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Hedonic Pricing Analysis of the Influence of urban green Spaces onto residential Prices: the Case of Leipzig, Germany

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Abstract

In the light of global urbanization and biodiversity loss, ecosystem services provided by urban green spaces (UGS) are becoming increasingly important, not least as a recovery and recreation opportunity for citizens. The valuation of UGS is significant for urban planners, who make decisions on the creation or removal of UGS. We analysed the influence of UGS on residential property prices in Leipzig, Germany, by applying a hedonic pricing analysis. This analysis complements the existing literature by considering both sale and rental prices for flats and houses; moreover, the shape of UGS is taken into account explicitly; finally, it is the first study in Germany to analyse UGS in hedonic studies to such an extent. The results demonstrate that the size of the nearest UGS has a stronger impact on prices compared to the distance from it. With respect to shape, we found that the simpler the UGS shape, the higher the prices. Although we find an impact of UGS on prices, the impact is smaller than that of other characteristics. The proposed valuation approach and obtained results inform urban planners regarding the design of new UGS and raise awareness about potential intended and unintended economic and social effects.

Keywords: Hedonic pricing, urban green spaces, housing market, ecosystem services, valuation, regression analysis

1. Introduction

Humanity is urbanizing quickly: more than half of the world's population lives in cities, and the proportion is expect to increase to 66% by 2050 (United Nation, 2014). Market values of housing in cities are determined by a considerable number of factors, such as the housing characteristics, proximity to the city centre and working place as well as the neighbourhood characteristics (e.g., the presence of schools, hospitals, unemployment rate, etc.). Increasingly, environmental characteristics and ecosystem services have been considered to be of importance. Cities appear to be stressful environments for their inhabitants due to the dominantly hectic lifestyles with only little space for rest and recovery (Bolund & Hunhammar, 1999). Next to a range of important ecosystem services, urban green spaces (hereafter UGS) can contribute to public health and increase the quality of citizens' lives directly or indirectly (D'Acci, 2014). In fact, the variety of parks and lakes can be psychologically very important for stress reduction (Ulrich et al., 1991).

Although many tend to agree that UGS are important, the extent of influence of UGS onto prices is difficult to determine (Tajima, 2003), especially because it is difficult to consider all potentially important variables. Moreover, apparently the comparability of various studies is complicated as the impact estimated for the same factor, for example proximity to UGS, can vary from one research to another, most likely due to different methods, input variables and characteristics of the case studies (D'Acci, 2014). Hedonic pricing analysis has been suggested to uncover such value determinants (Rosen, 1974). There is an increasing body of literature analysing housing prices, mostly for the U.S., Europe and Asia. As a background of our own study, we identified the following patterns and research gaps in the literature: first, most hedonic studies use selling prices of properties – usually houses – as dependent variables (e.g. Brander and

Koetse, 2011; Jim and Chen, 2006; Kong et al., 2007; Koramaz and Dokmeci, 2012; Kovacs, 2012; Melichar and Kaprová, 2013; Morancho, 2003; Ozus et al., 2007). Second, with respect to UGS variables, studies mostly consider: the size of UGS, distance to UGS, a combination of both as a so-called ‘size-distance’ index or an interaction of the two (detailed literature survey in Table S1 electronic supplementary material). Additionally, scholars have analysed the share of UGS within various spatial units, including both rather large spatial units, such as the share of UGS within a county or town, as well as quite narrow sizes such as radii of 200 m or 300 m around the property unit (Table S1). Also, the fragmentation and diversity of the landscape has been included as well as the view of the UGS from housing units, the number of street trees located in front of the property, the presence of an individual garden and ease of accessibility to the UGS with the proxy of walking distance (Table S1). However, to our best knowledge no hedonic study has used the shape of UGS as a variable in the analysis so far. This is surprising, as a whole body of literature in the area of environmental psychology and behaviour has established a fractal concept analysing forms of various landscapes and their perception (e.g. Cooper, Watkinson, & Oskrochi, 2010; Hagerhall, Purcell, & Taylor, 2004). Therefore, testing the effects of UGS shape onto housing prices is very interesting. Third, only few hedonic pricing studies have been conducted in Germany including UGS – however, mostly only as dummy variables without a detailed analysis or discussion (Ahlfeldt & Maennig, 2011; Brandt & Maennig, 2012; Buettner & Ebertz, 2009; Hamilton, 2007).

The present paper aims at filling the research gaps identified above. First, the shape of UGS is taken into account, in contrast to the majority of hedonic studies that consider only size and distance to UGS. The shape describes the spatial layout of a piece of land, for instance the relationship of the edge of the land and its area. Shape is a common measure in landscape ecology (Kevin McGarigal, 2013) and urban ecology (Alberti, 2005). The shape can be perceived by inhabitants when walking along the boundary of an UGS (e.g. a simple shape means long straight lines to follow, while a complex shape implies a meandering boundary). This could be related to the urban ecosystem service aesthetic appreciation (Haase et al., 2014) when entering an UGS or looking at it from a neighbouring flat and thus should be tested for its influence on housing prices. Second, we consider both sale and rental prices for flats and houses, whereas mostly selling prices were used in hedonic analyses to date. Third, the study will use the city of Leipzig as a case study, conducting a reasonably deep analysis of the importance of UGS in the German context for the first time. Thus, the guiding research question is: What is the influence of UGS (of different sizes, shapes) and distance to them on the rental and sale prices of residential property in Leipzig?

2. Materials and methods

2.1 Hedonic pricing model as a study framework

Hedonic pricing is based on the principle that the price of a marketed good is influenced by specific implicit characteristics of that good which can be disentangled and understood to either raise or lower the overall price (Rosen, 1974). The value that consumers attach to the particular characteristic will be reflected in the price of the differentiated product. The price of an individual characteristic is often referred to as the implicit or shadow price (Hamilton, 2007).

Bearing in mind that a housing unit is a multi-attribute good, its price can be determined by a set of independent variables, such as the number of available rooms, size, condition, etc. Moreover, environmental characteristics, such as proximity to UGS, size of the closest UGS and other spatial aspects, for instance, distance to roads or playgrounds, can explain further differences in the market prices of otherwise identical housing units. Adapting Geoghegan (1997) and Czembrowski (2016), the function of price can be formulated as follows:

$$P = \alpha \boldsymbol{X} + \beta \boldsymbol{U} + \gamma \boldsymbol{Z} + \varepsilon \qquad (1)$$

P - vector of housing prices (sales or rental);

X - matrix of housing characteristics;

U - matrix of environmental characteristics (UGS variables) without a market price (i.e., the hedonic variables);

Z - matrix of other spatial characteristics without a market price (e.g., distance to transportation stops, disamenities, etc.);

α, β, γ- vectors of estimated regression coefficients;

ε - vector of random error.

2.2 Case study

The study is conducted for the city of Leipzig, Germany, a city of approximately a half million inhabitants. The city of Leipzig has a relatively large amount of various forms and types of UGS that in total comprise approximately 4,900 ha, compared to 6,300 ha of residential area. What is particularly interesting for our analysis is that several large parks are located very close to the city centre and some forested areas are located within the city boundary, which makes UGS easily accessible. Finally, in Leipzig, similar to all German cities, renting is much more common than the purchase of residential properties.

2.3 Data

Two types of data are employed here: real estate data, which provide information on the residential prices as well as structural variables of the real estate (e.g. presence of balcony, elevator, etc.), and additional spatial data, which put the real estate information into the context not only of UGS but also of other relevant market value determining factors. Study variables were chosen based on the literature review presented in section 1 and taking into account data availability. Spatial data analysis was performed with ArcGIS v.10.1, and landscape metrics were computed using FRAGSTATS v4 (McGarigal, 2012). All statistics was calculated using R v.3.1.2 software (R Core Team, 2014).

2.3.1 Real estate data

The market data for the hedonic analysis (i.e. real estate prices and structural variables) was obtained from the real estate web-portal Immobilien Scout GmbH. The initial data set for the study area contained 308,586 real estate entries of housing units on offer for the period 2007-2013. Because the dataset depends on user entries on the website, it does not have high reliability throughout. To address potential data flaws, it was carefully analysed for inconsistencies, double entries and missing values. Based on the literature review, investigation of housing market features in Leipzig and specification of the data set, cut-off criteria were applied to exclude unrealistic outliers from the data. The minimum size for all housing units was set to 15 m^2 and the maximum to 300 m^2 for flats and 500 m^2 for houses, respectively. Additionally, the maximum number of rooms was defined as 6 for flats and 8 for houses. In total, 13,765 entries were eliminated due to implausibility and to ensure comparability, and 4,262 duplicate entries were identified and removed.

As an outcome of the housing data preparation, the following groups were formed: flats available for rent (261,827 entries), flats available for sale (19,465 entries), and houses available for rent (907 entries) and for sale (8,360 entries).

Using the full time period 2007-2013 enabled us to perform multiple statistics for all four housing categories separately. Although the financial crises had no significant effect on the German real estate market for residential properties (van der Heijden, Dol, & Oxley, 2011), we normalized housing prices with year 2007 being the base year and added the year as a dummy variable into the statistical models.

Due to privacy regulations of the real estate web-portal, the addresses of the housing units were assigned the geographical coordinates with some approximation before 2012, meaning that instead of the exact house number, the median point of the corresponding street section (which as a rule consisted of not more than 20 homes) was used; data from 2012 on is based on exact addresses. In the statistical analysis it was checked whether this approximation has an influence onto the results.

Some housing variables contained the high number of missing values. In order to overcome this obstacle imputation and logical recoding techniques were applied (see electronic supplementary materials for more details). To check the robustness of the regression models, the logically imputed variables were also imputed, and the models were run with different combinations of recoded and imputed variables. As there were no relevant changes we report models with logically recoded variables only (Table 1).

2.3.2 Additional spatial data

Additional data on land use was from the official administrative database ATKIS (Germany's nationally standardized official topographic-cartographic information system) for the year 2010, provided by the Federal Agency for Cartography and Geodesy of Germany. The spatial resolution of the maps is 1:25,000 with a positional accuracy of +/- 3 m. Additional spatial data were obtained from the City of Leipzig.

The spatial delineation for the purposes of the present study is the municipality of Leipzig in its administrative boundaries. Data on UGS and other spatial data on land use were considered in addition to the city boundaries for a 5 km buffer. This buffer was chosen to analyse the effect of UGS as well as the other land-use categories on the housing units located on the outskirts. Annex 1 presents the land use categories that were selected based on the literature review and the availability of the data in the case study area.

For the purpose of the study, we combined the land cover types of forests, parks, woods, allotments and cemeteries to represent UGS. We believe that these provide recreational services to local population to some extent and thus suit us the best in answering our research question. We differentiate UGS from other green areas such as agriculture. In total, 1,678 UGS were identified in the case study area extending to a 5 km buffer, with the smallest UGS equalling 0.0025 ha, the largest 568.3 ha and the average UGS equalling 5.89 ha. No minimum or maximum size was defined as a selection criterion for UGS or other spatial variables.

2.4 Study variables

Annex 2 presents the final set of variables and indicates their relevance to a particular group of housing. We indicate the expected effects on property prices as dependent variables based on the literature review complimented by our own expectations. Spatial and UGS variables are the same for all four groups of housing, whereas there are different combinations of housing variables for each group (as flats have different attributes than houses). Furthermore, we included a categorical variable **Districts** in order to account for aspects of the districts that potentially influence the housing prices but were either out of focus for our study or could not be quantified due to a lack of data.

Independent variables are classified into UGS, housing and spatial variables (Annex 2). Four UGS variables were included in the final regression models and are the focus of our analysis: (1) **Size** of the UGS nearest (linear distance) to the respective housing unit. (2) **Shape** measures the complexity of the UGS spatial form nearest to the housing unit by comparing it to a square as standard shape form. Shape is equal to 1 when the patch is maximally compact (i.e., it is a square) and increases without limit as patch shape becomes more irregular (McGarigal, 2012, see also Figure 1). (3) UGS **ShareBuffer** is a variable that represents the share of UGS within a 300 m buffer zone around the housing unit. Finally, (4) **Distance** refers to the distance of the closest UGS to the respective housing unit.

The dependent variables in our study are rental and sale prices in €/m^2 used for flats and houses offered for rent and sale. We decided not to use the total price, but rather the price per square meter, as a dependent variable because our research question focuses on the additional effect of UGS onto prices, which should be clearer in relative prices rather than hidden in absolute prices. Absolute prices are to a large extent determined by housing size, so that the impact on relative prices is easier to grasp. In doing so, we follow the approach of other hedonic pricing studies for UGS (Czembrowski & Kronenberg, 2016; Rehdanz & Maddison, 2008; Tyrväinen, 1997).

[Figure 1 near here]

2.5 Correlation analysis and linear regression models

As a final stage of data preparation, correlation analysis was performed to avoid collinearity in the regression model. Highly interconnected variables were detected in correlation analysis using Pearson's coefficient for numerical and Kendal's tau b for categorical variables. Highly correlated variables with $|r|>0.7$ were excluded from further analysis, following an often used approach for data sets with large numbers of explanatory variables (Dormann et al., 2013). Furthermore, each version of the regression model was differentiated for *rented flats*, *sold flats*, *rented houses* and *sold houses*.

We are aware of the advantages of the parametric spatial econometrics models (e.g. Ahlfeldt and Maennig, 2011; Czembrowski and Kronenberg, 2016; Larson and Perrings, 2013) and also of the disadvantages of parametric models (von Graevenitz & Panduro, 2015). Still, we decided to use the linear regression approach which was also used by number of scientists (Donovan & Butry, 2011; Hamilton, 2007; Jim & Chen, 2006; Kong et al., 2007; Melichar & Kaprová, 2013; Morancho, 2003; Rehdanz & Maddison, 2008; Tyrväinen, 1997) as we for the first time analyse data for the German case and rented housing and therefore intend to ease comparisons to other studies as far as possible. In our models, we include the districts as spatial fixed effect to control for spatial autocorrelation and simplify the models by means of AIC, Akaike's information criterion (Akaike, 1974). AIC is based on the trade-off between the goodness of fit and number of parameters required by model parsimony, with lower AIC indicating the better fit (Crawley, 2007). Thus, AIC instead of statistical significance was the decisive criterion for the best model fit. Notwithstanding, in the following section, the levels of significance are provided for the sake of completeness.

3. Results

3.1. Descriptive results

Figures 2 a and b show that real estate data fully cover the residential area of the city. This supports the assumption that there is no bias with respect to area sampling and that the data are comprehensive and representative.

[Figure 2 near here]

Annex 3 provides further descriptive statistics for the variables used in the hedonic analysis.

3.2 Hedonic pricing analysis

Table 1 represents the results of the hedonic analysis for all four housing categories, combining imputed and logically recoded data.

[Table 1 near here]

Figure 3 visualizes the results for the hedonic analysis for all four housing groups. It includes all UGS variables as well as three most important (i.e., highest absolute standardized coefficients) other independent variables.

[Figure 3 near here]

3.2.1 Influence of UGS variables

When comparing the standardized regression coefficients of UGS variables with other spatial variables and housing characteristics (Table 1 and Figure 3), we find that in most cases, the impact of UGS variables on prices is small compared to other variables. In some cases, however, UGS appeared to have a similar strength of influence and, in some cases even stronger impact on prices compared to other spatial variables, for example, *proximity to playgrounds* or *agricultural sites*.

The majority of UGS variables entered the final model with the expected direction of influence. Our results demonstrate one noteworthy exception, however: surprisingly, we find that increasing distance to the nearest UGS has a positive effect on the housing prices of *sold flats*.

The results demonstrate that the *shape* of the nearest UGS only influences housing prices in case of *rented* and *sold flats*. Namely, as the shape increases in complexity by 1 unit (see Figure 1 and Annex 2 for more details) the *rental price* decreases by 0.01 € for every m^2. In contrast, it leads to the increase of prices by 19.21 €/m^2 in case of *sold flats*. The *size* of the nearest UGS has a positive effect on prices. However, for both *rented flats* and *rented houses*, the effect as quantified with the regression coefficient is rather small. The *share* of the UGS in the 300 m buffer has a substantial influence on the prices per m^2, especially in the cases of *houses* and *flats* for *sale*. In other words, a 1% increase in the share of UGS causes a 1.52 € increase per m^2 for *sold flats*, and 1.15 € for *sold houses*. Finally, an increase in the *distance* to the nearest UGS by 100 m causes an increase in price by 14 €/m² for *sold flats*.

3.2.2 Influence of other variables

The *distance to the city centre* has the greatest impact on housing prices compared to other variables. As the distance to the city centre decreases by 1 km, every *rented flat* gains 0.07 €/m² in the price and every *rented house*, 0.20 €/m². For housing units available for sale, the increase in prices is 94 €/m² for *sold flats* and 44 €/m² for *sold houses* (Table 1).

Of the housing characteristics, the *year* in which the housing unit became available for rent or sale and its *size* are relevant. The *year* was included in three out of four final models, but the overall impact onto prices is rather limited. Compared to the year 2007, *flats for rent* were slightly more expensive in 2008 to 2010 and in 2012, but slightly cheaper in 2011 and 2013. A similar pattern was found for flats for sale, with flats being somewhat more expensive in 2008 to 2011, but slightly cheaper in 2012 and 2013 when compared to 2007. The *year* did not stay in the final model for houses for rent, and houses for sale were cheaper in the years after 2007. The *size of housing units* entered the final model with expected signs for all categories, besides *sold flats*, where with every additional m^2, the price increases by 3.9 €/m². Data on *balcony presence* was not available for houses, while for flats, its presence causes a price increase of 0.43€/$\mathbf{m^2}$ in the case of *rented flats* and 200 €/m² for *sold flats*.

Finally, the dummy variable which was coding the spatial approximation of addresses was not included in any final model.

4. Discussion

4.1 UGS variables

The following paragraphs will provide key insights into the interpretation of the regression analysis results regarding the UGS variables. Figure 4 summarizes the extent to which UGS variables influence the price of different housing categories.

[Figure 4 near here]

In our study, UGS have relatively low impact on housing prices compared to other independent variables. This goes in line with Jim and Chen (2006), who argued that in spite of the high ecological value of green spaces, they do not convince residents to pay more for housing units, which in turn, can be represented as a relatively low impact of UGS on housing prices. Two lines of argument could be relevant here: residents either do not highly value the ecosystem services provided by UGS, or they do not realize that ecosystem services – specifically indirect and intangible services, such as the improvement of air quality (Bolund & Hunhammar, 1999) – are actually provided by UGS and are higher as they move closer to those areas.

4.1.1 Size of the nearest UGS

As expected, the *size* of the nearest UGS has a positive influence on housing prices for *rented flats* and *rented houses*. This can be explained by many positive ecosystem services assumed to be related to UGS, in particular, the recreational feature of UGS. In fact, UGS *size* tends to be perceived differently by different people: small UGS usually have playgrounds and fields, while large parks may offer opportunities for hiking and access to flora and fauna (Larson & Perrings, 2013).

The *size* of the nearest UGS has influence on the *selling prices* for *houses* and *flats*. In this respect, it can be assumed that owners have different perceptions and preferences with regard to UGS compared to people renting their homes. Namely, homeowners may prefer to have private gardens rather than living next to a large public park, which might bring security issues. In contrast, rental tenants may be less willing to invest money and time in a garden given their limited-term occupancy, and these investments typically cannot be recouped when they move out (Donovan & Butry, 2011). Unfortunately, the presence of private gardens for houses is not included in the real estate data base. We assume this is due to the fact that it is not common to have access to a private garden for flats, therefore, it is important in a real estate data base to state if it is the case. However, for houses, a garden can be assumed, and, therefore, no variable is included. Thus, it was not possible to statistically compare the importance of private gardens for *sold flats* and *sold houses*.

4.1.2 Share of UGS within 300 m buffer zone

The *percentage* of UGS within a 300 m buffer zone has a positive influence on the prices of housing units that are available for sale. This is in line with the results of Kong et al. (2007), who found that housing properties with a higher percentage of green spaces around them have higher values.

However, the percentage of UGS in a 300 m buffer was not included in the final regression model for *rented flats* and *rented houses*. Together with the rather low importance of the other UGS variables for *rented flats*, it seems that UGS in general are of lower importance for *rented flats* than for the other housing types. One could assume that the reason for this is that renters usually stay for a limited period and, therefore, do not pay much attention to the surroundings of the housing unit (at least to the extent that they are willing to pay extra based on those surroundings); instead they prefer having one large UGS in the vicinity (as is proven by our abovementioned finding). In fact, statistical data for the city of Leipzig (Amt für Statistik und Wahlen, 2015) show that, on average, inhabitants of Leipzig stay 9.4 years in one housing unit; that the duration of living in one housing unit is negatively correlated with age; and that the duration is larger in districts with a higher share of owned houses. Additionally, Leipzig is one of the so-called ‘student cities’ (Hayat, 2014) with an average number of students and trainees in vocational schools equal to approximately 46,500, or 9% of the total population from 2010 to 2012 (Amt für Statistik und Wahlen, 2013). This may further support the statement about unwillingness (and the lack of ability) to pay extra for surrounding UGS as the period of residence is less than 3 years and thus relatively short for young people between 21 and 28 years (Amt für Statistik und Wahlen, 2015).

4.1.3 Distance to the nearest UGS

The variable measuring the *distance* to the closest UGS did not enter the final models for *rented flats*, *rented houses* and *sold houses*. Surprisingly, for *sold flats*, the distance variable has a relatively high positive influence on prices. In other words, with every additional meter to the nearest UGS, the price per m^2 rises. In fact, the existing literature provides a controversial argumentation with respect to the impact of UGS *distance*. Therefore, on the one hand, our findings contradict some previous findings (Ahlfeldt & Maennig, 2011; Brandt & Maennig, 2012b; Palmquist, 1992; Tu, Abildrup, & Garcia, 2016) and our expectations. On the other hand, Kovacs noted that “the distance from parks does not always lower the property values” (Kovacs, 2012, p. 80). Moreover, Kong et al. (2007) argued that transformation of distance to and the size of the nearest UGS into one **Size-Distance** index is needed to avoid the bias that might occur if those variables are included separately. In our case, such an index was also calculated, however, it did not enter the final model due to its high correlation (|r|>0.7) with the variable **Size** of the nearest UGS. Furthermore, Bolitzer and Netusil (2000) found that housing units that are located too close to the UGS (i.e., less than 100 feet) do not command higher prices compared to those units that are more remote – supposedly due to negative externalities, such as noise, caused by the proximity. Alternatively, this phenomenon could also be explained by the findings of Lo and Jim (2012), who argued that vegetation can be used as a hiding place by criminals and potentially cause noise exposure (Kovacs, 2012; Larson & Perrings, 2013; Lo & Jim, 2012). This could also apply to Leipzig, which in 2013 had the tenth-highest rate of officially recorded criminal acts among German cities with a population over 200,000 people (Bundeskriminalamt, 2013). Additionally, large UGS could be an attractive place for teenagers to congregate, particularly at night (Lee, 1997), which is likely not desired by the majority of residents.

In addition to that, people who buy or rent houses may be concerned about the fact that trees produce organic litter and block the light, especially during the winter season when the days are short (Tyrväinen, 1997). Respondents identified this factor as somewhat annoying in the survey of Lo and Jim (2012). This can explain the fact that distance to nearest UGS did not enter the final model for the houses (i.e. both *rented* and *sold houses*).

To sum up, there is no single convincing interpretation of the findings, suggesting that that further investigation on the distance to the nearest UGS is needed. In particular, future studies should investigate the possibility of U-shaped effects as well as the influence of distances to other places (namely, distances to playgrounds, sport places, agricultural sites, waterways and transport stops) that were found to have unexpected signs in our study.

4.1.4 Shape of the nearest UGS

The *shape* of the nearest UGS is considered to be one of the novelties of our research, as it has not been previously discussed in the hedonic analysis of UGS in the literature. We hypothesized that besides *size* and *distance* to UGS, *shape* also influences housing prices. For two categories, *rented houses* and *sold houses*, the UGS shape did not enter the final model. This is in line with our interpretation that people who live in houses may prefer private gardens and are thus not concerned about characteristics of public UGS.

In both cases, the influence of *shape* onto prices as measured with the standardized regression coefficients is of similar weight as the other UGS characteristics. This finding indicates that this UGS characteristic will be worthwhile to investigate more deeply. However, the direction of effects is opposite for both housing types: for *rented flats*, *shape* has a negative influence on price, but a positive influence for *sold flats*. In other words, more complex *shapes* of UGS decrease the price of *rented flats*, while they increase the price in the case of *sold flats*. In the introduction, we hypothesized that *shape* could be perceived by inhabitants when walking along an UGS and when looking at it from a neighbouring house, meaning that *shape* would influence the aesthetic appreciation of UGS. In fact, previous studies have indicated that human-influenced landscapes have a simpler *shape* compared to natural landscapes (O'Neill et al., 1988; Tian, Jim, & Wang, 2014). This means that simpler UGS are not "wild" but rather "nice-looking". Following this line of thinking and the regression coefficients found in our study, one could conclude that people who rent flats prefer having nice UGS (i.e., with simpler shapes) next to their homes, while those buying flats prefer more variation or even "wild" UGS. In fact, a number of studies provides a deeper discussion of the influence of wild vs. tended natural environments on the well-being of the people (e.g. Martens, Gutscher, & Bauer, 2011). For instance, one study showed that well-kept natural environments more strongly increase restoration of concentration (Herzog, Maguire, & Nebel, 2003). However, Hagerhall (2004) argues that it is complicated to clearly relate preferences to the fractal dimension of natural environments. On top of that, also other factors such as criminality might be related to UGS *shape*, as more complex sites may be less easy to monitor, e.g., by video surveillance/closed circuit television (CCTV) of the edges and borders of the UGS where criminals could enter and leave the area. Finally, the *shape* of an individual UGS could also rather signify the overall fragmentation of the landscape in the immediate vicinity of the housing unit (Geoghegan, Wainger, & Bockstael, 1997). To sum up, the shape of UGS proved to be a relevant UGS characteristic for *flats*. However, this should not only be confirmed for other cities, but also the reasons should be analysed in more detail. In fact, there are several techniques applied in the other fields of research, for example, the method of photograph studies (Ulrich, 1986), experimental procedures applied in environmental psychology (e.g. Martens, Gutscher, & Bauer, 2011; Tyrväinen et al., 2014) and analysis of fractal dimensions with consideration of visual quality measurement (e.g. Cooper et al., 2010; Hagerhall et al., 2004).

4.2 Other variables

Distance to the city centre had a negative impact on the prices of all four housing groups, which corresponds to previous findings that *distance to the city centre* is one of the strongest explanatory variables (Ahlfeldt & Maennig, 2011; Donovan & Butry, 2011; Jim & Chen, 2006; Melichar & Kaprová, 2013; Tyrväinen, 1997).

Similar to Donovan and Butry (2011), the impact of housing properties in our case are consistent with previous hedonic studies, with a few minor exceptions.

The negative impact of the variable *housing size* onto prices can be explained by the fact that in our study we considered price per sq. meter. Thus, our finding indicates that relative prices are higher for smaller housing units. Often studies rather look at overall rent or selling prices that of course have a large and positive impact on absolute prices.

The presence of a *balcony* has a positive effect on the prices of flats, which is consistent with the findings of Brandt and Maennig (2012b, 2011) and Rehdanz and Maddison (2008). We think it is worth further analysis to examine whether balconies are perceived as a small and very personal form of UGS, especially by elderly people. Finally, the effect of the presence of a *garden* is consistent with our expectations and has a positive effect on flat prices. In fact, the given results support our previous argumentation that citizens might value private gardens to the detriment of public UGS. For houses, the information on the presence of gardens was unfortunately not available; thus, no corresponding statistical findings can be provided for our case study.

4.3 Limitations of the study

This research is marked by a number of limitations that offer a platform for further research. First, the quality of the real estate data was not perfect. There were many missing values that required various statistical procedures to overcome the given obstacles (i.e., logical recoding and imputation). Additionally, the relatively low impact of UGS on housing prices may be partly due to the approximation of coordinates for the real estate data, as it added some noise to the quantification of all spatial data including the UGS. However, after all models achieved the best fit by means of checking AIC (section 2.5.), the dummy variable coding the approximation of addresses did not stay in any of the models; so that we believe the approximation has only a marginal effect onto results. Moreover, some very important characteristics for our study, namely, the presence of private gardens in houses for rent or sale, were not available.

Secondly, not all areas that we would have liked to include as UGS could be identified because the spatial data on UGS provided no information on street tree cover. Furthermore, we used Euclidian distances for proximity to UGS rather than the street network. Given the short distances for the Leipzig case study (mean distances about 200 m, maximum distances less than 800 m), residents are likely to rather walk there than use another mode of transportation, the street network likely will not add much information. However, using travel times in a street network might be relevant for other cities that are less green overall.

Given the data availability from Immobilien Scout GmbH, we used listing prices (i.e. requested selling/renting prices stated on the web by the offering party) for housing units as the dependent variable instead of the actual transaction price (i.e. price at which housing units were sold or rented) - which were not available. Considering the features of the housing market in Germany, some negotiations are likely to take place for *houses* and *flats for sale*, whereas in case of renting, negotiations are an uncommon but not unprecedented practice. We assume, however, that there is no systematic pattern related to how UGS influence the negotiations, and thus, the listing price can be considered as an proxy of the actual transaction price.

Finally, the case of Leipzig might be a bit outstanding from the average European city due to its comparatively large stock of housing from the so-called “Gründerzeit” of the late 19th century.

4.4 Suggestions for future research

Building upon some of the abovementioned limitations, as well as the findings of the presented analysis, the following directions for further research are suggested. Returning to the less affluent students who might not care or be able to pay extra for UGS as discussed in section 4.1.2, first, we hypothesize more generally that the impact of UGS on prices differs for richer and poorer districts within a given city, as only the well-off can afford to live close to UGS. One way to approach this would be to compare the effects of UGS on prices for those city districts where housing prices and/or incomes are the highest with districts where housing prices and/or incomes are lowest. Second, it might be valuable to analyse the impact of different types of UGS types, as suggested by Panduro & Veie (2013), instead of aggregating them into one category, as different UGS might provide different ecosystem services and thus different benefits for residents as well as different impacts on the residential prices. Third, it might be valuable to include biodiversity to some extent, as Donovan and Butry (2011) noted that both the location of trees and their types, as expressed in their leaves and canopies, are important for housing units. Fourth, it could be interesting to further investigate the impact of the distance from UGS on housing prices, given the ambiguous effect found in our study and in the literature. Fifth, adding other variables such as population density (Brander & Koetse, 2011) or proximity to different additional points of interest, e.g., shopping centres, schools, kindergartens, or hospitals, could play a role in the perception of UGS. Sixth, according to Kong et al. (2007), the values that society attributes to UGS may also be related to social factors. For example, a family with children may place a higher value on the educational environment or presence of kindergartens than on environmental amenities. Thus, social factors should also be considered in future research. What is more, it might be valuable to calculate how the creation of additional green space can influence the market situation (Bartik, 1988) keeping in mind that the balance between greening strategies and social-inclusion should be kept (Haase et al., 2017). Furthermore, a more detailed analysis on the differences between the preferences of people who buys versus those who rent might be valuable. Additionally, keeping in mind the potential existence of spatial dependence effects and spatial processes which are being omitted, it might be of use to investigate other methods such as spatial hedonic modelling (Brandt & Maennig, 2011; Czembrowski & Kronenberg, 2016; Kovacs, 2012) as well as to perform a sensitivity analysis (von Graevenitz & Panduro, 2015) and investigate the effects of different flats in the same house and thus same UGS variables in future studies.

5. Conclusions

As an outcome of the hedonic analysis for Leipzig, we conclude that various UGS characteristics have a significant but fairly small impact on housing prices, which, in turn, depends on the housing category (i.e., *rented flats*, *sold flats*, *rented houses* and *sold houses*). This may correspond to different groups of people (i.e., people with high income, unemployed people, singles, families with children, etc.) having different perceptions or preferences with regard to the ecosystem services provided by UGS, which are indicated in their willingness to pay for various housing units considering different UGS amenities.

Returning to our research question, we can state that *size* of the nearest UGS has a more relevant impact on the price than the *distance* to the nearest UGS. The latter, in turn, has an unexpected direction of effect. This is somewhat surprising, as following with common sense; one would expect that proximity to parks would engender benefits, such as recreational opportunities and aesthetic satisfaction. In addition to benefits, however, being too close to UGS may also increase residents' exposure to potential disamenities associated with parks, such as noise and crime (Larson & Perrings, 2013). With respect to the *shape* of the nearest UGS, it was found that the simplest shape (i.e., similar to square) has the highest positive impact on the housing price. Even if it was not our intention at the beginning of the study, we came to the further conclusion that UGS have different impacts depending on the particular housing category (i.e., *rented flats*, *sold flats*, *rented houses*, and *sold houses*).

We assume that the different impacts of UGS on prices reflect the diverse preferences of different individuals. Lo and Jim (2012) suggested that more educated residents usually prefer one large park that can supply more ecosystem services and recreational facilities. Large parks serve as more effective ecological repositories by providing benefits to more users. They argued that employed citizens prefer large parks, whereas retired elderly residents prefer small parks that can be conveniently accessed. With less mobility, retired people are less amenable to traveling long distances to reach a large park. This argumentation can be applicable to the city of Leipzig, which is considered a ‘student city’; at the same time, however, it also has a substantial elderly population. In this respect, we assume that including the social variables (e.g., demographic statistics) in the hedonic study in future research may be very promising especially in order to study the revealed preferences for neighbourhood amenities. Similarly, we might assume that tenants are different than buyers, and also that flats are distinguished from houses according to and reflecting the preferences of their resident populations, which are partly related to UGS.

In conclusion, from the consumer’s perspective, we assume that people looking for new housing units are not always willing to pay more for UGS. In this regard, hedonic pricing is indicative of the lower value of the willingness to pay for UGS compared to presumptive results of stated preferences valuation studies. This leads to the conclusion that despite the relatively low impact found in our study, we should not underestimate the significance of the impact of UGS on housing prices when further considering the various demographic issues and residential mobility.

Moreover, when examining UGS issues from the viewpoint of urban planners, the value of UGS should be recognized and considered, especially in regard to decisions about creation or removal of existing UGS. This is specifically important for countries like Germany where current low interest rates together with high housing demand lead to a massive densification of cities, including displacement of UGS (Dosch, Haury, & Wagner, 2016). Additionally, the awareness about the UGS value can potentially assist in mediation and conflict management within Public Private Partnership models for urban development, where interaction between real estate developers, non-profit organizations and public bodies take place for meeting a consensus on construction decisions. Moreover, so-called urban greening strategies, as part of urban renewal, should be applied carefully in order to prevent gentrification which might occur as a result of increased housing prices (Haase et al., 2017). In this respect, hedonic pricing, as demonstrated in the present study, provides a means for estimating the value of UGS through the implicit price derived from the hedonic pricing equation. Such information has the potential to inform the sustainability of future landscape design if used in the setting of land-use policy. In other words, understanding how the value of UGS is capitalized in the housing market is important not only to real estate developers, who could potentially profit from building more desirable housing units, but also to urban planners and decision makers so that they can foster the adequate provision of local public goods provided by UGS through the application of land-use regulations (Saphores & Li, 2012). Thus, in the long run, this study contributes to the elaboration of scenarios for the joint development of UGS and housing.

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List of Tables

Table 1. Results of hedonic analysis based on linear multiple regression of residential data

See Annex 2 for abbreviations; Significance code: '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1.
'**-**' variable was not included in the final model due to AIC. '**NA**' **-** variable was either not applicable for housing group or no data were available. Some statistically non-significant variables entered the final model due to the application of AIC. The estimates for the 63 districts are not given here.
[a] Comparison of prices to 2007 (basis year).

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Figure 1. Different shape complexity in case of Leipzig UGS

Examples of UGS with (a) simple shape: shape index = 1; (b) medium complexity: shape index = 3.5; (c) complex shape: shape index = 5.2.
Sources: Own representation, ATKIS data

Figure 2. Location of (a) UGS and residential area overlaid with (b) real estate data in the case study area

Sources: Own representation, data from ATKIS, 2010 and Immobilien Scout GmbH. The white sections on the maps indicate other types of land uses (e.g. agricultural land, water, etc.)

Figure 3. Effect of selected variables on prices

Figure 4. Effect of UGS on housing prices

* Following abbreviations were used: FR - *rented flats*, FS – *sold flats*, HR – *rented houses*, HS – *sold houses*

Tables

Table 1

€ / m^2	Rented Flats 261,827 observations			Sold Flats 19,465 observations			Rented Houses 907 observations			Sold Houses 8,360 observations		
	Estimate	**Standard.**		**Estimate**	**Standard.**		**Estimate**	**Standard.**		**Estimate**	**Standard.**	
(Intercept)	4.51	0	***	1226.67	0	***	8.08	0	***	1830.93	0	***
a. UGS Variables												
Shape	-0.01	-0.01	***	19.21	0.02	***	-	-		-	-	
Size	1.6e-08	0.01	***	-	-		1e-07	0.08	*	-	-	
ShareBuffer	-	-		1.52	0.02	**	-	-		1.15	0.03	*
Distance	-	-		0.14	0.03	**	-	-		-	-	
b. Housing Variables												
HousingSize	-0.01	-0.17	***	3.90	0.23	***	-0.003	-0.09	*	-0.90	-0.09	***
Garden	0.08	0.04	***	108.73	0.07	***	NA	NA		NA	NA	
Year: 2008 [a]	0.04	0.01	***	30.65	0.01	.	-	-		-	-	
Year: 2009 [a]	0.03	0.01	***	12.78	0.01		-	-		-30.81	-0.02	.
Year: 2010 [a]	0.08	0.04	***	40.36	0.02	**	-	-		-31.75	-0.03	.
Year: 2011 [a]	-0.01	0.00		23.92	0.01		-	-		-27.78	-0.02	
Year: 2012 [a]	0.02	0.01	***	-5.75	0.00		-	-		-48.59	-0.04	**
Year: 2013 [a]	-0.03	-0.01	***	-72.51	-0.04	***	-	-		-87.65	-0.07	***
Proxy coordinates	-	-		-	-		-	-		-	-	
GuestWC	0.40	0.08	***	174.23	0.09	***	-0.24	-0.08	*	169.85	0.17	***
BathroomNr	0.67	0.12	***	141.17	0.07	***	0.33	0.15	***	NA	NA	
Elevator	0.36	0.15	***	204.65	0.14	***	NA	NA		NA	NA	
Kitchen	0.23	0.09	***	-132.54	-0.07	***	0.47	0.17	***	NA	NA	
Balcony	0.43	0.22	***	200.02	0.13	***	NA	NA		NA	NA	
Floor	-0.01	-0.02	***	-8.21	-0.02	***	NA	NA		NA	NA	
Condition: GoodState	-0.17	-0.06	***	-191.94	-0.03	***	-0.47	-0.14	***	NA	NA	
Condition:BadState	-0.25	-0.03	***	-182.46	-0.10	***	-0.21	-0.02		NA	NA	
HeatType: HeatCentr	-0.10	-0.02	***	NA	NA		NA	NA		NA	NA	
HeatType: HeatFurnance	-0.06	0.00	*	NA	NA		NA	NA		NA	NA	
HeatCotsIncl	-	-		NA	NA		NA	NA		NA	NA	
Monument	NA	NA		61.57	0.03	***	NA	NA		78.96	0.02	.
Deposit	0.12	0.02	***	NA	NA		-	-		NA	NA	
HolidayHome	NA	NA		-	-		NA	NA		NA	NA	
AddCosts	0.17	0.07	***	NA	NA		0.11	0.07	.	NA	NA	
c. Spatial Variables												
CBD	-7e-05	-0.13	***	-0.094	-0.24	***	-2e-04	-0.28	.	-0.044	-0.19	***
Playgrounds	7e-05	0.01	***	-	-		-	-		0.04	0.02	.
Agriculture	-	-		-	-		-	-		-	-	
Disamenities	-	-		-0.25	-0.06	***	0.0004	0.06		-	-	
Sport	-	-		-	-		-	-		-	-	
Leisure	-9.6e-05	-0.11	***	-0.03	-0.04	.	-1e-04	-0.19		-0.02	-0.06	
AreaType:ResidArea	-0.04	-0.02	***	-14.50	-0.01		-0.20	-0.07		-70.67	-0.06	***
AreaType:MixArea	0.01	0.01	*	22.79	0.01		0.05	0.02		30.87	0.03	*
Water	0.00	-0.07	***	-0.16	-0.07	***	-	-		-0.15	-0.10	***
Waterway	7.5e-05	0.03	***	0.04	0.02	*	-	-		-0.04	-0.03	.
TransportStop	-	-		0.22	0.03	***	0.0005	0.07	.	-	-	
LargeRoad	0.001	0.08	***	0.20	0.05	***	-	-		0.39	0.13	***
MunicipalRoad	-0.001	-0.01	***	2.89	0.05	***	0.01	0.07	*	-0.22	-0.02	
RailwayTrack	0.001	0.11	***	0.17	0.05	***	-	-		-	-	
r.sq	**0.41**			**0.51**			**0.29**			**0.22**		
adj. r. sq.	**0.41**			**0.50**			**0.23**			**0.21**		

Annexes

Annex 1. Land use categories used in the study

Category	Description/composition	Literature	Data source
UGS	Green areas, forests, gardens, parks, woods, allotments, cemeteries	Kong et al., 2007; Melichar and Kaprová, 2013; Morancho, 2003	ATKIS 2010
Disamenities	Disposal sites, waste treatment plants, industrial areas, power and heating plants	Ahlfeldt and Maennig, 2011; Brandt and Maennig, 2012a; Kong et al., 2007	ATKIS 2010
Sport places	Sports facilities, stadiums, swimming pools, golf courses	-	ATKIS 2010
Leisure places	Campsites, zoos, amusement parks	Tyrväinen, 1997	ATKIS 2010
Playgrounds	Playgrounds	-	Leipzig City
Agriculture	Gardening, grasslands, farmlands	Melichar and Kaprová, 2013	ATKIS 2010
Area type	Residential area (i.e., no commercial activities), mixed and other area	Din et al., 2001	ATKIS 2010
Water bodies	Lakes	Ahlfeldt and Maennig, 2011; Brandt and Maennig, 2012a; Saphores and Li, 2012	ATKIS 2010
Waterways	Rivers, canals, streams	Saphores and Li, 2012; Tyrväinen, 1997	ATKIS 2010
Stops of public transportation	Bus and tram stops, train stations	Ahlfeldt and Maennig, 2011; Baranzini and Ramirez, 2005; Brandt and Maennig, 2012a; Din et al., 2001	Leipzig City, ATKIS 2010
Large roads	Federal highways, federal routes, state streets, county roads	Saphores and Li, 2012	ATKIS 2010
Municipal roads	Roads which belong to specific municipality	-	ATKIS 2010
Railway tracks	Rail roads, tram roads	Saphores and Li, 2012	ATKIS 2010
City centre (CBD)	Center of the city/Central Business District (CBD), which is as a proxy defined at the location of the centrally located Main Station	Ahlfeldt and Maennig, 2011; Donovan and Butry, 2011; Melichar and Kaprová, 2013; Tyrväinen, 1997	ATKIS 2010
Districts	63 districts of Leipzig	-	ATKIS 2010

Annex 2. Variables used in hedonic analysis

Name	Description	Housing Group*	Expected influence on price**
I. Dependent Variables			
RentingPrice	Renting price per m^2 (in €)	FR, HR	NA
SellingPrice	Selling price per m^2 (in €)	FS, HS	NA
II. Independent Variables			
a. UGS Variables:			
Shape	The shape of UGS equalling patch perimeter (m) divided by the square root of patch area (m^2), adjusted by a constant for a square standard. Possible values: 1 to ∞	FR, FS, HR, HS	**?**
Size	Size of the nearest to housing unit UGS (m^2)	FR, FS, HR, HS	+
ShareBuffer	Share (%) of UGS within the circle of a 300 m radius of each housing unit	FR, FS, HR, HS	+
Distance	Distance (m) from the housing unit to the nearest UGS, calculated in ArcGIS from the housing unit to the boundary of the nearest UGS using Euclidean distances.	FR, FS, HR, HS	-
b. Housing Variables:			
HousingSize	Size of the housing unit (m^2)	FR, FS, HR, HS	-
Garden	Presence of garden (1 if yes, 0 otherwise)	FR, FS	+
Year	Year when the housing unit was available for rent/sale, included as a categorical variable	FR, FS, HR, HS	+
Proxy coordinates	Dummy binary variable to check that approximation of addresses did not bias the results (1 for years 2007-2011, 0 otherwise)	FR, FS, HR, HS	+
GuestWC	Presence of a guest bathroom (1 if yes, 0 otherwise)	FR, FS, HR, HS	+
BathroomNr	Number of bathrooms (count.)	FR, FS, HR	+
Elevator	Presence of an elevator (1 if yes, 0 otherwise)	FR, FS	+
Kitchen	Presence of a built-in kitchen (1 if yes, 0 otherwise)	FR, FS, HR	+
Balcony	Presence of a balcony (1 if yes, 0 otherwise)	FR, FS	+
Floor	Floor of the building on which the housing unit is located (count.)	FR, FS	**?**
Condition	Housing condition (1-'Excellent state,' 2-'Good state,' 3-'Bad state')	FR, FS, HR	+
HeatType	Type of heating: self-contained central heating ('Heat_Self-cont'), central heating ('Heat_Centr'), furnace heating ('Heat Furnace')	FR	**?**
HeatCostsIncl	If heating costs are included in the rent (1 if yes, 0 otherwise)	FR	+
Monument	If housing considered to be a building of historic importance (1 if yes, 0 - no)	FS, HS	+
Deposit	If rent deposit is required (1 if yes, 0 otherwise)	FR	**?**
HolidayHome	If the apartment can be used as vacation rental (1 if yes, 0 otherwise)	FS	**?**
AddCosts	Additional costs (in €) rate for heating, warm water, waste disposal etc.	FR, HR	+
c. Spatial Variables:			
CBD	Distance (m) from the housing to the city business centre (Central Station)	FR, FS, HR, HS	-
Playground	Distance (m) from the housing unit to the nearest playground	FR, FS, HR, HS	-
Agriculture	Distance (m) from the housing unit to the nearest agriculture site	FR, FS, HR, HS	-
Disamenities	Distance (m) from the housing unit to the nearest disamenity (e.g., disposal site, industrial area, etc.)	FR, FS, HR, HS	+
Sport	Distance (m) from the housing unit to the nearest sport place	FR, FS, HR, HS	-
Leisure	Distance (m) from the housing unit to the nearest place for leisure time	FR, FS, HR, HS	-
Districts	63 districts of Leipzig were included in hedonic analysis	FR, FS, HR, HS	**?**
AreaType	Type of the area in which the housing unit is located: residential area ('ResidArea') without any shops, mixed area ('MixArea'), other area type	FR, FS, HR, HS	**?**
Water	Distance (m) from the housing unit to the nearest water body (e.g., lake)	FR, FS, HR, HS	-
Waterway	Distance (m) from the housing unit to the nearest river, canal or stream.	FR, FS, HR, HS	-
TransportStop	Distance (m) from the housing unit to the nearest public transportation stop	FR, FS, HR, HS	-
LargeRoad	Distance (m) from the housing unit to the nearest large road	FR, FS, HR, HS	+
MunicipalRd	Distance (m) from the housing unit to the nearest municipal road	FR, FS, HR, HS	+
RailwayTrack	Distance (m) from the housing unit to the nearest rail or tram road	FR, FS, HR, HS	+

[*] Following abbreviations were used: FR - *rented flats*, FS – *sold flats*, HR – *rented houses*, HS – *sold houses*
[*] "+" / "-" indicate increasing/decreasing effects on housing prices (€/m^2); in some cases, an effect is undetermined ("?" sign).
[a] – all 63 districts were included in regression model, but for the sake of the simplicity of the result presentation, their coefficients are not presented in the paper.

Annex 3. Descriptive statistics for the numerical variables used [a, b]

Group	Variable	Rented Flats				Sold Flats				Rented Houses				Sold Houses			
		min	**max**	**median**	**mean**	**min**	**max**	**median**	**mean**	**min**	**max**	**median**	**mean**	**min**	**max**	**median**	**mean**
	Price (€/m²)	2	13.83	5	5.05	250	5,106	1,219	1,417	2.66	14	6.5	6.72	250	8,358	1,461	1,499
UGS[c]	Shape of nearest UGS (units)	1	6.16	1.94	2.05	1	6.16	1.91	2.03	1	6.16	1.61	2.01	1	7.04	1.65	2.03
	Size of nearest UGS (m^2)	1,094	5,471,457	35,105	232,100	1,123	5,471,457	35,105	309,627	816	5,471,457	28,405	273,367	368	5,471,457	21,833	274,339
	Distance (m) to nearest UGS	0.001	782.17	162.79	184.93	0.001	764.10	171.00	194.39	0.001	690.87	174.17	191.26	0.001	727.93	150.66	179.65
	ShareBuffer (%)	0	96.92	6.01	9.09	0	75.25	5.69	9.34	0	80.20	4.36	8.84	0	96.37	5.08	9.53
Housing	HousingSize (m^2)	15	300	64	68.05	15	300	72.5	83.96	23	300	127	132.17	24	500	130.41	140.73
	BathroomNr	1	4	1	1.03	1	4	1	1.13	1	3	1	1.42	NA	NA	NA	NA
	Floor	0	31	3	3.1	0	10	2	2.00	NA	NA	NA	NA	NA	NA	NA	NA
	AddCosts	0	12.50	2.01	2.03	NA	NA	NA	NA	-1.15	6.58	1.00	1.20	NA	NA	NA	NA
Other spatial	CBD (m)	81.35	12,564	3,156	3,445	294.03	10,461	3,044	3,317	594.99	12,564	6,173	5,898	399.24	13,592	6,381	6,290
	RailwayTrack (m)	0.003	3,782	115.09	154.57	0.19	2,628	125.42	172.79	3.79	3,576	309.23	450.05	0.38	3,765	302.55	468.79
	LargeRoad (m)	0.002	912.57	128.61	175.04	0.02	868.17	155.11	199.90	0.52	896.32	141.82	173.28	0.01	937.27	158.17	184.06
	MunicipalRd (m)	0.001	624.40	13.39	13.85	0.001	199.84	13.29	13.69	0.03	188.84	11.95	14.38	0.003	983.31	9.34	15.38
	TransportStop (m)	0.90	2,623	154.05	161.58	3.56	1,141	159.53	169.04	7.79	1,784	193.20	246.08	6.07	1,784	225.44	279.86
	Water (m)	0.001	1,492	567.71	580.44	0.001	1,503	514.30	531.03	0.67	1,378	416.67	475.16	0.001	1,537	504.19	533.21
	Waterway (m)	0.01	2,380	577.75	637.97	0.22	2,351	505.40	579.65	5.07	2,194	411.36	491.30	0.32	2,118	421.11	486.67
	Disamenities (m)	0.001	1,043	198.96	221.95	0.001	919.64	199.55	233.73	0.001	843.24	219.30	248.81	0.001	1,043	208.74	231.55
	Sport (m)	0.001	3,185	329.00	356.77	0.001	1,613	320.70	358.67	21.99	2,699	453.18	485.32	0.001	3,236	465.81	532.36
	Leisure (m)	0.001	10,951	1,760	1,887	8.48	8,663	1,877	1,956	59.31	8,772	2,571	2,914	0.001	10,951	2,538	2,797
	Playground (m)	2.15	2,737	265.30	300.29	9.89	1,482	272.36	308.12	22.53	2,142	320.46	394.81	4.39	3,147.13	366.31	437.87
	Agriculture (m)	0.001	686.63	158.43	179.08	0.001	586.89	167.49	185.58	0.001	562.88	57.96	100.27	0.001	540.47	66.63	92.53

[a] Binary and categorical variables were excluded;
[b] For ease of visualization all results were rounded to second decimal with two exceptions: 1) extremely small values were rounded to third decimal; 2) very big values (i.e. thousands) were rounded to whole number without decimals;
[c] Given values refer only to closest UGS (not to all UGS in the case study area).

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