The value of living in proximity to a forest, a lake and the sea - A large scale hedonic house price valuation

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The implicit price for living in proximity to a forest, a lake, and the sea was estimated in hedonic house price models across 48 separate housing markets that cover all of Denmark. The results shows that households are willing to pay a considerable price premium for living in proximity to a forest, a lake, and the sea. The hedonic models are used to calculate the capitalized value of living in proximity to a forest, a lake, and the sea. In this paper I argue that a capitalized value of a housing characteristic can also be interpreted as household individual preference parameter.

1 Introduction

The hedonic house price model were estimated for 48 separate housing markets that cover all of Denmark. The purpose was to identify the implicit prices and the capitalized value of living in proximity to a forest, a lake and the sea. These three externality was chosen as focus points for the analysis as these is mapped out for the entire country in an adequate price manner. The analysis is built on Rosen's (1974) hedonic price theory which has been extensively used to estimate the value of environmental externalities. The main attraction of Rosen's theory is that it is possible to obtain implicit prices of the different characteristics of a property from the hedonic price function, including the availability of various public goods. Numerous studies have used this approach to estimate the importance of recreational externalities as more spatial data, and computational capacity has become available, e.g., Tyrväinen and Miettinen (2000) and Lake et al. (2000) and new applications are added regularly (e.g., Sander et al. 2010; Panduro and Veie 2013).

The hedonic price function recovered in the first stage of the hedonic method relates each attribute to the property price at a given market equilibrium. The information revealed about the preferences of households is limited to their marginal willingness to pay for the amenity in question. This limit the interpretation of the welfare effects to marginal changes in amenities. Non-marginal or discrete changes in the provision of a amenity good cannot be assessed without additional assumptions and/or additional socioeconomic data on households.

Most notably Bartik (1988) argue that the implicit prices of the hedonic house price model can be used to calculate an upper bar welfare measure for non-marginal localized changes. This is done by multiplying the estimate of the marginal willingness to pay with a non-marginal change in consumption. The intuition is that the marginal willingness to pay will increase at a decreasing rate with the level of consumption for a positive externality. The estimate of the impact of a non-marginal change using the marginal willingness to pay estimate will therefore likely overshoot the welfare impact.

Bartiks (1988) main assumption is that the underlying utility function will envelop the parameter estimate of the hedonic house price model. This assumption is taken a step further by Bajari and Benkard (2005) that assume that utility function is additive and logarithmic in housing goods and linear in consumption of all other goods. This theoretical framework has recently been applied by Panduro et al. (2018) and von Gravenitz (2018). An attractive feature of this approach is that the capitalized value of a housing good can be interpreted as household individual preference parameter, that can be used to assess non-marginal changes. In this context the preference parameter can be used in an welfare assessment of non-marginal changes, not as an upper bar welfare estimate but as the actual welfare estimate. Still, the assumption is an approximation of the utility function and is likely to be less correct as the non-marginal change becomes less marginal.

2 Data

The data used in this analysis is based on the Danish house price database (Panduro, forthcoming). The data covers all homes in Denmark. The hedonic models were estimated using sales data that included 1,037,857 observation that covered the period from 01.01.2011 to 01.01.2017. The capitalized value and the relative capitalized value were calculated for all homes in Denmark in total 2,828,509 observations. The data is based on the OIS database that contain The BBR, ESR and SVUR registers. Spatial variables were mainly constructed from the spatial Geodanmark database.

The location-based variables in the data were calculated using Euclidean distance and enter into the model as proximity variables. Proximity is calculated by $x_{prox} = c_{cutoff} - x_{dist}$ where x_{dist} is Euclidean distance. Homes beyond the cut-off distance proximity is set to zero, $x_{prox}|x_{prox} < 0$. The proximity variable is easy to interpret as amenities are associated with positive coefficients. The cutoff value reflects that the service is declining with distance, and beyond some point effectively is zero. The cutoff value was initially chosen by mapping out the relationship between the sales price and dummy variables that capture the distance to externalities in steps of 100 meters using a simple regression model. After a certain distance the signal of the externality on the price trails off. These trail of points were chosen as cut-off values. The cutoff value for forest proximity and lake proximity were set to 600 meters while proximity to the sea was set to 1000 m.

Only large lakes above 5 Ha and forest above 18 Ha enters into the models. Initially smaller lakes and smaller forest were tested in the model. However, in the less developed areas of Denmark, where the housing market is thin, only strong signals of preference can be detected. To ensure similarity between models only the large forest and lakes entered into the models in the form of proximity measures.

3 Theory

A house is a composite good and can be described as a bundle of attributes, X_j. The price P_j of a house j in market equilibrium is a function of its attributes, $P_j(X_j)$.

Households obtain utility from consuming housing, X_j, and from all other goods described by a composite numeraire good, c_i. The annual flow of utility for household i living in house j is described by the utility function U(X_j,c_i;γ_i) where γ is the household specific preference parameters. Each household spends its total annual income y_i on housing and all other goods and occupies only one house so that i and j are interchangeable. Utility is assumed to be separable in time. We can therefor model the choice of housing as a static problem (Bajari and Benkard 2005). The annual cost of housing is calculated from the transaction price at time of purchase. Assuming perpetual life for the house asset and multiplying the price with an asset return rate π suitable for the house asset, the price is converted to a perpetual annuity.

Households are assumed to be rational utility maximizers and choose their preferred housing bundle given their income and preferences for housing goods and all other goods. Thus, they face the following maximization problem where γ_i captures household specific preference parameters determined by socioeconomic characteristics of the household and inherent preference heterogeneity:

$$max_{x,c}U(X_j, c_i, \gamma_i) \;\; s.t. \; y_i = \pi P_j(X_j) + c_i \tag{1}$$

For a housing bundle j* to be the utility maximizing choice for household i the marginal cost for house characteristic k assuming a continuous good X_{jk} must equal the households marginal rate of substitution. The following first order conditions must hold at the optimum:

$$\frac{\delta U(X_{j\star}), y_i - \pi P(X_{j\star})/\delta X_{jk}}{\delta U(X_{j\star}), y_i - \pi P(X_{j\star})/\delta c_i} = \pi \frac{\delta P(X_{j\star})}{\delta x_{jk}} \tag{2}$$

The right-hand side of (2) is the implicit annual price recovered from the hedonic price function. The left-hand side is the household's marginal rate of substitution between the amenity and the numeraire good, which can be interpreted as its marginal willingness to pay. As we only observe one choice per household we only have one point on each indifference curve. Without further information about household preferences, we cannot make inferences about the non-marginal willingness to pay. Bajari and Benkard (2005) obtain identification of household preferences by imposing a functional form for the utility function and assume weak separability in the k'th housing goods. They suggest that one possible assumption for the utility function could be that the utility is logarithmic in housing goods and linear in consumption of the numeraire good.

This leads to the following utility function:

$$U(X_j, c_i, \gamma_i) = \sum \gamma_{ki} log(x_{jk}) + c_i \tag{3}$$

The household specific preference parameter γ_{ki} captures the intensity of the taste for housing good, k. With this functional form, we can rewrite the first order condition as:

$$\frac{\gamma_{ik}}{x_{j\star k}} = \frac{\delta \pi P(X_{j\star})}{\delta x_{jk}} \tag{4}$$

$$\gamma_{ik} = x_{j\star k} \frac{\delta \pi P(X_{j\star})}{\delta x_{jk}} \tag{5}$$

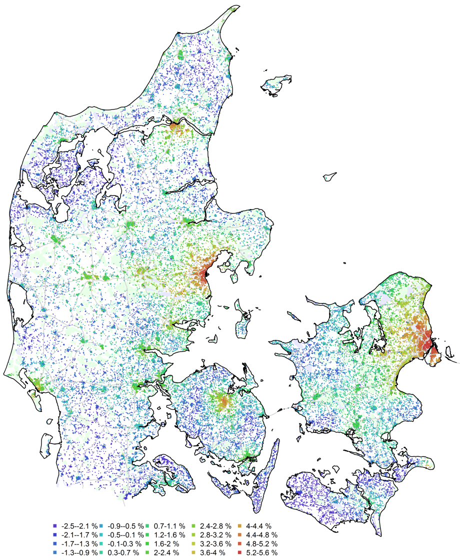
The measure$\delta \pi P(X_{j\star})/\delta x_{jk}$ is readily obtained from the first stage estimation of the hedonic price function. We directly observe $x_{j\star k}$, which is the realized consumption level of a specific housing good. We can therefor directly calculate γ_{ik}, which is the household specific preference parameter for attribute k. Equation (4) provides the second stage hedonic estimation for the willingness to pay (the marginal rate of substitution) for housing good k. The preference parameter calculated in (5) for each household can be used to calculate willingness to pay for changes in amenity k.

4 Housing markets

The separation of housing markets is crucial in hedonic pricing models. A key assumption is that the pricing function is an equilibrium function that describes a single market. A single hedonic pricing function cannot describe the price-relation in more than one market, and pooling transactions across markets would thus result in biased estimates. Nevertheless, the theory provides almost no guidance to what defines a market. The closest definition the literature provides is that a “true” market exists if market participants do not consider buying houses outside that particular market (Taylor, 2003). It follows from this reasoning that a housing market will have to have a similar price development. If a housing area has a dissimilar price development, that is housing areas which has prices that either increases or decreases more rapidly than other areas, the housing area must consists of more than one market. It is also reasonable to assume that housing markets are spatial entities that are delineated by their spatial extent.

The housing markets in this analysis were identified based on the difference in price development across space during the period from 2000 to 2015. In figure 1 the annual price development for all of Denmark is presented. The map shows that the annual price development has on averaged increased around the large city centers while prices have price have decreased in rural areas.

Figure 1: Annual price development from 2000-2015

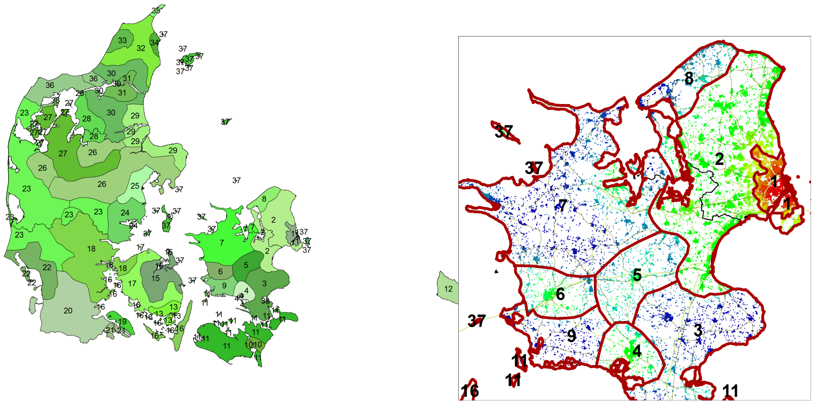


* note that the map was originally made by Hansen et al. (2018)

Denmark was delineated into 36 separate housing markets for single-family homes and row houses - these markets will be referred to as house markets. Apartments were treated in separate markets based on the assumption that household in the market for a house would not consider an apartment and *vise versa*. Apartments are concentrated in and around the major urban areas in Denmark. This meant that it was only possible to identify 12 apartments markets covering all of Denmark.

In figure 2 an overview of housing markets is presented together with a map of the markets on Zealand overlayed by the annual price development for Zealand. The map of Zealand shows that the price development follows almost discrete boundaries which serve as the extent of the housing markets. The markets were carved out of Denmark by following these boundaries of price development.

Figure 2: Overview of housing markets



*A table that provide the names of the different markets can viewed in the appendix.

5 Model

A hedonic house price model was estimated for each housing market. The hedonic model retain a similar specification across all markets for houses and across all markets for apartments, respectively. The objective was to ensure that model results can be compared between markets. The drawback is that specifications is likely to be dissimilar from market to market. Hedonic house price models for houses were specified as follows:

$$ln(P_{jl}) = \beta X_j + \theta x_{jforest} + \theta x_{jlake} + \theta x_{jcoast_{100}} + \theta x_{jcoast} + \rho W_{jP}P + \alpha_l + \epsilon_j \quad (6)$$

And house price models estimated for apartment housing markets were specified slightly different:

$$ln(P_{jl}) = \beta X_j + \theta x_{jforest} + \theta x_{jlake} + \theta x_{jcoast} + \rho W_{jP}P + \alpha_l + \epsilon_j \quad (7)$$

Where P_j the price of the jth house and X_j is housing attributes. The $x_{jforest}$, x_{jlake} and x_{jcoast} are proximity variables that living in proximity to a forest, a lake and the sea, respectively. The variable $x_{jcoast_{100}}$ is a dummy variable that capture house that are located wihtin 100 meters of the coastline.

Spatial autocorrelation is controlled for using postal codes,α, as spatial fixed effect (FE) for l number of codes. This follows the guidelines on how to handle spatial autocorrelation in hedonic house price models (Graevenitz & Panduro, 2015). An additional innovation is introduced into the models,$\rho W_{jP}P$, which is a spatial-temporal lag of the dependent variable. The term is designed to capture the information effect that household obtain in the buying process when they compare potential homes to each other. W_{jP} is a spatial-temporal weight matrix that describes the eight nearest houses sold within a year of house j. The term is unidirectional in time which ensures that the variable can be treated like any other explanatory variable in contrast to classical spatial dependent lag variables in spatial models.

The relative capitalized value and the capitalized value was calculated for each home using the following specifications. Equation 8 describe the relative price increase which can be explained for a specific house characteristic x_{jk} while $\hat{p_j}$ is the predicted price for house j. Note that equation 9 is a calculation of households individual preference parameter as defined in the theory section in equation 5.

$$exp(\beta_j x_{jk}) - 1 \quad (8)$$

$$\hat{p_j} * (exp(\beta_{jk} x_{jk}) - 1) \quad (9)$$

6 Results

The model estimate from housing market 2, 18 and 30 - "Stor Koebenhavn", "Trekanstomraade" and "Aalborg opland" - for houses is presented table 1 in section 6.1. The model estimate from housing market B, G and J - "Stor Koebenhavn", "Trekanstomraade" and "Aalborg opland" - for apartment is presented table 2 in section 6.1. The two tables serve as an example of model estimate. The model estimate for both house and apartments will be added as supplementary literature as a HTML file. Parameter estimates for the proximity to forest, lakes and the sea for all the models will be presented separately in section 6.2 and section 6.3

6.1 Example of model estimate

Estimates of the hedonic house price model for house market 2, 18 and 30 is presented in table 1. The models from market 2 and 18 represent fluent housing markets with many buyers and sellers while market 30 is less fluent. The variables conform to expectation for the most part. The lake proximity variable in market 30 lack significance which is likely due to a lack of variation in the lake variable.

Table 1: Model estimates of house models

	1- Stor Koebenhavn	18 - Trekanstom-raade	3 - Aalborg opland
Size (m^2)	0.007***	0.007***	0.009***
	(0.0001)	(0.0002)	(0.001)
Size squared (m^2)	−0.00001***	−0.00001***	−0.00001***
	(0.00000)	(0.00000)	(0.00000)
Row house * size (dummy, m^2)	−0.0002***	0.0004***	0.0002
	(0.00003)	(0.0001)	(0.0002)
non living space (m^2)	−0.002***	−0.002***	−0.002***
	(0.0001)	(0.0001)	(0.0004)
sales time (numerical, days)	−0.0004***	−0.0005***	−0.001***
	(0.00003)	(0.0001)	(0.0001)
sales time squared (numerical, days)	0.00000***	0.00000***	0.00000***
	(0.000)	(0.000)	(0.00000)
Garden (m^2)	0.00000***	0.00001***	−0.00000*
	(0.00000)	(0.00000)	(0.000)
Urban area size (m^2)	0.000***	0.000***	0.00000***
	(0.000)	(0.000)	(0.000)

Table 1: Model estimates of house models

	1- Stor Koebenhavn	18 - Trekanstom-raade	3 - Aalborg opland
Service diversity (number of services)	0.002^{***}	0.004^{***}	0.004^{***}
	(0.0002)	(0.0003)	(0.001)
Proximity windturbines (cen=3000 m)	-0.00003^{***}	-0.0001^{***}	0.0001^{***}
	(0.00000)	(0.00001)	(0.00001)
NO_2 ($\mu g/m^3$)	-0.015^{***}	-0.006^{**}	-0.028^{***}
	(0.001)	(0.002)	(0.007)
Located in the forest (dummy)	-0.096	0.06600	0.2590^{*}
	(0.290)	(0.135)	(0.148)
proximity to forest (cen=600m)	0.0001^{***}	0.0001^{***}	0.0002^{***}
	(0.00001)	(0.00002)	(0.00004)
proximity to lake (cen=600m)	0.0002^{***}	0.0004^{***}	-0.0001
	(0.00002)	(0.0001)	(0.0001)
located within 100 m of the sea (dummy)	0.353^{***}	0.445^{***}	0.492^{***}
	(0.014)	(0.028)	(0.110)
proximity to the sea (cen=1000m)	0.0003^{***}	0.0003^{***}	0.0002^{***}
	(0.00001)	(0.00002)	(0.00004)
Rail noise (dB)	-0.001^{***}	-0.013^{***}	-0.040
	(0.0002)	(0.003)	(0.051)
Road noise (dB)	-0.0005^{***}	-0.001^{***}	-0.001^{***}
	(0.0001)	(0.0001)	(0.0003)
Number of floors	-0.011^{**}	-0.007	0.00300
	(0.005)	(0.017)	(0.059)
Age of building 2000-2016 (dummy)	-0.188^{***}	-0.502^{***}	-0.525^{***}
	(0.013)	(0.022)	(0.061)
Age of building 1980-1999 (dummy)	-0.115^{***}	-0.446^{***}	-0.485^{***}
	(0.012)	(0.022)	(0.060)
Age of building 1960-1979 (dummy)	-0.041^{***}	-0.296^{***}	-0.332^{***}
	(0.012)	(0.020)	(0.058)
Age of building 1945-1959 (dummy)	-0.052^{***}	-0.215^{***}	-0.235^{***}
	(0.012)	(0.022)	(0.060)
Age of building1910-1944 (dummy)	-0.059^{***}	-0.204^{***}	-0.173^{***}
	(0.013)	(0.021)	(0.059)
Age of building1875-1909 (dummy)	-0.010	-0.068^{***}	-0.066
	(0.014)	(0.022)	(0.060)
Made of bricks (dummy)	0.055^{***}	0.077^{***}	0.085^{***}
	(0.005)	(0.015)	(0.029)
Made of wood (dummy)	0.062^{***}	0.091^{***}	0.190^{***}
	(0.008)	(0.027)	(0.049)
Flet roof (dummy)	0.044^{***}	0.071^{***}	0.120^{***}
	(0.006)	(0.015)	(0.032)

Table 1: Model estimates of house models

	1- Stor Koebenhavn	18 - Trekanstom-raade	3 - Aalborg opland
Tile roof (dummy)	0.040***	0.087***	0.095***
	(0.004)	(0.008)	(0.018)
Oldstyled house (dummy)	0.113***	0.216**	0.693***
	(0.029)	(0.085)	(0.189)
Heating - stove (dummy)	0.044***	0.088***	0.111***
	(0.004)	(0.008)	(0.015)
Heating - heat pump (dummy)	−0.041***	−0.278***	−0.062*
	(0.007)	(0.016)	(0.032)
Heating - electric (dummy)	−0.060***	−0.135***	−0.117***
	(0.006)	(0.016)	(0.030)
Heating - central heating (dummy)	0.020***	−0.020**	−0.091***
	(0.004)	(0.009)	(0.016)
Renovated in the 1970s (dummy)	−0.039***	−0.046***	−0.009
	(0.005)	(0.011)	(0.020)
Renovated in the 1980s (dummy)	−0.020***	0.01300	0.046**
	(0.006)	(0.014)	(0.021)
Renovated in the 1990s (dummy)	0.040***	0.060***	0.137***
	(0.008)	(0.013)	(0.022)
Renovated in the 2000s (dummy)	0.081***	0.131***	0.203***
	(0.007)	(0.014)	(0.024)
Renovated in the 2010s (dummy)	0.127***	0.133***	0.195***
	(0.016)	(0.035)	(0.051)
Renovated after being sold (dummy)	−0.222***	−0.329***	−0.328***
	(0.020)	(0.044)	(0.067)
Spatial-temporal lag (W)	0.00000***	0.00000***	0.00000***
	(0.000)	(0.000)	(0.00000)
Constant	14.767***	14.716***	14.487***
	(0.079)	(0.148)	(0.362)
Observations	43,122	18,209	6,420
R^2	0.573	0.493	0.515
Adjusted R^2	0.572	0.491	0.509
Residual Std. Error	0.289 (df = 43002)	0.402 (df = 18122)	0.438 (df = 6346)
F Statistic	485.824*** (df = 119; 43002)	204.843*** (df = 86; 18122)	92.134*** (df = 73; 6346)
Note:			*p<0.1; **p<0.05; ***p<0.01

6.2 Apartment model estimation

Estimates of the hedonic house price model for Apartment market A, G and J is presented in table 2.The models from market A and G represent fluent housing markets with many buyers and sellers while market J is less fluent. The variables conform to expectation for the most part. The forest proximity variable in market J is the wrong sign which is likely due to a lack of variation in the lake variable.

Table 2: Model estimates of apartments models

	Koebenhavn - A	Trekanstomraade - G	Aalborg opland -J
Size (m^2)	0.022***	0.012***	0.018***
	(0.0001)	(0.001)	(0.001)
Size squared (m^2)	−0.00005***	−0.00002***	−0.00003***
	(0.00000)	(0.00001)	(0.00000)
Non living space (m^2)	−0.0003**	−0.004**	0.001*
	(0.0001)	(0.001)	(0.0005)
Sales time (numerical, days)	−0.0002***	−0.001***	−0.001***
	(0.00003)	(0.0003)	(0.0001)
Sales time squared (numerical, days)	0.00000***	0.00000***	0.00000***
	(0.000)	(0.00000)	(0.00000)
Floor	0.015***	−0.017	−0.014*
	(0.001)	(0.011)	(0.008)
Urban area size (m^2)	−0.000***	−0.000	0.0000
	(0.000)	(0.000)	(0.000)
Service diversity (number of services)	0.004***	0.005***	0.008***
	(0.0002)	(0.001)	(0.001)
Proximity windturbines (cen=3000 m)	−0.00002***	0.00001	−0.00004
	(0.00000)	(0.0001)	(0.00003)
NO_2 ($\mu g/m^3$)	−0.004***	0.018***	−0.005
	(0.0002)	(0.004)	(0.003)
proximity to forest (cen=600m)	0.0003***	0.0003**	−0.0002***
	(0.00002)	(0.0001)	(0.0001)
proximity to lake (cen=600m)	0.0002***	0.001***	0.0003***
	(0.00001)	(0.0001)	(0.0001)
proximity to the sea (cen=1000m)	0.0002***	0.0004***	0.0002***
	(0.00001)	(0.0001)	(0.00005)
Rail noise (dB)	−0.001***	−0.050***	−0.143**
	(0.0002)	(0.015)	(0.066)
Road noise (dB)	−0.001***	−0.004***	−0.0002
	(0.0001)	(0.001)	(0.0003)
Number of floors in building	−0.007***	0.047***	0.00700
	(0.001)	(0.011)	(0.008)
Age of building 2000-2016 (dummy)	−0.206***	−0.406***	−0.237***
	(0.013)	(0.108)	(0.066)

Table 2: Model estimates of apartments models

	Koebenhavn - A	Trekanstomraade - G	Aalborg opland -J
Age of building 1980-1999 (dummy)	-0.052^{***}	-0.032	0.191^{***}
	(0.013)	(0.115)	(0.066)
Age of building 1960-1979 (dummy)	0.106^{***}	0.04700	0.287^{***}
	(0.012)	(0.107)	(0.061)
Age of building 1945-1959 (dummy)	0.061^{***}	0.00300	0.133^{**}
	(0.013)	(0.113)	(0.063)
Age of building1910-1944 (dummy)	0.01200	-0.052	0.06200
	(0.012)	(0.098)	(0.058)
Age of building1875-1909 (dummy)	-0.050^{***}	-0.030	0.141^{**}
	(0.012)	(0.097)	(0.058)
Made of bricks (dummy)	-0.001	-0.200^{*}	0.00300
	(0.007)	(0.102)	(0.043)
Made of concrete (dummy)	-0.015^{**}	-0.140	0.0940^{*}
	(0.007)	(0.110)	(0.049)
Flet roof (dummy)	0.00200	-0.055	-0.099^{***}
	(0.004)	(0.050)	(0.031)
Tile roof (dummy)	0.028^{***}	-0.038	0.02700
	(0.004)	(0.035)	(0.020)
Heating - stove (dummy)	0.059^{***}	-0.003	-0.006
	(0.011)	(0.066)	(0.051)
Heating - heat pump (dummy)	-0.106^{*}	0.06000	-0.087
	(0.064)	(0.320)	(0.255)
Heating - electric (dummy)	-0.053^{***}	0.03000	-0.063
	(0.017)	(0.122)	(0.054)
Heating - central heating (dummy)	-0.016^{**}	-0.011	0.05800
	(0.007)	(0.063)	(0.050)
Renovated in the 1970s (dummy)	0.00400	-0.032	-0.082^{**}
	(0.009)	(0.058)	(0.033)
Renovated in the 1980s (dummy)	0.062^{***}	-0.085	-0.039
	(0.014)	(0.053)	(0.030)
Renovated in the 1990s (dummy)	0.022^{**}	0.427^{***}	0.138^{***}
	(0.010)	(0.057)	(0.034)
Renovated in the 2000s (dummy)	0.089^{***}	0.855^{***}	0.227^{***}
	(0.008)	(0.050)	(0.038)
Renovated in the 2010s (dummy)	0.057^{***}	0.756^{***}	0.1550^{*}
	(0.021)	(0.158)	(0.083)
Renovated after being sold (dummy)	0.06200	-0.563^{***}	0.11600
	(0.057)	(0.218)	(0.100)
Spatial-temporal lag (W)	0.000^{***}	-0.000	-0.000
	(0.000)	(0.000)	(0.000)

Table 2: Model estimates of apartments models

	Koebenhavn - A	Trekanstomraade - G	Aalborg opland -J
Constant	13.300***	14.065***	12.604***
	(0.087)	(0.689)	(0.438)
Observations	48,356	2,242	3,797
R^2	0.781	0.475	0.655
Adjusted R^2	0.780	0.459	0.645
Residual Std. Error	0.274 (df = 48018)	0.630 (df = 2174)	0.436 (df = 3693)
F Statistic	508.905*** (df = 337; 48018)	29.340*** (df = 67; 2174)	67.944*** (df = 103; 3693)
Note:	*p<0.1; **p<0.05; ***p<0.01		

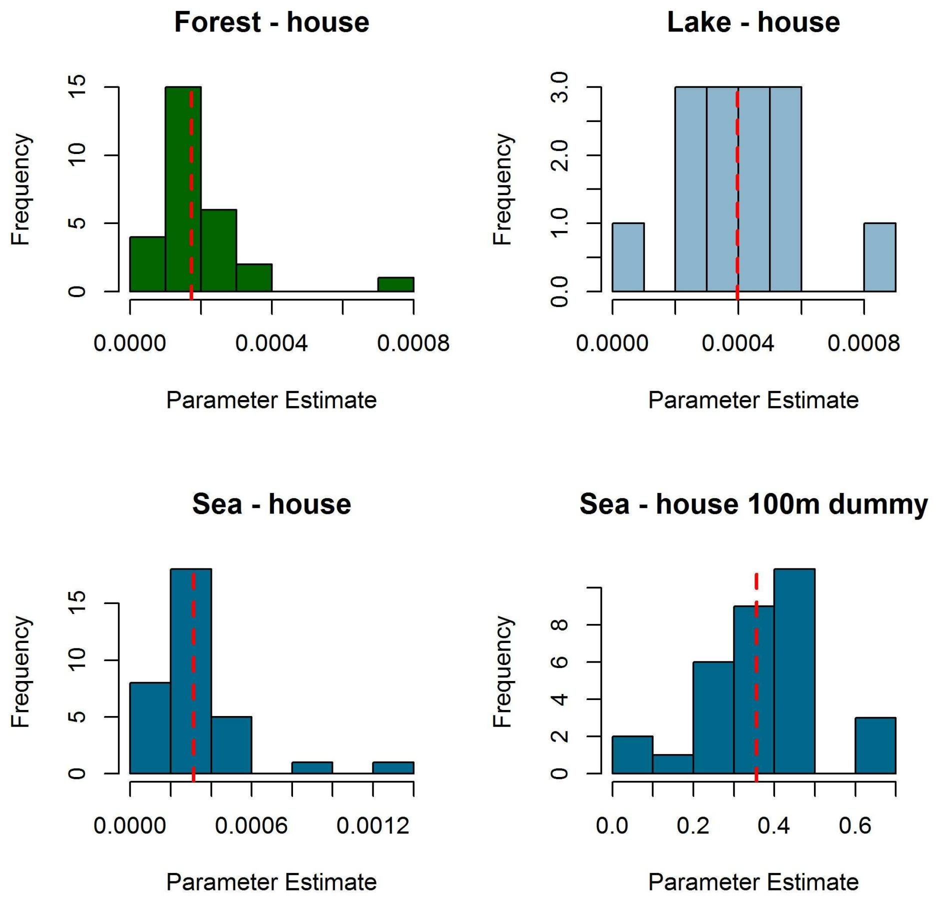
6.3 Overview of Parameter estimates

The parameter estimates for forest proximity, lake proximity, and sea proximity is presented in histograms in figure 3 and 4 for the 36 house market models and the 12 apartment market models. Only parameter estimates with a t-value above 1.645 have entered into the histograms. The red dotted line in each histogram represents a median parameter estimate. Tables of the parameter estimates is provided in the appendix.

The median parameter estimates for forest proximity is 0.00017, while the median parameter estimate for lake proximity is 0.00039 and the sea proximity is 0.00031. Houses located within 100 meters of the sea have an additional median parameter estimate of 0.33. Forest and lakes are measured on the same proximity scale going from 0 to 600 meters while sea proximity is measured on from 0 to 1000 meters to the sea. The impact of sea proximity is much higher than the two other variables given the scale difference. The parameter estimate represents marginal implicit prices that explain a proportion of the house price, i.e., houses increase on the median with 0.039 % for every meter the house is located nearer to a lake.

In most house market models, the parameter estimates of the proximity to a lake, a forest, and the sea conform to expectation - see figure 3. However, there are some parameter estimates which either are insignificant or has the wrong parameter estimates. In most of these cases the estimates can be attributed to lack of variation, i.e., there is simply too few observations within proximity to a lake, forest or the sea. The most obvious is the example is house market 5 located in the center of Zealand in and around the city of Ringsted which do not have a coastline. Similar examples can be found for the forest proximity and lake proximity variable for several house markets. However, there are exceptions where lack of variation cannot adequately explain why some parameter estimates are insignificant and/or have the wrong expected sign. In these cases omitted variable bias and endogeneity is the most likely explanation. An example of such a parameter estimate is the forest proximity estimate for market 22- the Esbjerg market. The main forest in market 22 is located in the largest military exercise area in Denmark. Such a forest might not be considered a good by residents but rather a bad due to inaccessibility and noise from explosions and large machines. Another example is, the sea proximity estimate for market 31 - the Aalborg market - where the parameter estimate implies the living in proximity to the sea is a bad. The explanation is likely that the model has not capture important aspects of the city structure of Aalborg, like the location of Hasseris and Nørresundby.

Figure 3: Overview of parameter distribution for house markets

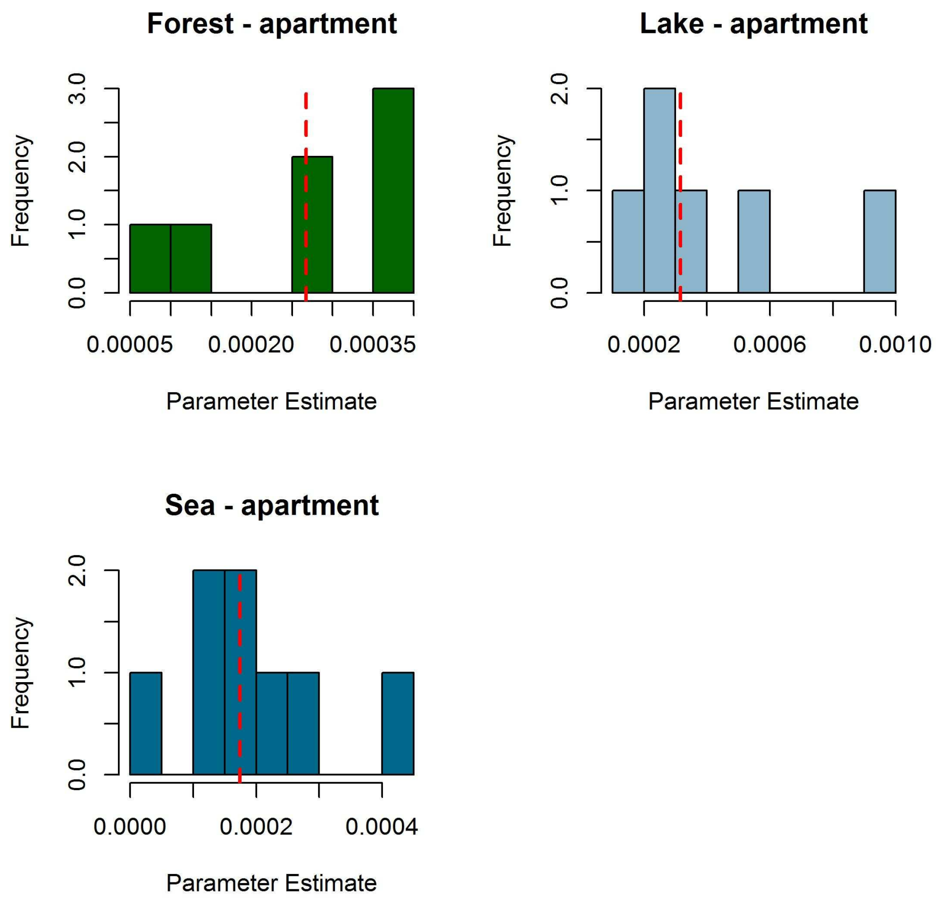


* The figure describe the distribution of parameter estimate for the proximity to forest, lake and the sea for the hedonic house market models. The dotted line in each histogram represent the median parameter estimate.

In the apartment market models, fewer parameter estimates of the proximity to lake, forest and the sea conform to expectation - see figure 3. The apartments are concentrated in the larger city centers of Denmark. In the city center markets, data provide enough variation to estimate the implicit marginal prices of proximity to forests, lakes and the sea. Endogeneity and omitted variable bias is likely to be present in the apartment models even with the large set of explanatory variables, spatial fixed effect and the spatial-temporal lag innovation.

The median parameter estimates for forest proximity is 0.00026, while the median parameter estimate for lake proximity is 0.00031 and for sea proximity is 0.00017. In contrast to the house models, the apart models do not have an additional dummy variable that describes whether the apartments are located within 100 meters of the sea. Forest and lakes are measures on the same proximity scale going from 0 to 600 meters while sea proximity is measured on from 0 to 1000 meters to the sea. The impact of sea proximity is much higher than the two other variables given the scale difference.

Figure 4: Overview of parameter distribution for apartment markets



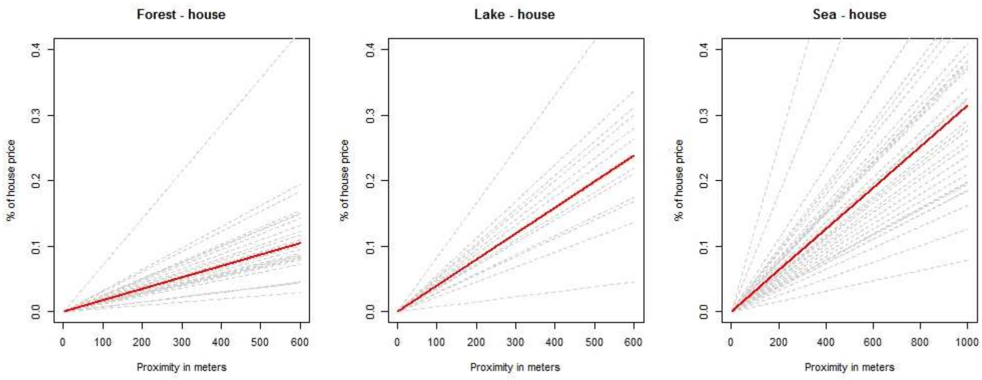
* The figure describe the distribution of parameter estimate for the proximity to forest, lake and the sea for the hedonic house market models. The dotted line in each histogram represent the median parameter estimate.

6.4 Parameter Interpretation

The impact of living in proximity to a forest a lake or the sea is considerable when considering the price difference between not having proximity and being a closer neighbor. In figure 5 the impact of the proximity to a forest, a lake and the sea is calculated using the median parameter estimate and the estimate for each market. The red line in the figure represents the value increase calculated based on the median parameter while the gray dotted lines represent value increased calculated for each market.

On the median, a house price will increase by about 12 % if the house is located at the border of a forest relative if the house were located more than 600 meters away from a forest. Proximity to lakes can on the median increase the house price by 20% while proximity to the sea can on the median increase the value of a house by about 30% in addition to the price premium of about 33% if the house is located closer than 100 meters from the sea. The gray dotted lines in the figure, that show the calculation for individual markets, reveal that the impact in some markets is much higher and in some markets lower. Much of the difference between the markets is likely due to different supply situation of the proximity of forest, lakes and the sea.

Figure 5: Parameter interpretation of house models

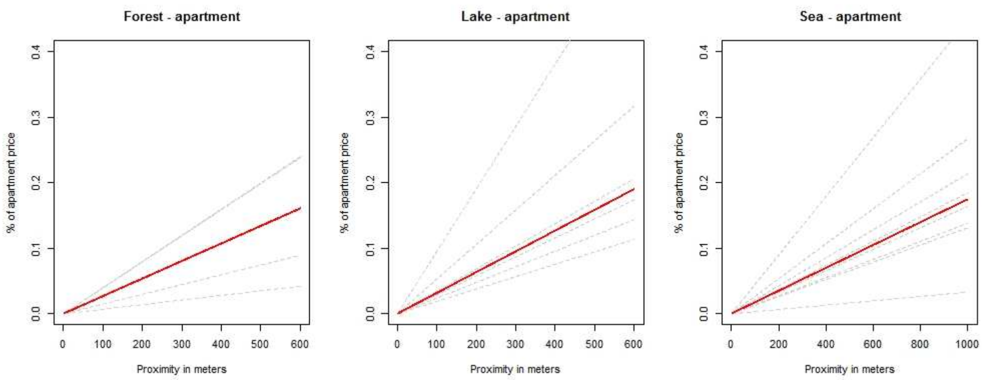


* The figures describe the median price increase due to proximity to forests,lakes and the sea. The red line is the median price increase and the dotted gray lines are calculations for individual markets.

In general, the calculated impacts for apartments are smaller than the calculated impacts for houses. On the median, an apartment price will increase by about 16 % if the apartment is located at the border of a forest relative if the house were located more than 600 meters away from a forest. Proximity to lakes can on the median increase the house price by 20% while proximity to the sea can on the median increase the value of a house by about 16%.

The gray dotted lines in the figure, that show the calculation for individual markets, reveal that the impact in some markets is much higher and in some markets lower. Note that only markets with parameter estimates with a t-value higher than 1.645 is represented in the figure. Much of the difference between the markets is likely due to different supply situation of the proximity of forest, lakes and the sea.

Figure 6: Parameter interpretation of apartment models



* The figures describe the median price increase due to proximity to forests,lakes and the sea. The red line is the median price increase and the dotted gray lines are calculations for individual markets.

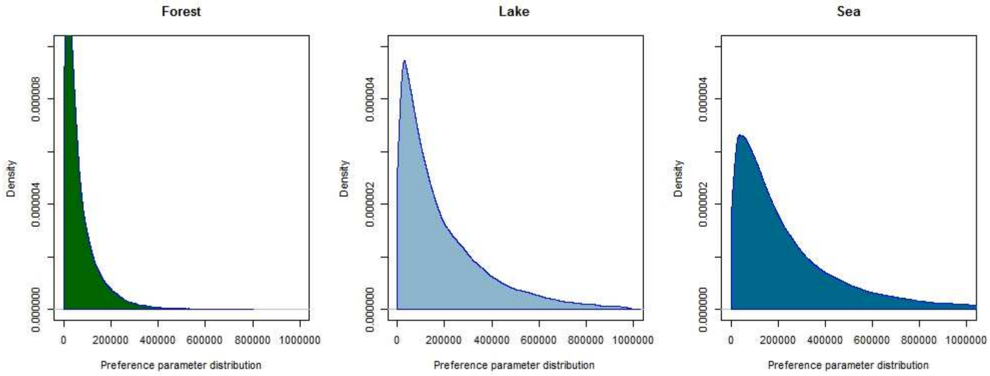
6.5 Individual preference parameter and benefit transfer exercise

According to the theory section, the parameter estimate of the hedonic house and apartment models can be interpreted as marginal willingness to pay. The parameter estimate can furthermore be used to calculate households individual preference parameter. This expression can also be understood as the individual capitalized value of specific housing characteristics. The preference parameter is defined in equation 5 and was calculated using the expression in equation 9.

The preference parameter were calculated for all houses and apartments. The parameter estimate in eq. 9 were replaced by with the median parameter estimate in markets where the parameter estimate were insignificant or had the wrong expected sign - see section 6.3. The price of each house and apartment were predicted using the estimated models for each market.

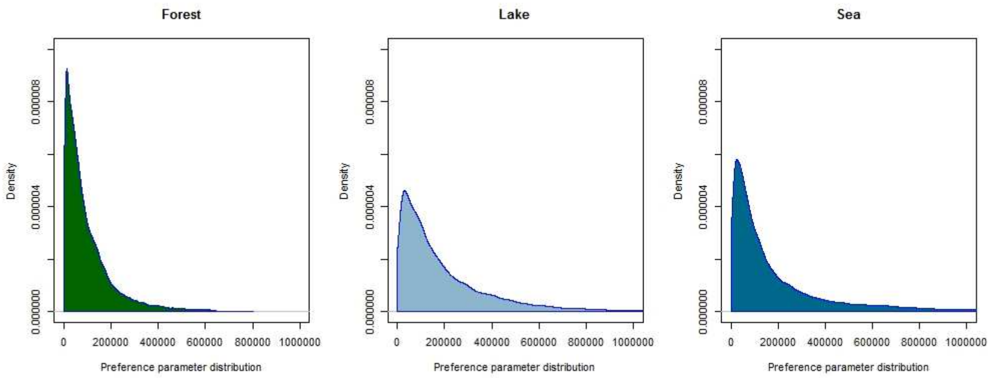
The distribution of household individual preference parameter is presented in figure 7 and figure 8 for households living in houses and apartments. Households who have not bought proximity is not included in the distributions. All the distributions of household individual preference parameter have a similar form with many values close to zero and right tail that extends well into the millions DDK. The figures were censored at 1,000,000 DDK but would have extended much further.

Figure 7: Preference parameter - house models



* The figure describe the distribution of household individual preferences for the proximity to forest, lakes and the sea.

Figure 8: Preference parameter - apartment models



* The figure describe the distribution of household individual preferences for the proximity to forest, lakes and the sea.

7 Concluding discussion

In this paper, I present the results of the most substantial hedonic house price analysis ever conducted on Danish data. In total 48 housing markets were identified using the spatial and temporal variation in price development across Denmark. For each market, a hedonic model was estimated with the purpose to assess households preferences for the proximity to forest, lakes and the sea. In most markets parameter estimates conform to expectations. However, in some markets, the variation of the proximity variable is not adequate to provide a reliable estimate. Also, some parameter estimate suffered from issues related to endogeneity and omitted variable bias.

The model estimates show that forest proximity, lake proximity, and sea proximity can describe a large proportion of the price for both houses and apartments. The estimate can be interpreted into a welfare economic context where both marginal willingness to pay and house individual preference parameter can be calculated. The results provide the opportunity to do second stage hedonic analysis where willingness to pay function for various housing goods can be constructed.

The analysis design has weaknesses. To ensure that it was possible to compare models across markets, the hedonic model estimated was almost similar for all markets. This essentially meant that the models were not adapted to the individual markets which are likely to result in mis-measurement, mis-specifications and omitted variable bias. The strength is of course that the models can be compared.

8 References

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9 Appendix

The table below describe housing markets for single family house/row houses and housing markets for apartments. Note that apartment markets is combined by several single-family-houses/row-houses markets as described by the third column.

Table 3: Overview of house and Apartment markets

market number houses	market names	Market letters for apartment
1	Koebenhavn	A
2	Stor Koebenhavn	B
3	Faxe-Vordingborg	C
4	Naestved	C
5	Ringsted	C
6	Slagelse	C
7	Odsherred-Kalundborg	C
8	Nordkysten	C
9	korsoer	C
10	Nykoebing-Falster	C
11	Lolland-Falster	C
12	Bornholm	D
13	Svendborg	E
15	Odense	F
16	Langeland og Oerne	E
17	Midtfyn-nordfyn	E
18	Trekanstomraade	G
19	Als	H
20	Soenderjylland	H
21	Soenderborg	H
22	Esbjerg	H
23	Vestjylland	H
24	Horsens	I
25	Aarhus	I
26	Silkeborg-Herning-Holstebro-Viborg	J
27	Skive-Mors	J

Table 3: Overview of house and Apartment markets

market number houses	market names	Market letters for apartment
28	Vesterhimmerland	J
29	Norddjurs-Mariager	J
30	Aalborg opland	J
31	Aalborg	K
32	Norsjylland	L
33	Hjoerring	L
34	Frederikshavn	L
35	Skagen	L
36	Thisted	L
37	Samsoe-Laesoe	M

10 Parameter estimates forest for house markets

10.1 Forest parameter - house markets

The table describe the parameter estimates for forest proximity. The table include t-values of the parameter estimates, number of observations (N) in each model, and how many observations which is located within intervals of 100 meter of a forest in the housing market, i.e 0-100 m, 101-200 and so forth. Eight of the house markets have few sales within the intervals. There is an overlap between these markets with few sales within the intervals and insignificant and/or wrong parameter sign. I most cases when the parameter estimate do not conform to expectation the lack of sales within proximity to a forest is a likely explanations. However, there is an exception as market 22 - the Esbjerg market- have a insignificant parameter estimate and the wrong expected sign. The main forest in market 22 is located in Denmark largest military exercise area. Such a forest might not be considered a good by local resident but rather a bad due to inaccessibility and noise from explosions and large machines.

Table 4: Forest parameter - house market

market number	Forest parameter	t-value	N	0-100	101-200	201-300	301-400	401-500	501-600
1	0.00025	11.34106	17215	404	502	546	509	565	499
2	0.00014	12.58139	43122	1952	2103	2158	2130	2299	2149
3	0.00026	5.55085	5149	168	169	210	299	281	275
4	0.00017	2.68202	2884	61	52	106	115	162	176
5	0.00013	2.30185	2559	90	93	71	98	142	139
6	0.00015	2.48203	2430	74	78	129	121	148	129
7	0.00008	2.19590	8828	380	265	325	313	406	379
8	0.00022	5.49136	3624	183	205	226	252	226	228
9	0.00011	1.36453	1724	44	61	66	61	67	74
10	0.00017	2.05772	1461	72	98	75	90	86	121

Table 4: Forest parameter - house market

37	-0.00047	-3.18732	1013	90	57	44	27	20	20
11	0.00031	4.38711	5914	159	114	148	170	206	195
12	0.00018	3.02480	2898	160	126	171	127	105	124
13	0.00024	4.87540	2700	150	106	207	208	177	253
15	0.00014	5.72872	12530	362	536	572	577	682	635
16	-0.00024	-1.96382	1583	49	38	65	56	69	65
17	0.00019	4.02665	4477	296	233	265	270	256	282
18	0.00007	3.88104	18209	1447	1266	1155	1045	924	942
19	-0.00025	-1.46961	873	17	39	23	26	27	28
20	0.00014	3.18958	6423	387	382	408	391	355	315
21	0.00018	2.39481	1685	30	43	52	61	87	53
22	0.00001	0.26024	6919	345	311	317	350	392	322
23	0.00020	5.09458	10662	464	446	396	440	446	411
24	0.00016	4.23693	7162	226	215	240	271	286	359
25	0.00007	3.66320	13953	403	417	702	689	729	868
26	0.00005	2.77936	22748	1718	1538	1477	1321	1346	1354
27	0.00012	2.73664	6550	355	333	270	306	272	241
28	0.00016	1.14409	1786	19	19	31	43	64	56
29	0.00017	3.42361	3937	307	337	256	244	176	213
30	0.00025	5.58053	6420	265	269	276	271	277	273
31	0.00020	6.54281	7209	285	306	266	280	297	287
32	-0.00011	-1.61785	3650	145	113	176	179	162	197
33	0.00014	2.50982	2180	83	109	98	111	97	87
34	0.00032	5.55906	2005	64	117	141	139	113	156
35	0.00071	2.67659	758	0	6	11	28	46	38
36	0.00014	1.29110	2308	38	33	37	63	62	67

10.2 Lake parameter - house markets

The table describe the parameter estimates for lake proximity. The table include t-values of the parameter estimates, number of observations (N) in each model, and how many observations which is located within intervals of 100 meter of a forest in the housing market, i.e 0-100 m, 101-200 and so forth. Many of the house markets have few sales within the intervals. There is an overlap between these markets with few sales within the intervals and insignificant and/or wrong parameter sign. I most cases when the parameter estimate do not conform to expectation the lack of sales within proximity to a lake is a likely explanations. In the few markets with a high number of sales within 600 meter of a lake the parameters estimates are both significant and have the expected sign.

Table 5: Lake parameter - house markets

Market number	Lake parameter	t-value	N	0-100	101-200	201-300	301-400	401-500	501-600
1	0.00028	12.08430	17215	257	468	476	466	446	530
2	0.00023	11.15508	43122	179	374	500	622	704	889

Table 5: Lake parameter - house markets

Market number	Lake parameter	t-value	N	0-100	101-200	201-300	301-400	401-500	501-600
3	0.00019	1.51410	5149	10	25	19	22	24	16
4	-0.00063	-0.35839	2884	0	0	0	0	0	8
5	0.00015	1.50279	2559	7	52	64	46	52	58
6	0.00050	6.51523	2430	32	69	97	73	58	51
7	0.00001	0.08220	8828	11	30	43	60	52	45
8	-0.00005	-0.41430	3624	1	14	18	17	26	25
9	0.00010	0.60310	1724	4	4	1	6	7	16
10	0.00038	0.56713	1461	0	0	1	2	4	0
11	0.00052	4.84248	5914	27	51	101	84	87	77
12	0.00056	3.37770	2898	1	9	15	31	55	62
13	0.00029	1.92139	2700	8	22	19	31	23	17
15	-0.00056	-4.73140	12530	12	16	22	27	33	49
16	0.00035	0.63477	1583	0	0	3	6	12	5
17	0.00018	1.32115	4477	4	8	20	62	54	73
18	0.00039	7.45076	18209	54	102	153	168	231	247
19	-0.00003	-0.20921	873	26	48	28	26	37	35
20	0.00007	0.63185	6423	12	23	54	79	81	52
21	-0.00245	-3.94843	1685	0	0	0	1	3	3
22	-0.00119	-1.93196	6919	0	0	0	0	6	21
23	0.00044	4.77951	10662	32	57	63	77	120	127
24	0.00035	4.56931	7162	7	33	70	82	75	125
25	0.00040	9.55876	13953	64	127	114	159	173	265
26	0.00047	14.54245	22748	246	467	589	642	619	619
27	0.00036	2.85422	6550	9	22	31	35	46	76
28	0.00083	3.20002	1786	0	5	12	15	28	25
29	0.00021	0.84198	3937	1	3	9	2	2	4
30	-0.00007	-0.89724	6420	32	64	74	94	75	67
31	0.00008	1.67933	7209	39	114	178	221	244	206
32	-0.00062	-1.46986	3650	0	1	1	4	6	2
33		0	2180	0	0	0	0	0	0
34		0	2005	0	0	0	0	0	0
35		0	758	0	0	0	0	0	0
36	-0.00035	-1.90571	2308	9	13	7	13	6	6
37	0.00014	0.39559	1013	2	2	0	1	0	0

10.3 Sea parameter - house markets

The table describe the parameter estimates for sea proximity and sea 0-100m dummy variable. The table include t-values of the parameter estimates, number of observations (N). Except for market 5 and market 31 the parameter estimate conform to expectation. Market 5 do not have any coastline located in the center of zealand while market 31 is the city of Aalborg. The sea parameter for

Aalborg is likely to suffer from endogeneity, i.e. there might be some omitted variables that is related to the harbor areas of Aalborg which have not been properly described in the model. A few markets do not have sales in within the first 100 meters from the coastline. In these cases the parameter estimate is set to zero.

Table 6: Sea parameters - house markets

market number	sea parameter	sea t-value	sea 100m parameter	sea 100m t-value	N
1	0.00034	20.87907	0.07425	3.10451	16976
2	0.00025	28.10554	0.35289	22.35484	43081
3	0.00031	9.29917	0.31810	6.37240	5149
4	0.00008	2.39546	0.31595	3.72613	2898
5					2551
6	-0.00025	-3.06274			2435
7	0.00013	5.41103	0.30777	8.30622	8854
8	0.00033	11.31838	0.48592	9.14468	3637
9	0.00018	3.04701	0.49311	7.52751	1734
10	0.00020	4.10468	0.31147	4.50419	1459
11	0.00024	6.59393	0.40924	8.48495	5976
12	0.00038	8.43484	0.31784	8.18186	2915
13	0.00048	14.19061	0.43537	10.54148	2707
15	0.00016	6.68288	0.25608	5.97952	12552
16	0.00047	7.14810	0.25959	4.04070	1586
17	0.00037	8.76512	0.40762	7.44120	4500
18	0.00032	20.63703	0.44475	16.53180	18292
19	0.00055	5.62989	0.04178	0.13682	872
20	0.00038	8.71265	0.44139	7.18924	6469
21	0.00032	8.26132	0.42954	7.26682	1686
22	0.00019	6.06970	0.35805	5.16818	6925
23	0.00039	11.13840	0.24678	5.05357	10697
24	0.00028	10.84041	0.62166	9.52983	7185
25	0.00038	18.01715	0.27292	5.86397	13903
26	0.00022	5.70140	0.23053	4.71194	22794
27	0.00029	6.76989	0.63174	9.42872	6576
28	0.00026	4.16051	0.32344	3.00912	1793
29	0.00041	8.17900	0.39188	5.47289	3950
30	0.00021	4.97809	0.49249	7.39563	6438
31	-0.00005	-1.48806	-0.00752	-0.10713	7215
32	0.00019	2.61672	0.66985	6.71866	3678
33	0.00127	13.29340			2186
34	0.00020	5.57394	0.26827	4.00220	2002
35	0.00089	6.48968	0.42937	3.43938	758
36	0.00028	6.01609	0.14142	1.74573	2333
37	0.00045	5.04456	0.45604	3.45477	1013

10.4 Forest parameter - apartment markets

The table describe the parameter estimates for forest proximity. The table include t-values of the parameter estimates, number of observations (N) in each model, and how many observations which is located within intervals of 100 meter of a forest in the apartment market, i.e 0-100 m, 101-200 and so forth. Half of the apartment markets have few sales within the intervals. There is an overlap between these markets with few sales within the intervals and insignificant and/or wrong parameter sign. I most cases when the parameter estimate do not conform to expectation the lack of sales within proximity to a forest is a likely explanations. However, there is two exceptions as market J and H do not conform to expectation even though the markets have a reasonable variation of sales in relation to forest proximity. In these cases endogeneity and omitted variable bias may the main source of explanation for the parameter estimate in market J and H.

Table 7: Forest parameter - apartment markets

Market letter	forest parameter	t-value	N	0-100	101-200	201-300	301-400	401-500	501-600
A	0.00026	11.58998	48352	188	608	784	632	449	694
B	0.00013	5.58288	12701	629	638	397	448	436	670
C	-0.00032	-3.72708	3122	42	55	84	263	214	261
D	0.74339	0.27749	39	0	0	0	0	1	0
E	0.00040	3.99770	3075	22	34	34	35	117	83
F	0.00015	0.31259	351	2	0	23	26	3	8
G	0.00027	2.38733	2241	152	120	144	138	100	98
H	-0.00008	-0.61673	2314	51	56	32	72	113	182
I	0.00007	2.44555	10217	319	394	240	464	418	438
J	-0.00021	-3.07837	3801	95	122	252	149	221	138
K	0.00040	8.24345	4952	24	91	159	235	150	294
L	0.00040	1.70595	1091	9	8	14	8	38	85

10.5 Lake parameter - Apartment markets

The table describe the parameter estimates for lake proximity. The table include t-values of the parameter estimates, number of observations (N) in each model, and how many observations which is located within intervals of 100 meter of a forest in the apartment market, i.e 0-100 m, 101-200 and so forth. Many of the house markets have few sales within the intervals. There is an overlap between these markets with few sales within the intervals and insignificant and/or wrong parameter sign. I most cases when the parameter estimate do not conform to expectation the lack of sales within proximity to a lake is a likely explanations. In the few markets with a high number of sales within 600 meter of a lake the parameters estimates are both significant and have the expected sign.

Table 8: Lake parameter - apartment markets

Market letter	Lake parameter	t-value	N	0-100	101-200	201-300	301-400	401-500	501-600
A	0.00023	14.41879	48352	871	1206	1796	1685	1853	1847

Table 8: Lake parameter - apartment markets

Market letter	Lake parameter	t-value	N	0-100	101-200	201-300	301-400	401-500	501-600
B	0.00018	4.81860	12701	43	117	167	214	431	245
C	0.00035	1.32300	3122	2	32	34	88	20	15
D			39	0	0	0	0	0	0
E	0.02190	3.80324	3075	0	0	0	0	2	0
F	0.00034	0.31313	351	0	0	1	8	3	10
G	0.00095	4.90101	2241	31	94	84	75	65	52
H	-0.00104	-4.19411	2314	6	6	18	7	12	20
I	0.00031	4.43697	10217	46	51	30	68	75	3
J	0.00024	3.11851	3801	96	46	144	98	129	68
K	0.00006	0.98414	4952	3	123	84	128	155	48
L	-0.00060	-1.69659	1091	5	7	14	4	8	10

10.6 Sea parameter - apartment markets

The table describe the parameter estimates for sea proximity. he table include t-values of the parameter estimates, number of observations (N) in each model, and how many observations which is located within intervals of 100 meter of the sea in the apartment market, i.e 0-100 m, 101-200 and so forth. The markets with little variation in the the sea proximity variable do not conform to expectation.

Table 9: Sea parameter - apartment markets

Market letter	Coast parameter	t-value	N	0-100	101-200	201-300	301-400	401-500	501-600
A	0.00018	23.30687	48356	8437	1334	1539	1369	1440	1557
B	0.00027	13.76299	12702	1029	213	219	389	423	311
C	0.00021	4.31811	3125	1072	58	91	80	116	140
D	0.02545	3.73896	39	29	3	4	0	0	0
E	-0.00018	-3.34481	3074	348	78	165	138	69	154
F	0.00021	1.37274	351	218	21	17	9	21	10
G	0.00045	8.38693	2242	655	92	119	115	151	167
H	0.00013	3.21296	2314	836	280	148	101	102	83
I	0.00003	2.53077	10215	2605	610	437	670	716	362
J	0.00016	3.38976	3797	293	44	72	117	97	128
K	0.00014	7.48440	4952	2093	305	372	361	192	52
L	0.00013	1.35405	1091	554	23	37	22	10	5