejlev or to train tracks in Sperrestrup were also created and tested, however in both areas their coefficient showed up as positive and highly significant. As the inclusion of these dummy variables with rather unexplainable results increased the positive proximity effect of afforestation areas it was decided not to include them in further analysis in order to ensure a conservative estimation of forest amenity values.

The final datasets for the analyses presented in this paper are based on the house sales in the period after afforestation started, i.e. from 1996-2005 for Drastrup and Kirkendrup and 1997-2005 for Sperrestrup. Table 2 allows for a comparison of the mean continuous characteristics across sites, while Table 3 summarizes dummy variables for the three areas. Total amount of observations available after afforestation was started did vary considerably between sites, with 185 sales in Drastrup, 476 in Kirkendrup and 259 in Sperrestrup. Average sales prices were highest in Sperrestrup, followed by Drastrup and Kirkendrup.

Table 2 Summary of continuous variables for house sales

Variable	Units	Drastrup	Kirkendrup	Sperrestrup
N Obs	N	185	476	259
Sales price	DKK	1,142,857	1,063,356	1,493,016
Off. valuation	DKK	1,144,703	1,023,866	1,460,038
Price (2004)	DKK	1,479,584	1,370,993	1,750,506
Construction date	Year	1974	1968	1970
Deed signature	Year	2000	2000	2002
Weighted measure of living space	m^2	149	138	132
Lot size	m^2	830	842	635
Number of rooms	N	5	5	4
Age at time of sale	Years	27	32	33
Distance to newly planted forest area (dnewforest)	m	402	977	1,230
Distance to nearest lake (distlake)	m	1,097	325	443
Distance to nearest wetland area (dwetland)	m	1,023	537	613
Distance to nearest recreational area (drecreatio)	m	298	288	217
Distance to nearest old/existing forest area (doldforest)	m	170	166	216
Distance to nearest heath area (distheath)*	m	3,071	9,629	24,431
Distance to nearest coast (distcoast)*	m	4,520	2,568	4,485
Distance to nearest industrial area (distend)	m	426	480	518
Distance to nearest elementary school (distschool)	m	786	954	575
Distance to nearest childcare institution (dchildcare)	m	302	717	377
Distance to nearest central station (distcs)	m	4,063	3,902	870
Distance to nearest highway (distmw)*	m	4,351	6,858	12,500
Distance to nearest highway exit (distmwexit)*	m	4,992	7,768	12,559
Distance to nearest building with min. 2 stories (dhighbuild)*	m	3,953	1,458	3,536
Distance to city centre (distcity)*	m	7,052	3,995	28,669

* Measured but not included in analysis, see explanation in text.

Table 3 Summary of dummy variables

		Drastrup (N Obs: 185)		Kirkendrup (N Obs: 476)		Sperrestrup (N Obs: 259)	
	Value	Freq.	Percent	Freq.	Percent	Freq.	Percent
semi_detach	0	157	84.86	-	-	187	72.2
	1	28	15.14	-	-	72	27.8
flat_roof	0	164	88.65	460	96.64	221	85.33
	1	21	11.35	16	3.36	38	14.67
tile	0	162	87.57	280	58.82	234	90.35
	1	23	12.43	196	41.18	25	9.65
fireplace	0	161	87.03	407	85.5	246	94.98
	1	24	12.97	69	14.5	13	5.02
not_brick	0	183	98.92	447	93.91	207	79.92
	1	2	1.08	29	6.09	52	20.08
extoilet	0	55	29.73	210	44.12	103	39.77
	1	130	70.27	266	55.88	156	60.23
FREJL_EAST	0	144	77.84	-	-	-	-
	1	41	22.16	-	-	-	-
OELSOUTH	0	-	-	-	-	138	53.28
	1	-	-	-	-	121	46.72
OELEAST	0	-	-	-	-	179	69.11
	1	-	-	-	-	80	30.89

Model selection and reduction

Theory does not proscribe a specific functional form for the hedonic price function (1), with the exception that it is monotonically increasing in desirable characteristics (Palmquist (1999)). For the current analyses functional form specification is based on residual analysis and added variable plots. In this sense this study's approach differs from other applications of the hedonic pricing method that have determined the functional form based on the results of estimations using the general quadratic Box-Cox function suggested by Halvorson and Pollakowski (1981).[38] However, Box-Cox parameter estimates are influenced by the most influential variables on house prices, i.e. living area, lot size, age etc. Thus transformation parameters estimated for these variables may not necessarily be adequate for the environmental variables. Cropper et al. (1988) found in their simulation study of a housing market that when explanatory variables are measured with errors or need to be replaced by proxies, the simple form of transformations, i.e. linear, semi-log, inverse semi-log and double-log perform best.

In all areas the graphical analyses suggested that the price of the house should be log-transformed. For two areas, Drastrup and Kirkendrup the graphical analyses suggested that also all explanatory variables should be log-transformed thus resulting in a double-log functional form for the hedonic price equation. For the

[38] The Box-Cox routine in STATA 9 allowing estimation of different parameters for the dependent and explanatory variables was used to estimate a general Box-Cox function (without quadratic terms) for the three datasets. Using the transformations suggested by this estimation distance to newly planted forest was only significant in one model (Sperrestrup simple).

Sperrestrup area, distance to wetland, old forest, school and age at the time of sale should remain untransformed.

After deciding on functional forms the three datasets were examined for outliers. Some observations in Kirkendrup and Sperrestrup are located somewhat separated in the country site and thus might exhibit a different hedonic price schedule than the other observations. These are therefore deleted from the dataset. Before estimating final models the datasets and model specifications were checked for outliers with high studentized residuals or large Cook's distance. This resulted in the deletion of four outliers in Drastrup, three in Kirkendrup and two in Sperrestrup.[39] Final models are than estimated by successively discarding insignificant variables, starting with the variable with the highest p-value, until all remaining variables in the model have a maximum p-value of 0.1.

For the Drastrup analysis the total effect of deleting the four outliers was neutral with regard to the coefficient estimate for distance to new forest measures. Deletion of two outliers increased significance and size of coefficient for distance to new forest, while deletion of two other outliers had the opposite effect. For the Kirkendrup analysis deleting the three outliers had no impact on the coefficient result for distance to new forest measure. In Sperrestrup the exclusion of outliers did substantially change size and significance level of the coefficient for distance to new forest areas from insignificant to highly significant. Both outliers had unusually low sales prices compared to their characteristics. Sale prices were however, only slightly below the official valuation which could indicate that both houses were in need for larger repairs not captured in the housing register data.

Heteroskedasticity

Application of Ordinary Least Squares (OLS) requires that the assumption of homoskedasticity (i.e. constant error variance) is fulfilled. This assumption will fail and thus suggest that heteroskedasticity is present in the model when the error variance increases or decreases with increasing or decreasing values of one or more independent variables. If heteroskedasticity is present the estimated variances for the coefficients are biased and thus the OLS standard errors can no longer be used for constructing confidence intervals and t statistics.

[39] There were different reasons for the exclusion of these outliers from further analysis. In four cases the sales price (inflated to 2004 prices) was substantially below the official valuation, i.e. with price-valuation ratios of 0.7 or worse, indicating that these houses were probably not sold in "arms-length" transactions. In one case the outliers proved to be the only observation with an age of zero in the dataset, while in three cases both sales price and official valuation for the outlier were substantially lower than expected given the general characteristics of the houses. For yet another outlier the sales price was about 2 times the official valuation (with otherwise average characteristics).

For the current analyses model results are tested for the presence of heteroskedasticity using the Breusch-Pagan/ Cook-Weisberg test. This test runs a regression of the squared residuals against the fitted values of the dependent variable in the model. As the fitted values of the dependent variable are a linear function of the independent variables, this test is in effect a special form of the White test (White (1980)). Under the assumption of homoskedasticity coefficients estimated by this procedure should be equal to zero, i.e. the error term should not be effected by the values of the independent variables. Thus if the p-value for this test statistic is sufficiently small, the null hypothesis of homoskedasticity can be rejected (see Wooldridge (2003), p. 266-269 for a more detailed description).

None of the models analysed for the Drastrup afforestation area showed evidence of heteroskedasticity. For Kirkendrup, after deletion of rural outliers and semi-detached houses the different models did not show evidence of heteroskedasticity. For the three datasets only the models for Sperrestrup showed signs of heteroskedasticity. Thus for these models heteroskedasticity-robust standard errors are calculated using the "robust" function available in STATA (see White (1980) for a more detailed explanation).

Multicollinearity

Problem of multicollinearity in hedonic pricing appears when independent variables are highly correlated with each other. High correlation between independent variables means that the R^2_j obtained from a regression of an independent variable against the other independent variables in the model is high, which in turn will cause the variance of the estimated coefficient to become larger as illustrated in equation (3) below.

$$Var(\hat{\beta}_j) = \frac{\sigma^2}{SST_j(1 - R_j^2)} \quad (3)$$

where

σ^2 = error variance

SST_j = total sample variation in x_j, $SST_j = (x_{ij} - \bar{x}_j)^2$

R^2_j = R^2 from regressing x_j on all other independent variables

All other things equal larger variances result in larger confidence intervals and thus imprecise measurements of the true population parameter β_j. The problem of multicollinearity is examined in the different models by looking at the individual correlation coefficients between the independent variables in the final model and by calculating variance inflation factors (VIF) for the independent variables in the final models (see equation (4)). Of special interest is of course the correlation of the distance to new forest variable with other independent variables in the model as it is the coefficient from this variable that we will use to calculate marginal willingness to pay for forest proximity.

$$VIF(\hat{\beta}_j) = \frac{1}{1 - R_j^2} \qquad (4)$$

In all final models individual VIF's turn out to be below 5 for advanced models and below 3 for simple models. Normally a VIF of 10 is considered the point where multicollinearity becomes a serious problem (Besley et al. (1980)). In the Drastrup final advanced model there is a high correlation between the coefficient for distance to wetland and distance to new forest area of .80. In the Kirkendrup area there is a relatively high correlation between coefficients for distance to newforest and distance to central station of .55. There is a relatively high correlation between distance to newforest and "Oelstykke East" (-0.55) in the Sperrestrup final models.

Results of regression analysis

The following regression results are determined by applying the hedonic pricing method as described before and are based on the following general model form:

$$\ln P_i = \alpha + \sum_j^J \beta_j S_{ji} + \sum_k^K \delta_k L_{ki} + \lambda Q_i + \varepsilon_i \qquad (5)$$

Where

P_i = transaction price of property i, inflated to 2004 prices

S_{ji} = j structural characteristics of property i, i.e. the log transformation of weighted area measure, lot size, number of rooms, and age at the time of sale (age remained untransformed in the Sperrestrup dataset) and dummy variables for flat roof, tile, fireplace, not-brick as building material and extra toilet.

L_{ki} = k locational characteristics of property i, i.e. log transformation of distance to industry, central station, lake, childcare institution, recreational area, wetland and old forest as well as dummy variable for sub-markets in Drastrup and Sperrestrup.

Q_i = distance to new forest area, dependent on the model included as untransformed, log transformed or inverse transformation. It is assumed that increasing distance to new forest area – all else equal - will lead to decreasing housing values, i.e. λ is hypothesized to be negative for the untransformed and log-transformed distance measure and positive for the reciprocal distance measure.

ε_i = error term, which is assumed to have a conditional mean of zero and a constant variance

Ordinary least squares was used for estimation of the hedonic price function and two basic types of models were estimated for each case study area:

(1) A so-called "simple" version, i.e. one that only includes the classical structural housing variables, the distance to new forest and the dummy variable for sub-markets in Drastrup and Sperrestrup (i.e. a model where all location-related variables L_{ki} are excluded) and

(2) an "advanced" version that besides the variables of the simple model does include all other locational related variables that might have a negative or positive effect on housing values.

For each of these two general model types three different transformations of the distance to new forest variable are tested, one where the variable remains untransformed, one where it is log-transformed and one were distance is entered as its reciprocal value. This resulted in total of 9 different models analysed per model type. The results for these models and the three different transformations tested for the distance to new forest variable are summarized in Table 5 and Table 6 below.

With a few exceptions the parameter estimates for structural variables turned out as expected a priori. From the classical structural housing variables the weighted area measure and the age at the time of sale proved to be highly significant in all models. The number of rooms does not seem to have a significant effect on housing values, the reason most likely being that the effect of extra rooms is strongly correlated with the area measure of a house. The size of the lot was only significant in the Drastrup afforestation area, and here only in those models where the dummy variable for semi-detached houses was not significant in the final models.

Semi-detached houses were only included in the datasets for Drastrup and Sperrestrup. The dummy variable was highly significant in the Sperrestrup area where it showed that semi-detached houses were about 9-10 % cheaper than detached houses. In the Drastrup area the dummy variable was only significant in the advanced model with distance to new forest untransformed. Here it showed that semi-detached houses were about 13 % cheaper than detached houses.

Other structural variables showed the expected sign when significant, e.g. negative sign for flat-roof and "not brick", positive sign for tile as roof material and existence of fireplace. A dummy variable indicating if there was more than one toilet in the houses was not significant in any of the models.

As described before both in the Drastrup and Sperrestrup case study area extra dummy variables measuring the effect of submarkets needed to be included. Two of these sub-areas, "Frejlev-east" in Drastrup and "Oeleast" in Oelstykke showed positive and significant coefficients in all models, indicating that houses in these areas were 10 % more expensive than the remaining houses.

Besides distance to new forest areas about eight other spatial measures where included in the advanced models for the three case study areas that did measure direct distances to industry, central station, lakes, schools, childcare institutions, wetland areas, recreational areas and old forest areas. From these eight measures only distance to industry, central station, childcare institution, wetland and old forest did show a significant effect and only in some models. In three models, none of these additional measures proved to have a significant effect on housing prices. Distance to lake, school and recreational areas did not have a significant effect in any of the three case study areas.

Distance to industrial areas was only significant in the Kirkendrup area where it had a positive coefficient indicating that living closer to industrial areas is regarded a disamenity. Distance to central station had a highly significant and negative coefficient. In this area distance to central station is measuring the distance to city centre of Odense. Distance to nearest childcare institution appeared with a positive sign in Kirkendrup, while it was negative and significant in two out of three models in Sperrestrup. Distance to wetlands had a negative sign in one model in Drastrup and two models in Sperrestrup, indicating that proximity to wetlands is an amenity, while distance to old forest areas only was significant and with a negative sign in the Kirkendrup area.

In all models the coefficient for distance to new forest has the expected negative sign for the un-transformed and log-transformed variables and positive sign for the reciprocal transformation (with the exemption of the simple model for Sperrestrup), thus indicating that house prices decrease with increasing distance from the forest edge. The reciprocal transformation was not statistically significant in any of the three areas, neither in the advanced nor in the simple models. The untransformed distance proved to be statistically significant in all models besides the simple model for the Drastrup area. The log-transformed distance to new forest areas was only significant in the simple model for the Sperrestrup area and in both the advanced and simple model for Kirkendrup afforestation area.

Table 4 Summary of parameter results and calculated marginal prices for the models with significant parameter of distance to new forest[40]

Forest	Drastrup		Kirkendrup				Sperrestrup	
Transformation	Dnewforest		Dnewforest		Lnnewforest		Dnewforest	Lnnewforest
Model type	Simple	Advanced	Simple	Advanced	Simple	Advanced	Simple/Advanced	Simple
N Obs	185	185	476	476	476	476	259	259
Size of forest area (ha)	232	232	75	75	75	75	115	115
Parameter value	-0.000089	-0.000312	-0.000053	-0.000075	-0.034	-0.040	-0.000053	-0.024
P-value	0.159	0.005	0.004	0.001	0.005	0.003	0.000	0.005
Standard error	0.000063	0.000109	0.000019	0.000023	0.012	0.013	0.000014	0.008
95 % CI up	0.000035	-0.000096	-0.000017	-0.000031	-0.010	-0.014	-0.000025	-0.007
95 % CI low	-0.000213	-0.000527	-0.000090	-0.000120	-0.057	-0.066	-0.000081	-0.040
Average house price (DKK)	1,479,584	1,479,584	1,370,993	1,370,993	1,370,993	1,370,993	1,756,401	1,756,401
Mean forest distance (m)	402	402	977	977	977	977	1236	1236
Implicit price/m at mean values (DKK)	-132	-462	-73	-103	-47	-56	-93	-34
95 % CI up (DKK)	52	-142	-23	-42	-14	-19	-44	-10
95 % CI low (DKK)	-315	-780	-123	-164	-80	-92	-142	-57
R2	0.684	0.686	0.574	0.610	0.573	0.609	0.692	0.686
Adj R2	0.674	0.673	0.569	0.603	0.569	0.601	0.682	0.675
AIC	-133.2	-132.2	-296.0	-330.9	-295.9	-329.0	-413.8	-408.6
BIC	-110.7	-106.5	-271.0	-289.3	-270.9	-287.4	-381.8	-376.5

[40] The results for the simple Drastrup models are included here as the parameter estimate for the distance to new forest measure was nearly significant and in order to show the large variations in results for this area based on the inclusion of other location-related variables.

Table 4 provides a summary of parameter results for the distance to new forest measure for those models where the estimated coefficient for distance to new forest was significant (or close to being significant at the 10 % as in the Drastrup simple model). For those models in semi-log form, the parameter estimate (times 100) for distance to new forest should be interpreted as the percentage decrease per meter. For Drastrup advanced model this would for example result in a price decrease of -0.0312 %/m distance to the newly planted forest area, while the price distance gradient would be -0.0053 %/m for the simple models in Kirkendrup and Sperrestrup.

In the semi-log form the marginal price as a percentage of the house price is constant over the range of distance to new forest in the dataset, i.e. independent of the distance to the forest edge. Normally one would expect a diminishing effect with distance that approaches zero at some point, which for example a log-transformation or inverse transformation would have achieved. For the double-log function forms for the simple and advanced model in Kirkendrup and the simple model in Sperrestrup the coefficient for the log-transformed distance to forest measure represents the elasticity of house price with respect to distance to new forest, which for example for the simple Kirkendrup model implies that a one percent increase in distance decreases the house price by about 0.034 percent. Evaluated at the mean distance to the forest edge the percentage decrease per meter for the simple Kirkendrup model would be -0.0035 %/m (at 977m distance) (see Table 1 for the formula for implicit price calculations).

Based on the average house price and average distance to new forest in the respective datasets marginal prices per meter have been calculated (see Table 1 for the formula for semi-log and double-log models). The results presented in Table 4 show the large variations of implicit prices per meter across models and datasets, ranging from -34 to -462 DKK/m. But also "within model" variation can be high, i.e. the uncertainty attached to the individual parameter estimates illustrated by the width of the confidence intervals. For example does the implicit price per meter based on the Drastrup advanced model range from -142 to -780 DKK/m.

Given that both prices and distances vary across datasets it is rather difficult to compare results based on the estimated parameters alone. Therefore Figure 2 shows the mean percentage decrease in housing prices because of increasing distance to the forest edge and the 95 %- confidence intervals for those percentage decreases. Percentage differences for 100m intervals where calculated based on the estimated parameters for distance to new forest according to the following two formulas:[41]

[41] Given the semi-log function form and assuming all other housing characteristics beside distance to new forest remain constant, the percentage difference in house prices

1. for the untransformed distance to new forest:

   $\Delta \% = 100 * (1- \exp(\lambda * (D2 - D1)))$ and

2. for the log-transformed distance to new forest:

   $\Delta \% = 100 * (1- \exp(\lambda * (\log(D2) - \log (D1))))$

where Δ % is equal to the difference in housing prices calculated in % of house located at 100m distance from the forest edge (=D1), λ is the parameter value estimated in the respective model for the distance to new forest measure, D2 is distance to new forest measured starting at 100m and extending to the largest distance in the respective dataset. That is the decease in house price is calculated compared to a baseline price for a house with average characteristics located at 100m from the forest edge.

Results for Sperrestrup and Kirkendrup are surprisingly similar, while percentage decreases in Drastrup seem to be unusually large in the advanced model. For comparison therefore the results for the simple model in Drastrup are also included here, although the coefficient for distance to new forest had a p-value of 0.159. In both the Drastrup and Kirkendrup datasets advanced models produced a higher price-distance gradient for distance to new forest as can be seen in Figure 2.

Results for the Drastrup simple model differ from what previously was found in (Hasler et al. (2002), while coefficient results for the advanced model indicate price increases that are closer to the price increase found in that previous study of an average increase of 20 % of housing prices in the period after planting of trees was started. The advanced model exhibits though a high correlation between distance to wetland and distance to new forest (-0.8). The closest distance measured in the dataset to wetland areas is about 350m. The majority of wetland areas are located north from the built-up area which is sloping downwards in the northern direction, probably allowing some of the houses view over open land area and actually towards the Limfjorden further north. It is likely that it is this “view” effect that is measured by the wetland variable.

Assuming that the advanced models provide the more accurate description of the hedonic price functions for the different markets using “simple” model estimation results would have underestimated benefits (measured as the change in housing prices because of increased proximity to forest areas) by more than 70 % in Drastrup and about 30 % in Kirkendrup when distance to new forest is untransformed. For the Kirkendrup model with log-transformation of distance to new forest, benefits based on the

can be calculated as $100\left[\frac{\exp(\lambda D_1)-\exp(\lambda D_2)}{\exp(\lambda D_1)}\right]$. For the double-log functional form D1 and D2 are equal to the natural logarithm of the respective distances to new forest.

simple model would only have underestimated the benefits measured by the "true" advanced model" by 16 %.

Results partly confirm what earlier studies in Denmark have found (Hasler et al. (2002), Anthon et al. (2005), Præstholm et al. (2002)), i.e. forest areas are perceived as an amenity for house owners and at least part of these benefits are already in place within few years after planting started. Other European studies with similar results are Tyrväinen (1997), Garrod and Willis (1992a) and Tyrväinen and Miettinen (2000), while Thorsnes (2002) shows a positive proximity effect for forest areas for areas in Michigan, USA.

All of the previous Danish studies of forest amenity values have used simple models without incorporating other spatial measures that might affect housing values. Tyrväinen (1997) and Tyrväinen and Miettinen (2000) included distance measures to small forest parks, watercourses, beaches as well as distance to schools, shopping centres etc., but did not explicitly analysis the effect an omission of these extra spatial variables would have on the distance to urban forest measure. As can be seen from the results from this study including other spatial measures in the explanation of housing prices can affect the marginal price for forest amenity

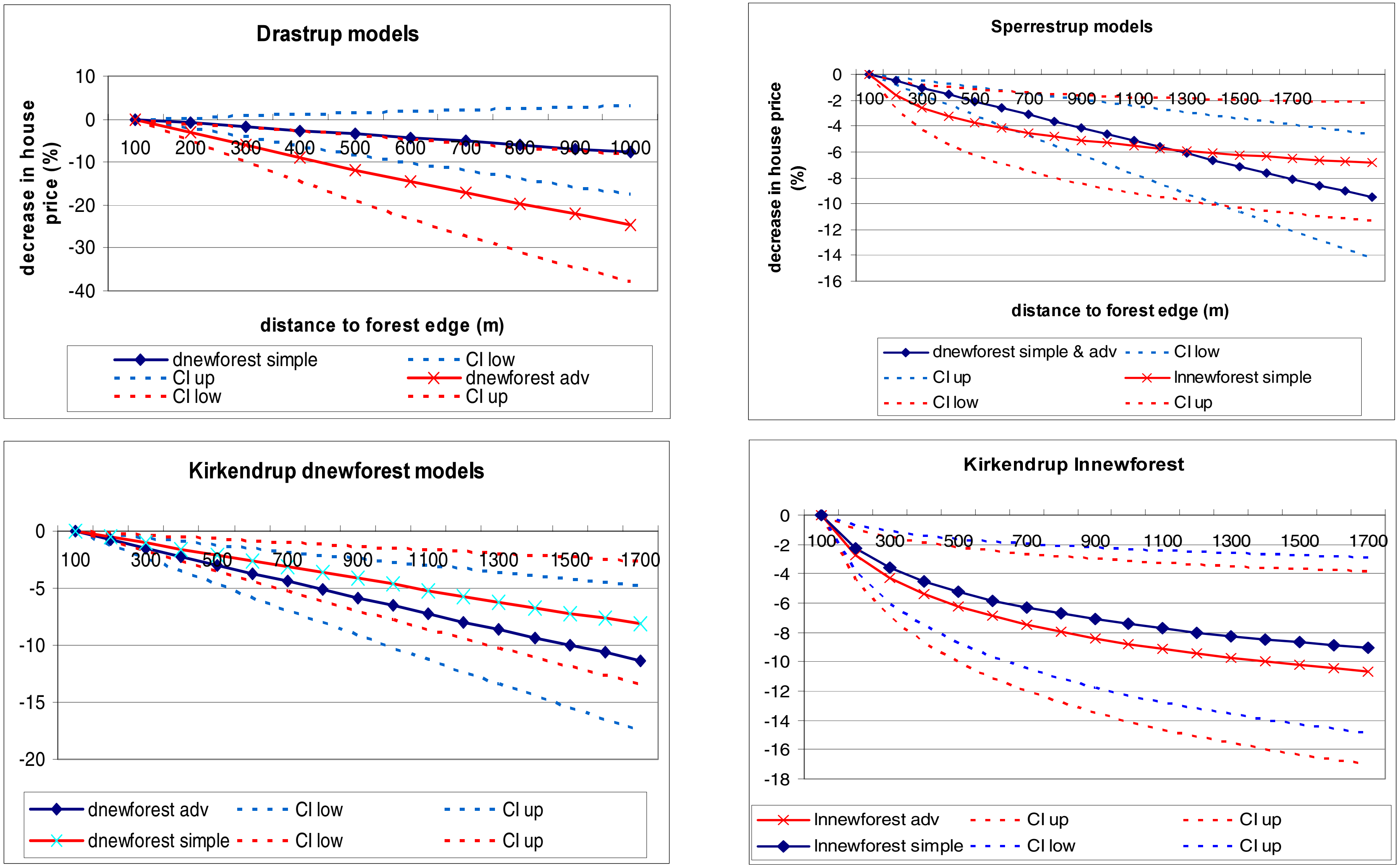

Figure 2 Percentage decrease in housing prices because of increasing distance to forest edge

Table 5 Results for final advanced models for Kirkendrup, Drastrup and Sperrestrup afforestation areas[a]

	Drastrup				Kirkendrup				Sperrestrup (robust standard errors)		
Variable	Dnewforest	Lnnewforest	Invnewfor	Variable	Dnewforest	Lnnewforest	Invnewfor	Variable	Dnewforest	Lnnewforest	Invnewfor
Lnarea	0.700***	0.706***	0.706***	lnarea	0.775***	0.776***	0.774***	Lnarea	0.557***	0.551***	0.551***
	0.067	0.066	0.066		0.036	0.036	0.036		0.047	0.048	0.048
Lnlot		0.120**	0.118**	lnlot				Lnlot			
		0.044	0.044								
Lnrooms				lnrooms				lnrooms			
Lnage	-0.110***	-0.117***	-0.114***	lnage	-0.043***	-0.043***	-0.043***	age_at_sal	-0.004***	-0.004***	-0.004***
	0.021	0.019	0.019		0.006	0.006	0.006		0.001	0.001	0.001
Forest dist.	-0.000312**	-0.020	0.111	Forest dist.	-0.000075***	-0.040**	2.788	Forest dist.	-0.000053***	-0.010	0.087
	0.000109	0.019	2.005		0.000023	0.013	2.262		0.000014	0.009	0.382
semi_detach	-0.134**			Semi_detach	NA	NA	NA	semi_detach	-0.109***	-0.089***	-0.084***
	0.052								0.020	0.021	0.020
flat_roof				flat_roof			-0.075	flat_roof	-0.123***	-0.125***	-0.124***
							0.044		0.034	0.035	0.035
Tile	0.131**	0.141***	0.135**	tile	0.042*	0.042*	0.032	tile			
	0.043	0.043	0.043		0.016	0.017	0.017				
Fireplace				fireplace				fireplace	0.066**	0.057**	0.052**
									0.024	0.023	0.022
not_brick				not_brick	-0.110**	-0.106**	-0.095**	not_brick	-0.061	-0.057	-0.058
					0.035	0.035	0.034		0.031	0.032	0.031
Extoilet				extoilet				extoilet			
Lnind				lnind	0.020*	0.021*	0.024*	lnind			
					0.010	0.010	0.010				
Lncs	NA	NA	NA	lncs	-0.221***	-0.192***	-0.167***	lncs			
					0.055	0.052	0.049				
Lnlake				lnlake				lnlake			
Lnschool	NA	NA	NA	lnschool				distschool			
lnchildcare				lnchildcare	0.058***	0.056***	0.065***	lnchildcare		-0.022	-0.027*
					0.015	0.015	0.016			0.013	0.012
Lnwetland	-0.185*			lnwetland				dwetland		-0.00012*	-0.00014**
	0.079									0.000050	0.000046

	Drastrup				Kirkendrup				Sperrestrup (robust standard errors)		
Variable	Dnewforest	Lnnewforest	Invnewfor	Variable	Dnewforest	Lnnewforest	Invnewfor	Variable	Dnewforest	Lnnewforest	Invnewfor
Indrecreatio				Indrecreatio			-0.020*	Indrecreatio			
							0.008				
lnoldforest				lnoldforest	-0.049***	-0.049***	-0.052***	doldforest			
					0.010	0.010	0.010				
frejl_east	0.096**	0.101**	0.088*					oeleast	0.104***	0.089***	0.082***
	0.036	0.037	0.035						0.025	0.024	0.023
_cons	12.409***	10.298***	10.191***	_cons	12.074***	12.023***	11.603***	_cons	11.872***	12.109***	12.084***
	0.752	0.278	0.260		0.444	0.448	0.394		0.231	0.255	0.260
N	185	185	185	N	476	476	476	N	259	259	259
r2	0.686	0.683	0.681	r2	0.610	0.609	0.610	r2	0.692	0.696	0.694
r2_a	0.673	0.672	0.670	r2_a	0.603	0.601	0.600	r2_a	0.682	0.683	0.682

[a]standard errors below parameter results

Note: Significantly different from zero at *0.05, **0.01 and ***0.001 levels.

Table 6 Results for final simple models for Kirkendrup, Drastrup and Sperrestrup afforestation areas[a]

	Drastrup				Kirkendrup				Sperrestrup (robust standard errors)		
Variable	Dnewforest	Lnnewforest	Invnewfor	Variable	Dnewforest	Lnnewforest	Invnewfor	Variable	Dnewforest	Lnnewforest	Invnewfor
Lnarea	0.701***	0.706***	0.706***	lnarea	0.810***	0.813***	0.816***	lnarea	0.557***	0.561***	0.554***
	0.066	0.066	0.066		0.037	0.037	0.037		0.047	0.047	0.051
Lnlot	0.125**	0.120**	0.118**	lnlot				lnlot			
	0.044	0.044	0.044								
Lnrooms				lnrooms				lnrooms			
Lnage	-0.122***	-0.117***	-0.114***	lnage	-0.049***	-0.049***	-0.048***	age_at_sal	-0.004***	-0.004***	-0.004***
	0.020	0.019	0.019		0.006	0.006	0.006		0.001	0.001	0.001
Forest dist.	-0.000089	-0.020	0.111	Forest dist.	-0.000053**	-0.034**	2.085	Forest dist.	-0.000053***	-0.024**	-0.124
	0.000063	0.019	2.005		0.000019	0.012	2.275		0.000014	0.008	0.468
semi_detach				Semi_detach	NA	NA	NA	semi_detach	-0.109***	-0.104***	-0.112***
									0.020	0.021	0.023
flat_roof				flat_roof			-0.091	flat_roof	-0.123***	-0.122***	-0.106***
							0.044		0.034	0.034	0.033
Tile	0.143***	0.141***	0.135**	tile	0.036*	0.037*		tile			
	0.043	0.043	0.043		0.017	0.017					
Fireplace				fireplace				fireplace	0.066**	0.071**	0.069*
									0.024	0.025	0.027
not_brick				not_brick	-0.130***	-0.130***	-0.129***	not_brick	-0.061	-0.057	-0.064*
					0.035	0.035	0.034		0.031	0.031	0.030
Extoilet				extoilet				extoilet			
frejl_east	0.109**	0.101**	0.088*					oelsouth			-0.048
	0.038	0.037	0.035								0.020
								oeleast	0.104***	0.089***	0.040
									0.025	0.024	0.023
_cons	10.223***	10.298***	10.191***	_cons	10.328***	10.485***	10.255***	_cons	11.872***	11.946***	11.860***
	0.259	0.278	0.260		0.184	0.195	0.186		0.231	0.238	0.251
N	185	185	185	N	476	476	476	N	259	259	259
r2	0.684	0.683	0.681	r2	0.573	0.573	0.568	r2	0.692	0.685	0.683
r2_a	0.673	0.672	0.670	r2_a	0.569	0.569	0.564	r2_a	0.682	0.675	0.672

*standard errors below parameter results

Note: Significantly different from zero at *0.05, **0.01 and ***0.001 levels.

Sensitivity of results with regard to the inclusion of spatial/locational variables (omitted variable bias)

If an explanatory variable that might influence the dependent variable is not included in the regression, this might cause the estimated parameters for the included independent variable to be biased. In studies based on observational data, i.e. where data is collected in the "real" world rather than in an experimental setting, it is rather common that the data collected is incomplete. The housing market is no exemption here. Data may be unavailable if it is not collected by authorities or too expensive to obtain or if the researcher is unaware of the potential influence of missing information on housing values relevant characteristics might simply not be taken into consideration.

For an omitted variable to cause a bias in multiple regression it must (a) be a determinant of the dependent variable, i.e. the price of the house and (b) be correlated with at least one of the independent variables. For the current analysis an omitted variable bias is especially interesting if it affects the parameter estimate λ for the distance to new forest measure, Q in equation (5). It is assumed that the essential structural parameters for house prices are fully specified and thus the omitted variable bias if existing will be related to the inclusion or omission of location-related variables, L_{ki}. Assuming that an essential location-related variable which is correlated with the environmental variable Q of interest has been omitted, the expected value for $\tilde{\lambda}$ can be described as follows:

$$E(\tilde{\lambda}) = \lambda + \delta_k \frac{Cov(Q_i, L_{ki})}{Var(Q_i)} \qquad (6)$$

where λ and δ_k are the unbiased estimates of the parameters for distance to new forest and the omitted location-related variable respectively, $Cov(Q_i, L_{ki})$ is the covariance between the distance to new forest and location-related variable and $Var(Q_i)$ is the variance of the distance to new forest variable (see Wooldridge (2003), pp 89-95 for further explanation). For the sake of simplicity equation (6) assumes that the two variables, Q_i, L_{ki}, are not correlated with the other independent variables in the model, an assumption that will of course not hold in reality. Depending on the direction of spatial correlation between variables the bias might be upward or downward and depending on the amount of correlation with other independent variables equation (6) will allow a more or less accurate prediction of the bias (see Deaton and Hoehn (2004) for a similar discussion of the issue).

Differences in terms of coefficient results for forest proximity between simple and advanced models for the same case study area indicate that omitted variable bias might have an effect on the estimation of marginal prices for this land category. However, the effect can work both ways. In Drastrup and Kirkendrup including other spatial measures increases the size and significance level of the coefficient for the untransformed distance to new forest measure, while it reduces the positive effect of forest proximity in the case of Sperrestrup for the log-transformed distance to new forest measure.

The main focus of this analysis is on measuring the effect of distance to new forest areas on housing prices. Thus the following sensitivity analyses focuses on the coefficient for this distance measure alone. The sensitivity of this coefficient to the inclusion of other spatial variables has been tested in two ways:

Using a "bottom-up" approach, starting with the simple model by incorporating one other spatial measure (in addition to the distance to new forest measure) and

Using a "top-down" approach, where based on the advanced model one spatial measure is deleted (and all other spatial measures remain in the model if they prove to be significant).

These two approaches represent of course only part of the numerous possible combinations of spatial measures that can be added or taken out of a model and are more meant to illustrate part of the effect of going from the simple to the advanced modelling approach and vice versa. One could for example imagine that adding or deleting a combination of two or more spatial measures at the same time would show different effects than the simple deletion or adding of one measure, depending on the correlation patterns between these measures.

Table 7 and Table 8 show the results of model re-estimation for the coefficient for the distance to new forest measure for the different models. Models are only re-estimated for the untransformed and log-transformed distance to new forest variables as the variable in the reciprocal transformation was not significant for any model type in all three areas.[42] The simple model for the Drastrup afforestation area is generally robust towards the inclusion of other spatial measures, only adding distance to wetland areas increases the size and significance level of the coefficient for distance to new forest area in its untransformed form. For the log-transformed variable the coefficient remains stable (but insignificant) and is unaffected by the inclusion of other spatial variables. Using the "top-down" approach where spatial measures are deleted from the advanced model one at a time, again deleting distance to wetlands decreases both size and significance level of the coefficient. Also the exclusion of distance to childcare as an explanatory variable decreases coefficient and significance level, because in a model

[42] Results for all variables included in the final models are included in the appendix for those models where the coefficient for distance to new forest was not robust over for the inclusion of deletion of other spatial variables.

without the childcare variable, the dummy variable for semi-detached houses becomes insignificant.

For Kirkendrup adding distance to industry, distance to schools and distance to old forest areas decreases the coefficient and significance level for both the untransformed and the log-transformed distance to new forest measure. Adding distance to schools as the only extra spatial variable, actually causes the coefficient for new forest areas to become highly insignificant. Obviously including distance to school as the only other spatial variable results in a highly significant effect for this variable, while the variable is not significant in the final advanced model. Adding distance to central station on the other hand, increases size and significance level for both transformations.

Table 7 Sensitivity analysis: Adding other spatial measures to simple model*

			Adding to simple model…							
	Transf.	Simple model	Distance to industry	Distance to central station	Distance to lake	Distance to school	Distance to childcare	Distance to wetland	Distance to recreational area	Distance to oldforest
Drastrup	No	-0.000089	-0.000089	NA	-0.000089	NA	-0.000089	-0.000221	-0.000089	-0.000089
		0.159	0.159		0.159		0.159	0.024	0.159	0.159
	log	-0.020	-0.020	NA	-0.020	NA	-0.020	-0.020	-0.020	-0.020
		0.296	0.296		0.296		0.296	0.296	0.296	0.296
Kirkendrup	no	-0.000053	-0.000036	-0.000081	-0.000053	-0.000013	-0.000053	-0.000053	-0.000053	-0.000040
		0.005	0.061	0.000	0.005	0.540	0.005	0.005	0.005	0.031
	log	-0.034	-0.023	-0.043	-0.034	-0.010	-0.034	-0.034	-0.034	-0.025
		0.005	0.058	0.001	0.005	0.467	0.005	0.005	0.005	0.033
Sperrestrup	no	-0.000053	-0.000053	-0.000053	-0.000053	-0.000053	-0.000053	-0.000053	-0.000053	-0.000053
		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	log	-0.024	-0.024	-0.017	-0.024	-0.024	-0.024	-0.015	-0.024	-0.024
		0.005	0.005	0.029	0.005	0.005	0.005	0.086	0.005	0.005

*p-values under parameter results

Decrease in significance level and size of coefficient

Increase in significance level and size of coefficient

For the top-down model the effects of deleting distance to industry is comparable to the bottom-up approach, the deletion of it increases size and significance levels for the coefficients for distance to new forest areas. The effect of deleting distance to central station has a direction that is comparable to that in the bottom-up approach, however, now the deletion actually causes the coefficients for both transformations to become insignificant. Deleting distance to old forest areas has the same effect as adding it to the simple model, in both cases the coefficient estimates for the distance to new forest measure and their significance levels are reduced. Also deleting distance to childcare institutions reduces the effect of forest proximity, while the inclusion of this distance measure in the simple model did not have an effect on forest proximity.

Table 8 Sensitivity analysis: Deleting other spatial measures from advanced model*

	Transf.	Advanced model	Deleting from advanced model… Distance to industry	Distance to central station	Distance to lake	Distance to school	Distance to childcare	Distance to wetland	Distance to recreational area	Distance to oldforest
Drastrup	No	-0.000312	-0.000312	NA	-0.000312	NA	-0.000221	-0.000089	-0.000312	-0.000312
		0.005	0.005		0.005		0.024	0.159	0.005	0.005
	log	-0.020	-0.020	NA	-0.020	NA	-0.020	-0.020	-0.020	-0.020
		0.296	0.296		0.296		0.296	0.296	0.296	0.296
Kirkendrup	no	-0.000075	-0.000080	-0.000019	-0.000075	-0.000075	-0.000042	-0.000075	-0.000075	-0.000052
		0.001	0.000	0.376	0.001	0.001	0.100	0.001	0.001	0.053
	log	-0.040	-0.042	-0.020	-0.040	-0.040	-0.013	-0.040	-0.040	-0.026
		0.003	0.002	0.121	0.003	0.003	0.348	0.003	0.003	0.085
Sperrestrup	no	-0.000053	-0.000053	-0.000053	-0.000053	-0.000053	-0.000053	-0.000053	-0.000053	-0.000053
		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	log	-0.010	-0.010	-0.010	-0.010	-0.010	-0.015	-0.017	-0.010	-0.010
		0.261	0.261	0.261	0.261	0.261	0.086	0.029	0.261	0.261

*p-values under parameter results

[grey shading] Decrease in significance level and size of coefficient

[boxed] Increase in significance level and size of coefficient

In the final advanced model for Sperrestup all other spatial distance measures proved to be not significant at the 10 % level, thus adding other spatial measures to the simple model does not have an effect on the coefficient for distance to new forest. The picture is similar for the model with distance to new forest log-transformed. However, here in the final model, adding distance to central station or distance to wetlands reduces the size of the coefficient and its significance level. Adding only distance to childcare institution does not have an effect on the distance to new forest coefficient although it appears in the final advanced model.

Taking the advanced model and deleting one spatial measure at a time shows similar sensitivities to the inclusion of wetland and childcare institution. Again the model with distance to new forest untransformed is relatively robust towards the inclusion of other spatial measures. They turn out to be insignificant in the final model and results for this transformation are thus the same for both the simple and advanced model. For the log-transformed version, deleting either distance to childcare or distance to wetland increases the significance level and size of the coefficient in the final model.

Results from the sensitivity analyses indicate that partial inclusion or exclusion of other location-related variables can have substantial impact on the parameter estimate of the distance to new forest measure. The direction of omitted variable bias can go both ways, i.e. decrease or increase the significance level and size of parameter estimates. Because of the inherent multicollinearity between spatial variables it is basically impossible to postulate the direction of bias before conducting the analysis.

Discussion and conclusions

Estimation results for the three case study areas presented in this paper indicate that proximity to afforestation areas results in amenity benefits to those living close to these areas. However, there are two problems associated with estimating these amenity benefits. The size of these benefits may depend on both, the functional form chosen for estimating the hedonic price function and the amount and type of location-related variables included in the analysis. These findings have some severe implications regarding (a) the policy use and reliability of marginal benefits obtained from applying the hedonic pricing method to measure non-market benefits from afforestation projects, but also other types of non-market benefits, e.g. noise, water quality or disamenity from waste sites, pig farms, etc. and (b) the general applicability of using the hedonic pricing method to value non-market goods and services in a "non-perfect" world, i.e. a world where data collection is bound to be flawed and incomplete. As (a) has been discussed in detail in another article (Birr-Pedersen (forthcoming)) the following discussion concentrates on (b).

The hedonic pricing method is part of the group of non-market valuation methods called "revealed preference methods". One of the claimed advantages of this group of methods is often, that they, in contrast to "stated preference methods" like contingent valuation or choice experiments, rely on real market transactions and do not need to create a hypothetical market for the non-market good of interest. In the case of the hedonic pricing method applied to housing market data, we know what consumers have paid for the composite good, the house they bought, we do not know, however, how much of this price was paid for the environmental good of interest. One could argue that based on the results from this study, in a hedonic pricing study the hypothetical element has just shifted place, from the consumer to the researcher trying to decide on grounds of statistical tests and data availability what type of independent variables to include in the regression.

While this study shows that going from the simple to the advanced model can change the parameter estimates for the independent variable of interest, in this case distance to afforestation areas, the set of location-related variables included here does by no means represent a complete set of spatial variables with potential impact on housing prices. Variables included in this study have been chosen partly on grounds of degree of expected influence, partly on grounds of easy access. Measures of the quality of schools, for example, were not easy accessible and thus left out, just like distance measures to local supermarkets and shopping areas have not been available in map format.

In theory there are no limits to the inclusion of independent variables but in reality the researcher will always face time and funding constraints. There will therefore always be some uncertainty with regard to the “true” marginal price estimated using the hedonic pricing method, which should be kept in mind when applying results in policy decision making.

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Appendix 4, Article 4
Testing the transferability of amenity benefits from afforestation areas in Denmark

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Abstract

Benefit transfer, i.e. the transfer of monetary estimates for environmental goods from a study site to a policy site, is a cost and time saving solution often applied in policy evaluation exercises. How uncertain such benefit transfers can be has been shown in several studies testing for accuracy of benefit transfer. Most of these benefit transfer testing studies are based on contingent valuation and travel cost models, only few are based on the hedonic pricing method, although this method is heavily applied in non-market valuation exercises.

This study tests for accuracy of benefit transfer of amenity values from afforestation projects in Denmark using both the classical test of assuming equality and equivalence testing, where inequality is assumed in the null hypothesis. Amenity values were estimated by applying the first stage of the hedonic pricing method and then calculating the percent differences in housing prices for different distance intervals. While tests for statistical equality of WTP estimates could not reject the null hypothesis of equality between WTP estimates for different distances in the majority of cases it would be inadequate to interpret these results in favour of validity of benefit transfer. Transfer errors can be substantial also for those transfers where equality of WTP estimates could not be rejected.

A cautious approach to benefit transfer is also warranted given the results from the equivalence tests. For none of the transfers the null hypothesis of inequality could be rejected with error margins of 50 %. Only for transfers between two areas with rather similar WTP results, the majority of transferred values are accepted to be equivalent within error ranges of 75 %.

Introduction

Increasing requirements to cost- benefit or cost-effectivness analyses for environmental policy on national and international level, require the assessment of environmental goods and services in monetary terms. As most of these goods do not have a market price it is necessary to elicit people's willingness-to-pay (WTP) for them using non-market valuation methods. Conducting an environmental valuation study is a costly and time-consuming affaire. Thus for most policy evaluation purposes so-called "benefit transfer" has become a necessary evil. Benefit transfer is defined as the transfer of monetary estimates of environmental values estimated at one site (study site) to another, so-called policy site.

But how accurate is the transfer of values for non-market goods and services and what level of transfer error is acceptable in policy evaluation? In the last decade a range of studies have been conducted that test for the accuracy of benefit transfer and summaries of these studies (Brouwer and Spaninks (1999) or Bateman et al. (2000)) show that transfer errors can be as high as 200-400 % with average errors that range between 20 and 40 %.

Previous benefit transfer testing papers are primarily based on contingent valuation studies and some few travel cost methods and choice experiments. Results from hedonic pricing studies are rarely applied in benefit transfer tests, Chattopadhyay (2003) being most likely the only exemption. This stands in stark contrast to the relatively frequent applications of the hedonic pricing method to value the (dis-)amenity effects of traffic noise, animal production farms, air pollution, green areas and other landscape features (e.g. Ihlanfeldt and Taylor (2004), Ready and Abdalla (2005), Anthon et al. (2005)).

What distinguishes most of these studies from Chattopadhyay (2003) is that they only use what is called the first stage of the hedonic pricing method. The first stage enables the determination of marginal prices for non-market goods and – in the case of localised externalities – also the estimation of non-marginal willingness-to-pay. The second stage, however, is required to estimate a willingness-to-pay function, which based on socio-economic characteristics of the individual consumer, marginal prices of other goods and the specific characteristics of the environmental good of interest can explain willingness-to-pay independently of local markets. However, second stage estimation involves substantial data requirements that are not always easy to obtain, which is clearly one of the explanations why hedonic pricing studies usually stop at the first stage.

In the absence of estimated benefit functions the transfer of unit values in terms of willingness-to-pay per house(-owner) is the only practical option available for policy analysts. However none of the first stage hedonic pricing studies producing these unit values has analysed the uncertainty involved with such benefit transfer applications. This study presents results from the application of a first stage hedonic pricing method for three different afforestation areas in Denmark in a way that allows a comparison of differences in housing prices based on the houses' proximity to newly planted forest areas. Spatial differences in house prices are calculated as the difference in house prices (using 100m intervals) to the average house price at the largest distance in the dataset. For benefit transfer purposes using percentage differences instead of total willingness to pay allows the calibration of the estimated non-marginal willingness-to-pay to the average house prices in an area and the calculated price gradient for forest distance can more easily be applied to the policy situation.

To illustrate the possible pitfalls involved in applying these price gradients in benefit transfer, transfer errors are calculated for 100m intervals from the forest edge up to 600m. The transfer of unit values for these 100m intervals is tested using both the classical testing procedure of equality as the null hypothesis and equivalence testing as suggested by Kristofersson and Navrud (2005) using three different potentially acceptable error margins.

The paper starts with a review of testing for accuracy of benefit transfer in previous studies. In the following section estimation results based on the application of the hedonic pricing method to three afforestation areas in Denmark are presented. Then the possibility for benefit transfer between these areas is tested by calculating average transfer errors for different distance intervals from the forest edge and by testing for equality of willingness-to-pay estimates between sites and for equivalence of transfers between sites. The last section contains the discussion and conclusion.

Testing for accuracy of benefit transfer

Approaches to benefit transfer are normally divided into four basic categories (see Navrud (2004)):

1. Unit value transfer
   a) Simple unit value transfer
   b) Unit value transfer with adjustment, e.g. income
2. Function transfer
   a) Benefit function transfer
   b) Meta-analysis

Simple unit value transfer assumes that the utility gain of an average individual at the study site corresponds exactly to that of an average individual at the policy site. Of course this assumption is unlikely to hold in most circumstances as individuals are likely to differ with regard to income, education and other socio-economic characteristics that will affect their preferences for the environmental good of interest. In addition there will always be differences in the type of environmental good valued, even if the researcher tries to find an original study for a matching site. Instead of transferring unadjusted unit values the researcher or policy analyst can adjust the value estimates to better reflect differences between policy and study site, e.g. by correcting for income differences and/or inflation if transfer takes place over time.

Benefit function transfer, i.e. the transfer of a function that explains willingness-to-pay by different explanatory variables, should in theory be more suited to account for differences in user and site characteristics. Still, the transfer of unit values is still the most applied method of benefit transfer, simply because time and money constraints make it often impossible for policy makers to collect the necessary information to conduct benefit function transfer. Studies testing for the accuracy of benefit transfer have also shown mixed results regarding the implied higher reliability of benefit function transfer.

Unit value transfer and benefit function transfer rely mostly on single studies that have been selected by a "search-for-identical-conditions" (Santos (1998)), i.e. achieving the highest possible correspondence between study and policy site. Instead it might be more useful for benefit transfer purposes to extract information on benefit values from a range of available studies by conducting a so-called meta-analysis. Meta-analysis originated in medical and psychological research, where it is a common tool employed to summarise results of different tests of treatments and medicine in a quantitative way. A meta-analysis investigates the relationship between benefit estimates (i.e. WTP) of different studies and the specific features of the environmental good to be valued and assumptions of the models used. Meta-analysis can thus be used to explain variations in results across studies. The calculated meta-function can than potentially be used to transfer values (i.e. re-calculate them) for policy sites by substituting independent variables with policy site values. Alternatively single coefficients derived from meta-analysis can be used to adjust unit values or benefit functions from a single study.

But how reliable is the transfer of benefit estimates from study to policy sites? For most real world applications of benefit transfer this question is impossible to answer as no "true" value exists for the policy site (obviously, as we otherwise would not have to rely on transferring values). Recently, a number of research studies have tried to test for accuracy of benefit transfer in a more formal way. These studies are summarized in Table 1.[43] In these "transfer experiments" benefit estimates for different sites are statistically compared to on-site estimates by conducting so-called convergent validity tests or value-surface tests (Boyle and Bergstrom (1992), Bergstrom and De Civita (1999)).

Convergent validity is established when the results from two different analyses are found to be statistically equivalent (Morrison and Bennett (2000)). Value-surface tests, on the other hand, assume the existence of a common grand valuation equation ex ante (Bergstrom and De Civita (1999)) and are mainly based on meta-analysis functions. Both types of tests are not tests for reliability or validity of the original estimate itself. Here one needs to keep in mind that the original study estimate does itself represent an estimate of an unknown value and not a "true" WTP.

In principle the design of the tests follows the same basic procedure:

1. Original valuation studies are conducted at different sites, let us call them A and B. Let the valuation function for each site be $w = g(\beta, x)$, where w is the willingness to pay, β is a parameter vector and x is a vector of explanatory variables, while g represents a particular functional form.
2. Mean values or benefit functions are transferred from site A to site B and vice versa. This could also involve combining data from different study sites (i.e. pooling data) to estimate a common benefit function and then comparing mean values or coefficients with the "policy" site values or coefficients.
3. The estimate (adjusted, unadjusted or calculated using the benefit function) is then compared to the originally estimated value at site A or B by using different statistical tests.

In Table 1 tests are further divided up into what could be called an "optimal" convergence tests and convergence tests conducted *ex post* on studies that were not originally designed for benefit transfer-testing purposes. Optimal tests are designed such as to exclude

[43] See also Brouwer and Spaninks (1999) and Bateman et al. (2000) for summary of tests up to 1997.

or control for as many "disturbing" factors as possible, which means using the same survey instrument, valuing the same type of environmental change and conducting surveys a the same point in time, e.g. Barton (2002) or Bergland et al. (1998). In the "adhoc" tests of convergent validity, the studies included in the testing exercise had been designed for other purposes than benefit transfer testing. Surveys were often based on data collected at different points in time (Brouwer and Spaninks (1999), Loomis (1992) Loomis et al. (1995)) and varied with regard to the questionnaire format, payment vehicle or scenario description. Judging from the error ranges presented in Table 1 there is no indication that the optimal convergent tests perform better (in terms of lower transfer errors).

Estimation methods employed vary across studies. Most benefit transfer-testing studies are based on contingent valuation studies and travel costs models. Only one study uses the hedonic pricing method (Chattopadhyay (2003)) and two other the random utility model (Parsons and Kealy (1994)). One study did also test for a more advanced adjustment of average WTP amounts by adjusting for policy site characteristics using marginal WTP estimates for those characteristics from a choice experiment study (Mogas and Riera (2003)). A comparison of results from choice experiments is only done in one study (Morrison et al. (2002)). Choice modelling studies might offer another promising approach to improve the benefit transfer for nature types as these studies are better able to explain differences in preferences for specific site characteristics (Barton (2002)). As shown by Morrison et al. (2002) this does not necessarily apply for the transfer of compensating surplus estimates derived from choice modelling studies across sites. Their study did, however, indicate a higher success rate for benefit transfer when the transfer values were implicit prices for the different non-market attributes.

Table 1 shows that average transfer errors for convergent validity tests are in the range of 10-45 % with the exception of benefit transfer testing over time done by Zandersen et al. (2005) which resulted in average errors of 150-290 %. Average error ranges cover though over the fact that individual benefit transfer tests resulted in errors of more than 200 % for unit value transfer (see Kirchhoff et al. (1997) and VandenBerg et al. (2001)) or over 400 % for benefit function transfer (Loomis et al. (1995)). One study (Chattopadhyay (2003)) actually reached error of more than 1000 %, but that seems to be an exception.

Benefit *function* transfer, being the theoretically ideal method, did perform slightly better in some cases, e.g. in Kirchhoff et al. (1997) for bird-watching sites in Arizona and Parsons and Kealy (1994) for lake recreation. In Brouwer and Spaninks (1999) benefit function transfer provided a more accurate prediction (in terms of lower absolute transfer error) for the one case where parameters of study and policy site function were consistent (i.e. the benefit function was found to be transferable). However, Barton (2002) and Ready et al. (2004) find that benefit function transfer does not improve the performance of benefit transfer. As suggested by Ready et al. (2004) one of the reasons for these differing findings could be that their study was based on international transfer and might thus involve transferring substantial unexplainable differences in preferences between countries. This does however, not explain the results by Barton (2002) who tested benefit function transfer within the country of Costa Rica.

An obvious prerequisite for successful (in the terms of "accurate") benefit transfer is the incorporation of socio-economic variables and site quality variables. This is also reflected in results from Barton (2002), where the hypothesis of a common underlying population for benefit functions from the two study sites was rejected when site-specific, localised phenomena and environmental attitudes where included. Site-quality variables (if accessible at all) are not always easy to determine, see Kirchhoff et al. (1997) where correction for flow levels was not enough to ensure convergent validity of white-water rafting benefits. Trip length should maybe have been included as well as consideration of substitute sites. Brouwer and Spaninks (1999) point out that it might be necessary to consider an even wider set of WTP motivation, maybe in the form of psychological and sociological profiling questions that can contribute to the explanation of preference construction. Collecting this kind of information at the policy site, however, is expensive and time-consuming, thus reducing the cost and time saving advantages of benefit transfer exercises substantially.

Instead of transferring only single site models some studies calculate pooled models based on n-1 study sites and transfer this model to the left out policy site. Piper and Martin (2001) found that their pooled models for WTP for domestic water supply improvements were generally transferable. Estimation errors resulting from the application of these n-1 pooled benefit functions were within 25 % of actual survey values. Similar results are obtained by Loomis (1992) who shows pooled function transfer performs better than value transfer for most rivers in his sample and VandenBerg et al. (2001) who compared WTP-measures for improvements in ground water quality. Their benefit transfer testing study showed that the n-1 pooled model approach generally improved transfer performance. A reason for better performance of pooled models could be the aggregation effect, where statistical reliability and accuracy are improved by increasing the number of observations and the range of situations covered by the study sites.

Kirchhoff et al. (1997) point out that more precise WTP measurements (i.e. with small confidence intervals), for example in cases where respondents are more familiar with the resource to be valued, might lead to higher rejection rates for benefit transfer tests based alone on statistical criteria. Apparently "reliable" benefit transfer can thus also be contingent on the existence of rather "unreliable" (i.e. imprecise) measurements of WTP in contingent valuation studies, which result in large confidence intervals. In general the variance and thus the confidence interval range depend to a large extent on the sample size where larger sample sizes and thus more accurate predictions of WTP will lead to a higher rejection rate of benefit transfer.

Most of the tests use the classical test procedure of assuming equality between values at policy and study site in the null hypothesis. A non rejection of the null hypothesis is then often interpreted as evidence for at benefit transfer is valid, despite the fact that the size of the beta-error, i.e. the probability of accepting the null hypothesis when in fact it is not true, is not known. Recently another type of test has been suggested by Kristofersson and Navrud (2005) that tests for equality of benefit estimates using so-called equivalence tests. As argued by Muthke and Holm-Mueller (2004) conducting these tests with different sets of transfer errors can provide an indication of what error margins should be applied in policy applications using the benefit transfer methodology. Policy contexts will differ and transfer errors of 50 % might be acceptable in one case while unacceptable in another.

Table 1 Summary of convergent validity and value-surface tests

Study	Subject	Valuation technique	Amount of test sites	Type of benefit transfer	Test hypothesis H_0 rejected?[44]	Error margins[a)] Value transfer (%)	Error margins[a)] Function transfer (%)
Optimal convergent validity tests							
Barton (2002)	Coastal water quality improvements, Costa Rica	CVM	2 sites	Unadjusted unit value transfer	Yes	22.5 – 29.5 (mean: 25.8)	
				Adjusted unit value transfer (for income)	Yes/No	10.4 – 19.5 (mean: 11.1)	
				Benefit function transfer	Yes/No		
				a) using socio-demographic covariates			a) 20.7 – 29.1 (mean: 24.4)
				b) using all covariates			b) 1.6 – 28.4 (mean: 11.0)
Bergland et al. (2002)	Water quality improvement, Norway	CVM	2 sites	Unadjusted unit value transfer	Yes	not reported	
				Benefit function transfer	Yes		not reported
Chattopadhyay (2003)	Air pollution	HPM	repeated sampling (1000 draws)	Unadjusted unit value transfer	Not reported	8 - 1491	
				Benefit function transfer	Not reported		10 - 1285
Downing and Ozuna (1996)	Recreational angling, fishing	CVM	8 (plus 3 time periods)	Unadjusted unit value transfer	Yes/No	Not reported	
Kirchhoff et al. (1997)	Water-dependent recreation and bird-watching	CVM	2 water-recreation sites, 2 bird-watching sites	Unadjusted unit value transfer	Yes	35.3 – 68.6 (24.2 – 56.4)*	
				Benefit function transfer	Yes/No		2.3 – 210.4 (6.3 – 228.5)*

[44] For unit value transfer the hypothesis H_0 assumes that the WTP at the study site is equal to the WTP at the policy site, for benefit function transfer the hypothesis H_0 assumes that WTP at the policy site is equal to the WTP calculated using the benefit function from the study site and relevant parameters from the policy site.

Study	Subject	Valuation technique	Amount of test sites	Type of benefit transfer	Test hypothesis H_0 rejected?[44]	Error margins[a)] Value transfer (%)	Error margins[a)] Function transfer (%)
Mogas and Riera (2003)	Forest value/functions, Spain	CVM and CE	2 forest sites	Adjusted unit value transfer	No	13.5	
Morrison et al. (2002)	Environmental improvements of wetlands, Australia	CE	2 sites/ 3populations (1 rural, two urban)	Unit value transfer of implicit prices for non-monetary attributes	Yes/No	Not reported	
				Unit value transfer of mean compensating surplus estimates for 9 alternative scenarios	Yes/No	4 % – 66 % (mean of 32 %)	
Parsons and Kealy (1994)	Lake recreation, water quality improvements, USA	Random utility (TC) model	Wisconsin residents divided up into Milvaukee residents and non-residents	Unadjusted transfer	Not reported	34	
				Benefit function transfer	Not reported		4 %
				Updated benefit model transfer (using small sample from policy site)	Not reported		1 - 15
				Bayesian updating of benefit model (using small sample from policy site)	Not reported		1 - 10
Ready et al. (2004)	Reduced morbidity/health improvements related to air and water quality	CVM	Five European countries	Unadjusted unit value transfer	Not reported	20.9 – 78.0 (average: 38)	
				Adjusted unit value transfer	Not reported	20.1 – 80.7 (average: 38	
				Benefit function transfer	Not reported		20.1 – 83.4 (average: 38)
Scarpa et al. (2000)	Forest recreation benefits	CVM	26, Ireland	n-1 pooled benefit function transfer	Yes/No		not reported
Thiele and Wronka (2002)	Biodiversity	CVM	2, Germany	Unadjusted unit value transfer	No	19	
				Benefit function transfer	No		8
VandenBerg et al.	Improvements in	CVM	12 sites (4 in each of three states,	Unadjusted unit value transfer	Yes/No	1.1 – 239.4, mean: 42.1 (0.2-105.0,	

Study	Subject	Valuation technique	Amount of test sites	Type of benefit transfer	Test hypothesis H_0 rejected?[44]	Error margins[a)] Value transfer (%)	Error margins[a)] Function transfer (%)
(2001)	ground water quality		USA)			mean:31.4)	
				Unadjusted unit value transfer	Yes/No	3.3 - 57, mean: 21.8 (3.1 – 100.1, mean:35.5)	
				Benefit function transfer using single site and n-1 pooled benefit functions	Yes/No		0.4-297.6, mean: 44.1 (0.8-55.6, mean:18.3 for pooled model)
				Benefit function transfer using pooled n-1 site model, grouped by states and grouped by contamination history	Yes/No		0.2 – 38.7, mean: 19.1 (2.1 – 50.4, mean:15.5 when grouped by previous experience)
Convergent validity test							
Brouwer and Spaninks (1999)	Amenities from agricultural peat meadow land, Netherlands	CVM	2 sites/3 subsamples	Unadjusted unit value transfer	Yes/No	26.6 – 36.1	
				Benefit function transfer	Yes		22.4 – 39.9
Delavan and Epp (2001)	Ground water protection from nitrate contamination, USA	CVM	3 sites	Unadjusted unit value transfer	Not reported	7.1 - 510	
				Benefit function transfer	Yes		3.4 – 370
Loomis (1992)	Recreational ocean salmon fishing, USA	Multi-site zonal TCM	Multi-site ZTCMs for four states	Benefit function transfer	Not reported		0.93-17.58
	Freshwater steelhead fishing, USA						
	Freshwater steelhead fishing, USA	Multi-site zonal TCM	10 different rivers within Oregon	Unit value transfer	Not reported	3.51–39.07	
Loomis et al. (1995)	Water (reservoir)-based recreation	Multi-site zonal TCM	26 reservoir sites within 3 regions	Benefit function transfer	Not reported		Range for all districts:1.2 – 475.4
							Range for Little Rock and Nashville

Study	Subject	Valuation technique	Amount of test sites	Type of benefit transfer	Test hypothesis H_0 rejected?[44]	Error margins[a)] Value transfer (%)	Error margins[a)] Function transfer (%)
							transfer: 1.2 – 24.8
Piper and Martin (2001)	Domestic water supply improvement, USA	CVM	4 sites, USA	Benefit function transfer: n-1 pooled benefit function transfer	No		2.7 – 23.3
				Single site benefit function transfer	not reported		5.6 – 149.1
Zandersen et al. (2005)	Forest recreation	RUM	52 forest sites & two time periods (1977 and 1997)	Benefit function transfer over time (not between sites) using two models:	not reported		Model A: 58 – 481 (average 148)
				A: included updated (to 1997) demand functions and			Model B: 48 – 783 (average 290)
				B: no update of demand function			
Value-surface tests							
Rosenberger and Loomis (2000)	Outdoor recreation, USA	meta-analysis	5 meta-analysis models (one national and 4 regional)	Meta-model transfer using national and regional mean values for explanatory variables	not reported		5 – 143**(national model) 6 – 293** (regional models)
Santos (1998)	Landscape values	meta-analysis	37 test sites	split-sample method using n-1 surveys in estimating meta-analytical function and then transferring results to the left out survey site	not reported		44 out of 66 observations predicted within 50 % error
				Unadjusted unit value transfer from each type of landscape change	not reported	26 out of 66 observations predicted within 50 % error	
Shrestha and Loomis (2001), Shrestha and Loomis (2003)	Outdoor recreation use values, USA	meta-analysis	27 out-of-sample test sides (from outside the US)	Meta-regression function transfer	No/Yes		0.51 – 21.1 (if H_0 not rejected) 35.2-80.8 (H_0 rejected)

Absolute transfer error (%) = $|100(w^s - w^p)/w^p|$. (w^s = transferred value from study site or calculated value (using study site coefficients) at policy site, w^p = value from original study conducted at policy site)

**) Average absolute transfer error per recreational activity across regions.

* Benefit transfer using sample mean instead of expected compensating variation based on Tobit model.

Applying the hedonic pricing method to afforestation areas in Denmark

From the more than 100 afforestation projects in Denmark, ongoing or already finalised, three areas were selected based on criteria as when planting of trees did start and how close the forest edge was to built-up areas in order to ensure enough house sales for the analyses. Figure 1 provides an overview over the spatial characteristics of the three areas and their location in Denmark.

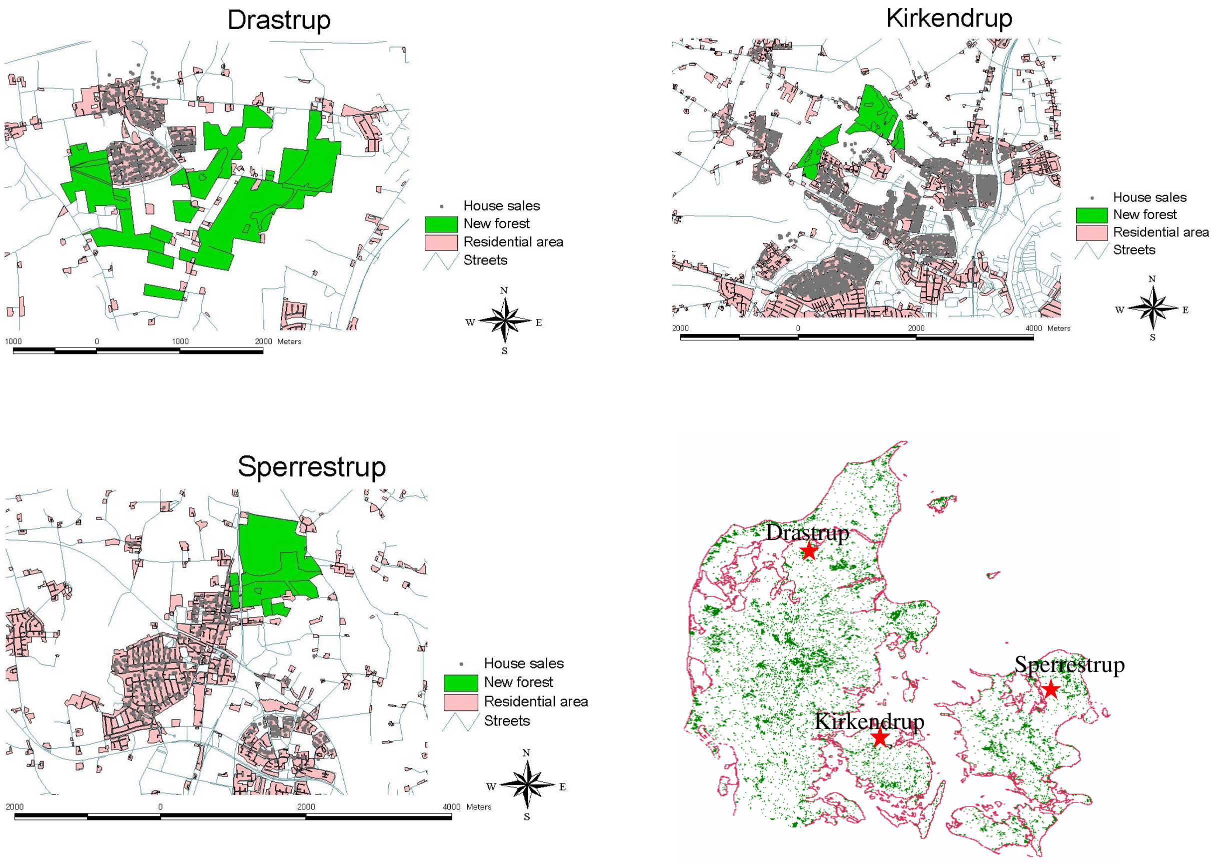

Figure 1 The three afforestation areas and their location

The Drastrup afforestation project is located close to Aalborg in the northern part of Jutland. Planting of trees started in 1996 and the total size of the afforestation area is about 200 ha. The Kirkendrup afforestation area is located on the island of Fyn, north-west from Odense, the third largest city of Denmark and has a total size of only 75 ha. Houses within the suburban area of Kirkendrup are within bicycling distance (2-7 km) to central Odense. The planting of trees started here also in 1996.

The Sperrestrup afforestation area is located on the island of Zealand, north from the village of "Oelstykke" and consists of 115 ha. Planting of trees did start in 1997. Oelstykke is connected to the

Greater Copenhagen area, the capital of Denmark, by S-train, which makes it an attractive area for people working in Copenhagen.

For these three areas amenity benefits from afforestation areas were estimated using the hedonic pricing method. This method is part of the group of valuation methods called revealed preference methods. The hedonic pricing method assumes complementarity between a market good and an associated public (or non-market) good. Rosen (1974) was the first to develop a formal theory of hedonic pricing. In the hedonic approach a good is assumed to consist of a set of attributes (so-called differentiated good) and the good's value or price thus can be considered a function of each attribute.

Environmental valuation studies that use the hedonic pricing method are almost entirely based on the housing market, where it is assumed that real estate prices are influenced by area attributes like traffic noise, air-quality, green space or for example quality of public schools. The hedonic price equation for the price of a house can be described as a function of the different attributes of the house or in a more formal way as

$$P = P(s, l, q) \qquad (1)$$

where

s = structural characteristics, e.g. house and lot size, number of rooms, age etc.,

l = location-related characteristics, e.g. distance to the city center, schools, etc.,

q = environmental good, e.g. distance to forest, noise level, air pollution.

By using the housing market as a substitute market for the non-market environmental good *q* it is possible to estimate the demand for *q* from the price differentials (i.e. differences in prices for houses with varying amounts of the attribute *q*) revealed in the private market. It should be remarked here that the hedonic pricing method can only capture use values and only those for the households living in the areas under investigation.

The partial derivative of the hedonic price function (1) with respect to any characteristic gives its marginal implicit price (Rosen (1974)):

$$\frac{\partial P}{\partial z_i} = p_{z_i} \qquad (2)$$

The marginal implicit price, p_{z_i}, is equal to the additional expenditure required to purchase a unit of the differentiated product with a marginally larger quantity of that characteristic. Assuming that the market is in equilibrium, consumers will have maximised their utility by choosing a particular house. This implies that they have equated their marginal willingness-to-pay (WTP) for the house's attributes to the attributes' marginal implicit prices. Thus the estimated coefficients for the different attributes can be used to calculate marginal WTP for the different characteristics of a house.

Palmquist (1992) has shown that in the case of localised externalities the hedonic price equation is also sufficient to determine WTP for non-marginal changes, as long as only a relative small number of properties within one housing market are affected. For the current project it is assumed that in the case of afforestation the change in forest cover will only affect a small part of the respective housing market. This extra premium paid for forest proximity in the three study areas in terms of higher house prices the closer one gets to the afforestation area (assuming all other housing characteristics are kept at some constant value) represents the house owners' WTP for amenity values from forests for different distances.

Information about housing characteristics is collected from two different data sources. The official Danish Housing registers (BBR/ESR registers) contain information about the structural characteristics of houses while information about neighbourhood characteristics is collected using Geographical Information Systems (GIS), specifically ArcGIS and ArcView. The house price index issued by the Danish Tax Authorities (Told- og Skattestyrelsen (2004)) is used to inflate sales prices to 2004 prices.[45]

Continuous variables for structural characteristics of individual houses in the dataset include the number of rooms, size of the lot, age at sale and the sales price inflated to 2004 prices and a weighted area measure.[46] Dummy variables were added for semi-detached houses, fireplace and if the house had more than one toilet. In addition dummy variables were used to indicate the type of roof material (flat roof or tile) and if the outer wall construction material was not made up of brick stones (e.g. fibercement, wood, concrete, gas concrete and others).

GIS tools (ArcView and ArcGIS) are used to measure the Euclidian distance, "as the crow flies", to the edge of the afforestation area. Based on information available in TOP10DK maps (Kort & Ma-

[45] The index varies by the population size of the county the house is located in and special indexes are issued for the northern part of Zealand and the Greater Copenhagen Area, where house prices have risen substantially more than in other parts of the country during the last decade.

[46] The Danish Ministry of Taxation uses a weighted measure of living space for the tax assessments (Told & Skat (2004)) and the same measure is used in the following analysis. This measure attributes different weights to the size of ground and other floors, attic and basement and also includes the size of garage, carport, outhouse and patio. Formulas to calculate this weighted measure differ with regard to the type of house (detached or semi-detached) and the size of the county the house is located in.

trikelstyrelsen (2001)) a number of other continuous variables for spatial characteristics are included in the dataset, i.e. distance to the nearest industry area, lake, heath, wetland, old forest and other recreational areas, e.g. parks, public green areas and playgrounds. Maps with train stations, elementary schools and childcare institutions in the area and the nearest larger town were constructed and the direct distances to these facilities from each observation were measured.

Total amount of observations available after afforestation started vary considerably between sites, with 185 sales in Drastrup, 476 in Kirkendrup and 259 in Sperrestrup. Sales prices were highest in Sperrestrup, followed by Drastrup and Kirkendrup.

The following regression results are determined by applying the hedonic pricing method and are based on the following general model form using Ordinary Least Squares (OLS) as the estimation method:

$$\ln P_i = \alpha + \sum_{j}^{J} \beta_j S_{ji} + \sum_{k}^{K} \delta_k L_{ki} + \lambda Q_i + \varepsilon_i \quad (3)$$

Where

P_i = transaction price of property i, inflated to 2004 prices

S_{ji} = j structural characteristics of property i;.

L_{ki} = k locational characteristics of property i,;

Q_i = direct distance to new forest area from property i; and

ε_i = error term.

Estimated differences in house prices

Three different transformations of the distance to new forest variable are tested, one where the variable remains untransformed, one where it is log-transformed and one where distance is entered as its reciprocal value. It is assumed that increasing distance to new forest area – all else equal - will lead to decreasing housing values, i.e. λ in equation (3) is hypothesized to be negative for the untransformed and log-transformed distance measure and positive for the reciprocal distance measure. Table 6 in the annex presents detailed estimation results for those models that had significant parameters for the distance to new forest measure.

In all models the coefficient for distance to new forest had the expected negative sign for the un-transformed and log-transformed variables and positive sign for the reciprocal transformation, thus indicating that house prices decrease with increasing distance from the forest edge. The reciprocal transformation was, however, not statistically significant in any of the three areas. The untransformed distance proved to be statistically significant in all models. The log-transformed distance to new forest areas was only significant in the model for Kirkendrup afforestation area.

Table 2 Summary of parameter results and calculated marginal prices for the models with significant distance to new forest parameters

Forest	Drastrup	Kirkendrup		Sperrestrup
Transformation of distance to new forest areas	No transformation (semi-log)	No transformation (semi-log)	Log transformation (double-log)	No transformation (semi-log)
N Obs	185	476	476	259
Size of forest area (ha)	232	75	75	115
Parameter value	-0.000312	-0.000075	-0.040	-0.000053
P-value	0.005	0.001	0.003	0.000
Standard error	0.000109	0.000023	0.013	0.000014
95 % CI up	-0.000096	-0.000031	-0.014	-0.000025
95 % CI low	-0.000527	-0.000120	-0.066	-0.000081
Average house price (DKK)	1,479,584	1,370,993	1,370,993	1,756,401
Average distance to forest (m)	402	977	977	1236
Implicit price at average distance (DKK)	-462	-103	-56	-93
Implicit price 95 % CI up (DKK)	-142	-42	-19	-44
Implicit price 95 % CI low (DKK)	-780	-164	-92	-142
R^2	0.686	0.610	0.609	0.692
Adj R^2	0.673	0.603	0.601	0.682
Total value per afforestation area				
Max distance in data set (m)	1000	1700	1700	2000
One-family houses within max distance	381	1,080	1,080	350
Average price increase per house (DKK)	222,911	37,740	18,850	67,155
Total value of afforestation area (million DKK)	84.9	72.3	36.1	23.5
Value per ha (DKK)	366,073	963,636	481,305	204,385

Table 2 provides a summary of parameter results for the distance to new forest measure for those models where the estimated coefficient for distance to new forest was significant. For those models in semi-log form, the parameter estimate (times 100) for distance to new forest should be interpreted as the percentage decrease per meter. In the semi-log form the marginal price as a percentage of the house price is constant over the range of distance to new forest in the dataset, i.e. independent of the distance to the forest edge. Normally one would expect a diminishing effect with distance that approaches zero at some point, which for example a log-transformation or inverse transformation would have achieved. For the double-log functional forms for Kirkendrup the coefficient for the log-transformed distance to forest measure represents the elasticity of house price with respect to distance to new forest, i.e. a one percent increase in distance decreases the house price by about 0.04 percent.

With a few exceptions the parameter estimates for structural variables turned out as expected a priori (see Table 6 in the annex). From the eight other spatial measures included in the models only distance to industry, central station, childcare institution, wetland and old forest did show a significant effect and only in some models. In the Sperrestrup model, none of these additional measures proved to have a significant effect on housing prices.

Based on the average house price and average distance to new forest in the respective datasets marginal prices per meter have been calculated. Marginal price for the semi-log form are calculated as

$$\partial P/\partial Q_i = \lambda_i * P \quad (4)$$

while the marginal price for the double-log form should be calculated as

$$\partial P/\partial Q_i = \lambda_i/Q_i * P \quad (5)$$

where Q_i is the distance to the new forest, λ_i is the parameter estimate and P is the average price of the house in the dataset.

In the typical policy situation where amenity values from afforestation areas will be a useful input, the policy analyst will have information about the placement of the area (preferable in the form of a digital map) and information about the number of houses located in different distances from the forest edge. In order to be able to apply the results from previous studies of amenity benefits their results should be reported in terms of price increases for different distances to the forest. Given that house prices can vary substantially between regions, absolute price differences based on forest proximity are likely to do the same. Instead of transferring absolute values per house it is thus better to transfer relative price changes as this allows for an adjustment to differences in house prices across sites.

Therefore Figure 2 shows the mean percentage difference in housing prices because of increasing distance to the forest edge and the 95 %- confidence intervals for those percentage differences. Percentage differences for 100m intervals where calculated based on the estimated parameters for distance to new forest according to the following two formulas:[47]

for the untransformed distance to new forest:

$$\Delta \% = 100 * (\exp(\lambda * (D_i - D_{max}))-1) \quad (6)$$

and

for the log-transformed distance to new forest:

$$\Delta \% = 100 * (\exp(\lambda * (\log(D_i) - \log(D_{max})))-1) \quad (7)$$

where Δ % is equal to the difference in housing prices calculated in percent of house located at the maximum distance in the respective dataset D_{max}, λ is the parameter value estimated in the respective model for the distance to new forest measure, D_i is distance to new forest measured at 100m intervals starting from 100m and extending to the largest distance in the respective dataset D_{max}, thus $D_i \in$ [100m, 200m, 300m, …, D_{max}]. As described earlier, the difference in average house prices for different distances from the forest edge can be interpreted as the unit value of non-marginal willingness-to-pay of the house owners for forest proximity and the amenity values associated with it.

[47] Given the semi-log function form and assuming all other housing characteristics beside distance to new forest remain constant, the percentage difference in house prices can be calculated as $100 * \left[\frac{\exp(\lambda D_i) - \exp(\lambda D_{max})}{\exp(\lambda D_{max})}\right]$. For the double-log functional form D_i and D_{max} are equal to the natural logarithm of the respective distances to new forest.

Table 3 Price differences (in %) for houses located at different distances from forest edge compared to houses at maximum distance in dataset including confidence intervals (CI)

	Drastrup		Kirkendrup				Sperrestrup	
Distance to forest edge	No transf. (semi-log)	(CI low - CI up)	No transf. (semi-log)	(CI low - CI up)	Log transf. (double-log)	(CI low - CI up)	No transf. (semi-log)	(CI low - CI up)
100	32.4	(9.0 - 60.7)	12.8	(5.0 - 21.1)	12.0	(4.0 - 20.5)	10.5	(4.8 - 16.5)
200	28.4	(8.0 - 52.5)	12.0	(4.7 - 19.7)	8.9	(3.0 - 15.1)	10.0	(4.6 - 15.6)
300	24.4	(7.0 - 44.6)	11.1	(4.4 - 18.3)	7.2	(2.4 - 12.1)	9.4	(4.3 - 14.7)
400	20.6	(5.9 - 37.2)	10.3	(4.1 - 16.9)	5.9	(2.0 - 10.0)	8.8	(4.0 - 13.8)
500	16.9	(4.9 - 30.2)	9.5	(3.7 - 15.5)	5.0	(1.7 - 8.4)	8.2	(3.8 - 12.9)
600	13.3	(3.9 - 23.5)	8.6	(3.4 - 14.1)	4.2	(1.5 - 7.1)	7.7	(3.5 - 11.9)
700	9.8	(2.9 - 17.1)	7.8	(3.1 - 12.7)	3.6	(1.2 - 6.0)	7.1	(3.3 - 11.0)
800	6.4	(1.9 - 11.1)	7.0	(2.8 - 11.4)	3.0	(1.0 - 5.1)	6.5	(3.0 - 10.2)
900	3.2	(1.0 - 5.4)	6.2	(2.5 - 10.1)	2.6	(0.9 - 4.3)	6.0	(2.8 - 9.3)
1000	0.0	(0.0 - 0.0)	5.4	(2.2 - 8.8)	2.1	(0.7 - 3.6)	5.4	(2.5 - 8.4)
1100	-	-	4.6	(1.9 - 7.5)	1.8	(0.6 - 2.9)	4.9	(2.3 - 7.5)
1200	-	-	3.8	(1.5 - 6.2)	1.4	(0.5 - 2.3)	4.3	(2.0 - 6.7)
1300	-	-	3.1	(1.2 - 4.9)	1.1	(0.4 - 1.8)	3.8	(1.8 - 5.8)
1400	-	-	2.3	(0.9 - 3.7)	0.8	(0.3 - 1.3)	3.2	(1.5 - 5.0)
1500	-	-	1.5	(0.6 - 2.4)	0.5	(0.2 - 0.8)	2.7	(1.2 - 4.1)
1600	-	-	0.8	(0.3 - 1.2)	0.2	(0.1 - 0.4)	2.1	(1.0 - 3.3)
1700	-	-	0.0	(0.0 - 0.0)	0.0	(0.0 - 0.0)	1.6	(0.7 - 2.4)
1800	-	-	-	-	-	-	1.1	(0.5 - 1.6)
1900	-	-	-	-	-	-	0.5	(0.2 - 0.8)
2000	-	-	-	-	-	-	0.0	(0.0 - 0.0)

Table 3 shows the percentage increase in house prices with increasing proximity to the afforestation area. Results for the semi-log models for Sperrestrup and Kirkendrup are surprisingly similar with price differences of 10-12 % for houses located within 100m from the forest edge and going down to about 5 % for 1000m distance. Compared to these two areas percentage increases in Drastrup seem to be unusually large with average values between 32 % and 13 % for the first 100m – 600m distances. In general the uncertainty attached to the percentage increases is high, especially in the Drastrup area, where percentage increases for houses within 100m to the forest edge vary between 9 % and 60 %, with an average increase of 32 %. As can be seen in Table 3 and Figure 2 the confidence intervals are increasing in terms of percentage points the closer one comes to the forest edge. Given the semi-log and double-log functional forms of the hedonic price functions standard errors measure a percentage change of house price or as in this case of the difference in house prices between two distances. The relative size of the confidence intervals stays, however, the same.

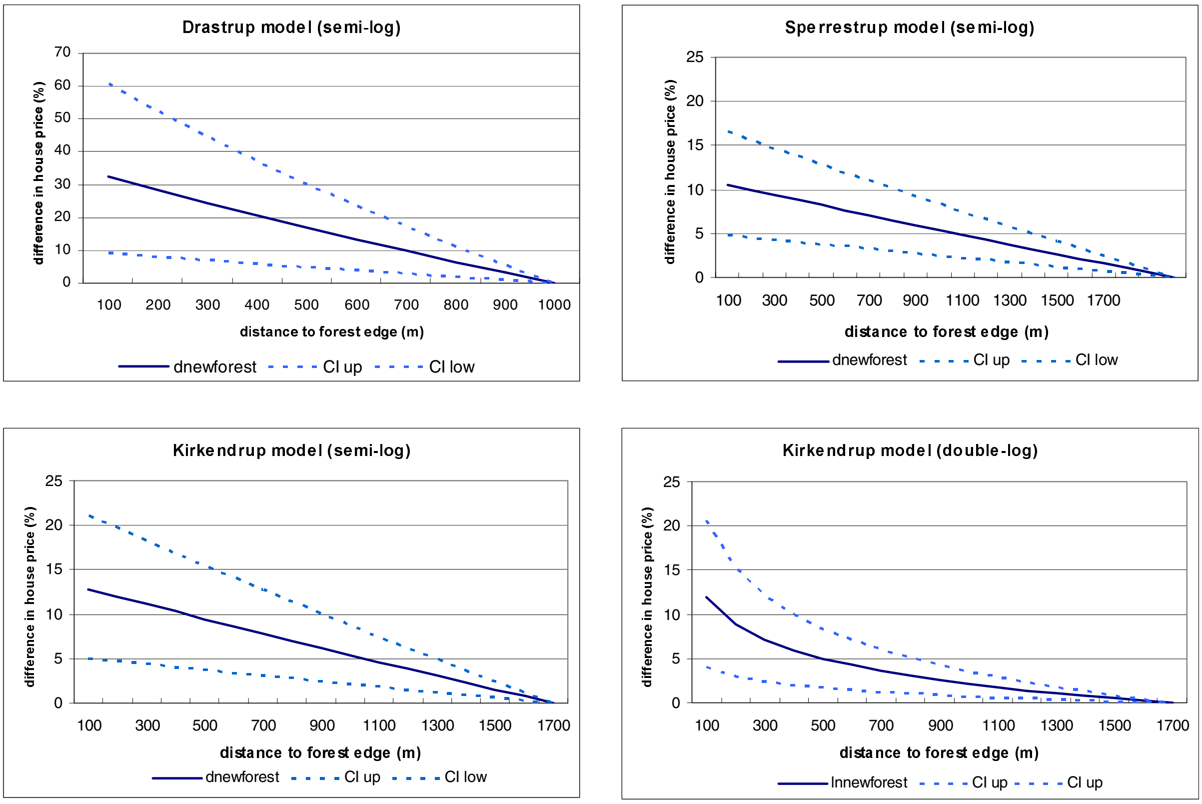

Figure 2 Percentage decrease in housing prices because of increasing distance to forest edge

Benefit transfer between areas

As study results are only based on the first stage of the hedonic pricing method, it is not possible to compare willingness-to-pay for forest proximity using a benefit function. Thus the calculation of transfer errors and test for statistically significant differences between areas are basically comparisons of unit values of non-marginal willingness-to-pay estimates for different forest distances. In order to enable a comparison between areas where both the estimated parameter for distance to new forest measure, the marginal prices calculated on the basis of these parameters and the distance range in the dataset differ, benefit transfer testing is based on the percentage differences presented in Table 3.

In order to simulate the policy relevant situation the three afforestation areas are treated interchangeably as study and policy sites. Willingness-to-pay estimated for a distance interval at the study site is transferred to the same distance interval at the policy site and then compared to the "true" WTP value at the policy site. Table 4 and Table 5 show the transfer errors for benefit transfer between sites, calculated in per cent as

$$\text{transfer error} = 100^* (WTP_S - WTP_P) / WTP_P \qquad (8)$$

where WTP_S represents the average non-marginal willingness to pay for forest proximity at the study site while WTP_P is equal to the average non-marginal willingness-to-pay at the policy site. For both sites willingness-to-pay is calculated in terms of percentage differences in house prices between the respective distance to the forest edge and the maximum distance in the respective dataset. Thus a negative transfer error represents an underestimation of benefits while a positive transfer error represents an overestimation of benefits. For illustration purposes in this paper the calculation of transfer errors is restricted to the first 600m from the forest edge.

Transfer errors vary between an underestimation of benefits by 11 % and an overestimation of benefits by 247 %. As expected errors are largest for transfers between Drastrup and the two other afforestation areas. Transfer errors (in absolute terms) decrease with increasing distance from the forest edge for transfers of estimates based on models where both distance to new forest measures were untransformed, while transfer errors increase for transfers between the double-log model in Kirkendrup and other areas.

Table 4 Transfer errors for distances 100m – 600m and test results, true WTP_P assumed to be known with certainty

Study site	Policy site	Transfer errors for 100m-distance intervals (in %) (Standard errors in parentheses)						
		100m	200m	300m	400m	500m	600m	Range of absolute transfer errors
Drastrup dnew-forest	Kirkendrup dnew-forest	153 (102)	137 (94)	120 (86)	100 (77)	79 (68)	54 (57)	54 - 153
Drastrup dnew-forest	Kirkendrup lnnew-forest	171 (109)	218 $ (126)	241 $ (133)	247 $ (133)	238 $ (128)	214 $ (117)	171 – 247
Drastrup dnew-forest	Sperrestrup dnew-forest	208 $ (124)	185 (113)	160 (102)	134 (90)	105 (78)	74 (65)	74 – 208
Kirkendrup dnewforest	Drastrup dnewfo-rest	-61$ * (13)	-58 $ * (13)	-54 $ * (14)	-50 $ * (16)	-44 $ ** (18)	-35 $ ** (20)	35 – 61
Kirkendrup lnnewforest	Drastrup dnewfo-rest	-63 $ * (13)	-69 $ * (11)	-71 $ * (10)	-71 $ * (10)	-70 $ * (10)	-68 $ * (11)	63 – 71
Kirkendrup dnewforest	Sperrestrup dnew-forest	22 * (39)	20 * (38)	19 * (38)	17 * (37)	15 ** (36)	13 ** (35)	13 – 22
Kirkendrup lnnewforest	Sperrestrup dnew-forest	14 * (40)	-11 ** (31)	-24 ** (26)	-33 ** (23)	-39 $ ** (21)	-45 $ * (19)	11 – 45
Sperrestrup dnewforest	Drastrup dnewfo-rest	-68 $ * (9)	-65 $ * (10)	-62 $ * (11)	-57 $ * (12)	-51 $ ** (14)	-42 $ ** (16)	42 – 68
Sperrestrup dnewforest	Kirkendrup dnew-forest	-18 ** (23)	-17 ** (23)	-16 ** (24)	-14 ** (24)	-13 ** (24)	-11 ** (25)	11 – 18
Sperrestrup dnewforest	Kirkendrup lnnew-forest	-12 ** (25)	12 ** (31)	31 * (37)	48 (41)	65 (46)	81 (50)	12 – 81
	Range of absolute transfer errors	12 - 208	11 - 218	16 - 241	14 - 247	13 - 238	11 - 214	

$: Rejection of null hypothesis of equality H_0

Accept of alternative hypothesis H_1 with the following limits of tolerance: ***50 %, **75 %, *100 %

Table 5 Transfer errors for distances 100m – 600m and test results, true WTP_P measured with uncertainty

Study site	Policy site	Transfer errors for 100m-distance intervals (in %) (Standard errors in parentheses)						
		100m	200m	300m	400m	500m	600m	Range of absolute transfer errors
Drastrup dnew-forest	Kirkendrup dnew-forest	153	137	120	100	79	54	54 - 153
		(130)	(121)	(110)	(100)	(88)	(75)	
Drastrup dnew-forest	Kirkendrup lnnew-forest	171	218	241	247	238	214	171 – 247
		(145)	(168)	(177)	(178)	(172)	(158)	
Drastrup dnew-forest	Sperrestrup dnew-forest	208	185	160	134	105	74	74 – 208
		(151)	(138)	(125)	(111)	(96)	(81)	
Kirkendrup dnewforest	Drastrup dnewfo-rest	-61$ *	-58 $ *	-54 $ *	-50 $ *	-44 *	-35 *	35 – 61
		(20)	(21)	(23)	(25)	(28)	(32)	
Kirkendrup lnnewforest	Drastrup dnewfo-rest	-63 $ *	-69 $ *	-71 $ *	-71 $ *	-70 $ *	-68 $ *	63 – 71
		(20)	(17)	(15)	(15)	(15)	(16)	
Kirkendrup dnewforest	Sperrestrup dnew-forest	22	20	19	17 *	15 *	13 *	13 – 22
		(52)	(51)	(50)	(49)	(48)	(47)	
Kirkendrup lnnewforest	Sperrestrup dnew-forest	14 *	-11 *	-24 *	-33 *	-39 *	-45 $ *	11 – 45
		(51)	(40)	(34)	(30)	(27)	(24)	
Sperrestrup dnewforest	Drastrup dnewfo-rest	-68 $ *	-65 $ *	-62 $ *	-57 $ *	-51 $ *	-42 $ *	42 – 68
		(16)	(17)	(18)	(20)	(23)	(27)	
Sperrestrup dnewforest	Kirkendrup dnew-forest	-18 *	-17 **	-16 **	-14 **	-13 **	-11 **	11 – 18
		(35)	(35)	(36)	(36)	(37)	(37)	
Sperrestrup dnewforest	Kirkendrup lnnew-forest	-12 *	12 *	31	48	65	81	12 – 81
		(40)	(50)	(58)	(65)	(72)	(79)	
	Range of absolute transfer errors	12 - 208	11 - 218	16 - 241	14 - 247	13 - 238	11 - 214	

$: Rejection of null hypothesis of equality H_0

Accept of alternative hypothesis H_1 with the following limits of tolerance: ***50 %, **75 %, *100 %

The comparison of willingness-to-pay estimates between Kirkendrup and Sperrestrup showed that absolute transfer errors between these two areas are within the range of 11-81 %. Using results from the semi-log models for these two areas reduces the error range to 13-22 % overestimation or 11 to 18 % underestimation. This allows a positive outlook towards their potential for application in future policy evaluation exercises. Results for these two areas are also similar to those obtained in earlier studies in Denmark, e.g. Hasler et al. (2002a) for old forest areas and Anthon et al. (2005) for afforestation areas. Applying WTP estimates from Drastrup to the other two areas results in average transfer errors well above 100 %, showing the high uncertainty involved in using benefit transfer. Given that estimates for this area are substantially different from the other two areas in this study and previous study results, their application in benefit transfer exercises is not recommended.

The percentage differences calculated according to equation (6) or (7) are functions of the statistical estimators for the distance to new forest measure. In order to test if these percentage effects are equal across sites we test if the relative difference (i.e. the transfer error) between percentage increases in house prices for each 100m interval, is significantly different from zero. Thus the null-hypothesis for the classical test of equality is

$$H_0: f(\lambda_1, \lambda_2) = \frac{(WTP_S - WTP_P)}{WTP_P} = 0 \qquad (9)$$

where

$$WTP_S = 100 * (\exp(\lambda_1 (D_i - D_{S\max})) - 1) \text{ and}$$

$$WTP_P = 100 * (\exp(\lambda_2 (D_i - D_{P\max})) - 1).$$ [48]

Assuming that both λ_1 and λ_2 are approximately Normal distributed the general case for estimating the variance of a function of λ_1 and λ_2 using the Delta-method (see Wooldridge (2002), Section 3.5.2) is

$$\text{var}(f(\lambda_1, \lambda_2)) = (df/d\lambda_1)^2 * \text{var}(\lambda_1) + (df/d\lambda_2)^2 * \text{var}(\lambda_2) \qquad (10)$$

Two types of variances are calculated for transfer testing, one based on the assumption that the true WTP at the policy site is known with certainty, i.e. WTP_P is a fixed percentage and not a random estimate. In that case the variance for each relative difference for distance intervals 100m – 600m is calculated according to

$$\text{var}(f) = \left(\frac{(D_i - D_{S\max}) \exp(\lambda_1 (D_i - D_{S\max}))}{(\exp(\lambda_2 (D_i - D_{S\max})) - 1)} \right)^2 * \text{var}(\lambda_1) \qquad (11)$$

If it is assumed that WTP_P is also measured with uncertainty, e.g. by applying a non-market valuation method to obtain the "true" WTP of the population, the variance for the relative difference takes on the following form:

$$\text{var}(f) = \left(\frac{(D_i - D_{\max}) \exp(\lambda_1 (D_i - D_{\max}))}{(\exp(\lambda_2 (D_i - D_{\max})) - 1)} \right)^2 * \text{var}(\lambda_1)$$

[48] Note that $D_{P\max}$ and $D_{S\max}$ differ between sites. When percentage differences from double-log model are transferred (D_i-$D_{\max}$) is calculated as ($\log D_i$-$\log D_{\max}$).

$$+\left(-\frac{\exp(\lambda_1(D_i-D_{\max}))-1}{(\exp(\lambda_2(D_i-D_{\max}))-1)^2}(D_i-D_{\max})\exp(\lambda_2(D_i-D_{\max}))\right)^2 * \mathrm{var}(\lambda_2) \qquad (12)$$

The standard errors calculated based on these two different variance equations are included in Table 4 and Table 5. As expected are standard errors for the first case, where WTP_P is assumed to be known with certainty lower than in the second case, where also the "true" WTP at the policy site is assumed to be uncertain.

The test statistic for the classical test of equality is

$$z=\frac{f(\lambda_1,\lambda_2)}{\sqrt{\mathrm{var}(f(\lambda_1,\lambda_2))}} \qquad (13)$$

and the rejection region

$$z<-z_{\alpha/2} \quad or \quad z>z_{\alpha/2}$$

The 10 % critical value for a two-tailed test, assuming Normal distribution, is equal to 1.645. As can be seen in Tabel 4 equality of transfers from Kirkendrup to Drastrup and from Sperrestrup to Drastrup are rejected at the 10 % for all distance intervals. Transfers in the opposite direction, i.e. from Drastrup to the two other areas are only rejected for five out of six from Drastrup to Kirkendrup, where true WTP_P is based on the double-log model and one out of six for transfers from Drastrup to Sperrestrup. Thus in quite a lot of cases H_0 could not be rejected despite the fact that transfer errors are larger than 100 %.

Reason for the failure to reject H_0 is clearly the large uncertainty attached to the parameter estimates for forest proximity. Standard errors in all models are high because of the relatively few observations available for each area. Thus this case study illustrates the drawbacks associated with using the classical null hypothesis of equality as pointed out by Kristofersson and Navrud (2005), where increasing variances of parameter estimates actually increase the likelihood that the null hypothesis of equality will not be rejected. If this non-rejection is then interpreted as a sign for validity of benefit transfer wrong policy recommendations might emerge.

Equality of transfers between Kirkendrup and Sperrestrup is only rejected in two cases where WTP from Kirkendrup double-log model is transferred to Sperrestrup. But can these results be interpreted as validity of benefit transfer between these areas and do the transfer errors calculated between thoses sites provide a correct indication of the error margins that should be applied in sensitivity analyses when WTP measures are applied in policy evaluations?

Instead of the classical testing procedure for equality implemented above, Kristofersson and Navrud (2005) recommend the application of equivalence tests for testing the validity of benefit transfer approaches. These tests assume as the null hypothesis that values are different. Thus by being able to reject the null hypothesis one can conclude that the values are equivalent. In contrast to the classical null hypothesis of equality using equivalence tests requires the definition of an acceptable transfer error. What constitutes an acceptable transfer error in benefit transfer is still an ongoing debate and will most certainly depend on the type of application of benefit transfer, i.e. pre-screening for conducting original studies, cost-benefit analysis of policy options or the determination of compensation payments for environmental damages (see Desvousges et al. (1998) for discussion of accuracy requirements for different benefit transfer applications).

In the following equivalence tests are conduced for benefit transfer between the three areas for three different potentially acceptable error margins, 50 %, 75 % and 100 % and for the first 600 meters distance from the forest edge using 100m-intervals. Following the terminology applied in Muthke and Holm-Mueller (2004) the working hypothesis (or alternative hypothesis) for equivalence testing is

$$H_1: \theta_1 < (WTP_S - WTP_P)/ WTP_P < \theta_2 \tag{14}$$

where

$\theta_1 = -\theta_2$, and $\theta_1 < \theta_2$.

WTP is here the willingness-to-pay in terms of percentage difference (or extra price) paid for a house located at a certain distance from the forest edge compared to a house at maximum distance in the dataset, where the suffix S and P stand for study site and policy site respectively. Thus $(WTP_S - WTP_P)/ WTP_P = f(\lambda_1, \lambda_2)$ of the previous calculations. θ_2 takes on values of 0.5, 0.75 and 1 respectively.

Depending on if the calculated difference is negative or positive the null hypothesis is either

$$H_0: (WTP_S - WTP_P)/ WTP_P \leq \theta_1 \text{ (for negative differences)} \tag{15}$$

OR

$$H_0: (WTP_S - WTP_P)/WTP_P \geq \theta_2 \text{ (for positive differences).} \tag{16}$$

Using the two one-sided test (TOST) applied in Kristofersson and Navrud (2005) and Muthke and Holm-Mueller (2004), the respective test statistics and rejection regions are

$$z_1 = \frac{f(\lambda_1, \lambda_2) - \theta_1}{\sqrt{\operatorname{var}(f(\lambda_1, \lambda_2))}} \geq z_\alpha \quad \text{and} \quad z_2 = \frac{\theta_2 - f(\lambda_1, \lambda_2)}{\sqrt{\operatorname{var}(f(\lambda_1, \lambda_2))}} \geq z_\alpha, \quad \text{where } \alpha = 0.05.$$

In these cases, if the null hypothesis can be rejected given sufficient statistical evidence to the contrary, the transferred values can be assumed to be equivalent given the acceptable transfer error defined. Just like in classical testing of equality between parameters high standard errors will make it more difficult to reject the null hypothesis.

The results of the equivalence tests are incorporated into Table 4 and Table 5, where the transfers for which the null hypothesis can be rejected are marked with stars. None of the transfers can reject the null hypothesis of difference between values when the acceptable error margins are set to 50 %, despite the fact that the average transfer error between Kirkendrup and Sperrestrup (in both directions) in the majority of cases is below 50 %. 14 out of 24 transfers between these two areas can be accepted with error margins of 75 % in the case where WTP_P is assumed to be known with certainty. Seven transfer are only acceptable with error margins of 100 % while for three transfers the null hypothesis of inequality can not be rejected even with 100 % acceptable transfer error.

All of the transfers from Kirkendrup and Sperrestrup to Drastrup are acceptable with errors of 100 %, which can be explained by the fact that an underestimation of more than 100 % could only occur in cases where negative WTP_S would have been transferred (see formel (8)). However, a few transfers are also acceptable with errors of 75 %.

As can be seen in Table 5 in the case where WTP_P is assumed to be measured with uncertainty fewer transfers can be accepted with error margins of 75 % and 100 % because of the higher standard errors attached to the relative difference measures (i.e. transfer errors). Larger standard errors provide also the explanation for the fact that the null hypothesis of equality in the standard classical testing procedure is rejected in fewer cases.

Discussion and conclusion

Given time and cost constraints in policy evaluation benefit transfer has become a necessary and potentially useful evil. Previous tests for the transferability of benefit estimates have mainly focused on contingent valuation and travel cost methods, with a few applications of choice experiments and one example based on the hedonic pricing method. This study has illustrated the uncertainties associated with benefit transfer of amenity values from afforestation areas in Denmark using results from a first stage hedonic pricing study.

Results suggest that benefit transfer of amenity values using percentage differences for distance intervals might be a viable option in policy evaluation in some cases, given the absence of more detailed willingness-to-pay functions based on the second stage of the hedonic pricing method. However, while transfer errors between two of the three areas (Kirkendrup and Sperrestrup) are rather small, transfers involving the third area (Drastrup) reveal errors larger than 200 % in several cases.

Although in the majority of cases the hypothesis of equality between willingness-to-pay estimates for different distances could not be rejected at conventional significance levels, the size of a potential transfer error for unit value transfer between sites is still large. Using equivalence tests as an alternative test for accuracy of benefit transfer applications, shows that only about one third of all transfers are equivalent with a large error margin of 75 % while two thirds of all transfers can be accepted with error margins of 100 %. None of the transfers pass equivalence tests with error margins of 50 %, which could under certain circumstance be judged acceptable in policy evaluations.

Testing for accuracy of benefit transfer is basically a theoretical exercise that can illustrate the uncertainty associated with benefit transfer. In real life benefit transfer applications the "true" WTP at the policy site is not known and thus determining an acceptable transfer error is a meaningless exercise as testing if transferred and true WTP are equivalent is not possible. Suggesting margins for sensitivity analysis in benefit transfer applications based on average transfer errors from former accuracy tests (see Table 1) might undervalue the true uncertainty attached to such benefit transfers, especially if the uncertainty from estimating the "true" WTP at the policy site is taken into consideration. The results from equivalence testing might offer better guidance for determining the error margin that should be applied in sensitivity analyses in benefit transfer applications as pointed out by Muthke and Holm-Mueller (2004).

Results from the application of the hedonic pricing method have been presented in terms of percentage increases in house prices for different distance intervals for two reasons. Firstly the transfer of unit values in terms of percentage changes in house prices instead of absolute values allows an adjustment to the housing price level in an area. For areas with higher housing prices this transfer approach would result in higher absolute WTP values. These could still represent the same change in utility from before to after afforestation, because as normally assumed in the CBA literature the marginal utility of income is decreasing – see e.g. Johansson (1993).

Secondly in addition to allowing for income adjustment the calculation of percentage differences in house prices for different distance intervals simplifies the application of estimated WTP values in policy evaluations. In cases where the location of future afforestation areas can be recorded in the form of digitalised maps the benefit transfer methodology is straight forward. Based on the spatially referenced information in the Danish housing registers the total number of one family houses within different distances can be determined. Based on the average pre-afforestation house price in the area and the estimated price increases for different distances predicted price increases for houses can be calculated. Summing up over all houses and distances yields an estimate for the total willingness-to-pay in terms of extra housing values for the planned afforestation area.

Based on the testing results presented here it is clearly necessary to conduct a sensitivity analysis. Benefit transfer using the values from Drastrup is not recommended. Even if the estimated percentage differences reflect the true price-distance gradient in that area for forest proximity these results might not reflect the average increase in housing prices to be expected for future afforestation areas. If benefit transfer is based on the WTP values estimated in Kirkendrup or Sperrestrup, a sensitivity analysis with +/-75 % is recommended.

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Annex to Appendix 4, Article 4

Table 6 Results for final models for Kirkendrup, Drastrup and Sperrestrup afforestation areas[a]

Drastrup		Kirkendrup			Sperrestrup (robust standard errors)	
Variable	Dnewforest	Variable	Dnewforest	Lnnewforest	Variable	Dnewforest
Lnarea	0.700***	lnarea	0.775***	0.776***	Lnarea	0.557***
	0.067		0.036	0.036		0.047
Lnlot		lnlot			Lnlot	
Lnrooms		lnrooms			lnrooms	
Lnage	-0.110***	lnage	-0.043***	-0.043***	age_at_sal	-0.004***
	0.021		0.006	0.006		0.001
Forest dist.	-0.000312**	Forest dist.	-0.000075***	-0.040**	Forest dist.	-0.000053***
	0.000109		0.000023	0.013		0.000014
semi_detach	-0.134**	Semi_detach	NA	NA	semi_detach	-0.109***
	0.052					0.020
flat_roof		flat_roof			flat_roof	-0.123***
						0.034
Tile	0.131**	tile	0.042*	0.042*	tile	
	0.043		0.016	0.017		
Fireplace		fireplace			fireplace	0.066**
						0.024
not_brick		not_brick	-0.110**	-0.106**	not_brick	-0.061
			0.035	0.035		0.031
Extoilet		extoilet			extoilet	
Lnind		lnind	0.020*	0.021**	lnind	
			0.010	0.010		
Lncs	NA	lncs	-0.221***	-0.192***	lncs	
			0.055	0.052		
Lnlake		lnlake			lnlake	
Lnschool	NA	lnschool			distschool	
lnchildcare		lnchildcare	0.058***	0.056***	lnchildcare	
			0.015	0.015		
Lnwetland	-0.185*	lnwetland			dwetland	
	0.079					
lndrecreatio		lndrecreatio			lndrecreatio	
lnoldforest		lnoldforest	-0.049***	-0.049***	doldforest	
			0.010	0.010		
frejl_east	0.096**				oeleast	0.104***
	0.036					0.025
_cons	12.409***	_cons	12.074***	12.023***	_cons	11.872***
	0.752		0.444	0.448		0.231
N	185	N	476	476	N	259
r2	0.686	r2	0.610	0.609	r2	0.692
r2_a	0.673	r2_a	0.603	0.601	r2_a	0.682

[a]standard errors below parameter results

Note: Significantly different from zero at *0.05, **0.01 and ***0.001 levels.

Appendix 5 (to Chapter 1 to 5)

Table 7 Box-Cox results for advanced models

	Drastrup advanced				Kirkendrup advanced				Sperrestrup advanced		
	Coef.	Std. Err.	P>z		Coef.	Std. Err.	P>z		Coef.	Std. Err.	P>z
/lambda	0.433	0.294	0.141	/lambda	0.380	0.074	0.000	/lambda	0.351	0.062	0.000
/theta	0.199	0.175	0.256	/theta	0.254	0.106	0.016	/theta	0.943	0.189	0.000
	Coef.	chi2(df)	P>chi2(df)		Coef.	chi2(df)	P>chi2(df)		Coef.	chi2(df)	P>chi2(df)
Notrans				Notrans				Notrans			
semi_detach	-1.900	0.776	0.378					semi_detach	-19208.140	0.430	0.512
flat_roof	-0.573	0.324	0.569	flat_roof	-1.801	1.437	0.231	flat_roof	-88119.210	13.208	0.000
tile	3.375	10.206	0.001	tile	1.058	3.415	0.065	tile	-5988.134	0.088	0.767
fireplace	0.742	0.700	0.403	fireplace	0.964	1.598	0.206	fireplace	26828.280	1.513	0.219
not_brick	0.215	0.006	0.938	not_brick	-3.411	8.074	0.004	not_brick	-45006.520	6.770	0.009
extoilet	0.808	1.022	0.312	extoilet	0.577	0.777	0.378	extoilet	16106.570	1.670	0.196
frejl_east	2.886	5.149	0.023					oelsouth	28135.880	1.073	0.300
								oeleast	54370.220	2.267	0.132
_cons	72.359			_cons	108.019			_cons	172325.600		
Trans				Trans				Trans			
w_area	6.094	30.028	0.000	w_area	3.576	128.204	0.000	w_area	71393.740	78.144	0.000
ejd_matr_a	0.921	2.867	0.090	ejd_matr_a	0.066	0.576	0.448	ejd_matr_a	3186.244	1.564	0.211
vaerelse_a	2.193	2.170	0.141	vaerelse_a	1.175	2.190	0.139	vaerelse_a	12837.310	0.421	0.517
age_at_sal	-1.705	15.649	0.000	age_at_sal	-1.399	87.816	0.000	age_at_sal	-28875.750	72.876	0.000
distind	-0.195	0.535	0.464	distind	0.085	3.105	0.078	distind	54.076	0.001	0.978
				distcs	-0.337	11.436	0.001	distcs	-161.217	0.006	0.937
distlake	-0.471	0.093	0.760	distlake	0.022	0.115	0.735	distlake	1927.483	0.745	0.388
dnewforest	-0.430	0.939	0.333	dnewforest	-0.084	1.826	0.177	dnewforest	-1454.643	0.942	0.332
				distschool	0.002	0.001	0.969	distschool	288.736	0.026	0.873
dchildcare	-0.393	1.347	0.246	dchildcare	0.194	7.685	0.006	dchildcare	-3371.978	4.140	0.042
dwetland	-0.779	0.264	0.607	dwetland	0.034	0.368	0.544	dwetland	-4551.203	3.553	0.059
drecreatio	0.002	0.000	0.995	drecreatio	-0.035	0.468	0.494	drecreatio	-1522.992	1.178	0.278
doldforest	-0.093	0.130	0.719	doldforest	-0.238	9.379	0.002	doldforest	-281.548	0.030	0.863
/sigma	3.742			/sigma	5.622			/sigma	71551.440		

Table 8 Box-Cox results for simple models

	Drastrup advanced				Kirkendrup advanced				Sperrestrup advanced		
	Coef.	Std. Err.	P>z		Coef.	Std. Err.	P>z		Coef.	Std. Err.	P>z
/lambda	0.094	0.209	0.654	/lambda	0.414	0.073	0.000	/lambda	0.341	0.062	0.000
/theta	0.184	0.172	0.284	/theta	0.220	0.105	0.037	/theta	0.913	0.187	0.000
	Coef.	chi2(df)	P>chi2(df)		Coef.	chi2(df)	P>chi2(df)		Coef.	chi2(df)	P>chi2(df)
Notrans				Notrans				Notrans			
semi_detach	0.126	0.016	0.900					semi_detach	-15935.040	0.706	0.401
flat_roof	-0.285	0.239	0.625	flat_roof	-1.138	1.432	0.231	flat_roof	-50557.870	10.652	0.001
tile	1.873	9.529	0.002	tile	0.562	2.403	0.121	tile	-7589.567	0.388	0.533
fireplace	0.442	0.779	0.378	fireplace	0.457	0.896	0.344	fireplace	26055.420	3.452	0.063
not_brick	-0.198	0.015	0.901	not_brick	-2.406	11.109	0.001	not_brick	-28531.300	6.522	0.011
extoilet	0.490	1.121	0.290	extoilet	0.565	1.881	0.170	extoilet	9234.560	1.296	0.255
frejl_east	1.349	6.413	0.011					oelsouth	12459.790	0.654	0.419
								oeleast	36624.170	3.551	0.060
_cons	28.661			_cons	69.979			_cons	25080.250		
Trans				Trans				Trans			
w_area	5.111	38.209	0.000	w_area	1.941	135.875	0.000	w_area	49412.990	80.829	0.000
ejd_matr_a	1.014	5.064	0.024	ejd_matr_a	0.031	0.563	0.453	ejd_matr_a	2247.121	1.717	0.190
vaerelse_a	1.209	1.723	0.189	vaerelse_a	0.510	1.134	0.287	vaerelse_a	11687.780	0.801	0.371
age_at_sal	-1.226	26.360	0.000	age_at_sal	-0.898	116.617	0.000	age_at_sal	-18711.390	71.756	0.000
dnewforest	-0.054	0.107	0.744	dnewforest	-0.019	1.009	0.315	dnewforest	-1791.857	3.718	0.054
/sigma	2.182			/sigma	3.600			/sigma	47503.410		

Table 9 Drastrup: Summary of continuous variables

Variable	Obs	Mean	Std. Dev.	Min	Max
Sales price	185	1,142,857	359,892	455,970	2,585,000
Off. valuation	185	1,144,703	287,372	650,000	2,000,000
Price (2004)	185	1,479,584	428,690	648,515	2,753,130
Construction date	185	1974	13	1913	2003
Deed signature	185	2000	2	1996	2005
Weighted measure of living space	185	149	38	77	281
Lot size	185	830	272	182	1,856
Number of rooms	185	5	1	3	10
Age at time of sale	185	27	13	1	90
dnewforest	185	402	231	16	982
distlake	185	1,097	250	642	1,631
dwetland	185	1,023	292	350	1,667
drecreatio	185	298	182	11	705
doldforest	185	170	113	12	581
distheath	185	3,071	283	2,407	3,660
distcoast	185	4,520	334	3,802	5,151
distind	185	426	243	14	908
distschool	185	786	340	122	1,343
dchildcare	185	302	153	21	692
distcs	185	4,063	373	3,510	4,805
distmw	185	4,351	359	3,724	5,080
distmwexit	185	4,992	288	4,429	5,546
dhighbuild	185	3,953	269	3,477	4,527
distcity	185	7,052	269	6,556	7,636

Table 10 Kirkendrup: Summary of continuous variables

Variable	Obs	Mean	Std. Dev.	Min	Max
Sales price	476	1,063,356	272,970	420,000	2,100,000
Off. valuation	476	1,023,866	209,154	500,000	1,850,000
Price (2004)	476	1,370,993	372,246	516,229	3,019,805
Construction date	476	1968	16	1900	2002
Deed signature	476	2000	3	1996	2005
Weighted measure of living space	476	138	32	62	278
Lot size	476	842	260	327	2,917
Number of rooms	476	5	1	1	11
Age at time of sale	476	32	16	0	101
dnewforest	476	977	447	22	1,698
distlake	476	325	152	50	833
dwetland	476	537	281	39	1,472
drecreatio	476	288	269	9	1,235
doldforest	476	166	123	5	490
distheath	476	9,629	1,213	6,938	11,497
distcoast	476	2,568	1,182	821	5,395
distind	476	480	352	13	1,404
distschool	476	954	496	57	2,540
dchildcare	476	717	511	22	2,237
distcs	476	3,902	934	2,503	6,432
distmw	476	6,858	760	4,853	8,582
distmwexit	476	7,768	626	6,437	9,493
dhighbuild	476	1,458	1,054	37	4,254
distcity	476	3,995	930	2,605	6,518

Table 11 Sperrestrup: Summary of continuous variables

Variable	Obs	Mean	Std. Dev.	Min	Max
Sales price	259	1,497,862	285,540	663,000	2,350,000
Off. valuation	259	1,462,857	261,644	880,000	2,100,000
Price (2004)	259	1,756,401	320,543	756,234	2,816,425
Construction date	259	1,970	16	1,902	2,004
Deed signature	259	2,002	1	1,999	2,005
Weighted measure of living space	259	132	27	68	237
Lot size	259	634	299	146	2,044
Number of rooms	259	4	1	2	8
Age at time of sale	259	33	16	0	101
dnewforest	259	1,236	556	8	2,000
distlake	259	443	170	82	906
dwetland	259	613	200	88	1,090
drecreatio	259	217	195	5	1,311
doldforest	259	216	116	5	492
distheath	259	24,433	376	23,130	25,277
distcoast	259	4,483	733	3,267	5,892
distind	259	517	255	32	1,191
distschool	259	576	258	107	1,594
dchildcare	259	377	157	29	1,047
distcs	259	872	347	46	1,937
distmw	259	12,503	596	10,876	13,624
distmwexit	259	12,562	587	10,882	13,677
dhighbuild	259	3,531	892	1,675	4,646
distcity	259	28,666	898	26,715	29,915

Table 12 Drastrup simple models: Model results for full model and two final models*

	Dnewforest			Lnnewforest			Invnewforest		
Variable	Full model	Final model (t>=1.0)	Final model (p<=0.1)	Full model	Final model (t>=1.0)	Final model (p<=0.1)	Full model	Final model (t>=1.0)	Final model (p<=0.1)
lnarea	0.605	0.608	0.701	0.614	0.611	0.706	0.613	0.604	0.706
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
lnlot	0.123	0.122	0.125	0.126	0.117	0.120	0.130	0.114	0.118
	0.043	0.009	0.005	0.038	0.011	0.007	0.033	0.013	0.008
lnrooms	0.105	0.100		0.098	0.098		0.096	0.098	
	0.187	0.187		0.216	0.200		0.226	0.198	
lnage	-0.116	-0.115	-0.122	-0.110	-0.110	-0.117	-0.108	-0.107	-0.114
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Distance to new forest	-0.000073	-0.000068	-0.000089	-0.011	-0.012	-0.020	-0.622	-0.628	0.111
	0.305	0.302	0.159	0.592	0.547	0.296	0.763	0.758	0.956
frejl_east	0.111	0.102	0.109	0.100	0.093	0.101	0.090	0.082	0.088
	0.008	0.009	0.004	0.013	0.015	0.007	0.017	0.021	0.013
semi_detach	-0.004			0.012			0.022		
	0.957			0.854			0.728		
flat_roof	-0.022			-0.021			-0.023		
	0.622			0.631			0.609		
tile	0.137	0.142	0.143	0.135	0.140	0.141	0.131	0.136	0.135
	0.003	0.001	0.001	0.003	0.002	0.001	0.004	0.002	0.002
fireplace	0.033			0.031			0.030		
	0.386			0.419			0.433		
not_brick	-0.019			-0.014			-0.011		
	0.878			0.907			0.927		
extoilet	0.033	0.040		0.039	0.044		0.048	0.052	
	0.353	0.237		0.266	0.193		0.165	0.113	
_cons	10.500	10.492	10.223	10.457	10.543	10.298	10.371	10.516	10.191
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
N	185	185	185	185	185	185	185	185	185
r2	0.691	0.690	0.684	0.690	0.689	0.683	0.690	0.688	0.681
r2_a	0.670	0.676	0.673	0.668	0.674	0.672	0.668	0.674	0.670
aic	-125.6	-132.6	-133.2	-124.7	-131.8	-132.3	-124.5	-131.5	-131.1
bic	-83.7	-103.6	-110.7	-82.9	-102.8	-109.7	-82.7	-102.6	-108.6

*p-values under parameter results

Table 13 Drastrup advanced models: Model results for full model and two final models*

Variable	Dnewforest Full model	Final model (t>=1.0)	Final model (p<=0.1)	Lnnewforest Full model	Final model (t>=1.0)	Final model (p<=0.1)	Invnewfor Full model	Final model (t>=1.0)	Final model (p<=0.1)
lnarea	0.573	0.563	0.700	0.584	0.602	0.706	0.569	0.604	0.706
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
lnlot	0.081	0.083		0.097	0.126	0.120	0.099	0.114	0.118
	0.205	0.185		0.135	0.007	0.007	0.127	0.013	0.008
lnrooms	0.115	0.126		0.109	0.091		0.118	0.098	
	0.154	0.107		0.181	0.233		0.148	0.198	
lnage	-0.102	-0.112	-0.110	-0.103	-0.106	-0.117	-0.107	-0.107	-0.114
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Distance to new forest	-0.000426	-0.000357	-0.000312	-0.033	-0.015	-0.020	-1.913	-0.628	0.111
	0.021	0.005	0.005	0.444	0.456	0.296	0.497	0.758	0.956
frejl_east	0.128	0.143	0.096	0.124	0.099	0.101	0.119	0.082	0.088
	0.012	0.000	0.009	0.017	0.011	0.007	0.022	0.021	0.013
semi_detach	-0.092	-0.117	-0.134	-0.066			-0.067		
	0.296	0.149	0.010	0.454			0.448		
flat_roof	-0.028			-0.024			-0.024		
	0.532			0.599			0.603		
tile	0.137	0.142	0.131	0.142	0.141	0.141	0.141	0.136	0.135
	0.003	0.001	0.003	0.003	0.001	0.001	0.003	0.002	0.002
fireplace	0.034	0.040		0.031			0.038		
	0.384	0.282		0.435			0.339		
not_brick	0.012			0.009			0.006		
	0.923			0.945			0.961		
extoilet	0.027			0.038	0.047		0.042	0.052	
	0.450			0.286	0.167		0.240	0.113	
lnind	-0.022	-0.026		-0.016			-0.011		
	0.347	0.218		0.507			0.632		
lnlake	0.139			-0.079	-0.057		-0.219		
	0.469			0.668	0.317		0.166		
lnchildcare	-0.051	-0.049		-0.036			-0.016		
	0.089	0.072		0.271			0.588		
lnwetland	-0.356	-0.215	-0.185	-0.043			0.108		
	0.088	0.015	0.020	0.804			0.383		
lndrecreatio	0.012			-0.005			-0.033		

	Dnewforest			Lnnewforest			Invnewfor		
Variable	Full model	Final model (t>=1.0)	Final model (p<=0.1)	Full model	Final model (t>=1.0)	Final model (p<=0.1)	Full model	Final model (t>=1.0)	Final model (p<=0.1)
	0.685			0.890			0.293		
lnoldforest	-0.007			-0.007			-0.009		
	0.748			0.738			0.669		
_cons	12.905	12.982	12.409	12.097	10.932	10.298	11.937	10.516	10.191
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
N	185	185	185	185	185	185	185	185	185
r2	0.704	0.702	0.686	0.696	0.690	0.683	0.696	0.688	0.681
r2_a	0.672	0.681	0.673	0.663	0.674	0.672	0.663	0.674	0.670
aic	-121.51	-131.73	-132.22	-116.22	-130.89	-132.27	-116.08	-131.54	-131.13
bic	-60.32	-89.86	-106.46	-55.03	-98.68	-109.73	-54.89	-102.56	-108.59

*p-values under parameter results

Table 14 Kirkendrup simple models: Model results for full model and two final models*

	Dnewforest			Lnnewforest			Invnewforest		
Variable	Full model	Final model (t>=1.0)	Final model (p<=0.1)	Full model	Final model (t>=1.0)	Final model (p<=0.1)	Full model	Final model (t>=1.0)	Final model (p<=0.1)
lnarea	0.744	0.774	0.810	0.747	0.749	0.813	0.742	0.777	0.816
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
lnlot	-0.005			-0.002			0.012		
	0.890			0.949			0.736		
lnrooms	0.040			0.044	0.041		0.039		
	0.354			0.310	0.328		0.360		
lnage	-0.048	-0.048	-0.049	-0.049	-0.048	-0.049	-0.049	-0.049	-0.048
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
dnewforest	-0.000051	-0.000050	-0.000053	-0.032	-0.031	-0.034	2.336	2.243	2.085
	0.009	0.008	0.005	0.010	0.009	0.005	0.315	0.332	0.360
flat_roof	-0.068	-0.071		-0.070	-0.069		-0.078	-0.084	-0.091
	0.141	0.121		0.133	0.132		0.094	0.069	0.044
tile	0.032	0.033	0.036	0.032	0.033	0.037	0.025	0.026	
	0.070	0.060	0.035	0.065	0.061	0.031	0.155	0.135	
fireplace	0.008			0.009			0.007		
	0.736			0.716			0.771		
not_brick	-0.117	-0.120	-0.130	-0.118	-0.118	-0.130	-0.112	-0.114	-0.129
	0.001	0.001	0.000	0.001	0.001	0.000	0.002	0.001	0.000
extoilet	0.031	0.032		0.029	0.029		0.029	0.029	
	0.124	0.118		0.159	0.153		0.159	0.151	
_cons	10.601	10.480	10.328	10.730	10.706	10.485	10.456	10.421	10.255
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
N	476	476	476	476	476	476	476	476	476
r2	0.579	0.578	0.573	0.578	0.578	0.573	0.573	0.572	0.568
r2_a	0.569	0.571	0.569	0.569	0.571	0.569	0.564	0.566	0.564
aic	-291.7	-296.8	-296.0	-291.5	-295.3	-295.9	-285.6	-290.6	-290.3
bic	-245.9	-263.4	-271.0	-245.6	-257.8	-270.9	-239.8	-257.3	-265.4

*p-values under parameter results

Table 15 Kirkendrup advanced models: Model results for full model and two final models*

	Dnewforest			Lnnewforest			Invnewforest		
Variable	Full model	Final model (t>=1.0)	Final model (p<=0.1)	Full model	Final model (t>=1.0)	Final model (p<=0.1)	Full model	Final model (t>=1.0)	Final model (p<=0.1)
lnarea	0.658	0.709	0.775	0.661	0.733	0.776	0.660	0.729	0.774
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
lnlot	0.012			0.013			0.017		
	0.753			0.737			0.642		
lnrooms	0.075	0.054		0.078	0.061		0.077	0.059	
	0.087	0.185		0.072	0.140		0.077	0.154	
lnage	-0.043	-0.042	-0.043	-0.043	-0.043	-0.043	-0.043	-0.042	-0.043
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
dnewforest	-0.000045	-0.000072	-0.000075	-0.030	-0.033	-0.040	3.780	2.175	2.788
	0.191	0.002	0.001	0.062	0.017	0.003	0.095	0.352	0.218
flat_roof	-0.064	-0.062		-0.063	-0.064		-0.066	-0.067	-0.075
	0.182	0.164		0.184	0.149		0.163	0.132	0.093
tile	0.032	0.038	0.042	0.035	0.037	0.042	0.031	0.031	0.032
	0.071	0.025	0.011	0.053	0.029	0.011	0.077	0.063	0.053
fireplace	0.009			0.009			0.008		
	0.722			0.700			0.745		
not_brick	-0.080	-0.098	-0.110	-0.082	-0.100	-0.106	-0.080	-0.097	-0.095
	0.035	0.006	0.002	0.030	0.004	0.002	0.034	0.005	0.006
extoilet	0.031	0.022		0.028			0.026		
	0.141	0.263		0.184			0.214		
lnind	0.029	0.022	0.020	0.030	0.024	0.021	0.029	0.023	0.024
	0.009	0.028	0.046	0.007	0.016	0.032	0.008	0.028	0.016
lncs	-0.208	-0.222	-0.221	-0.208	-0.207	-0.192	-0.184	-0.168	-0.167
	0.001	0.000	0.000	0.001	0.000	0.000	0.001	0.001	0.001
lnlake	0.010			0.008			0.009		
	0.568			0.644			0.605		
lnschool	0.004			0.002			0.011	0.019	
	0.844			0.912			0.492	0.183	
lnchildcare	0.055	0.054	0.058	0.059	0.065	0.056	0.057	0.058	0.065
	0.002	0.000	0.000	0.001	0.000	0.000	0.002	0.001	0.000
lnwetland	0.007			0.006			0.003		
	0.660			0.699			0.859		
lndrecreatio	-0.013			-0.016	-0.014		-0.020	-0.019	-0.020

	Dnewforest			Lnnewforest			Invnewforest		
Variable	Full model	Final model (t>=1.0)	Final model (p<=0.1)	Full model	Final model (t>=1.0)	Final model (p<=0.1)	Full model	Final model (t>=1.0)	Final model (p<=0.1)
	0.222			0.109	0.093		0.043	0.024	0.018
lnoldforest	-0.048	-0.047	-0.049	-0.048	-0.050	-0.049	-0.047	-0.046	-0.052
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
_cons	12.206	12.304	12.074	12.357	12.234	12.023	11.919	11.635	11.603
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
N	479	476	476	479	476	476	479	476	476
r2	0.587	0.615	0.610	0.589	0.615	0.609	0.588	0.613	0.610
r2_a	0.571	0.605	0.603	0.573	0.605	0.601	0.572	0.602	0.600
aic	-272.9	-330.2	-330.9	-274.7	-330.2	-329.0	-274.0	-326.0	-326.0
bic	-193.6	-276.0	-289.3	-195.5	-276.1	-287.4	-194.8	-267.7	-276.1

*p-values under parameter results

Table 16 Sperrestrup simple models: Model results for full model and two final models*

Variable	Dnewforest			Lnnewforest			Invnewfor		
	Full model robust	Final model (t>=1.0) robust	Final model (p<=0.1) robust	Full model robust	Final model (t>=1.0) robust	Final model (p<=0.1) robust	Full model robust	Final model (t>=1.0) robust	Final model (p<=0.1) robust
lnarea	0.537	0.567	0.557	0.529	0.572	0.561	0.519	0.565	0.554
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
lnlot	0.013			0.020			0.029		
	0.650			0.485			0.334		
lnrooms	0.033			0.035			0.037		
	0.505			0.490			0.477		
age_at_sal	-0.004	-0.004	-0.004	-0.004	-0.004	-0.004	-0.004	-0.004	-0.004
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
dnewforest	-0.000072	-0.000051	-0.000053	-0.017	-0.023	-0.024	-0.198	-0.134	-0.124
	0.017	0.000	0.000	0.252	0.006	0.005	0.665	0.774	0.792
semi_detach	-0.082	-0.102	-0.109	-0.081	-0.097	-0.104	-0.076	-0.104	-0.112
	0.026	0.000	0.000	0.032	0.000	0.000	0.052	0.000	0.000
flat_roof	-0.145	-0.132	-0.123	-0.130	-0.132	-0.122	-0.119	-0.117	-0.106
	0.000	0.000	0.000	0.001	0.000	0.000	0.001	0.001	0.001
tile	-0.031	-0.032		-0.031	-0.033		-0.032	-0.034	
	0.183	0.184		0.192	0.175		0.183	0.160	
fireplace	0.061	0.064	0.066	0.068	0.068	0.071	0.065	0.066	0.069
	0.014	0.010	0.008	0.013	0.007	0.005	0.022	0.014	0.010
not_brick	-0.063	-0.063	-0.061	-0.063	-0.059	-0.057	-0.069	-0.067	-0.064
	0.051	0.042	0.054	0.045	0.053	0.068	0.020	0.026	0.034
extoilet	0.005			0.006			0.008		
	0.793			0.755			0.682		
oelsouth	0.035			-0.012			-0.041	-0.046	-0.048
	0.371			0.725			0.054	0.023	0.020
oeleast	0.146	0.112	0.104	0.085	0.098	0.089	0.053	0.050	0.040
	0.003	0.000	0.000	0.030	0.000	0.000	0.051	0.046	0.085
_cons	11.819	11.811	11.872	11.871	11.879	11.946	11.766	11.793	11.860
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
N	259	259	259	259	259	259	259	259	259
r2	0.696	0.694	0.692	0.689	0.687	0.685	0.687	0.685	0.683
r2_a	0.680	0.682	0.682	0.672	0.676	0.675	0.670	0.672	0.672

	Dnewforest			Lnnewforest			Invnewfor		
Variable	Full model robust	Final model (t>=1.0) robust	Final model (p<=0.1) robust	Full model robust	Final model (t>=1.0) robust	Final model (p<=0.1) robust	Full model robust	Final model (t>=1.0) robust	Final model (p<=0.1) robust
aic	-407.15	-413.30	-413.84	-401.23	-408.11	-408.56	-399.69	-404.20	-404.56
bic	-357.35	-377.73	-381.83	-351.43	-372.54	-376.55	-349.89	-365.08	-368.99

*p-values under parameter results

Table 17 Sperrestrup advanced models: Model results for full model and two final models*

Variable	Dnewforest			Lnnewforest			Invnewfor		
	Full model robust	Final model (t>=1.0) robust	Final model (p<=0.1) robust	Full model robust	Final model (t>=1.0) robust	Final model (p<=0.1) robust	Full model robust	Final model (t>=1.0) robust	Final model (p<=0.1) robust
lnarea	0.529	0.566	0.557	0.517	0.564	0.551	0.510	0.565	0.551
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
lnlot	0.024			0.031			0.036		
	0.466			0.348			0.296		
lnrooms	0.035			0.036			0.037		
	0.475			0.455			0.451		
age_at_sal	-0.004	-0.004	-0.004	-0.004	-0.004	-0.004	-0.004	-0.004	-0.004
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
lnind	0.002			0.002			0.001		
	0.914			0.911			0.965		
lncs	-0.017			-0.025			-0.028		
	0.516			0.352			0.323		
lnlake	-0.010			0.002			0.006		
	0.713			0.951			0.801		
dnewforest	-0.000059	-0.000059	-0.000053	-0.012	-0.009	-0.010	0.176	0.220	0.087
	0.155	0.052	0.000	0.333	0.297	0.261	0.766	0.595	0.820
distschool	0.000050			0.000023			0.000027		
	0.325			0.648			0.604		
lnchildcare	-0.023	-0.022		-0.021	-0.018	-0.022	-0.023	-0.022	-0.027
	0.144	0.108		0.189	0.149	0.088	0.156	0.056	0.021
dwetland	-0.000094	-0.000102		-0.000116	-0.000125	-0.000122	-0.000118	-0.000143	-0.000143
	0.182	0.073		0.081	0.011	0.015	0.077	0.002	0.002
lndrecreatio	-0.009			-0.011	-0.010		-0.011	-0.011	
	0.382			0.273	0.193		0.293	0.167	
doldforest	0.000053			0.000033			0.000023		
	0.507			0.668			0.762		
semi_detach	-0.058	-0.079	-0.109	-0.055	-0.093	-0.089	-0.051	-0.088	-0.084
	0.147	0.001	0.000	0.168	0.000	0.000	0.217	0.000	0.000
flat_roof	-0.143	-0.148	-0.123	-0.141	-0.135	-0.125	-0.136	-0.135	-0.124
	0.000	0.000	0.000	0.001	0.000	0.000	0.001	0.000	0.000
tile	-0.030	-0.027		-0.033	-0.025		-0.034	-0.025	

Variable	Dnewforest			Lnnewforest			Invnewfor		
	Full model robust	Final model (t>=1.0) robust	Final model (p<=0.1) robust	Full model robust	Final model (t>=1.0) robust	Final model (p<=0.1) robust	Full model robust	Final model (t>=1.0) robust	Final model (p<=0.1) robust
	0.206	0.247		0.181	0.297		0.160	0.291	
fireplace	0.048	0.050	0.066	0.046	0.053	0.057	0.043	0.050	0.052
	0.048	0.024	0.008	0.059	0.027	0.017	0.074	0.032	0.020
not_brick	-0.057	-0.058	-0.061	-0.057	-0.061	-0.057	-0.060	-0.062	-0.058
	0.110	0.077	0.054	0.107	0.058	0.074	0.080	0.052	0.065
extoilet	0.013			0.013			0.014		
	0.517			0.510			0.471		
oelsouth	0.056	0.049		0.026			0.007		
	0.209	0.202		0.488			0.814		
oeleast	0.152	0.155	0.104	0.106	0.088	0.089	0.085	0.082	0.082
	0.012	0.001	0.000	0.019	0.001	0.000	0.026	0.001	0.000
_cons	12.120	11.983	11.872	12.183	12.067	12.109	12.125	12.043	12.084
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
N	259	259	259	259	259	259	259	259	259
r2	0.705	0.701	0.692	0.703	0.699	0.696	0.702	0.698	0.694
r2_a	0.678	0.687	0.682	0.676	0.684	0.683	0.675	0.683	0.682
aic	-398.72	-414.02	-413.84	-397.04	-411.66	-412.99	-396.34	-410.84	-411.84
bic	-320.47	-367.78	-381.83	-318.79	-365.42	-373.86	-318.09	-364.60	-372.71

*p-values under parameter results

Table 18 Drastrup: Adding spatial measures to the simple model, final model results*

Variable	Simple model	Adding to simple model… Distance to industry	Distance to lake	Distance to childcare	Distance to wetland	Distance to recreational area	Distance to oldforest
dnewforest	-0.000089	-0.000089	-0.000089	-0.000089	-0.000221	-0.000089	-0.000089
	0.159	0.159	0.159	0.159	0.024	0.159	0.159
lnarea	0.701	0.701	0.701	0.701	0.684	0.701	0.701
	0.000	0.000	0.000	0.000	0.000	0.000	0.000
lnlot	0.125	0.125	0.125	0.125	0.132	0.125	0.125
	0.005	0.005	0.005	0.005	0.003	0.005	0.005
tile	0.143	0.143	0.143	0.143	0.141	0.143	0.143
	0.001	0.001	0.001	0.001	0.001	0.001	0.001
lnage	-0.122	-0.122	-0.122	-0.122	-0.109	-0.122	-0.122
	0.000	0.000	0.000	0.000	0.000	0.000	0.000
frejl_east	0.109	0.109	0.109	0.109	0.110	0.109	0.109
	0.004	0.004	0.004	0.004	0.004	0.004	0.004
lnwetland					-0.130		
					0.077		
_cons	10.223	10.223	10.223	10.223	11.175	10.223	10.223
	0.000	0.000	0.000	0.000	0.000	0.000	0.000
N	185	185	185	185	185	185	185
r2	0.684	0.684	0.684	0.684	0.690	0.684	0.684
r2_a	0.673	0.673	0.673	0.673	0.677	0.673	0.673

*p-values under parameter results

Table 19 Drastrup: Deleting spatial measures from the advanced model, final model results*

		Deleting from advanced model…					
Variable	Simple model	Distance to industry	Distance to lake	Distance to childcare	Distance to wetland	Distance to recreational area	Distance to oldforest
Variable	final2	finalind2	finallake2	finalchi~2	finalwetl2	finalrecr2	finaloldf2
lnarea	0.700	0.700	0.700	0.684	0.701	0.700	0.700
	0.000	0.000	0.000	0.000	0.000	0.000	0.000
lnwetland	-0.185	-0.185	-0.185	-0.130		-0.185	-0.185
	0.020	0.020	0.020	0.077		0.020	0.020
tile	0.131	0.131	0.131	0.141	0.143	0.131	0.131
	0.003	0.003	0.003	0.001	0.001	0.003	0.003
lnage	-0.110	-0.110	-0.110	-0.109	-0.122	-0.110	-0.110
	0.000	0.000	0.000	0.000	0.000	0.000	0.000
dnewforest	-0.00031	-0.00031	-0.00031	-0.00022	-0.00009	-0.00031	-0.00031
	0.005	0.005	0.005	0.024	0.159	0.005	0.005
frejl_east	0.096	0.096	0.096	0.110	0.109	0.096	0.096
	0.009	0.009	0.009	0.004	0.004	0.009	0.009
semi_detach	-0.134	-0.134	-0.134			-0.134	-0.134
	0.010	0.010	0.010			0.010	0.010
lnlot				0.132	0.125		
				0.003	0.005		
_cons	12.409	12.409	12.409	11.175	10.223	12.409	12.409
	0.000	0.000	0.000	0.000	0.000	0.000	0.000
N	185	185	185	185	185	185	185
r2	0.686	0.686	0.686	0.690	0.684	0.686	0.686
r2_a	0.673	0.673	0.673	0.677	0.673	0.673	0.673

*p-values under parameter results

Table 20 Kirkendrup dnewforest: Adding spatial measures to the simple model, final model results*

		Adding to simple model…							
Variable	Simple model	Distance to industry	Distance to central station	Distance to lake	Distance to school	Distance to childcare	Distance to wetland	Distance to recreational area	Distance to oldforest
dnewforest	-0.000053	-0.000036	-0.000081	-0.000053	-0.000013	-0.000053	-0.000053	-0.000053	-0.000040
	0.005	0.061	0.000	0.005	0.540	0.005	0.005	0.005	0.031
lnarea	0.810	0.742	0.819	0.810	0.797	0.810	0.810	0.810	0.783
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
tile	0.036	0.040	0.033	0.036	0.033	0.036	0.036	0.036	0.037
	0.035	0.018	0.055	0.035	0.055	0.035	0.035	0.035	0.029
not_brick	-0.130	-0.098	-0.133	-0.130	-0.133	-0.130	-0.130	-0.130	-0.096
	0.000	0.006	0.000	0.000	0.000	0.000	0.000	0.000	0.006
lnage	-0.049	-0.046	-0.049	-0.049	-0.044	-0.049	-0.049	-0.049	-0.046
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
lnind		0.026							
		0.005							
extoilet		0.035							
		0.080							
lncs			-0.110						
			0.011						
flat_roof			-0.076						
			0.096						
lnschool					0.048				
					0.001				
lnoldforest									-0.043
									0.000
_cons	10.328	10.458	11.223	10.328	10.015	10.328	10.328	10.328	10.639
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
N	476	476	476	476	476	476	476	476	476
r2	0.573	0.583	0.581	0.573	0.584	0.573	0.573	0.573	0.594
r2_a	0.569	0.576	0.575	0.569	0.578	0.569	0.569	0.569	0.589
aic	-296.04	-302.45	-300.89	-296.04	-305.43	-296.04	-296.04	-296.04	-317.16
bic	-271.05	-269.12	-267.56	-271.05	-276.27	-271.05	-271.05	-271.05	-288.00

*p-values under parameter results

Table 21 Kirkendrup Innewforest: Adding spatial measures to the simple model, final model results*

		Adding to simple model…							
Variable	Simple model	Distance to industry	Distance to central station	Distance to lake	Distance to school	Distance to child-care	Distance to wet-land	Distance to recrea-tional area	Distance to oldforest
lnnewforest	-0.0335	-0.0232	-0.0430	-0.0335	-0.0099	-0.0335	-0.0335	-0.0335	-0.0251
	0.0049	0.0577	0.0012	0.0049	0.4666	0.0049	0.0049	0.0049	0.0330
lnarea	0.8132	0.7465	0.8221	0.8132	0.7982	0.8132	0.8132	0.8132	0.7856
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
tile	0.0373	0.0414	0.0333	0.0373	0.0333	0.0373	0.0373	0.0373	0.0375
	0.0305	0.0157	0.0558	0.0305	0.0512	0.0305	0.0305	0.0305	0.0259
not_brick	-0.1300	-0.0983	-0.1309	-0.1300	-0.1334	-0.1300	-0.1300	-0.1300	-0.0960
	0.0002	0.0061	0.0002	0.0002	0.0001	0.0002	0.0002	0.0002	0.0057
lnage	-0.0494	-0.0466	-0.0495	-0.0494	-0.0446	-0.0494	-0.0494	-0.0494	-0.0467
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
lnind		0.0268							
		0.0033							
extoilet		0.0335							
		0.0967							
lncs			-0.0812						
			0.0435						
flat_roof			-0.0786						
			0.0873						
lnschool					0.0480				
					0.0007				
lnoldforest									-0.0429
									0.0000
_cons	10.4851	10.5560	11.1785	10.4851	10.0655	10.4851	10.4851	10.4851	10.7564
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
N	476	476	476	476	476	476	476	476	476
r2	0.573	0.583	0.579	0.573	0.584	0.573	0.573	0.573	0.594
r2_a	0.569	0.577	0.573	0.569	0.578	0.569	0.569	0.569	0.588
aic	-295.86	-302.55	-298.40	-295.86	-305.59	-295.86	-295.86	-295.86	-317.03
bic	-270.87	-269.23	-265.07	-270.87	-276.43	-270.87	-270.87	-270.87	-287.87

*p-values under parameter results

Table 22 Kirkendrup dnewforest: Deleting spatial measures from the advanced model, final model results*

Variable	Advanced model	Deleting from advanced model…							
		Distance to industry	Distance to central station	Distance to lake	Distance to school	Distance to childcare	Distance to wetland	Distance to recreational area	Distance to oldforest
dnewforest	-0.000075	-0.000080	-0.000019	-0.000075	-0.000075	-0.000042	-0.000075	-0.000075	-0.000052
	0.001	0.000	0.376	0.001	0.001	0.100	0.001	0.001	0.053
lnarea	0.775	0.787	0.780	0.775	0.775	0.784	0.775	0.775	0.786
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
not_brick	-0.110	-0.119	-0.103	-0.110	-0.110	-0.108	-0.110	-0.110	-0.128
	0.002	0.001	0.003	0.002	0.002	0.002	0.002	0.002	0.000
tile	0.042	0.040	0.035	0.042	0.042	0.036	0.042	0.042	0.040
	0.011	0.017	0.039	0.011	0.011	0.031	0.011	0.011	0.019
lnage	-0.043	-0.044	-0.044	-0.043	-0.043	-0.045	-0.043	-0.043	-0.044
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
lnind	0.020			0.020	0.020		0.020	0.020	0.028
	0.046			0.046	0.046		0.046	0.046	0.006
lncs	-0.221	-0.195		-0.221	-0.221	-0.073	-0.221	-0.221	-0.173
	0.000	0.000		0.000	0.000	0.087	0.000	0.000	0.003
lnoldforest	-0.049	-0.055	-0.037	-0.049	-0.049	-0.035	-0.049	-0.049	
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
lnchildcare	0.058	0.051		0.058	0.058		0.058	0.058	0.028
	0.000	0.001		0.000	0.000		0.000	0.000	0.061
lnschool			0.028			0.026			0.032
			0.069			0.081			0.036
_cons	12.074	11.995	10.416	12.074	12.074	11.018	12.074	12.074	11.303
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
N	476	476	476	476	476	476	476	476	476
r2	0.610	0.607	0.597	0.610	0.610	0.599	0.610	0.610	0.595
r2_a	0.603	0.600	0.591	0.603	0.603	0.592	0.603	0.603	0.587
aic	-330.94	-328.86	-318.52	-330.94	-330.94	-319.50	-330.94	-330.94	-312.65
bic	-289.29	-291.37	-285.20	-289.29	-289.29	-282.01	-289.29	-289.29	-270.99

*p-values under parameter results

Table 23 Kirkendrup lnnewforest: Deleting spatial measures from the advanced model, final model results*

		Deleting from advanced model…							
Variable	Advanced model	Distance to industry	Distance to central station	Distance to lake	Distance to school	Distance to childcare	Distance to wetland	Distance to recreational area	Distance to oldforest
lnnewforest	-0.040	-0.042	-0.020	-0.040	-0.040	-0.013	-0.040	-0.040	-0.026
	0.003	0.002	0.121	0.003	0.003	0.348	0.003	0.003	0.085
lnarea	0.776	0.789	0.782	0.776	0.776	0.781	0.776	0.776	0.786
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
lnoldforest	-0.049	-0.056	-0.055	-0.049	-0.049	-0.037	-0.049	-0.049	
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
not_brick	-0.106	-0.115	-0.103	-0.106	-0.106	-0.103	-0.106	-0.106	-0.126
	0.002	0.001	0.003	0.002	0.002	0.003	0.002	0.002	0.000
lnage	-0.043	-0.044	-0.044	-0.043	-0.043	-0.044	-0.043	-0.043	-0.043
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
lnind	0.021			0.021	0.021		0.021	0.021	0.029
	0.032			0.032	0.032		0.032	0.032	0.005
lncs	-0.192	-0.160		-0.192	-0.192		-0.192	-0.192	-0.152
	0.000	0.002		0.000	0.000		0.000	0.000	0.005
tile	0.042	0.040	0.036	0.042	0.042	0.035	0.042	0.042	0.040
	0.011	0.017	0.033	0.011	0.011	0.037	0.011	0.011	0.020
lnchildcare	0.056	0.049	0.030	0.056	0.056		0.056	0.056	0.026
	0.000	0.001	0.017	0.000	0.000		0.000	0.000	0.076
lnwetland			0.025						
			0.084						
lndrecreatio			-0.016						
			0.088						
lnschool						0.028			0.035
						0.061			0.019
_cons	12.023	11.922	10.527	12.023	12.023	10.474	12.023	12.023	11.236
	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
N	476	476	476	476	476	476	476	476	476
r2	0.609	0.605	0.600	0.609	0.609	0.597	0.609	0.609	0.594
r2_a	0.601	0.598	0.592	0.601	0.601	0.591	0.601	0.601	0.586
aic	-329.01	-326.33	-318.47	-329.01	-329.01	-318.62	-329.01	-329.01	-311.86
bic	-287.36	-288.84	-276.82	-287.36	-287.36	-285.30	-287.36	-287.36	-270.20

*p-values under parameter results

Table 24 Sperrestrup : Adding spatial measures to the simple model, final model results*

Variable	Simple model	Adding to simple model…							
		Distance to industry	Distance to central station	Distance to lake	Distance to school	Distance to childcare	Distance to wetland	Distance to recreational area	Distance to oldforest
lnnewforest	-0.02373	-0.02373	-0.01673	-0.02373	-0.02373	-0.02373	-0.01483	-0.02373	-0.02373
	0.0047	0.0047	0.0294	0.0047	0.0047	0.0047	0.0855	0.0047	0.0047
lnarea	0.561067	0.561067	0.571848	0.561067	0.561067	0.561067	0.55721	0.561067	0.561067
	0	0	0	0	0	0	0	0	0
not_brick	-0.05657	-0.05657	-0.0541	-0.05657	-0.05657	-0.05657	-0.05496	-0.05657	-0.05657
	0.0682	0.0682	0.0976	0.0682	0.0682	0.0682	0.0775	0.0682	0.0682
oeleast	0.089461	0.089461	0.084673	0.089461	0.089461	0.089461	0.093265	0.089461	0.089461
	0.0003	0.0003	0.0024	0.0003	0.0003	0.0003	0.0002	0.0003	0.0003
age_at_sal	-0.00377	-0.00377	-0.00392	-0.00377	-0.00377	-0.00377	-0.00405	-0.00377	-0.00377
	0	0	0	0	0	0	0	0	0
semi_detach	-0.10413	-0.10413	-0.09355	-0.10413	-0.10413	-0.10413	-0.09204	-0.10413	-0.10413
	0	0	0	0	0	0	0	0	0
flat_roof	-0.12159	-0.12159	-0.13209	-0.12159	-0.12159	-0.12159	-0.11941	-0.12159	-0.12159
	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004
fireplace	0.070572	0.070572	0.055603	0.070572	0.070572	0.070572	0.064358	0.070572	0.070572
	0.0048	0.0048	0.0141	0.0048	0.0048	0.0048	0.009	0.0048	0.0048
lncs			-0.03299						
			0.0297						
tile			-0.0486						
			0.0415						
dwetland							-0.00011		
							0.0291		
_cons	11.9464	11.9464	12.07529	11.9464	11.9464	11.9464	11.97402	11.9464	11.9464
	0	0	0	0	0	0	0	0	0
N	259	259	259	259	259	259	259	259	259
r2	0.685477	0.685477	0.693683	0.685477	0.685477	0.685477	0.692508	0.685477	0.685477
r2_a	0.675413	0.675413	0.681331	0.675413	0.675413	0.675413	0.681394	0.675413	0.675413
aic	-408.557	-408.557	-411.404	-408.557	-408.557	-408.557	-412.413	-408.557	-408.557
bic	-376.546	-376.546	-372.279	-376.546	-376.546	-376.546	-376.844	-376.546	-376.546

*p-values under parameter results

Table 25 Sperrestrup : Deleting spatial measures from the advanced model, final model results*

Variable	Advanced model	Deleting from advanced model…							
		Distance to industry	Distance to central station	Distance to lake	Distance to school	Distance to childcare	Distance to wetland	Distance to recreational area	Distance to old forest
Lnnewforest	-0.00991	-0.00991	-0.00991	-0.00991	-0.00991	-0.01483	-0.01673	-0.00991	-0.00991
	0.2614	0.2614	0.2614	0.2614	0.2614	0.0855	0.0294	0.2614	0.2614
lnarea	0.551255	0.551255	0.551255	0.551255	0.551255	0.55721	0.571848	0.551255	0.551255
	0	0	0	0	0	0	0	0	0
semi_detach	-0.08949	-0.08949	-0.08949	-0.08949	-0.08949	-0.09204	-0.09355	-0.08949	-0.08949
	0	0	0	0	0	0	0	0	0
flat_roof	-0.12472	-0.12472	-0.12472	-0.12472	-0.12472	-0.11941	-0.13209	-0.12472	-0.12472
	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004
age_at_sal	-0.00408	-0.00408	-0.00408	-0.00408	-0.00408	-0.00405	-0.00392	-0.00408	-0.00408
	0	0	0	0	0	0	0	0	0
dwetland	-0.00012	-0.00012	-0.00012	-0.00012	-0.00012	-0.00011		-0.00012	-0.00012
	0.0146	0.0146	0.0146	0.0146	0.0146	0.0291		0.0146	0.0146
fireplace	0.056536	0.056536	0.056536	0.056536	0.056536	0.064358	0.055603	0.056536	0.056536
	0.0167	0.0167	0.0167	0.0167	0.0167	0.009	0.0141	0.0167	0.0167
oeleast	0.089305	0.089305	0.089305	0.089305	0.089305	0.093265	0.084673	0.089305	0.089305
	0.0003	0.0003	0.0003	0.0003	0.0003	0.0002	0.0024	0.0003	0.0003
not_brick	-0.05651	-0.05651	-0.05651	-0.05651	-0.05651	-0.05496	-0.0541	-0.05651	-0.05651
	0.0743	0.0743	0.0743	0.0743	0.0743	0.0775	0.0976	0.0743	0.0743
lnchildcare	-0.02202	-0.02202	-0.02202	-0.02202	-0.02202			-0.02202	-0.02202
	0.0876	0.0876	0.0876	0.0876	0.0876			0.0876	0.0876
lncs							-0.03299		
							0.0297		
tile							-0.0486		
							0.0415		
_cons	12.10882	12.10882	12.10882	12.10882	12.10882	11.97402	12.07529	12.10882	12.10882
	0	0	0	0	0	0	0	0	0
N	259	259	259	259	259	259	259	259	259
r2	0.695549	0.695549	0.695549	0.695549	0.695549	0.692508	0.693683	0.695549	0.695549
r2_a	0.683273	0.683273	0.683273	0.683273	0.683273	0.681394	0.681331	0.683273	0.683273
aic	-412.987	-412.987	-412.987	-412.987	-412.987	-412.413	-411.404	-412.987	-412.987
bic	-373.862	-373.862	-373.862	-373.862	-373.862	-376.844	-372.279	-373.862	-373.862

*p-values under parameter results

NERI **National Environmental Research Institute**

DMU Danmarks Miljøundersøgelser

National Environmental Research Institute, NERI, is a part of University of Aarhus.

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Urban forests provide substantial non-market benefits to residents and out-of-town visitors in the form of amenity and recreational values. This has been confirmed by a number of non-market valuation studies in Denmark, Sweden and other European countries. Using these monetary estimates in benefit transfer applications, however, can involve substantial uncertainties. In this PhD thesis benefit transfer has been applied in three cases including one based on original empirical research. The results are pre-sented in four articles included in the appendix of this report. Results from the empirical research confirm the positive effect of proximity to forested areas on housing prices found in earlier studies in Denmark. However, they also illustrate the problems involved in the implementation of the hedonic pricing method caused by omitted variable bias. Testing for accuracy of benefit transfer using both the classical test of assuming equality and equivalence testing show high transfer errors even in cases where the null hy-pothesis of equality of estimates between sites could not be rejected. For none of the equivalence tests the null hypothesis of inequality could be rejected with error margins of 50 %. Only for transfers between two areas with rather similar willingness-to-pay results, the majority of transferred values are accepted to be equivalent within error ranges of 75 %.

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Measurement and benefit transfer of amenity values from afforestation projects
– A spatial economic valuation approach using GIS technology