DEPARTMENT OF FOOD AND RESOURCE ECONOMICS
UNIVERSITY OF COPENHAGEN

IFRO Working Paper

Estimating demand schedules in hedonic analysis: The case of urban parks

Toke Emil Panduro
Cathrine Ulla Jensen
Thomas Hedemark Lundhede
Kathrine von Graevenitz
Bo Jellesmark Thorsen

2016 / 06

IFRO Working Paper 2016 / 06

Estimating demand schedules in hedonic analysis: The case of urban parks

Authors: Toke Emil Panduro, Cathrine Ulla Jensen, Thomas Hedemark Lundhede, Kathrine von Graevenitz, Bo Jellesmark Thorsen

Published: September 2016

See the full series IFRO Working Paper here:
www.ifro.ku.dk/english/publications/foi_series/working_papers/

Department of Food and Resource Economics (IFRO)
University of Copenhagen
Rolighedsvej 25
DK 1958 Frederiksberg DENMARK
www.ifro.ku.dk/english/

Estimating demand schedules in hedonic analysis: The case of urban parks

Corresponding author
Toke Emil Panduro
Email: tepp@ifro.ku.dk

Affiliation
Department of Food and Resource Economics
Faculty of Science, University of Copenhagen
Rolighedsvej 23
1958 Frederiksberg Copenhagen, Denmark

Authors:

Toke Emil Panduro[1], Cathrine Ulla Jensen[1], Thomas Hedemark Lundhede[1,2], Kathrine von Graevenitz[3], Bo Jellesmark Thorsen[1,2]

Affiliation:

[1] Department of Food and Resource Economics, Faculty of Science, University of Copenhagen, Rolighedsvej 23, 1958 Frederiksberg Copenhagen, Denmark
[2] Center for Macroecology, Evolution and Climate, University of Copenhagen, Rolighedsvej 23, 1958 Frederiksberg Copenhagen, Denmark
[3] Department of Environmental and Resource Economics, Centre for European Economic Research (ZEW), P.O. Box 103443, 68034 Mannheim, Germany.

Acknowledgement:

This paper benefited from funding through the project ”Benefits from investing in urban life and urban qualities” funded in a collaboration between the municipalities of Aarhus, Albertslund, Brøndby, Frederiksberg, Gladsaxe, Glostrup, Herlev, Hvidovre, Ishøj, Københavns, Lyngby-Taarbæk, Rødovre, Skanderborg and Vallensbæk as well as the Capital Region of Denmark, the Ministry of Environment and Food, the developers Kildebjerg Ry A/S and By & Havn I/S and University of Copenhagen.

Abstract:

The hedonic pricing method has been used extensively to obtain implicit prices for availability of urban green space, but few hedonic studies have obtained households' preference parameters. We estimate willingness to pay functions for park availability in Copenhagen using an approach that places identifying restrictions on the utility function. We do this for two different measures of park availability. We apply our results to a policy scenario and show how estimates of aggregate welfare changes are highly sensitive to the measure of park availability applied. Thus, the approach in this study applies an alternative path for estimation of demand schedules for public goods using hedonic data. The findings also stress the importance of paying attention to how public goods are defined when undertaking welfare economic policy analyses.

Keywords: Hedonic house price model, green space, preference heterogeneity, identification.

Introduction

Urban green space and parks provide recreational opportunities for urban residents and visitors. Urban green spaces furthermore provide climate regulation functions, may function as a flooding buffer, can harbor biodiversity under pressure elsewhere and provide many other ecosystems services. As it is the case with many other public goods, it is unlikely that green space is provided in optimal quantities in a competitive urban land development market, unless regulated. Urban authorities can ensure provision either through such regulation of private developers or they can themselves secure land is set aside. However, in the absence of thorough insights into the values of urban green space, the values and the need for such regulation may be neglected whenever new neighborhoods are planned and developed.

For that reason environmental economists have undertaken numerous studies which estimate the value of urban parks and green spaces in order to provide a sounder basis for appropriate social cost benefit analyses and regulation of urban development. To that end, they have used various environmental valuation techniques, notably including Rosen's (1974) hedonic pricing framework where properties are treated as a bundle of goods, which the households obtain when buying a house or an apartment. The availability of parks in the area surrounding a property can be thought of as one of these goods, and hence as a characteristic of the houses or apartments in focus. Rosen showed how, under suitable assumptions, one could 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 as more spatial data and computational capacity has become available, including e.g. Tyrväinen and Miettinen (2000) and Lake et al.(2000), and this field is still growing with new applications being added regularly (e.g. Sander et al. (2010); Panduro and Veie (2013)).

The hedonic pricing function recovered in the first stage of the hedonic method only relates each attribute to the price at the given market equilibirum. It does not provide information about the preferences of the population of households and hence the demand schedule for the good in question. To obtain this crucial information for good policy evaluation, the second stage of the hedonic framework needs to be completed. There are, however, surprisingly few studies in environmental economics which undertake a second stage analysis and only one of these addresses the demand for urban parks (Poudyal et al. 2009). Undoubtedly, one of the main reasons for this gap in the literature is the difficulties in obtaining good instruments for handling the endogeneity of the level of amenities chosen with their implicit prices, which is embedded in the empirical problem.

An analysis of how willingness to pay for urban parks varies across space and across various socio-demographic patterns can provide policy-makers with information about the welfare impacts of green space policies, which can support efficiency, as well as give them insights into the distributional impacts of such policies. This, however, requires knowledge on the structure of preference heterogeneity, and due to the lack of second stage hedonic studies, this issue remains understudied in the literature.

Another important issue for policy evaluation is the specification of measures of quantity or/and quality of the public good in question applied in the models and analyses. The estimation of preference parameters and hence welfare gains and losses resulting from changes may be sensitive to this specification, and valid policy evaluation should investigate this. With the lack of studies obtaining preference parameters for urban green space this aspect remains insufficiently studied, in spite of the existing hedonic pricing functions using a plethora of different specifications of urban green space availability and quality.

The main aims of the present paper are firstly to further the development of the field by introducing an alternative approach to recover preference parameters into the environmental economics literature. The approach relies on functional restrictions on the utility function for identification. This approach was first applied by Chattopadhyay (1999) and then later by Bajari and Benkard (2005) and Bajari and Khan (2005) on preference for air quality and racial composition in neighborhoods. In this paper we apply the approach to a study of preferences for urban park availability in central Copenhagen, Denmark, and secondly we decompose how preference heterogeneity relates to observable socio-demographics. Thirdly, using two different but commonly used park availability measures, we investigate how sensitive estimates of the aggregate as well as the distribution of policy induced welfare changes are to the specification of the good.

Previous Work

Measures of urban green space in hedonic valuation studies

Few fields have been as responsive to Rosen's (1974) hedonic pricing framework as the environmental valuation field studying the value of urban green spaces. The number of studies investigating the role of various aspects of urban green space for house prices is impressive, and the space here does not allow for more than a partial coverage with the purpose of illustrating the variation in measures of urban green space availability that have been applied in the literature. All of the studies, with one exception, rely solely on first stage hedonic price functions for their analyses.

In general most measures have focused on two aspects of supply; distance to the green area and the amount of green area. Proximity to urban green areas, represented by various distance measures from the property to one or more green areas has often been used. To mention some examples, Lake et al. (2000) used measures of walking distance to nearest park in a UK study of house price determinants. Mansfield et al. (2005) applied various measures, including linear distance to various types of urban and peri-urban forest lands. Kong et al. (2007) evaluated various measures of distance to urban green space, combined with different measures of quality and substitutes such as size or share of green in the vicinity. Tyrväinen and Miettinen (2000) applied linear distance to peri-urban forests as well as the presence of a view. Morancho (2003) also used presence of view as well as distance to urban green areas, and also Orford (2002) used an inverse distance measures interacted with the size of the park.

Jia and Liu (2010) applied truncated distance dependent functions in the form of geographic field measures. These are closely related to the distance measures applied in our study, where effects of proximity are constrained to equal zero at distances where our empirical analyses suggest the effect of park proximity is no longer present in the house prices. This approach is often superior to simple distance measures with infinite non-zero range and can track steeper declines and influence better, see e.g. Panduro and Veie (2013), who use a set of similar censored proximity measures to various urban green spaces.

The other measure often applied in these studies is the amount of green area available, either in absolute terms, (e.g. size of the nearest green area, or the area available within a given radius) or various relative measures of green space density within a radius of the property. Kong et al. (2007) used density and patchiness measures of urban green space in combination with distance measures. Cho et al. (2009) evaluated the value of various types of peri-urban forest patches in North Carolina, US, and used measures of patch size, patch density and edge density of deciduous and evergreen forest types around the properties in focus. Mansfield et al. (2005) included measures of density of forest land in discrete distance zones around each property; Jiao and Liu (2010) also used density measures, whereas Morancho (2003) used a measure of the size of the urban green space nearest to each property.

In addition to these core quantity measures, quite a few studies have investigated the role of more subtle quality attributes of urban green spaces. There is a stream of literature studying the value of urban trees and tree cover explicitly, in which various measures of urban tree cover on property, in the streets and urban green areas have been used. See Sander et al. (2010) for an overview of approaches to this and Panduro and Veie (2010) for a recent application. Donovan and Butry (2010) also address the value of street trees, analyzing trees outside single family houses in Portland, Oregon. Bark et al. (2009) use a small set of variables that measure ecological quality aspects of riparian areas in Tuscon, Arizona, and find that ecologically high quality areas have higher impact on housing prices. Bin et al (2009) also study the value of being placed in a riparian area using a simple dummy variable to describe the relationship between property prices and riparian area. Zhou et al. (2013) investigate the additional value of ponds and lakes in parks, in a study addressing climate adaptation measures to extreme precipitation events.

All of the above studies only present first stage hedonic price functions, which reflect the difficulties often faced in second stage estimation, making them rare among hedonic studies in spite of their clear policy evaluation relevance. To our knowledge only Poudyal et al. (2009) present a second stage analysis of urban green space demand, where they use distance to nearest park as well as size of nearest urban park. Poudyal et al. (2009) use a different approach to identification in the second stage than the one used in this paper. They also do not investigate the role of their choices of urban green space measures for welfare economic estimates.

Uncovering the willingness to pay function

As the above non-exhaustive literature review has revealed, there is an abundance of hedonic studies applying GIS-based data and regression techniques of varying sophistication to uncover implicit prices from the hedonic price function. However, to obtain preference parameters of households in order to estimate demand functions for a good like urban green space, we need to handle the non-trivial obstacle of endogeneity of the implicit prices.

Generally speaking, only two different approaches to tackle this issue are found in the broader literature of second stage hedonic models. The first and perhaps most used is the utilization of multiple markets. Conditioning on the observed demographics preferences are assumed identical across markets and no sorting takes place across markets based on unobserved characteristics. . In this setting, cross-market variation in prices arises solely from differences in the supply of housing with different attributes. This allows for a market indicator to function well as an instrument. Poudyal et al. (2009) used the multiple market approach to complete the second stage hedonic regression and applied cluster techniques to identify sub-markets, from which they obtained sufficient price point estimates to perform the second stage regression. Brasington and Hite (2005) used the approach to uncover preference parameters for environmental qualities as well as school quality. Preferences for other urban (dis-) amenities like noise have been uncovered by Day et al. (2007) using a related approach based on spatially lagged implicit prices across distances as instruments. Netusil et al. (2010) studied the demand for tree canopy cover in an area of Portland, Oregon using a second stage hedonic model. In the second stage of their analysis, they obtained identification through functional form restrictions and resolved the problem of endogeneity by instruments obtained from a survey on a subset of the households, which house transactions were the basis of the first stage retrieval of the implicit price measures. In some of these instances the validity of these instruments could be questioned. For multiple markets within the same urban area it is hard to argue that no sorting takes place. Instruments based on household preferences for other goods are also hard to justify as being exogenous to the housing choice. A convincing instrumental variable strategy thus remains absent from the literature.

An alternative approach to recover preference parameters secures identification through restrictions on the utility function. This approach was first applied by Chattopadhyay (1999) in analysis of air quality in Chicago and later applied by Bajari and Benkard (2005) and Bajari and Khan (2005) focusing on the racial composition of neighborhoods. This approach has been used to a very limited extent. von Graevenitz (2013) is one of few examples, and there has been no use of this approach in relation to urban green space demand either. It is this approach which we apply in the present study. Assumptions on the functional form of preferences are frequently found in e.g. choice modelling (Train, 2003) and an advantage of the approach is its transparency in contrast to the instrument variable approaches described above, where the necessary properties for instruments to be valid are often hard to satisfy in practice.

Theoretical framework

Our estimation procedure involves three steps, parallel to Bajari and Benkard (2005), Bajari and Kahn (2005) and von Graevenitz (2013). In the first step we estimate a hedonic house price function; in the second step we recover household-specific preference parameters; and in the third step we decompose variation in willingness to pay using observed socioeconomic characteristics.

A house is a composite good and can be described as a bundle of attributes, X_j, one attribute being access to green space. The price P_j of a house j in a market in equilibrium is the result of numerous interactions between buyers and sellers and is a function of its attributes, $P_j(X_j)$.

Households obtain utility from consuming housing, X_j, and all other goods described by a composite numeraire good, c_i. The utility for household i living in house j is described by the utility function $U(X_j, c_i; \gamma_i)$ 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 and we can thus model the choice of housing as a static problem (Bajari and Benkard 2005)[1]. The utility function should be interpreted as the utility obtained from the flow of housing goods. The model refers to the annual cost of housing which 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. They face the following maximization problem where γ_i captures household

[1] This assumption is obviously quite strong though quite standard in the hedonic literature. Recent work to incorporate the dynamic nature of the problem includes Bishop and Murphy (2011), who show that the assumption of myopic consumers can lead to biased estimates, especially for attributes which are expected to change over time. As the current paper examines urban green space and the supply of green space is relatively static over time in the area under study, we believe any resulting bias to be limited.

specific preference parameters determined by socioeconomic characteristics of the household and inherent preference heterogeneity:

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

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:

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

The right hand side of the equation is the annual implicit price recovered from the hedonic price function. The left hand side is the household's or marginal willingness to pay, where we only observe one choice for each household and therefore only have one point on each indifference curve.

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* housing goods[2]. They suggest that one possible assumption for the utility function could be that the utility is logarithmic in housing goods and quasilinear in income. We adopt this flexible assumption here and discuss the sensitivity of this choice later. This leads to the following utility function:

$$U(X_j, c_i; \gamma_i) = \sum_k \gamma_{ki} \log(x_{jk}) + c_i \qquad (3)$$

The household specific preference parameter γ_{ik} captures the intensity of the demand for housing good *k*. Imposing these assumptions on the functional form of the utility function we can rewrite the first order condition as:

[2] The utility function most cut the price-function from the right angle, in other words the second order condition must hold. The concaveness of the utility function depends on the preference parameter γ_{ik} and it implicates that the concavity of the utility function flattens at low consumptions and increases at larger consumptions. This in turn implies that, even though both the first and second order condition hold, the identification of the tangent bundle becomes less precise as the amount of x approaches zero.

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

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

The measure $\frac{\delta\, \pi_t P(X_{j*})}{\delta x_{jk}}$ is readily obtained from the first stage estimation of the hedonic price function. We directly observe x_{j*k}, and are therefore able to calculate γ_{ik}, which is the household specific preference parameter for attribute *k*. The preference parameter calculate in Equation 5 for each household produce a willingness to pay estimate for housing good *k.* Hence, Equation 5 provides the second stage hedonic estimation for the willingness to pay for housing good *k*.

Households are characterized by their demographics, *d*. Using these attributes the preference parameter, γ_{ik}, can be decomposed into an average preference for *k* shared by all households, α_k, and household specific preferences α_{kd} based in part on observed demographics S_{id} and unobserved heterogeneity ω_{ik}:

$$\gamma_{ik} = \alpha_k + \textstyle\sum_d \alpha_{kd} S_{id} + \omega_{ik} \tag{6}$$

Econometric model

In the first step we estimate the hedonic house price model using a Generalized Additive Model, with a gamma distribution using a logarithmic link function (Wood 2006).

$$\ln(P_j) = X_j\theta + G_j\beta + f_1(t_j; S_1) + f_2(x_j, y_j; S_2) + \delta_j + \mathrm{u}_j \tag{7}$$

Here, *P* is the price of the *j*'th house. We distinguish between the variable, *G*, which is measured as the proximity to or density of parks, or both, and other characteristics, *X*. The matrix *X* contains numerous characteristics describing the dwelling and its location. We control for spatial autocorrelation using spatial fixed and smoothing splines as suggested by (von Graevenitz and Panduro 2015). δ_j is a spatial fixed effect on school districts. The functions $f_1(t_i; S_1)$ and $f_2(x_i, y_i; S_2)$ controls for time and space, please see (Wood 2006) for a technical description or (von Graevenitz and Panduro 2015) for an application.

2nd step: Recovering preference parameters

In the second step the preference parameter of each household, γ_{ik}, is calculated based on the first order condition outlined in eq. 5. The parameter estimate $\hat{\beta}$ of the hedonic house price model in eq. 7 is multiplied with the asset return rate π in order to transform the capitalized value into a perpetual annuity. The yearly flow of park value enjoyed by each household is then multiplied by the predicted individual virtual price $\hat{P}_{j*,2012}$, based on the X_j bundle of apartment characteristics. The transaction time for the virtual price is set to the beginning of 2012 and the residuals $\hat{u}_{j*}$ of the first step hedonic model are added to the predicted virtual price. The preference parameter $\hat{\gamma}_i$ is then recovered for each household by multiplying with the park variable G_{j*} found in the observed housing choice.

$$\hat{\gamma}_i = G_{j*} \times (\hat{P}_{j*,2012} + \hat{u}_{j*}) \times \pi \times \hat{\beta} \quad (8)$$

In order for eq. 5 to hold, the good needs to be available in continuous amounts. If not, then the marginal rate of substitution and the marginal cost is not necessarily tangential in the bundle and we cannot use the first order condition outlined in eq. 5 to recover the preference parameter all over the distribution of the good. Both green space variables are continuous and if a household have chosen to buy the proximity to, or density of parks we can use the condition in eq. 8 to estimate the preference parameter, γ_{ik}. Due to the construction of our park availability variables, (which we explain in details below) there may be apartments in the sample where the level of supply or access is zero. The preference parameters are unidentified for the households which have chosen these apartments, because the first order condition in eq. 5 does not necessarily hold at or below the kink of the censored proximity distance variable[3].

3rd step: Decomposing preference heterogeneity

In the third step the socio-demographic variables of households, *i*, are regressed on the recovered preference parameter. Here the heterogeneity in the estimated preferences of households is regressed on observed socioeconomic characteristics such as age, income, children and so forth. The regression is estimated using a generalized linear model (GLM):

$$ln(\widehat{\gamma_{ik}}) = \alpha_k + \sum_d^D \alpha_{kd} S_{di} + \omega_{ik} \quad (9)$$

[3] Censoring at zero implies that the second order condition will always hold. In the case of a good the utility function is strictly concave and the price-function is strictly convex.

where α_k is an intercept that captures the average preference for the park measure G, S_{di} are D observed socioeconomic characteristics and α_{kd} is a vector of parameters describing the variation that can be explained by each observable characteristic. The parameter ω_{ki} captures the household's residual idiosyncratic taste heterogeneity for park proximity, park density or both.

Data

The data used in the analysis consists of 9,326 apartments traded in central Copenhagen from the beginning of 2007 and to the end of 2011. The data include only arm length transactions. A small number of apartments traded for more than 2,421,240 EUR or less than 13,451 EUR were removed as they were considered to be either part of a different market (for very high end properties) or reflect in data, respectively. The data only included properties bought as residential apartments by private households. Besides sales price, date of transaction and type of sale, the data also include information on structural characteristics such as number of rooms, size of the living area, outer wall construction material and so forth. The information was extracted from the Danish Registry of Buildings and Housing, which contains information on all dwellings in Denmark. The registry also contains information on the exact coordinates of the location of each property, which allowed us to calculate several proximity variables, e.g. to relevant spatial public goods, such as railway stations or shopping possibilities for each property using R (R Core Team 2015) and ArcGIS 10.2.1 (ESRI 2011 2015). To ensure that the analysis did not suffer from an edge effect all spatial externalities less than 3 km outside of the border of the housing market were included in the calculation of spatial variables – see figure 1. The spatial data were supplied by the Danish Geodata Agency based on the kort10 database (The Danish Geodata Agency 2011) and by Danish Business Authority based on the CVR Register (Danish Business Authority 2011).

Individual level socio-economic data from Statistics Denmark were joined with each traded apartment using coordinates. Due to the sensitive nature of individual level socio-economic data, these were delivered spatially blurred using a raster mosaic of 100x100 meters after which it was further refined and matched to individual properties by Geomatic A/S[4]. The socio-economic data applied in the analysis is on household level. The precision of the household socio-economic data depends on the matching procedure applied by Geomatic.

[4] A description of summary statistics of the data applied in this study are supplied for review purposes and can be found in Appendix 1 (and be made as online resources).

Study area

The study area is located in the inner city area of Copenhagen which is the capital of Denmark and is the most densely populated and urbanized area in the country. The study area is also one of the most attractive real estate markets for apartments in Denmark. The area is characterized by high sales prices of properties and high income earning residents relative to the rest of Copenhagen. The study area was selected by spatial analysis of the residuals from a naïve hedonic house price model for the greater Copenhagen area (Lundhede and others 2013). The residuals showed a clear pattern with areas of over and under prediction following distinct barriers in the urban landscape such as large roads, railway tracks and large green spaces indicating that the pricing of the study area is distinctly different from the rest of Copenhagen city and can therefore be considered a single homogenous property market for apartments.

The inner city of Copenhagen includes a former industrial harbor and several recreational parks. Over the recent decades, the harbor has been transformed into a place for recreational activities. The larger recreational parks in Copenhagen originally served other purposes, such as defense systems, green pastures owned by University of Copenhagen, the Church or the Danish Monarchy. To some extent the parks outline the historical city limit over different historical periods (see Figure 1).

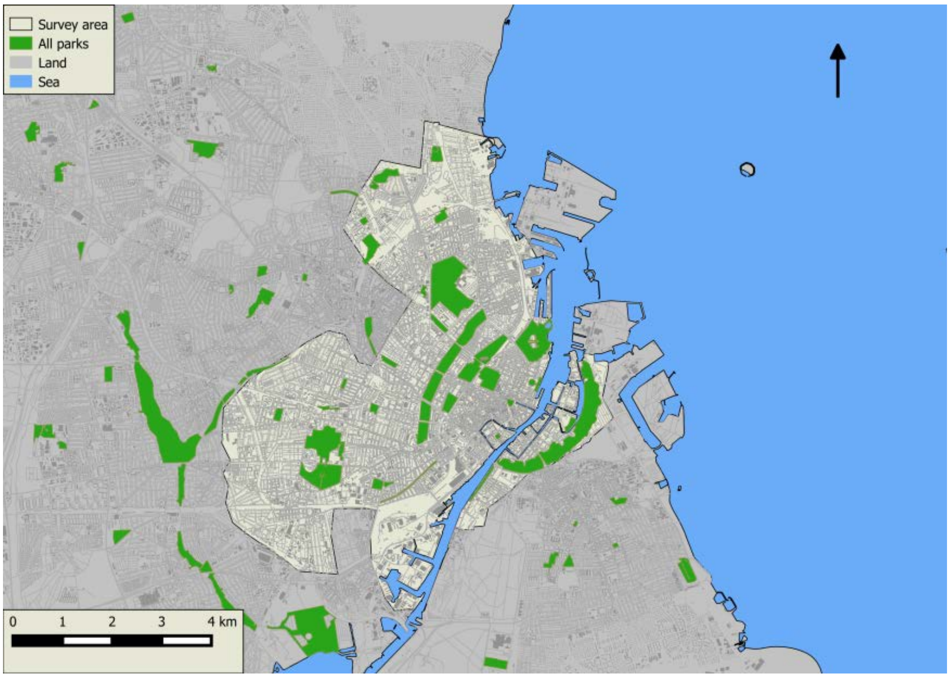

Figure 1: The outline of the inner city apartment market used as study area. Green areas mark the recreational areas coded as parks in this study.

Park availability variables

We define a green space as a park only if the area has a high maintenance level with well-kept vegetation and a range of recreational possibilities. The area has to have footpaths make the area available to the public, making it possible to walk in the area and enjoy different features such as small lakes, trees, lawns, flowers, and sport activities. This excludes e.g. urban green areas around industrial buildings and around infrastructure like railroads.

We apply two different measures: A simple proximity measure and a density measure. The two measures are illustrated in Figure 2 and follow the main strategies applied in the literature on valuation of green space using the hedonic house price method. We included a number of distance or density dummies to investigate the empirical spatial extent of each measure in the data and then identified different cut-off distances, where we were able to detect a significant impact on price. From these measures we chose the one yielding the best model-fit.

The proximity measure is calculated from a Euclidian distance GIS calculation. The degree of proximity was calculated by $X_{prox} = C_{cutoff} - X_{dist}$ where X_{dist} describes Euclidian distance and C_{cutoff} is set to 300 meter. For apartments beyond this cut-off distance the measure of proximity is set to zero. In this way the proximity variable is easy to interpret, because positive preferences for a park will result in the estimation of a positive coefficient. The cut-off value reflects that the value of the service will be declining with distance, and beyond some point it will effectively be zero (Panduro and Thorsen 2014). The proximity measure implicitly assumes that what matters for utility is the proximity to the nearest green area, as long as it is within 300 meters. The measure is insensitive to how large that area is as well as to other areas within 300 meter or beyond.

The density measure describes how many hectares of park each individual apartment has access to within in a 1,000 meters radius. The measure reflects any mixture of park composition from a range of smaller parks to the presence of a single larger park. The density measure implies that the utility of park supply to the household depends solely on the total area of parks available within 1,000 meters of the property, but is insensitive to where in that radius the park is.

The two park measures are simple, but commonly used measures. They represent two distinctly different approaches to describe the relationship between property value and parks. They furthermore operate on very different spatial scales with very different density radius and cutoff values. The choice of spatial scale implies that a few households in our sample have not bought park availability, as measured by the density variable and as many as approximately 65% households have not bought access to a park, as measured by our proximity variable. As shown in table 2 no apartment in the sample is closer than approx. 20 m from a park (300 – 276 m) and for those apartments situated within 300 m from a park has a mean distance of 180 meters (300 – 119.8). The apartment with highest park density has approx. 20% of the area within a 1,000 meter radius covered by parks while the mean density is approx. 20 ha.

Both park measures were calculated using Euclidian distance, however, networks distance measures were also considered. The network distance measures did not perform better in terms of parameter efficiency or model fit. We therefore choose to present the simpler Euclidian measures to describe park density and park proximity.

Figure 2: The two measures for park supply - proximity (left) figure 2a and park density (right) figure 2b. The (red) spot indicates the property and for the distance measure the arrow indicates the bee line distance to the nearest green area (< 300 m). On the left, the circle indicates the 1,000 m radius around the same property; a circle spanning slightly more than 314 ha.

Table 1 Summary statistics for park variables for the sample with non-zero consumption.

Variable	N	Mean	St. Dev	Min	Max
Density measured in ha within 1,000 m	8,922	20.470	18.958	0.002	73.844
Proximity to park within 300 meters (in100 m)	3,200	1,198	0.730	0.004	2.760

Results

The hedonic price function

We estimated three different hedonic price models where only the park variables included varied across the three specifications. The first model included only the density measure, the second model included only the distance measure and the third model included both measures. Results are shown in table 2 where we only list estimates of the relevant park variables together with models statistics. The full models include more than 40 explanatory variables which is not shown[5] and 9326 house sales. Here it suffices to say that the explanatory variables are stable across the three specified models and conform to expectations, e.g. number of rooms and living space is associated with higher prices and increasing the distance to the coastline is associated with lower prices. The explanatory power measured by pseudo R-square (> 0.70) and Log Likelihood value is high and approximately the same across all models.

Table 2 Estimated implicit prices for Park, Density and Park proximity

	Model 1	**Model 2**	**Model 3**
Variable	**Density-model**	**Proximity-model**	**Combination-model**
Density (ha)	0.00159***		0.00153***
	(0.00028)		(0.00030)
Proximity sq. (100 m)		0.00444**	0.00158
		(0.00205)	(0.00212)
Adjusted R^2	0.71641	0.71538	0.71628
Log Likelihood	-117,013.3	-117,026.6	-117,014.1
UBRE	0.05035	0.05049	0.05036
N	9,326	9,326	9,326

Note: *** 0.1 percent., ** 1 percent., * 5 percent.

Proximity sq.: Squared proximity.

[5] The full model is included for review purposes and can be seen in Appendix 2, and it may also be made available as online resources if possible.

The parameter for the density measure is significant in both the models, where it appears. It can be interpreted as the marginal implicit price of an increase in park availability of one ha within 1,000 m radius of the property. It corresponds to a price premium of 0.15-0.16 % per ha, which again corresponds to a marginal willingness to pay of 537 EUR per Ha per year for the average apartment in the sample[6]. The proximity park measure captures the distance to the closest park within 300 meters (in 100 meters). Note that the proximity measure is related to the sales price by a quadratic specification i.e. proximity is squared. The marginal willingness to pay for increasing proximity to the nearest park will therefore vary with the proximity to the park. An apartment with a proximity of 250 meters will on average have an additional property value of 2.2%, which equates to 7,436 EUR in annual payment for the average apartment. When incorporating both variables in one model, we found that the parameter of the density variable was largely unaffected, whereas the parameter for the proximity measure became insignificant. One may worry if our estimates are endogenous to unobserved spatial variables correlating with price and the variables of interest. To evaluate that we followed the sensitivity analysis approach suggested by Graevenitz and Panduro (2015). This approach consists of re-estimating the model with different specifications designed to capture omitted variables (e.g. fixed effects) to see how sensitive the estimates are to assumptions made about the spatial scale of such omitted variables. We have applied both a spatial additive model with two-dimensional splines of varying dimensionality fit to the xy-coordinates and a standard fixed effect model based on a variety of spatial entities. We found the parameters of the park availability measures to be robust over several increases in basis dimensionality for the spatial generalized additive model. Likewise, we found them to be stable across a number of spatial resolutions of the fixed effects specifications, including postal codes, school districts, combinations thereof, infrastructure segmentation and finally ownership organisations for apartment buildings.

The 2nd step: Recovering preference parameters

Preference parameters were recovered from the Density measure-model and the Proximity-measure model. We did not estimate the preference parameter for the combination model due to the lack of significance of the proximity parameter in the model. As can be seen from Table 3 a total of 8,922 households bought an apartment in the period 2007-2011, with a non-zero area of park within 1,000 meter radius, meaning that they had purchased density as part of their housing attribute bundle. The mean

[6] Mean in the sample is 325,712 EUR (2012)

preference parameter for those 8,922 households corresponds to a willingness to pay of 562 EUR/year for the available amount of parks, with a median of 253 EUR/year. A total of 3,201 households had bought an apartment within 300 meters from a park and we find a mean preference parameter for that model corresponding to a willingness to pay of 309 EUR/year and a median of 172 EUR/year.

Table 3 Preference parameters estimated using Model 1 and 2 from Table 2

Model	Variable	N	Mean	Median	SD	Min	Max
1	Density	8,922	561.48	252.68	717.06	0.00	8,187.65
2	Proximity	3,201	308.79	171.78	402.98	0.00	6,222.41

Note: The results are presented in EUR/year across all households. Preference parameters are only recovered for the households who bought the good.

Figure 3 shows that both measures have a distribution with a very long tail where some households have a willingness to pay far higher than the mean, and hence have bought considerably more green space quantity. Our data reveal a large variation in taste across households where only a small proportion of the households have a very high willingness to pay. We also see that the distribution for the density measure has a longer fat tail compared to the preference parameter distribution for the proximity measure.

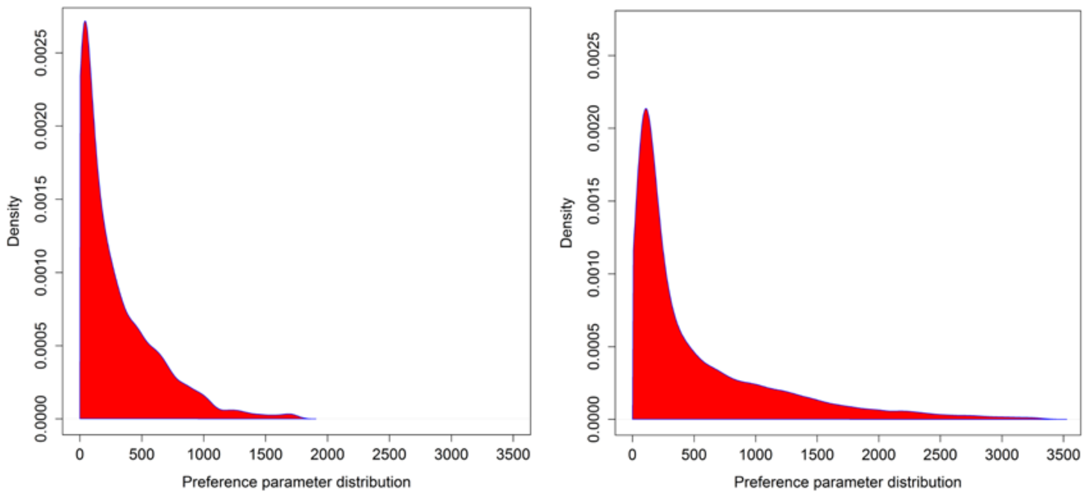

Figure 3: The distribution of the preference parameter for park proximity (left) and park density (right).

The 3rd step: Decomposing preference variation

The results for both park proximity and park density are presented in table 4, where households' estimated preferences for paying for park availability are regressed on a number of sociodemographic variables. The signs of the estimated parameters largely conform to expectations and are of equal size across the two models when significant. The larger sample and the larger variation in preferences obtained from the models applying park density result in a somewhat richer pattern of heterogeneity explained.

Younger households (defined by the oldest household member) show a weaker taste for both park proximity and park density compared to households with the oldest household member in the age bracket 30 to 60. On the other hand, households where the oldest member is above 60 show a stronger preference for density to parks. Thus, the preference and willingness to pay for park availability increases with the age of the household heads.

Car owners appear to be less willing to pay for park availability, which may reflect the higher ease with which the household can reach green recreational areas elsewhere. Families with children (indicated by a dummy variable) are inclined to buy more park availability, though the effect is almost exactly canceled if it is a single parent with children and undoubtedly a tighter economic trade-off to make.

The issue of being a single person household is interesting as this is a fast growing household type in many western urbanized regions, including Copenhagen. Our analyses reveal that being single tends to increase preferences for park availability, except for those above 60 in age.

Finally, we find that the higher the educational attainment of the household heads, the higher the preference for park availability. Education tends to correlate with income, as do also car ownership and age. Having corrected for these variables our analysis reveals that preferences' dependence on income is best described by a quadratic function for park density; for park proximity the squared income variable has an insignificant yet also negative parameter. The implication is that the willingness to pay for park density will increase with 28% with an annual income increase of 10,000 EUR. With micro data observations in the thousands it is not so surprising that only a fraction of the variation can be explained. The density model explains only 15 % and the distance model only 5% of the variation in preferences measured by McFadden's pseudo R^2. Thus, a large part of the variation is captured as unobservable taste variation.

Table 4 Heterogeneity in preferences explained by socio-demographics

Model	Density	Distance
Constant	3.954***	4.286***
	(0.135)	(0.121)
Under age 30	-0.571***	-0.397***
	(0.028)	(0.051)
Above age 60	0.459***	0.227
	(0.142)	(0.194)
Income	0.026***	0.011***
(1000 EUR)	(0.002)	(0.003)
$Income^2$	-0.0001***	-0.00001
(1,000 EUR)	(0.00001)	(0.00002)
Min 5 years higher education	0.114***	0.107**
	(0.028)	(0.050)
Car owner	-0.189***	-0.086
	(0.046)	(0.076)
Single	1.287***	0.885
	(0.110)	(1.200)
Children	1.261***	0.844
	(0.108)	(1.198)
Single parents	-1.222***	-0.928
	(0.112)	(1.199)
Single above	-1.099***	-1.333***
age 60	(0.157)	(0.245)
N	8,922	3,201
Log Likelihood	-64,408.490	-21,049.740
Akaike Inf. Crit.	128,839.000	42,121.490

Note: *** 0.1 percent., ** 1 percent., * 5 percent.

Policy evaluation – welfare estimation

The above results provide the possibility to assess the welfare effects of a non-marginal change in the availability of the park good. Based on the preference parameter for parks, the willingness to pay for a change in park consumption can be calculated as follows $\hat{\gamma}_{Gi}\left(\log\left(G_i^1\right) - \log\left(G_i^0\right)\right)$, where current proximity or density of parks is represented by G_i^0 and G_i^1 represents the scenario of change, e.g. a new park established or alternatively an existing park cancelled and developed for other purposes. A scenario like the latter, where a park is converted to other land-use purposes e.g. parking lots, commercial activities or apartment blocks is fictional, yet not implausible in a dense city like Copenhagen. Like any other major city in a western European country, the pressure to convert remaining open urban spaces to other types of land-uses is high in Copenhagen given the relatively high land rent.

To exemplify the impact of a policy intervention where an entire park is converted to something else we calculate the welfare loss of removing the romantic style and more than 150 years old Horticultural Garden (Landbohøjskolens Have) of University of Copenhagen. The Horticultural Garden is mapped in Figure 4 along with the catchment areas of the proximity measure and density measure. Note that The Horticultural Garden is located on the Frederiksberg Campus of University of Copenhagen resulting in few apartments located adjacent to the park. An inspection of the other parks in Copenhagen revealed that it is not uncommon to have non-residential buildings (public buildings, business etc.) located between the parks and apartment buildings. The Horticultural Garden is similar to other parks in Copenhagen in terms of accessibility measured in proximity and availability measured in density. We assume that whatever the area is developed into does not in itself affect the values of the apartments in focus, e.g. it may be further residential building blocks. In the calculation we account for possible substitution effect. The elimination of the Horticultural Garden park will for some apartments have the consequence that another park is within 300 meters of the apartments.

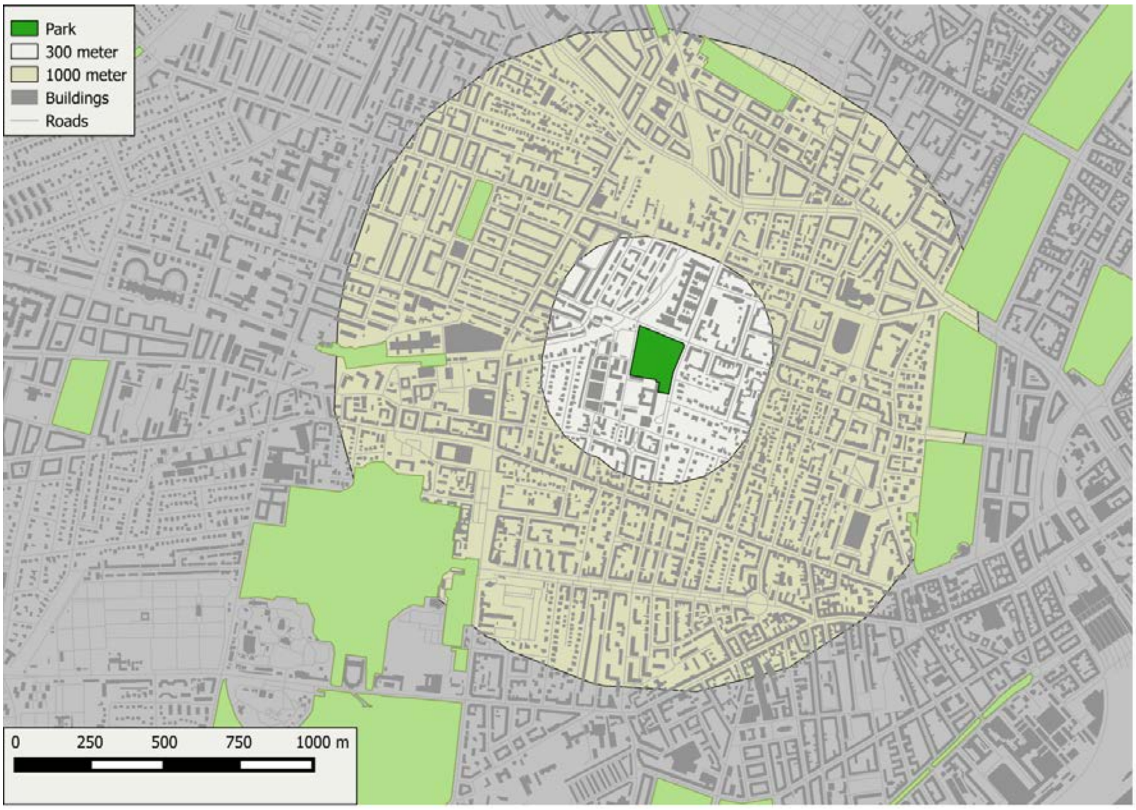

Figure 4: The proximity catchment area (small circle) and density catchment area (larger circle) around the Horticultural Garden of University of Copenhagen.

We calculated annual welfare loss of the reduction in recreational options for a scenario without the Horticultural Garden for both the proximity measure and the density measure. The calculation accounts for all apartments within the catchment area of the park. The apartments transacted within the analysis period of the first stage hedonic model only make op a small fraction of the apartments used in this calculation. The results of the calculation are presented in Table 5. The aggregated annual welfare loss is estimated to 2,688,386 EUR/year for the proximity measure, whereas the welfare loss is estimated more than 17 % lower at 2,220,890 EUR/year for the density measure. The difference between the two welfare economic calculations is a result of both the spatial extent of each measure and its distributional implications. Using the density measure, removing a park affects in a 1,000 m radius, compared to 300 m when using the proximity measure. In our case it means that about 10 times as many apartments are affected when using the density measure compared to the proximity measure. The effect of the difference in distributional impact can be seen on the mean and median willingness to pay between the two measures, where the individual household's welfare loss is five times higher for the proximity measure compared to when using the density measure.

Table 5 The distribution of welfare loss measured in EUR/year

	Max	1st Qu.	Median	Mean	3rd Qu.	Min	N	Aggregated welfare loss
Proximity	16,400	827	272	786	78	0	3470	2,688,386
Density	306	69	53	58	41	5	38,300	2,220,890

The non-marginal effect on individual households can be rather large depending on location and choice of measurement. However, the shock to the Copenhagen apartment market is limited. The predicted capitalized value increase using the first stage hedonic house price model indicates a relative price increase of 0.07% for the proximity measure and 0.06% for the density measure. In this perspective one might argue that the hypothetical removal of the Horticultural Garden could be following the definition of Bartik (1988) of a non-marginal localized event in the housing market, and is unlikely to lead to e.g. sorting effects in the short to medium run.

The difference in result of the two policy evaluations stresses the importance of how the relationship between parks and property price is constructed in the hedonic model. The definition of the relationship clearly has important implications for the welfare economic analysis, including the distribution of effects, and thus the potential policy implications when applying the two measures aggregated welfare loss is approximately the same regardless of the measure, but they differ in how the burden is dispersed across households. Using one measure approximately 3,500 households share the loss, where half of the households lose 272 EUR/year or more. In the other case, a smaller loss is shared by 10 times as many households and ¾ lose less than 69 EUR/year.

Discussion

Our main aim with this study is to bring further the environmental valuation field by reintroducing the alternative approach suggested by Bajari and Benkard (2005) to handle the non-trivial identification problems typically associated with the second stage of the hedonic analysis. This approach also enabled an analysis of preference variation across urban residents for environmental attributes of their neighborhood. Our second aim was to stress the importance of an appropriate specification of variables measuring the good in question. We used the approach to demonstrate just how critical the choice of park availability measures is for the assessment of welfare economic impacts of, in our case, an urban planning policy change. Here we discuss the estimations up against these aims and the literature as such.

The first stage hedonic price function

Many studies have presented first stage hedonic price functions using various measures of park availability for urban residents. In the present study, we apply two of the most prominent measures each in their own model, and combined in a joint model. These are park proximity, measured as distance to nearest park and censored at 300 m, and park density, which measures the area of parks available within a radius, here 1,000 m. Similar measures are used extensively in the literature (e.g. Lake et al. 2000; Mansfield et al. 2005; Kong et al. 2007; Cho et al . 2009; Jiao and Liu 2010). We find that both measures have significant explanatory power and parameters are of a meaningful size compared to earlier studies. We also find, however, that in our case including both in the same model results in only the density measure having a largely unchanged and significant ability to explain property prices, whereas the proximity measure decreases and becomes highly insignificant. This suggests that in our case, the density measure captures better the underlying utility experienced by households. This remains an empirical issue to be evaluated and assessed by the analyst in a transparent way from case to case.

The second stage: Recovering preference parameters

There are very few second stage hedonic price studies in the environmental economics literature all together, and in fact only one who has addressed the demand for urban green space, namely Poudyal et al. (2009). Part of the explanation for this is possibly the difficulties in setting up valid identification strategies, e.g. through the use of valid instruments. Here, we introduce to the field a transparent identification strategy based on functional form, which was suggested and applied by Bajari and Benkard (2005) and has been later applied by Bajari and Khan (2005) and von Graevenitz (2013). The functional form restriction can be criticized for being a strong, and potentially inaccurate, restriction. However, this in part remains an empirical question and the chosen form can be seen as a (good specific) local approximation for the unknown true form. Note that there are also theoretical as well as empirical challenges with the use of instrumental variable approaches as applied in the literature so far.

The results of our second stage estimation clearly show that parks in the inner city of Copenhagen provide a considerable flow of value to the local residents. Households in Copenhagen are willing to pay a considerable amount for parks be it either proximity or high density of parks near their homes. As shown in Table 3 and Figure 3, the two different modelling approaches result in mean willingness to pay estimates, which are in the same order of magnitude, and for a cursory glance have similar distribution. However, the density measure model has a longer and fatter tail involving a larger number of residents who spend more than 1,500 EUR/year on park availability.

Decomposing preference heterogeneity

Any policy change has distributional consequences, and in addition drivers like demographic changes may imply calls for new demands and policies. Therefore, it is of interest to policy makers and urban designers to analyze how preference heterogeneity can be explained by observable socio-demographic characteristics. We find that the preference variation to some extent can be explained by the socio-economic background of the households. In particular the patterns relating to families with or without children, to age and to the issue of single person households are interesting and can be used to inform city planners about how the heterogeneity in strength of taste between different socio-demographic groups living in the city may influence current and future needs and demands from the population. The growing number of single households is one urban trend, which our results suggest could enhance the demand for urban park availability. The aging population, however, in general has the opposite effect.

Policy evaluation and the choice of park availability measure

Our case study demonstrates that policy evaluation outcomes may hinge on which of the two park measures that are applied or believed to correctly reflect peoples' preferences for parks; proximity or density. Removing the Horticultural Garden in the core of Copenhagen results in an aggregated total welfare loss for the neighboring households within the same scale for both park availability variables, though it is 17 % lower for the density measure. However, the aggregated loss using proximity is shared by approximately 3,500 households only, whereas the aggregated loss using the density variable is shared by more than 38,000 households. Clearly, for both measures, the people living closest to the park stand to lose the most from a potential closure, but where the 25% worst off households according to a model using the density measure face a total loss of at least 69 EUR/year, a model using the proximity measure predicts they stand to lose at least more than 10 times as much, in fact at least 827 EUR/year, cf. table 5. Both measures captures the households situated close to the park, but where the model using the proximity measure predicts that it this group who will suffer the major part of the loss, the model using the density measure distribute more of the loss to people living further away.

Thus, the specifications differ in their numerical impact in ways that cannot be neglected. As noted earlier, the density measure appeared the stronger variable in the joint model, suggesting that in our case, this variable would be the preferred one from an empirical point of view.

On a more strategic level for urban planning, the implications of picking either of the two park measures here could likely result in different policy strategies being developed. If the proximity was the basis of a park policy strategy for Copenhagen, new parks would be planned and old parks would be preserved based on whether the park provided easy access to as many households as possible. This could lead to a strategy of many smaller parks given that (aggregate) size is ignored when using the proximity measure. The opposite would be true if the density measure was the basis of a park policy strategy. The planner would in this case be indifferent to the accessibility issue and would not have a specific strategy for having lots of small parks or one big park. The key goal would be to ensure a high level of park availability as measured in by the density measure.

Caveats

There are specific and general caveats in the approach and results presented in this paper worth mentioning. Starting with the specific, it should be noted that our datas describing sociodemographic variables for all households are related to the residents in in the last year of our cross section, 2011. Using coordinates of dwellings these were joined with all sales in the period 2007-2011. Hereby we essentially assume that the new residents moving to the area in the period 2007-2011 have the same observed socioeconomic characteristics as those who are already living in the area – or at least that the socio-demographic mean parameters of the 100×100 m fitted mean estimates were constant over the period. This might not be the case and could potentially explain our moderate ability to estimate how taste parameters for parks vary with sociodemographic measures. On the other hand, across the entire study area we have no reason to believe that the composition of people in terms of socio-demographic characteristics has changed substantially during the relatively short period.

A second general caveat of the hedonic method which is also true for our application here is, that when using the hedonic method for a policy change like the one evaluated, we only include the welfare effects of people living in the neighborhood. People further away, who e.g. work in the area (e.g. the more than 1,500 university employees and 4,000 students on that part of the campus), who visit the Horticultural Garden when visiting family or have other bonds to the garden may also experience welfare effects. These are not accounted for in the above or in any hedonic analysis.

We also note that the welfare economic loss here does not include attention to property taxes. As noted by Anthon et al. (2005), the fact that property owners in Denmark pay property taxes based on the market value of their property implies that part of any change in value – upward or downward – is transferred to the authority receiving the taxes. In our case, the drop in property values from closing a park will in part be transferred to the municipality as the households would have to pay slightly less property taxes. Thus, our estimated loss here is a conservative measure of the true loss as the ability to transfer part of the loss would reduce the shock on property prices.

The suggested approach to identification of the households' preference parameters for park is subject to criticism as already noted above. We have chosen a fairly simple and general functional form, which is flexible and allow for easy applications (Bajari and Benkard 2005). It can only be considered a local approximation to the unknown true functional form. We also note that similar assumptions are common elsewhere in the consumption literature, e.g. the discrete choice modelling literature based on the Random Utility Model framework (McFadden 1973).

Concluding remarks

The value of urban parks and green space for urban residents continuously attracts the interest of many types of research, including economics. A fairly large number of studies have estimated hedonic price functions for parks, other green areas, trees and similar goods and it is all but likely that this literature of applied environmental economics will continue to grow and increase the evidence for the obvious values of urban parks and green spaces.

However, there is an unfortunate shortage of studies addressing the estimation of demand for urban parks and green spaces; that is succeeding in estimating the so called second stage of the hedonic model framework. This is undoubtedly due to the difficulties in accounting appropriately for the endogeneity of price, typically the challenge being one of finding appropriate instruments.

In this study we aimed to bring further the field of studying urban green space values by introducing an alternative approach to the non-trivial identification problems typically associated with the second stage of the hedonic analysis, i.e. the estimation of demand schedules. Specifically, we suggest the functional form restrictions approach suggested elsewhere by Bajari and Benkard (2005). Second, having obtained that, we demonstrated how this may be used to elucidate the preference variation across urban residents for such environmental attributes of the neighborhood. We found that there is considerable willingness to pay for park availability. Patterns include that middle aged and senior households as well as households with children have a higher preference for park availability. Thirdly, using two standard measures of park availability, we demonstrated just how critical the choice of such measures is for the policy evaluation outcome.

Bibliography

Bajari, Patrick and C. Lanier Benkard. 2005. "Demand Estimation with Heterogeneous Consumers and Unobserved Product Characteristics: A Hedonic Approach." *Journal of Political Economy* 113(6).

Bajari, Patrick and Matthew E. Kahn. 2005. "Estimating Housing Demand with an Application to Explaining Racial Segregation in Cities." *Journal of Business & Economic Statistics* 23 (1).

Bark, RH, DE Osgood, BG Colby, G. Katz, and J. Stromberg. 2009. "Habitat Preservation and Restoration: Do Homebuyers have Preferences for Quality Habitat?" *Ecological Economics* 68 (5): 1465-1475.

Bartik, Timothy J. 1988. "Measuring the Benefits of Amenity Improvements in Hedonic Price Models." *Land Economics* 64 (2): 172.

Bin, Okmyung, Craig E. Landry, and Gregory F. Meyer. 2009. "Riparian Buffers and Hedonic Prices: A Quasi-Experimental Analysis of Residential Property Values in the Neuse River Basin." *American Journal of Agricultural Economics* 91 (4): 1067-1079.

Brasington, David M. and Diane Hite. 2005. "Demand for Environmental Quality: A Spatial Hedonic Analysis." *Regional Science and Urban Economics* 35 (1): 57-82.

Cho, Seong-Hoon, Suhyun Jung, and Seung Gyu Kim. 2009. "Valuation of Spatial Configurations and Forest Types in the Southern Appalachian Highlands." *Environmental Management* 43 (4): 628-644.

Danish Business Authority. 2011. *The Central Company Register* Danish Business Authority.

Day, Brett, Ian Bateman, and Iain Lake. 2007. "Beyond Implicit Prices: Recovering Theoretically Consistent and Transferable Values for Noise

Avoidance from a Hedonic Property Price Model." *Environmental and Resource Economics* 37 (1): 211-232.

Donovan, Geoffrey H. and David T. Butry. 2010. "Trees in the City: Valuing Street Trees in Portland, Oregon." *Landscape and Urban Planning* 94 (2): 77-83.

ESRI 2011. 2015. *ArcGIS Desktop*. Vol. 10.2.1. Redlands, CA: Environmental Systems Research Institute.

Jiao, Limin and Yaolin Liu. 2010. "Geographic Field Model Based Hedonic Valuation of Urban Open Spaces in Wuhan, China." *Landscape and Urban Planning* 98 (1): 47-55.

Kong, Fanhua, Haiwei Yin, and Nobukazu Nakagoshi. 2007. "Using GIS and Landscape Metrics in the Hedonic Price Modeling of the Amenity Value of Urban Green Space: A Case Study in Jinan City, China." *Landscape and Urban Planning* 79 (3): 240-252.

Lake, Iain R., Andrew A. Lovett, Ian J. Bateman, and Brett Day. 2000. "Using GIS and Large-Scale Digital Data to Implement Hedonic Pricing Studies." *International Journal of Geographical Information Science* 14 (6): 521-541.

Lundhede, Thomas, Toke Emil Panduro, Linda Kummel, Alexander Ståhle, Axel Heyman, and Bo Jellesmark Thorsen. 2013. *Værdisætning Af Bykvaliteter-Fra Hovedstad Til Provins: Appendiks* Institut for Fødevare-og Ressourceøkonomi, Københavns Universitet.

Mansfield, Carol, Subhrendu K. Pattanayak, William McDow, Robert McDonald, and Patrick Halpin. 2005. "Shades of Green: Measuring the Value of Urban Forests in the Housing Market." *Journal of Forest Economics* 11 (3): 177-199.

McFadden, Daniel. 1973. "Econometric Models for Probabilistic Choice among Products." *The Journal of Business* 53 (3): S13-S29.

Morancho, Aurelia Bengochea. 2003. "A Hedonic Valuation of Urban Green Areas." *Landscape and Urban Planning* 66 (1): 35-41.

Netusil, Noelwah R., Sudip Chattopadhyay, and Kent F. Kovacs. 2010. "Estimating the Demand for Tree Canopy: A Second-Stage Hedonic Price Analysis in Portland, Oregon." *Land Economics* 86 (2): 281-293.

Orford, Scott. 2002. "Valuing Locational Externalities: A GIS and Multilevel Modelling Approach." *Environment and Planning B* 29 (1): 105-128.

Panduro, T. E. and B. J. Thorsen. 2014. "Evaluating Two Model Reduction Approaches for Large Scale Hedonic Models Sensitive to Omitted Variables and Multicollinearity." *Letters of Spatial and Resource Sciences* 7: 85-102.

Panduro, Toke Emil and Kathrine Lausted Veie. 2013. "Classification and Valuation of Urban Green Spaces - A Hedonic House Price Valuation." *Landscape and Urban Planning* 120: 119-128.

Poudyal, Neelam C., Donald G. Hodges, and Christopher D. Merrett. 2009. "A Hedonic Analysis of the Demand for and Benefits of Urban Recreation Parks." *Land use Policy* 26 (4): 975-983.

R Core Team. 2015. *R: A Language and Environment for Statistical Computing*. Vol. 3.2.0. Vienna, Austria: R Foundation for Statistical Computing.

Rosen, S. 1974. "Hedonic Prices and Implicit Markets - Product Differentiation in Pure Competition." *Journal of Political Economy* 82 (1): 34-55.

Sander, Heather, Stephen Polasky, and Robert G. Haight. 2010. "The Value of Urban Tree Cover: A Hedonic Property Price Model in Ramsey and Dakota Counties, Minnesota, USA." *Ecological Economics* 69 (8): 1646-1656.

The Danish Geodata Agency. 2011. *Kort10*. Vol. 2011.

Train, K. E. 2003. Discrete Choice Methods with Simulation. Cambridge: Cambridge University Press, Cambridge.

Tyrväinen, Liisa and Antti Miettinen. 2000. "Property Prices and Urban Forest Amenities." *Journal of Environmental Economics and Management* 39 (2): 205-223.

von Graevenitz, K. 2013. "*Improved Methods for the Valuation of the Environment in an Urban Setting*."University of Copenhagen,.

von Graevenitz, Kathrine and Toke Emil Panduro. 2015. "An Alternative to the Standard Spatial Econometric Approaches in Hedonic House Price Models." *Land Economics* 91 (2): 386-409.

Wood, Simon. 2006. *Generalized Additive Models: An Introduction with R* CRC press.

Zhou, Qianqian, Toke Emil Panduro, Bo Jellesmark Thorsen, and Karsten Arnbjerg-Nielsen. 2013. "Adaption to Extreme Rainfall with Open Urban Drainage System: An Integrated Hydrological Cost-Benefit Analysis." *Environmental Management* 51 (3): 586-601.