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Classification and valuation of urban green spaces – A hedonic house price valuation

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Abstract:
In this paper we propose a categorization of green space into eight different types and quantify their impact on housing prices in the city of Aalborg using the hedonic house price method. The categorization was made manually according to an idealized description of the eight types of green space and a rating system in which each green space was rated according to accessibility, maintenance levels and neighboring negative land-use. The hedonic house price schedule for each of the green spaces was estimated using a generalized additive model, which allows for a data driven adjustment of underlying omitted spatial processes. To our knowledge the use of a spatial generalized additive model is novel to the hedonic valuation literature. We find that types of green space, which are rated highly in terms of accessibility and maintenance level, have high implicit prices whereas types with low ratings are not identified or provide ambiguous results. Green space buffering unattractive land-use such as infrastructure and industry is found to provide negative implicit prices despite controlling for the negative neighboring land-use. Our results clearly indicate that green space is not a uniform environmental amenity but rather a set of distinct goods with very different impacts on the housing price.

Keywords: Hedonic Valuation, Green Space, Classification, Planning.
JEL: R31, R52, Q51

Indholdsfortegnelse

1. Introduction

Provision of green space in a dense urban environment is costly. The rent from alternative land-use for areas allocated to green space is high. At the same time, green space provides a number of valuable direct and indirect services to surrounding parcels. These services span from provision of recreational opportunities to floodways and improved air quality as well as benefits associated with reduced housing density (e.g. more light and reduced noise levels). Green space in cities exists in a broad variety of types spanning from the high maintenance urban park to natural areas and buffer space between noisy infrastructure and other land uses. From such a degree of heterogeneity in the type of green space it follows that the benefits (and costs) generated by different green space provision vary greatly.

The value of green space has been the subject of a good deal of research using the hedonic method and stated preference methods as surveyed in, e.g. McConnells and Walls (2005) and Waltert and Schläpfer (2010). The results are generally mixed with both positive, negative and insignificant effects found for the same types of green space. With the notable exceptions of Anderson and West (2006) and Irwin (2002) much of the existing literature primarily deals with either a few specific types of green space such as nature preserves or agricultural fields (Morancho, 2003; Towe, 2009; Tyrväinen & Miettinen, 2000) or with categorization of green space by size and/or proximity (Abbott & Klaiber, 2010; C. Y. Jim & Chen, 2006a; Kong, Yin, & Nakagoshi, 2007; Morancho, 2003).

Green space is often treated as a homogeneous good with distinctions in some cases being made with regard to ownership (Cheshire & Sheppard, 1995) or conservation status (Irwin & Bockstael, 2001). As stressed in the survey by Waltert and Schläpfer (2010), the measurement and definition of green space in the literature varies substantially, making it difficult to compare results across studies and to use studies for benefit transfers. Different definitions and aggregations of types of green space may be one explanation for the large variation in results discussed in both surveys.

Evidence outside the field of valuation suggests that people perceive and value green space according to the services provided by the green space. Schipperijn et al. (2010) and Kienast, Degenhardt, Weilenmann, Wäger, and Buchecker (2012) find that the frequency of visits varies with the type of green space and landscape characteristics. In general, people seem to be able to appreciate both naturalistic and designed landscapes and find recreational benefits in both kinds (C.Y. Jim & Chen, 2006b; Özgüner & Kendle, 2006). It is evident that people distinguish between different types of green space; obviously valuation studies should do the same.

We take the heterogeneity of green space in an urban environment as our point of departure. Our hedonic analysis is based on a careful classification of urban green space into eight categories identified through aerial photos and information from the local municipality. These categories reflect a hierarchy of recreational and amenity services provided by urban green space. The aim of our analysis is to examine the differences in capitalized value related to these different types of green space.

The hedonic house price model is estimated using the Generalized Additive Model (GAM). This allows us to control for omitted spatial processes in a flexible way. Omitted spatial processes and temporal price variations are handled using smoothing splines. In light of recent critique of the standard spatial econometric approach using a spatial weight matrix, i.e. Gibbons and Overman (2012) and McMillen (2012), the GAM model is an attractive alternative as it imposes less restrictive assumptions on the unobserved spatial processes omitted from the hedonic model. We find that access to green space can be associated with both significantly higher and lower housing prices depending on the type of green space. In addition we find differences in the capitalization of different types of green space between apartments and houses.

2. Modeling the value of a residence

Housing is a composite good which provides a wide range of services including access to green space. We distinguish between houses (single family and terraced housing) and apartments. We model these housing types separately assuming that they are separate markets. This approach allows for differences in the hedonic price schedule between the two types of homes. In particular, the capitalization of green space may differ between the two. Residents of houses have private gardens which may substitute for other green space. Furthermore, the density of development in a neighborhood where residences consist of houses is lower than in most areas where the prevalent type of dwelling is an apartment. This implies that apartments may get a higher price premium from the reduced development density provided by green space than houses.

Although we have ample data on the characteristics of a dwelling and its surroundings, it is close to impossible to measure every characteristic of a home and a neighborhood. Similarly, it may be difficult to accurately model the functional form of individual components such as distance to the city center. Omitted variables or misspecification can result in spatial autocorrelation in the residuals (Anselin, 2010). Such concerns motivate a modeling approach which takes account of spatial variation at different scales.

We model the spatial context of the individual dwelling on two scales: On a large spatial scale, our approach is based on the recognition that we do not know a priori how the land rent gradient declines as distance from the center increases. For this reason, we model the location of the property through a smooth function of the spatial coordinates, which allows us to capture the shape of the land rent gradient. This geo-additive component accounts for the spatial structure of the housing market at an aggregate level. To capture the finer structure at a neighborhood level we include a vector of variables Z_i which describes the average visible characteristics of homes in the neighborhood of dwelling *i*. For houses these characteristics are calculated based on all houses on the same street as house *i* - including those not traded within our time frame. For apartments, measures are constructed on the outwardly visible characteristics of apartment buildings within 200 meters of the building in which apartment *i* is located. These measures are intended to proxy for unobservable neighborhood characteristics in close proximity to the individual dwelling and capture externalities derived from neighboring properties.

We modeled the hedonic price function using the semi-logarithmic functional form which is widely used in the hedonic literature (Palmquist, 2005). We estimated the model as a GAM using a logarithmic link function, which transforms the dependent variable:

$$E(P \mid X, G, Z, x, y, t) = \exp(X\beta_X + G\beta_G + Z^{lag}\beta_Z + f_1(x_{lon}, y_{lat}; k_1) + f_2(t; k_2)) \quad (1)$$

We distinguish between green space, G, and other characteristics, X. The matrix X contains numerous characteristics describing the dwelling and its location. A full list is given in table 1. The term $f_1(x_{lon}, y_{lat}; k_1)$ is a smooth function over the spatial coordinates of each dwelling and $f_2(t; k_2)$ is a smooth function over the time of sale for the properties. The smooth functions: $f_1(x_{lon}, y_{lat}; k_1)$ and $f_2(t; k_2)$ are fitted using thin plate regression splines with a penalty on "wiggliness", which is found through Generalized Cross Validation (GCV). This approach determines the appropriate level of smoothing by repeated estimations, leaving out one observation and predicting its value based on the estimated model. This generates a prediction error. The penalty terms are found by minimizing this mean squared prediction error. The model coefficients, β, are estimated with a penalized likelihood, i.e.:

$$l_p(\hat{\beta}) = l(\hat{\beta}) - \frac{1}{2}\sum_j \lambda_j \beta^T S_j \beta \quad (2)$$

Where, $l(\beta)$ is the value of a standard likelihood function and describes the model's fit to the data. The second term contains the penalty, λ_j , for the j^{th} smooth function and a measure of flexibility or wiggliness, S, e.g. the second derivatives of the smooth functions. The idea underlying the penalty on wiggliness is that the fitted function should be as close to the true function as possible without overfitting the data. More information on the fitting of GAM with thin plate regression splines and the use of GCV can be found in, e.g. Wood (2006) and in the vignette for the mgcv package in R.

A distinct advantage of the GAM over parametric alternatives is, that it does not require the researcher to know the scale of the omitted spatial processes exactly. Instead of capturing omitted spatial variables through a "one-size fits all" spatial weight matrix, the splines used to fit the smooth function in coordinate space are determined by the data. The researcher does make decisions about the degree of flexibility overall in choosing the number of basis functions *k* to be included in the model. The choice of basis dimension corresponds to choosing the number of knots where splines are connected. This choice is a balancing act between accurately capturing the locational attribute without overfitting the model, although the penalty term also reduces the probability of overfitting. Several different rules of thumb exist for determining the appropriate number of basis functions, *k*, given the number of observations. Kim and Gu (2004) argue that k should be proportional to $n^{2/9}$, where n is the number of observations. Ruppert (2002) recommends setting $k = \min\{40, \frac{n}{4}\}$ whereas Wood (2006) argues that the choice of *k* is context specific. We set k_1=40 for the geoadditive term and k_2 = 10 for the temporal smooth as there is less variation in the data over time. We estimated the model with several different choices of k_1 and k_2 to determine sensitivity to choice of k.

3. Data

The data set covers the sales of houses and apartments in the city of Aalborg, Denmark, over the period from 2000 to 2007. The study area is depicted in figure 1 which shows the distribution of transacted properties on a map of Aalborg. In terms of owner occupied dwellings, approximately half of the available housing units consist of houses with apartments making up the remainder. In total 12,928 transactions were included in the analysis.

Aalborg is the fourth largest city in Denmark with approx. 125,000 inhabitants (2010). Aalborg is the provincial capital of the northern region in Denmark. The area surrounding Aalborg consists in general of smaller towns and rural area. Historically, Aalborg has been dominated by heavy industry, which has direct access to the global market through the extensive harbor area. Modern day Aalborg has been developed in two urban expansion periods with increased construction activity and urbanization during the 1940s and the 1960s. Since the oil crisis in 1973, construction activity has declined until the 1990s where the activity leveled out. During the analysis period, Aalborg has been characterized by very little construction activity and urbanization, preserving both land-use and the city structure.

The data set contains information about the transactions in terms of price, date and type of sale. Data also contains information on structural characteristics of the property such as number of rooms, size of the living area, and so forth. A summary of the control variables in the data set is found in table 1. The information was extracted from the Danish Registry of Buildings and Housing database which contains information on all dwellings in Denmark (Ministry of Housing Urban and Rural Affairs, 2012). The data are a "snapshot" of the house and are continuously updated. Our data therefore reflect the characteristics of the house in August 2011 when the data were collected. The date of larger renovations is also registered allowing us to capture the effect of renovations after the sale. We use discrete dummy variables to describe age and renovation as we hypothesize that they are perceived as discrete characteristics capturing types of architecture and building trends. The registry also contains information on the exact coordinates of the location of each dwelling. Based on this information and maps from the Danish Geodata Agency (DGA) (2011), a number of measures of proximity have been calculated using ArcGIS desktop 10.1, e.g. proximity to large roads wider than 6 meter, industrial sites, green space and so forth.

Table 1: Control variables describing housing characteristics

The neighborhood variables contained in our vector Z_i^{lag} hold information about the appearance of surrounding properties in terms of the average age, average of dummies for renovation in the years preceding the sale, and the style of the building as captured by roof type and brick walls. In addition, the average size of gardens for houses was included as this gives an idea of the development density in the area. A set of descriptive statistics of the data set is found in the In the supplementary literature.

3.1 Mapping green space

We mapped green space in Aalborg based on high resolution aerial photos from 2003, 2008 and 2010 covering the entire Aalborg region. In addition, we received data from the DGA on areas categorized as being recreational and data from Aalborg municipality on areas maintained by the municipality. The data from DGA was inconsistently mapped. Only half of the recreational green space was mapped in the DGA data. The data from the municipality only focused on areas which were maintained by the municipality. Areas that were not the responsibility of the municipality were not mapped. The municipality data contained a rich set of information, i.e. maintenance objectives divided into high, medium and low maintenance levels. We combined the data from DGA with the municipality data and divided Aalborg into cells of 1x1 kilometers. We went through each cell validating the combined data and mapped new areas using the high resolution photos from 2003, 2008 and 2010. We used data from several time periods to ensure that the areas remained stable over time. The final map of green space in Aalborg has a precision and quality which we consider to be adequate to feed into the analysis.

3.2 Classification of green space

In the valuation literature green space has in most instances been treated as a uniform good (McConnells & Walls, 2005). In rare cases hedonic valuation studies have treated green space as a more heterogonous good based on "objective" measures such as green space density, size, or vegetation concentration in an attempt to introduce a quality measure which describes the character of each green space (Kong et al., 2007; Saphores & Li, 2012). These measures of green space quality are attractive as they are reproducible and possible to validate. What matters in valuation studies, are people's perception of the amenity. As such, any objective measure will be a proxy. The goal in a valuation exercise is to capture as accurately as possible the way the good is perceived in the population. In our classification of green spaces we attempt to do exactly that.

Urban green space is divided into eight types inspired by the classifications of green spaces by Bell, Montarzino, and Travlou (2007). We believe that people relate to green space not as a uniform good with a continuum scale of quality but rather a hierarchy of distinct goods which provide a range of services that enable different recreational activity and in some cases no activity. Some types of green space provide amenity services where people go to have recreational experiences (Peschardt, Schipperijn, & Stigsdotter, 2012). Other types of green space are associated with disamenities, e.g. through negative visual effects, or where neighboring land use reduces the recreational value of the green space significantly. An example could be green space near noisy infrastructure (Ham, Champ, Loomis, & Reich, 2012).

Based on the initial mapping of generic green space, each space was categorized as one of eight different types. The classification is an attempt to emulate the way an area is perceived by the public. Each green space was manually assigned to one of the eight different types green space based on the same aerial photos which were used to map the green space. In order to ensure an accurate classification, and that land-use did not change during the analysis period, green spaces were investigated looking both at the 2003, the 2008 and the 2010 aerial photos. The municipality data on green space was used to aid the categorization of green spaces. The classification was finally validated by two people with in-depth knowledge of land-use in the city of Aalborg.

Our classification of different types of green space relies on the quantity and quality of services provided. It is generally recognized that accessibility plays an important role in defining potential services (Kienast et al., 2012; Zhang, Chen, Sun, & Bao, 2013). We divide accessibility into three distinct categories, which restrict and define the level of service provided by the different types. "External accessibility" deals with the physical access to the urban green space such as entrances, pathways, and roads into the urban green space. "Internal accessibility" deals with the physical access within the green space. Pathways and roads open up the area and provide access throughout the area. "Social accessibility" deals with the legal and social perception of the area. Some types of public green space such as common areas are essentially a kind of "club good" in the sense that access is de facto restricted to households in the immediate vicinity of the green space. A fourth characteristic of green space is its level of "Maintenance". An area requiring a high level of maintenance often provides a variety of visual impressions and has an ordered appearance (see section 3.3). Areas with low maintenance may even have a negative visual impact on neighboring properties. A final consideration is the desirability of the land use in neighboring lots. Some neighbors can detract substantially from the attractiveness of a green space, e.g. industry, railways or motorways. Based on these criteria each green space was rated and assigned to one of the eight types of green spaces see table 2.

Table 2. Types of green space and criteria for categorization.

In addition, to the rating system, the classification was supplemented by an idealized description of each type of green space - see the description below. The distinct characteristics of the green spaces made the classification relative easy. Still, borderline classification problems occurred where the type of green space was less obvious. In these situations classification was made using the rating system and if possible the green space data from the municipality.

The different types of green space can be characterized as follows:
1. Parks: Green space categorized as a park has a high maintenance level with well-kept vegetation and a wide range of recreational possibilities. Footpaths open the green area to the public and make it possible to walk in the area and enjoy different features such as small lakes, trees, lawns, flowers, and sport activities.
2. Lakes: Some green space in cities is characterized primarily by the presence of water bodies such as lakes. In cases where a lake is the dominant feature of the green space,

this is treated as a distinct type of space as the access and maintenance features differ from that of a park or a natural area, suggesting that the services provided differ as well.
3. Nature: On the edge of the city, large areas of green space can be found which often contain open fields of grass, tree cover, and lakes. Most often these areas contain small gravel roads and nature paths, which enable people to move through the landscape. The area is less well kept than an urban park. Fields and pastures often border the natural area.
4. Churchyards: These are often open to the public during daytime and have a high level of maintenance with flowers and hedges. While footpaths provide internal accessibility, there is little space for other activities than walking, and more lively social activities are rarely socially acceptable.
5. Sports fields: Schools and institutions often have access to green space, which facilitates sport activities and playground for the pupils. These areas often form a square and are outlined by trees. Sports facilities connected to sports clubs often have similar characteristics, e.g. similar size. In some cases these facilities are fenced limiting access.
6. Common areas: Communities of houses or apartment buildings in Denmark often have shared "common green space" which is maintained by the property owner association or landlord. Well-kept lawns and small playgrounds often dominate such space. The users are mainly local residents and as such the areas are semi-public in terms of accessibility. Common areas are often relatively small, consisting of patches of green space connected by footpaths. We divided common areas into two separate types of space depending on whether the space is related to apartment buildings or houses. Given the semi-public character of common areas, they are mainly used by residents in the immediate vicinity.
7. Agriculture fields: These areas are usually relatively large and homogeneous in nature. Most often there are no footpaths or roads allowing access into the fields and often meadows are fenced. Public access is restricted in these areas by Danish law.
8. Green buffers: Green space can be found in connection to infrastructure such as highway, larger roads, and railways. Often covered by trees, the main function of such areas is to reduce the negative impact of noise and air pollution coming from the neighboring infrastructure. Likewise, industrial areas often contain patches of green space. The latter areas often consist of a kept lawn potentially surrounded by trees and do not invite recreational activities. We grouped these areas together due to the unattractive character of the neighboring land use.

Fig. 1 Green space and transactions in Aalborg

3.3 Example of classification

To exemplify the classification process we present two examples of classification of green space in Aalborg (see figure 2). The red lines represent the outline of the green spaces. The green space to the left has been classified as a nature area and the green space to the right has been classified as a park. The nature area is located south of the city while the park area is located in the center of the city.
The nature area is large and has a smaller number of pathways, which consist of gravel roads and nature paths. These roads and paths provide internal accessibility. The eastern part of the nature area is covered by trees while the rest of the area can be described as open unkempt fields. The nature area has several external access points going into the nature area in the form of roads and pathways. The nature area has a high level of external accessibility, but a medium level of internal accessibility – the movement in the nature area will mainly be restricted to the roads and paths in the area. Maintenance levels are low and primarily concern the gravel roads cf. municipality data. Both apartments and houses surround the area. The southern part of the nature area is flanked by a heavily trafficked road. Given the size of the nature area, the trafficked road is not a dominating neighbor. The sheer size of the nature area prevents the area from being a de facto club good with a low level of social accessibility.

The Park has a large number of pathways, well-kept lawns, a lake and a soccer field. It is possible to identify benches and flowerbeds if zooming further in than in figure 2. The municipality data classify the area as having a high level of maintenance. This area has both a high level of external and internal accessibility. The openness of the area and number of functions makes it unrestricted in terms of social accessibility. This park is mainly neighbor to apartment buildings.

Fig. 2. Examples of green spaces in Aalborg

Additional information on the green space categories can be found in the supplementary literature and along with an interactive high resolution map where spatial layers can be switched on and off.

A few descriptive statistics are given for the different types of green space in the sample of houses and apartments respectively (see table 3). The location of different types of dwelling with respect to different types of green space varies, with apartments generally being closer to parks and houses closer to natural areas. This reflects apartments being located closer to the historical center of Aalborg where population is dense. Undeveloped, natural areas are more likely to be found further away from the center. This is consistent also with the location of houses generally being closer to fields than most apartments. Common green space is generally found within a fairly short distance of either type of dwelling. For Green buffers there is little difference between the distance to houses or apartments, which perhaps reflects the relative abundance of this type of green space in Aalborg.

There is substantial variation in the size of the different types of green space from very small areas to rather large areas. As one might have expected, the largest types of green space are natural areas, fields and Green buffers. Referring to figure 1, the largest of these areas can be found at the edges of the urban landscape. Some types of green space are abundant whereas others such as lakes, parks and cemeteries are found in a more limited number. Aside from fields at the boundary of the urban landscape, Green buffers are the most frequently occurring type of green space.

Table 3. Descriptive statistics of the types of green space.

3.4 Modeling access to green space

We hypothesize that a high level of accessibility and maintenance provides a high level of quality of the recreational services (cf. table 2). For instance, parks provide a wide range of recreational and amenity services while outdoor sport facilities invite a narrower use. Open fields may provide a pleasant landscape but low accessibility levels prohibit non-owners from spending time in the fields. Additionally, farming is associated with a number of negative externalities (e.g. smell and noise) as discussed in Kuminoff (2009). Finally, in the case where the green space serves mainly as a buffer against undesirable neighboring land uses, the recreational services provided are very limited. We expect the quality of the recreational and amenity services to be reflected in the price of neighboring properties. The distribution of different types of green space in the survey area can be seen in figure 1 and table 3.

We describe accessibility to green space using a series of variables depending on the type of green space: Proximity is measured in Euclidian distance in steps of 100 meters from the property to all types of green space except "common areas" and lakes. For common areas, size is likely to be more important than proximity as the distance to this type of green space in the sample is low. As common area green space may be a substitute for private gardens, we included an interaction term for garden size and common area size in the model for houses to test this hypothesis. The lakes and agriculture fields in Aalborg are located in such a way that access is rather limited for apartments. Therefore, only the agriculture fields and lake variable enters the model for houses and are omitted from the apartment model.

To capture different scales of capitalization for different types of green space, we work with two different proximity cut-offs for green space (Abbott & Klaiber, 2010). Some types of public green space are used for outings and people will be willing to travel further to enjoy a stay in such an green space, whereas other types of green space are de facto a club good being small and located in the middle of a residential area. Reduced accessibility should be reflected by capitalization of the latter types at a more local scale. We set the high cut-off to 600 meters, which reflects a 5-10 minute walking time for parks and natural areas. The cut-off value is supported by the findings of Kienast et al. (2012). They show that attractive green space must be reachable within 5–10 minute walking or biking distance in order to be effectively used by the local residents. The lower cut-off for club goods was set at 300 meters for the remaining types of green space. We model proximity as a quadratic function in order to allow for non-constant effects of increased proximity. Previous research on amenities and disamenities has indicated that the effect of reduced distance may be non-constant as distance grows (Cho, Lambert, Kim, Roberts, & Park, 2010; Ihlanfeldt & Taylor, 2004; S. G. Kim, Cho, & Roberts, 2011).

The logged size of the green space is included for some types (i.e. parks, natural areas and common areas). We consider it likely that that the implicit price of size increases with distance at a decreasing rate. We hypothesize, that having a view is an important characteristic for people buying an apartment and less important for people buying a house. Hence, a variable proxying for the view of a park, natural area, or common area was included for apartments above ground level. The view variables were not tested for houses, except for the lakeside view variable. The model specification for each type of green space is summarized in table 3.

4. Results

The GAM model is estimated using maximum likelihood. The model is estimated with the gamma distribution to account for a relationship between the mean and the variance of the dependent variable. Additionally, the gamma distribution has the desirable property that it is always positive, so the house price cannot be negative in our model. Given that the data set comprises 8 years it was necessary to capture inflationary movements in housing prices. Our smooth function with k_2=10 basis functions of the number of days from January 1st, 2000 to the date of sale corrects for temporal price variation, leaving remaining variation across observed sales prices to be explained by the housing characteristics in the model. We carried out sensitivity analysis for the stability of parameters across time by estimating the model on data for a shorter time span and found only minor variations.

According to Wood (2006) the choice of basis dimensions is a part of model specification and the modeler should aim to ensure that sufficient flexibility is available for the individual application. The results presented here are for a basis dimension of $k_1 = 40$ for the geographical coordinates. Sensitivity analysis for several different choices of k_1 was carried out. We found several of the spatial covariate to be sensitive to the choice of k_1 including several types of green space. The estimated spatial structure with $k_1 = 40$ can be seen in the contour plots in the supplementary literature. Generally speaking, our results indicate that a monocentric urban model fits Aalborg rather well with prices declining at varying rates with distance from the most attractive residential areas.
Focus in this paper is on the price premium associated with access to green space. The estimated coefficients for the full model can be seen in the supplementary literature. The current discussion relates only to the estimated coefficients for the green space variables shown in tables 4 and 5. The association between access to green space and house prices varies significantly across the different types of green space for both houses and apartments. We follow best practice and only estimate the hedonic model once for each of the housing markets based on the hypothesis outlined in section 3.4 thereby avoiding the problem of pre-test bias.

To ensure that houses and apartments are sold on separate markets we perform an ANOVA test on a hedonic model containing both houses and apartments and a nested model which includes a dummy variable for houses which were interacted with all explanatory variables in the model. The ANOVA tests the hypothesis that the markets are the same, i.e. all coefficients on the dummy variables for house and its interactions are jointly zero. The ANOVA test rejects this hypothesis, which indicates that houses and apartment should be treated in separate hedonic models.

For houses, several types of green space are not associated with a significant housing price premium. However, proximity to parks and size of the park is associated with higher prices - the effect of size is small with approx. 0.01 percent increase in the price with a one percent increase in the size. Houses with a view of a lake are more expensive with approx. seven percent higher prices. Proximity to cemeteries and to natural areas is also associated with higher prices, but only at a 10 percent significance level. Some types of green space are associated with lower prices. Proximity to green buffers is associated with a significantly lower house price even though we have controlled for the proximity of the undesirable neighbor separately. Common area is not associated with any significant change in house prices and we find no evidence of complementarity or substitutability between common areas and private gardens.

Table 4: Estimates for houses

For apartments the access to parks is also associated with higher prices. Having a view of a park is associated with a price premium of almost 6 percent. Proximity to natural areas is not associated with a similar significant increase in prices, nor does the size of nearby natural areas play a significant role. Sensitivity analysis where we adjust for spatial autocorrelation using different dimensions of k_1 for the geographical coordinates show that natural areas are sensitive to the basis dimension chosen. The size of common areas is associated with statistically significant higher property prices. A one percent increase in the size of a common area coincides with a 0.01 percent increase in property price. An elasticity of 0.01 percent may not sound like much. Note that most common areas are rather small and a one percent increase in size is therefore also a small improvement.

On the negative side, proximity to green buffers is associated with significantly lower prices. Likewise, proximity to cemeteries is associated with lower prices. This is surprising in light of the opposite result for houses. Very few apartments in the sample are close to lakes and were therefore not included in the model for apartments.

Table 5: Estimates for apartments

4.1 Proximity effects

The property price premium increases with proximity to green space, as implied by the quadratic specification. There is less value added from reducing the distance to a park by 100 meters when the outset is 600 meters distance, than there is when the distance is just 200 meters. To illustrate these differences we calculated a "Green space Appreciation Index" showing the percentage change in prices associated with a change in the distance to a type of green space. The percentage change is calculated as:

$$\%\,\text{change in P} = \frac{(dP/dG)}{P} * 100 = (2 * B_{OS} * G_{OS}) * \frac{P}{P} * 100 \quad (3)$$

Where, $\frac{dP}{dG} = (2 * B_{OS} * G_{OS}) * P$ provides an expression of the absolute value for a particular type of green space. The index calculated for the statistically significant green space variables is shown in table 6. The value of reduced distance to parks grows from 0. 5 percent per 100 meters far away from the park to almost 3 percent per 100 meters close to the park for houses, and results are very similar for apartments. It should be noted that the view of parks is captured in a separate variable for apartments, so the reduction in distance captures increased ease of access rather than views. The negative effect of proximity to green buffers is larger than the positive effect of access to parks for properties located close to green buffers. We find a decrease in prices of 4 percent for houses and 3 percent for apartments. The negative effect declines more steeply with increased distance and is again remarkably similar across houses and apartments.

Green buffers which combine green space related to industry and infrastructure comes with a negative price premium for both apartments and houses. In the hedonic models, we separately control for proximity to industrial areas, highways, larger roads and railways (see supplementary literature). The number of sold properties and the size of the survey area ensures enough spatial variation in the data to find properties related to industry and infrastructure with and without green space. The green buffer estimate is therefore trustworthy, in the sense that it captures the presence of green buffer space and is not a proxy for the related negative externalities.

For proximity to cemeteries, the price change is similar in size but goes in the opposite directions. In particular, the negative effect for apartments is very large. This is hard to explain. Overall the magnitude of the marginal effects of increased proximity is quite similar across different types of green space. The results lie within the range of estimates from existing studies as summarized in table 1 of McConnells and Walls (2005). The non-linear relationship between implicit prices and distance to an environmental good is also found by Cho et al. (2010) and Kim et al. (2011).

Table 6: Green space Appreciation Index

5. Discussion

The results of hedonic house price valuation provide valuable insights into the values that local residents attain from their surroundings. Such information should feed into the planning process to evaluate different policy scenarios in the urban landscape. However, results from valuation of green space are seldom applied in policy assessments and when they are applied they are often based on stated preference techniques (Banzhaf, 2010). We speculate that one possible reason for the limited impact of hedonic valuations on actual policy may be the academic tendency to model the amenities too coarsely for planning purposes.

The existence of different types of green space with different types of services seems to carry through in our estimations. Given the heterogeneity in estimated coefficients of different types of green space, treating green space as a homogeneous good is misleading. Depending on the types and locations of green space in a given study area, the results of an aggregation would be a weighted average effect which would be hard to interpret. The distinction between different types of green space is important if the results of hedonic analysis are to be put to practical use in the planning process.

Our motivation for dividing green space into different categories was based on the notion that green spaces are not one but several distinct goods. We rated the different types of green spaces according to accessibility, maintenance level and neighboring land-use. Parks and lakes were rated as having high recreational potential. In our estimations we find that both Parks and Lakes are associated with a large price premium. In contrast, Sport fields and Agriculture fields were hypothesized to have more limited recreational value and we found no significant effect of proximity to these types. The small price premium associated with nature areas may have something to do with a dimension of green space, with which we have not concerned ourselves due to lack of data on the status of individual area. Irwin (2002) finds that permanent green space is more valuable than space which may in time be put to other use. If this is the way natural areas are perceived in Aalborg, that may be an explanation for the low value associated with access to them. Most of the other areas in our study aside from agriculture fields are unlikely to be converted into other land use.
The value of common areas differs between apartments and houses. We find a significant positive effect of the size of common areas for apartments and no effect for houses. Residents of houses might be indifferent to common areas as they have access to a private garden. While we did attempt to identify such an effect by interacting garden size and common area size, no effect was found. If gardens and common space are substitutes, access to a private garden may be enough to render common areas unimportant.

From a planning perspective what do these values imply? For instance, should planners in the future disregard green space around industrial areas or infrastructure and focus on parks instead? Green buffers' primary function is to shield areas with other land-use from the negative effect of industrial areas and infrastructure. If green buffers were effective at reducing the negative effects, we would have expected to find positive coefficients on proximity to green buffers. The negative effects we estimated suggest that green buffers are unattractive in their own right. Recalling our scoring of different types of green space in table 2, green buffers have low access, low maintenance and undesirable neighbors. Hence, green buffers provide low levels of recreational service, if any at all.

Our results concern residential values. Therefore we can say nothing about the value of green space for non-residential neighbors. Likewise, our estimates do not capture the value provided to non-local residents. Schipperijn et al. (2010) find that a considerable amount of people are willing to travel more than 1000 meters to enjoy recreational benefits of green space on a daily basis. In this perspective, the estimates of marginal benefits from the models can be understood as a conservative estimate of the marginal value ascribed to the amenities as the value for non-local residents should be added.

While some of our findings conform to prior expectations, in some cases the estimated coefficients are unexpected, e.g. no significant price premium associated with natural areas for apartments or the varying findings for churchyards. It should be noted that several of our estimates for the spatially varying regressors are sensitive to the choice of the number of smoothing basis functions for the geoadditive term k_1. This is not unexpected given the spatial nature of the data set and the fact that spatially varying regressors are likely to be correlated with each other (we provide a correlation matrix for the parametric spatial regressors in the supplementary literature). A higher choice of basis dimensions leads to more stable models, but fewer significant coefficient estimates for spatially varying covariates as the smooth spatial component "sucks up" a larger part of the spatial variation in the data. We conjecture that this is related to a point made in the literature on spatial smoothing. Binner and Day (2010) emphasize that variation in the spatial regressor of interest must be on a finer scale than the variation in spatial omitted variables in order to be identified. The trade-off between handling omitted spatial processes and identifying parameters for observed spatial amenities is a challenge. The advantage of the GAM model is that the unknown underlying spatial pattern of the omitted processes in the model is not a priori defined. The identification and control of the spatial processes is handled using the data driven method of smoothing basis functions of the x,y coordinates. This is clearly an improvement compared with previous hedonic studies which often use standard spatial econometric models with predefined unknown underlying spatial correlation (Gibbons & Overman, 2012).

6. Concluding remarks

The heterogeneity of green space in and around the urban environment is rarely treated explicitly in the literature on green space valuation. Green space is not a homogeneous entity. To ignore this fact would lead to a wrong conclusion regarding the relationship between property prices and access or exposure to different types of green space. We find that access to green space in cities can be associated with both significantly higher and lower housing prices depending on the type of green space. In addition, we find differences in the capitalization of different types of green space between apartments and houses. The findings indicate that distinguishing between different types of green space is important. In particular, an implication of our work is that neighboring land use cannot be ignored when planning new recreational areas.

For a better understanding of the value of green space, future studies should look more carefully at the characteristics of green space in their data and attempt to define homogeneous categories. Agreeing on a categorization in the literature would naturally aid in comparing different studies and identify interesting general results. In this way academic valuation exercises would increase their relevance for practical policy and urban planning.

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List of tables

Table 1: Control variables describing housing characteristics

Structural variables	**Locational Variables**
Size of living area (log)	Highway
Room (log)	Large Road (wider than 6 meters)
Garden area	Railway track
Basement	Industrial area
Number of floors	Coastline
Number of apartments	Hasseris – high income area
Low basement	Geographical coordinates
Renovation 1970s	
Renovation 1980s	**Neighborhood variables**
Renovation 1990s	Spatial lag: Garden
Renovation 2000s	Spatial lag: Brick
Built before 1927	Spatial Lag: Age
Built between 1927 and 1939	Spatial Lag: Tile roof
Built between 1939 and 1955	Spatial Lag: Renovation in 1970s
Built between 1955 and 1975	Spatial Lag: Renovation in 1980s
Built between 1975 and 1999	Spatial Lag: Renovation in 1990s
Brick	Spatial Lag: Renovation in 2000s
Tile roof	
Fiber board roof	

Table 2. Types of green space and criteria for categorization.

Accessibility	Park	Lake	Nature	Churchyard	Sports field	Common area	Agriculture field	Green Buffer
External	H	H	H	H	H	M	L	L
Internal	H	M	M	M	H	H	L	L
Social	H	H	H	M	H	M	L	L
Maintenance	H	M	L	H	M	H/M	M	L
Neighbor land use	R	R	R	R	R	R	(R)	I
Note: H: High level, M: Medium level, L: Low level. For neighboring land use: R: Residential/Commercial, I: Industry/Infrastructure								

Table 3. Descriptive statistics of the types of green space.

typologies	Spec.	N.	Size, ha			Distance, m (House)			Distance, m (Ap.)		
			Max	Min	SD	Min	Me*	Mean	Min	Me*	Mean
Park	View, Size, Prox.	18	32.9	0.24	8.2	3.7	943.8	1277.1	2.8	368.6	527.7
Nature	View, Size, Prox.	60	207.9	0.60	43.4	0	486.8	562.8	0	780.3	919.0
Lake	View	6	30.2	0.57	12.7	0	1739.6	1779.6	20.8	1795.9	1693.3
Common area (houses)	View, Size	113	23.8	0.20	2.4	0	221.5	270.4			
Common area (apartments)	View, Size	125	26.5	0.20	2.4				0	91.9	161.3
Sport fields	Prox.	62	82.5	0.26	15.0	5.5	345.3	376.7	4.8	487.7	502.5
Agriculture fields	Prox.	334	277.8	0.21	31.0	0	781.8	946.8	37.2	1923.3	1785.1
Green Buffer	Prox.	269	184.6	0.20	17.0	2.4	366.9	420.5	4.1	371.0	428.4

Note: Spec:specification. N:number. Max:maximum. Min:minimum. Me:median.SD:standarddiviation. Prox.:Proximity

Table 4: Estimates for houses

Variable	Estimated Coefficient	Standard Deviation	P-value
Park (prox. sq.)	0.002***	0.001	0.000
Park size (log)	0.009***	0.003	0.001
Nature (prox. sq.)	0.001	0.000	0.058
Nature size (log)	-0.001	0.001	0.367
Lake (view, dummy)	0.071**	0.023	0.002
Common area (view, dummy)	-0.005	0.009	0.588
Common area size (log)	-0.002	0.005	0.639
Common area size (log) X Garden size	0.000	0.000	0.892
Green buffer (prox. sq.)	-0.006***	0.002	0.000
Sport field (prox. sq.)	0.002	0.002	0.141
Church yard (prox. sq.)	0.004	0.003	0.075
Agriculture field (prox. sq)	-0.004	0.003	0.174
Approximate significance of smooth terms:			
	Effective DF		p-value
$f_1(x_{lon}, y_{lat,} k_1=40)$	38.187***		0.000
$f_2(t, k_2=10)$	7.078***		0.000
GCV-score	0.039		
R^2 (Adj.)	0.80		
Note: Significance is denoted by ***: 0.1 percent, **: 1 percent, * 5 percent, Prox,sq.: Squared Proximity			

Table 5: Estimates for apartments

Variable	Estimated Coefficient	Standard Deviation	P-value
Park (view dummy)	0.056***	0.012	0.000
Park (prox. sq.)	0.002***	0.000	0.000
Park size (log)	-0.001	0.002	0.567
Nature (view dummy)	0.026	0.033	0.423
Nature (prox. sq.)	0.000	0.001	0.624
Nature size (log)	0.001	0.002	0.391
Common area size (log)	0.011***	0.003	0.000
Common area (view dummy)	0.005	0.005	0.280
Green buffer (prox. sq.)	-0.005**	0.002	0.003
Sport field (prox. sq.)	0.000	0.002	0.822
Church yard (prox. sq.)	-0.012***	0.002	0.000
Approximate significance of smooth terms:			
	Effective DF		p-value
$F_1(x_{lon}, y_{lat,} k_1{=}40)$	36.959***		0.000
$F_2(t, k_2{=}10)$	8.134***		0.000
GCV-score	0.018		
R^2 (Adj.)	0.88		
Note: Significance denoted by ***: 0.1 percent, **: 1 percent, * 5 percent. Prox,sq.: Squared Proximity			

Table 6: Green space Appreciation Index

Percentage change in price associated with a 100 m decline in distance		Distance from green space					
		600 m	500 m	400 m	300 m	200 m	100 m
Houses	Park	0.5	0.9	1.4	1.8	2.3	2.7
	Nature[(a)]	0.2	0.3	0.5	0.6	0.8	0.9
	Green buffer	Cut-off at 300 m			-1.3	-2.5	-3.8
	Church yard[(a)]				0.9	1.8	2.7
Apartments	Park	0.3	0.7	1.0	1.4	1.7	2.1
	Green buffer	Cut-off at 300 m			-1.0	-2.0	-3.0
	Church yard				-2.3	-4.6	-7.0
Note	[(a)] Significant at a 10 percent level.						

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Fig. 1 Green space and transaction in Aalborg.

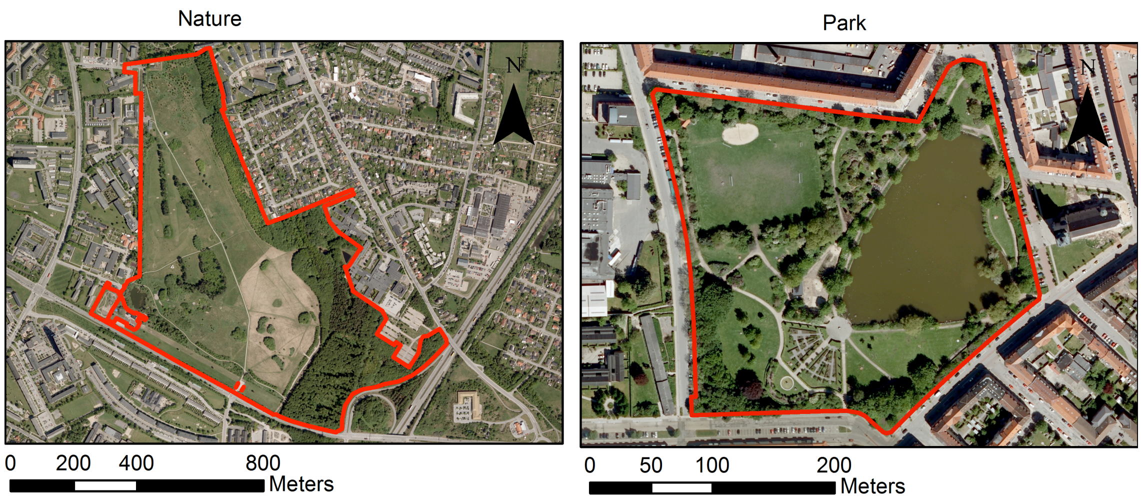

Fig. 2. Examples of green spaces in Aalborg