Spatial sorting, attitudes and the use of green space in Brussels

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Abstract

Extensive evidence exists on the benefits provided by urban green space (UGS) but evidence is lacking about whether and how socio-economic benefits accrue to all residents or disproportionally depending on their socio-economic status or residential location. We model joint effects of socio-economic and locational attributes on attitudes and use of UGS in Brussels (BE). The analysis is based on a survey conducted along an urban-suburban continuum with respondents sampled across non-park public space. Patterns of use are depicted by the frequency and the distance travelled to the most used UGS. Attitudes are analysed along three dimensions: willingness to (i) pay for UGS, (ii) trade off housing for green space and (iii) substitute private for public green. Our results stress the importance of separating effects of attitudes from socio-economic and locational effects to quantify UGS use, and suggest endogenous effects of green space with residential sorting.

Keywords: urban green space, residential sorting, green space amenities, stated attitudes, Brussels

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Extensive evidence exists on the benefits provided by urban green space (UGS) but evidence is lacking about whether and how socio-economic benefits accrue to all residents or disproportionally depending on their socio-economic status or residential location. We model joint effects of socio-economic and locational attributes on attitudes and use of UGS in Brussels (BE). The analysis is based on a survey conducted along an urban-suburban continuum with respondents sampled across non-park public space. Patterns of use are depicted by the frequency and the distance travelled to the most used UGS. Attitudes are analysed along three dimensions: willingness to (i) pay for UGS, (ii) trade off housing for green space and (iii) substitute private for public green. Our results stress the importance of separating effects of attitudes from socio-economic and locational effects to quantify UGS use, and suggest endogenous effects of green space with residential sorting.

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1. Introduction

Urban green space (UGS) is important for making cities more sustainable. It provides ecosystem services (De Groot et al., 2002) such as direct uptake and deposition of pollutants (Jayasooriya et al., 2017) or the reduction of heat islands (Bowler et al., 2010; Kabisch & Haase, 2014), and makes cities more attractive to people by increasing quality of life by improving physical, social and psychological wellbeing (Chiesura, 2004; Fuller & Gaston, 2009; Keniger et al., 2013) or supporting social interaction (Martin et al., 2004).

The actual benefits people derive from UGS vary according to availability and distance from residential locations (Box & Harrison, 1993; Harrison et al., 1995; Giles-Corti et al., 2005; Chiesura, 2004; Neuvonen et al., 2007; Kabisch et al., 2015). Local, national and even supranational regulatory bodies have therefore set up proximity criteria to improve the general provision of UGS in cities and ensure equal access by all residents (CABE, 2010). However, even though the provision of public UGS meets the per capita standard in many cities, their spatial distribution can still facilitate UGS benefits disproportionately among the population depending on their socio-economic status and residential location (Barbosa et al., 2007; Comber et al., 2008).

From urban economic theory we know that residential markets sort households by income along an urban-suburban continuum and the housing/transport cost trade-off (Fujita, 1989). This trade-off can, however, be dominated in the presence of exogenous central amenities (e.g. parks) or endogenous effects (e.g. high income attracting high income) and pull better-off households towards the center, adding discrepancies in accessibility to green amenities by different socio-economic groups (Brueckner et al., 1999). Tiebout's hypothesis implies that marginal benefits from localized amenities are the same for all households in a given location and that the market leads to efficient sorting of households by income based on the spatial distribution of the local amenities. However, empirics (Hoyt & Rosenthal, 1997) point to non-efficient sorting and endogenous socio-economic sorting in the demand for localized amenities in general, especially due to self-selection and geographically varying attitudes.

Self-selection in the choice of residential location in proximity to UGS has been suggested by Krizek (2003) or Maat & de Vries (2006). Socio-economic characteristics of residential communities influence expectations and demand for UGS (Byrne & Sipe, 2010; Lo & Jim, 2010). Having a private garden provides recreational alternatives (Heynen et al., 2006; Ibes, 2015) or owning a car attenuates the cost of distance (Chang & Liao, 2011) and, thus, alter the effect of distance to UGS. Also UGS benefits depend not only on the provision of UGS but also on residents' perception and actual valuation of ecosystem services (Brown, 2008). Therefore, researchers now argue that we should further investigate how UGS are distributed relative to social needs (Nicholls, 2001; Talen, 2010; Byrne, 2012; Lin et al., 2014; Ibes, 2015) and that distance to UGS should not be considered as the unique limiting factor of use (Van Herzele & Wiedemann, 2003; Schipperijn et al., 2010).

The present study aims at assessing attitudes towards UGS and use of public UGS by residents of the region of Brussels in Belgium, including joint effects of individual socio-economic and locational characteristics of the residential environment. Our analysis is based on a survey that includes users and non-users of UGS from a variety of residential locations, namely having good or bad provision of local green, or being close or distant to the city centre.

The remainder of this article is structured as follows. Section 2 takes stock of literature and outlines our contribution. Section 3 describes our survey data and complementary GIS and exploratory analysis. Section 4 presents descriptive statistics and results of the econometric analysis. Section 5 offers a discussion and Section 6 concludes.

2. State-of-the-art and contribution

2.1. Preferences and attitudes towards UGS

People's attitudes towards UGS have been considered in previous studies (Balram & Dragićević, 2005; López-Mosquera & Sánchez, 2011; Kabisch & Haase, 2014; Ives et al., 2017), while few have focussed on people actually declaring UGS benefits Jim & Chen (2006); Bertram & Rehdanz (2015). Expressing the value of UGS in monetary units also helps to understand user preferences and the relative value people place on direct (e.g. recreational) and indirect (e.g. health) benefits of UGS (Jim & Chen, 2006; de Groot et al., 2012). There are multiple approaches to quantify attitudes towards UGS in monetary terms, examples being hedonic pricing (e.g. Tyrväinen & Väänänen, 1998; Bolund & Hunhammar, 1999; Lutzenhiser & Netusil, 2001; Dehring & Dunse, 2006; Jim & Chen, 2006; Tyrväinen et al., 2007; Sander & Zhao, 2015), contingent valuation (e.g. Tyrväinen & Väänänen, 1998; Balram & Dragićević, 2005; Bateman et al., 2009) or choice experiments (e.g. Christie et al., 2007; De Valck et al., 2014, 2017).

2.2. *Locational effects and self-selection*

Few studies provide comprehensive statistical analyses of which factors influence attitudes (e.g. Jim & Chen, 2006; López-Mosquera & Sánchez, 2011; De Valck et al., 2017), the use of UGS (e.g. Giles-Corti et al., 2005; Maat & de Vries, 2006; Schipperijn et al., 2010) and the distance travelled to use UGS (e.g. Schipperijn et al., 2010). Even fewer studies adopt a comprehensive perspective linking those three aspects. Bell et al. (2003) explain the use of urban fringe woodlands by different age groups with individuals' preferences and accessibility. They highlight the differences in attitudes per age group and subsequent use patterns. Lin et al. (2014) compare availability and accessibility effects to attitude effects on frequency and duration of urban park use. They find that opportunity is the principal driver for use and that people with a strong attitude towards nature are more likely users. Zhang et al. (2015) address the level of satisfaction during physical activities in public UGS and reasons for not using green space in proximity. They find that the living context, vegetation quality and accessibility influence satisfaction levels; further, physical activities and UGS size explain UGS use patterns. Tyrväinen et al. (2007) study the spatial distribution of UGS values derived by inhabitants based on attitudes towards and use of green areas, socio-demographic characteristics and childhood environment. The study stresses the need to understanding values of UGS for local residents with different characteristics. Maat & de Vries (2006) test the compensation theory where an individual who lives in a less green environment would value a park more and visit it more often. They find no such compensation behaviour, which they explain by self-selection within the residential choice process.

2.3. Capturing joint effects

We aim to contribute to the literature on UGS benefits by quantifying and explaining (i) people's stated attitudes towards UGS, (ii) the influence of these attitudes along with locational and socio-economic aspects on the frequency of UGS use and (iii) the travel distance to UGS. We therefore attempt to reveal interdependencies between socio-economic, locational and attitudinal effects on patterns of UGS use. This paper also constitutes an innovation in that it considers three dimensions of attitudes: a direct monetary valuation of UGS (willingness to pay), a trade-off with housing space (willingness to trade housing space for the provision of UGS) and a potential substitution with private green space (willingness to substitute private green space for public green space). Moreover, most studies on the impact of UGS access and attitudes on use originate from the United States, the United Kingdom, Australia and a growing number from China (Wolch et al., 2014). Our analysis of Brussels, thus, provides empirical knowledge on a continental European city where the socio-spatial distributions of UGS may differ from other parts of the world. The spatial distribution of activities, including UGS, in European cities derive from a long history of urbanisation. In Brussels, there is a gradient of increasing vegetation cover from the medieval centre to the more recent suburban developments (Van de Voorde, 2017). The spatial distribution of socio-economic profiles does not strictly follow this gradient.

3. Data and methods

3.1. Study area and survey

The study area is the capital region of Brussels, with a population of 1.2 million and an area of 161 km^2 (BISA, 2017). With $>30m^2$ per capita UGS provision, Brussels offers a high percentage of UGS coverage in comparison to other European agglomerations with more than 100 000 inhabitants (Fuller & Gaston, 2009). UGS represents more than 40% of the urban area and the mean UGS size is 2.3 ha (OSM, 2016). The largest UGS (Bois de la Cambre, 123 ha) is situated in the South East of the study area (Figure 1).

In June 2016, a face-to-face survey was conducted among 540 residents of the study area in 18 non-park public places (for instance commercial centres, street intersections, public squares). Non-parks spaces were needed in order to reach both non users and users of parks, and in order for informal UGS to be declared by respondents. The survey sites were chosen along two urban-suburban transects and across neighbourhoods differently provisioned with green space. The aim was to reach respondents with various socio-economic backgrounds within different combinations of residential environments (e.g. central but green, central without green, leafy suburbs) in line with literature on sorting and amenities (Tiebout). The survey was conducted by one of the authors and a graduate student trained as interviewer. The questionnaire (available online at greenspace.uni.lu) consists of closed questions, but the face-to-face interaction permitted clarifications in order to increase the reliability of answers.

3.2. Socio-economic characteristics

Individual and household data were retrieved, including age, occupational status, household size, highest level of diploma, car ownership and nationality. From the literature, we expect they influence both attitudes towards UGS and the choice of residential location. Expected causal relationships are described in Section 3.5.

Multiple correspondence analysis (MCA) and clustering (k-means along the first 2 correspondence axes) were used to reduce dimensionality and approximating income level, leading to 4 distinct socio-economic profiles (Table A.1 in the appendix). We depict the groups as : ”young/students”, which include predominantly respondents of age less than 25 or with student status; ”low”, which represent a low socio-economic situation mainly explained by being members of a single or couple household, above the age of 55 and being at home as main occupation; ”medium”, which represent a mixed-up group of either educated multi-person households with members working part-time/ being at home or educated single households with full-term occupation and therefore medium household income; and finally ”high”, predominantly full-time employees aged 25 to 55 with university degrees, living in multi-person and multi-worker households, often owning 2 cars. Residential locations of respondents are mapped by socio-economic profiles in Figure 1, showing no particular spatial pattern, by construction, given the selection of survey sites and respondents explained above.

In addition to socio-economic profiles, we asked respondents whether they own a dog, assuming that walking the dog triggers a daily use of UGS.

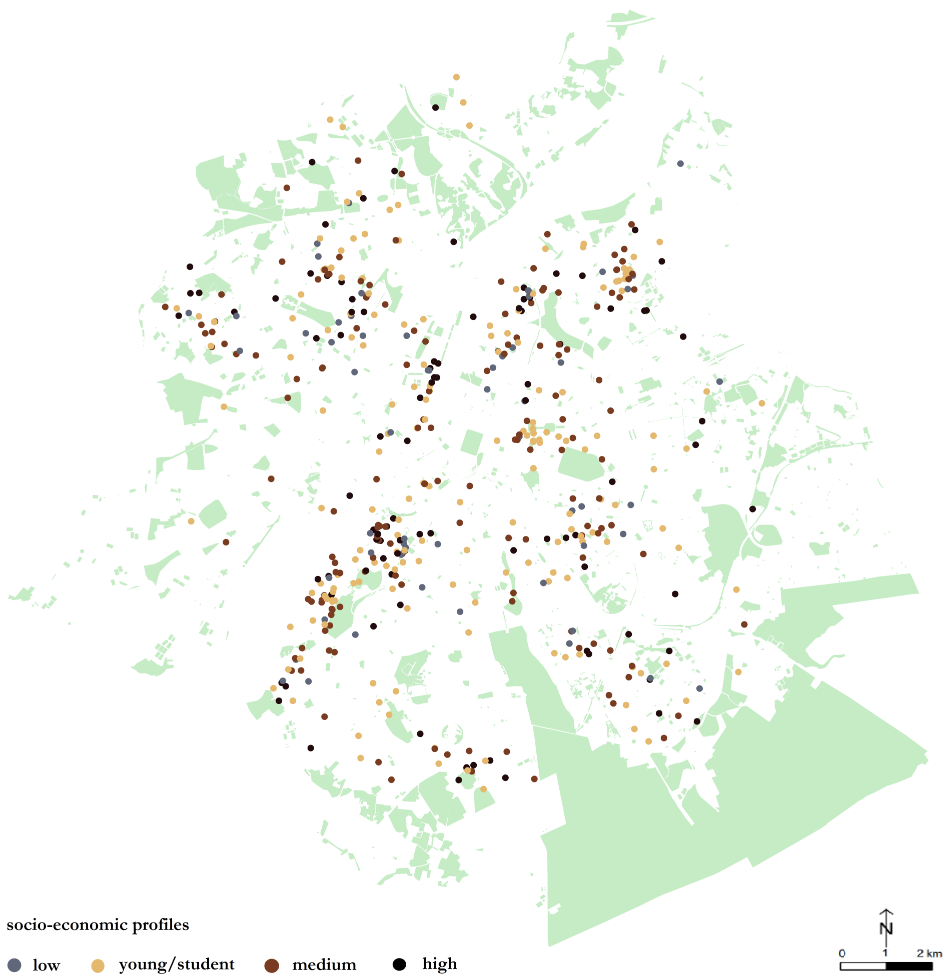

Figure 1: Map of respondents' residential location, classified by socio-economic profiles as result of a MCA and cluster: grey - low income, yellow - young/student, red - medium income, black - high income. All available UGS are shown as light green polygons (OSM data).

3.3. Residential environment

Respondents were asked to point their home on a map, from which we derived residential characteristics. The Euclidean distance between the residential place and the city hall was calculated in order to capture centrality effects and the related housing/transport cost trade-off (Fujita, 1989). In order to test for compensatory effects respondents were asked whether they had access to a private garden (i.e. private green which is not publicly accessible) or a balcony.

We computed two objective measures of UGS provision around residential locations: the network distance by foot to the nearest UGS and the share of UGS within a 400m buffer (in line with Van Herzele & Wiedemann (2003) and which is also the distance which the first quartile of our respondents travels to their most used UGS). The OSM network data was used to determine cost paths to all UGS and identify the closest UGS. The UGS considered for describing the residential environment were taken from OSM, in accordance with the work of Le Texier et al. (forthcoming) who find that OSM is a good compromise between a remotely sensed vegetation map (Landsat NDVI) and official cadastral data in order to retrieve UGS. A subjective measure of UGS was also retrieved: respondents stated their level of satisfaction with the quality of UGS within a 5-minutes-walk from their home.

3.4. Stated attitudes and use of UGS

Individual attitudes towards UGS were recorded through three dimensions: willingness to (i) pay for the provision of UGS (WTP), (ii) substitute housing space for the provision of UGS (WTSH) and (iii) substitute private green space for UGS (WTSG). For the first attitude (WTP), respondents were asked with an open-ended question to state their willingness to pay through local annual taxes for free use of UGS in the region, given that the city spends currently 1.18EUR/year per inhabitant on UGS (authors' own computation from allocated municipal budget; precise questions available at greenspace.uni.lu). The responses were transformed ex-post into a scaled index to ease generalization since the budget for UGS may vary from year to year and the analysis aims at identifying distinct respondent groups rather than reporting EUR amounts. The data-driven scaling is also a response to potential biases of contingent valuation analysis as discussed by Boyle (2003) and, thus, translates the stated monetary valuation into distinctive groups of respondents. For the second attitude dimension, WTSH, respondents were asked when deciding where to live whether they would accept living in a smaller house if there is satisfying green space nearby. Similarly, the third dimension, WTSG, was captured by asking whether they would in this situation accept a smaller garden.

Respondents stated their frequency of UGS use in a discrete manner ranging from "never/seldom" to "daily".

Following for instance Tyrväinen et al. (2007); Zhang et al. (2015); Arnberger & Eder (2012), respondents located the UGS they use the most on a map. An UGS was defined during the survey as any open space in the city, such as parks, forests or green-ways, that is publicly accessible. No finite set was presented to the respondents. The size of all most used UGSs was retrieved from Open Street Map (OSM) data. In addition, respondents' homes and their most used UGS were paired to retrieve network based travel distances

Tables 1 and 2 provide overall descriptive statistics for the attitudes and use variables, and means per socio-economic profiles.

Table 1: Share of respondents and averages for variables used in the analysis.

Variable	Share of respondents [%]
Willingness to pay for UGS	
Less	6.54
Equal ≡ 1.18 EUR/year	24.23
More	39.62
Much more	29.62
Willingness to substitute housing space for UGS	
Not at all	37.12
Somewhat	23.08
Strongly	39.81
Willingness to substitute private green space for UGS	
Not at all	35.77
Somewhat	20.77
Strongly	43.46
Frequency of UGS use	
Never / Seldom	12.12
Monthly	14.04
Weekly	30.58
Several times per week	27.69
Daily	15.58
Provision of UGS near residential location	
$<$ 1 % ≡ $<$ 0.6 ha	9.42
1 - 5 % ≡ 0.6 - 3.1 ha	36.15
5 - 15 % ≡3.1 - 9.2 ha	34.04
$>$ 15 % ≡$>$ 9.2 ha	20.38
Satisfaction with quality of UGS near residential location	
Not at all	14.62
Somewhat	28.27
Very	57.12
Socio-economic profiles	
young / student	11.80
low income	20.08
medium income	31.68
high income	36.43
	Mean
Eucl. distance from residential location to city hall [km]	3.40
Walking network distance from residential location to most used UGS [km]	2.44
Walking network distance from residential location to nearest UGS [km]	0.16
Size of most used UGS [km^2]	1.36

Figure 2 shows the links between residential locations and the UGS each

Figure 2: Map of links (black segments) between residential locations of respondents and stated most used UGS (dark green dots). All available UGS in Brussels are shown as light green polygons (OSM data).

Table 2: Means per socio-economic profile.

Variable	low	young/student	medium	high
Distance residential location - city hall	3.54	3.16	3.38	3.44
Distance residential location - most used UGS	2.39	2.26	2.31	2.67
Distance residential location - nearest UGS	0.15	0.15	0.18	0.17
Size of most used UGS	1.05	0.28	1.00	1.40

respondent stated to use the most (green dots). All available UGS patches are shown as grey polygons (OSM data). Most respondents do not use the UGS nearest to their home location. The average network walking distance to the most used UGS is 2.54km, while it is 0.16km to the nearest UGS.

3.5. Hypotheses and econometric design

In the absence of a theoretical base that would explicitly link residential sorting with UGS attitudes and use in terms of frequency and distance, we conduct our exploration along the following three hypotheses. Everything else being equal, we expect:

1. *stated positive attitudes towards UGS*(WTP, WTSH, WTSG) to increase with higher socio-economic status, having children or a dog, higher provision of and satisfaction with the green space around residential locations, distance to the centre and lower compensatory capabilities (e.g. no private garden or balcony).
2. *frequency of UGS use* to increase with accessibility and availability of UGS in proximity of residential locations, positive attitudes towards UGS and higher satisfaction with the quantity and quality of UGS in residential proximity.
3. *distance to the most used UGS* to either decrease or increase with positive attitudes towards UGS since households choose residential loca-

tions where UGS provision is high or choose UGS which satisfy certain valued criteria.

Comparing the different attitudes towards UGS, different factors are expected to influence each, suggesting to consider them separately in the analysis. First, monetary valuation of UGS (WTP) is likely determined by socio-economic characteristics. Second, from urban economic theory we expect the trade-off effect (WTSH) to be additionally driven by an urban-suburban gradient as housing prices tend to decrease with distance to the centre. Finally, substitution effects (WSTG) are expected to be influenced by the availability and quality of compensatory capabilities.

Given these assumptions and the nature of the data collected, we construct a three-step approach, modelling successively i) attitudes, ii) frequency of UGS use and then iii) distance to the most used UGS. Attitudes and frequency of UGS use being categorical, our first two models rely on multinomial logistic regression (MLR). We did not employ ordinal logistic regression since the assumption of proportional odds between categories did not hold. Our third model, i.e. for distance to the most used UGS, is a quantile regression to retrieve separate coefficients for different ranges of distance. This is justified by our third hypothesis that distance effects are not linear.

4. Results

The sequence of 3 models is presented for each attitude dimension in turn, i.e. WTP (4.1), WTSH (4.2) and WTSG (4.3). The models presented were selected based on goodness of fit. The goodness of fit of the models was tested with the Hosmer-Lemeshow test, the accuracy rate of correct prediction and the standard errors as reported in appendix B. For clarity of the expos, coefficients and relative probabilities for the MLR models of attitudes and frequency are deferred to appendix B and quantile regression estimates for the distance travelled are deferred to appendix C. In the text, we keep a graphical scheme summarizing results for each attitude dimension in turn.

4.1. Relation between WTP, frequency of use and distance to most used UGS

4.1.1. Willingness to pay for UGS (WTP)

Table B.1 shows the coefficients and probabilities resulting from the MLR model with WTP as dependent variable. We find that WTP is significantly determined by socio-economic profiles, with higher profiles (i.e. indirectly higher income) willing to pay more. Interestingly, socio-economics is the only variable influencing WTP for UGS. Satisfaction with the quality of UGS within a 5-minutes walk, compensatory opportunities (balcony, private garden) or urban-suburban differences play no role.

4.1.2. Frequency of UGS use

As expected, households' attitudes significantly influence how often respondents use UGS. In general, the higher the willingness to pay for UGS is, the more likely are respondents to use UGS more often (Table B.2). Conversely, a respondent who stated a low valuation of UGS is most likely to use UGS seldom or never. Hence, since the "low" group is associated with the highest probability among all groups to express a WTP of less than 1.18 EUR/year, the "low" group is also more likely to use UGS only seldom or never. The association between WTP and daily visits is, however, not significant. Daily visits are instead well explained by the use of UGS to walk the dog and a strong satisfaction with the quality of UGS within a 5-minutes walk from residential locations.

In sum, WTP for UGS (controlled for respondents' socio-economic profile) significantly explains frequent visits of UGS, while the daily use of UGS is rather explained by the purpose of UGS use (e.g. walking the dog) and the quality of UGS provision. Using WTP as reference for residents' valuation of UGS suggests that non-use of UGS is, thus, a choice rather than the result of constraints. A lack of quantity of UGS provision or the urban-suburban gradient show no explicit influence and were, thus, removed from the model.

4.1.3. Distance to most used UGS

We expect the frequency of visits to influence the distance travelled. Yet, since we observed that attitudes influence the frequency of use, we choose only the attitudes as potential explanatory factor. Results are reported in Figure C.1. Interestingly, WTP or urban-suburban differences show no significant effect, although larger distances are associated with suburban locations and low WTP. The distance respondents travel to visit their most used UGS is significantly associated with the quantity of UGS around their residential location and characteristics of the most used UGS, i.e. its size. A low provision of UGS ($< 5\%$) and the size of UGS explain, therefore, extra travel to UGS. While the relationship between the size of the most used UGS and distance travelled is linear, less than 1% of UGS around a residential location shows peak effects on the 0.7 distance quantile. Note that we do not observe a simple significant urban-suburban effect and that there is no strict linear increase of the quantity of UGS around residential locations with distance to the centre.

Figure 3 summarises the findings from the three-step modelling approach using WTP. Socio-economic characteristics influence WTP, which in turn influences the frequency of use (but not distance) along with characteristics of the residential environment.

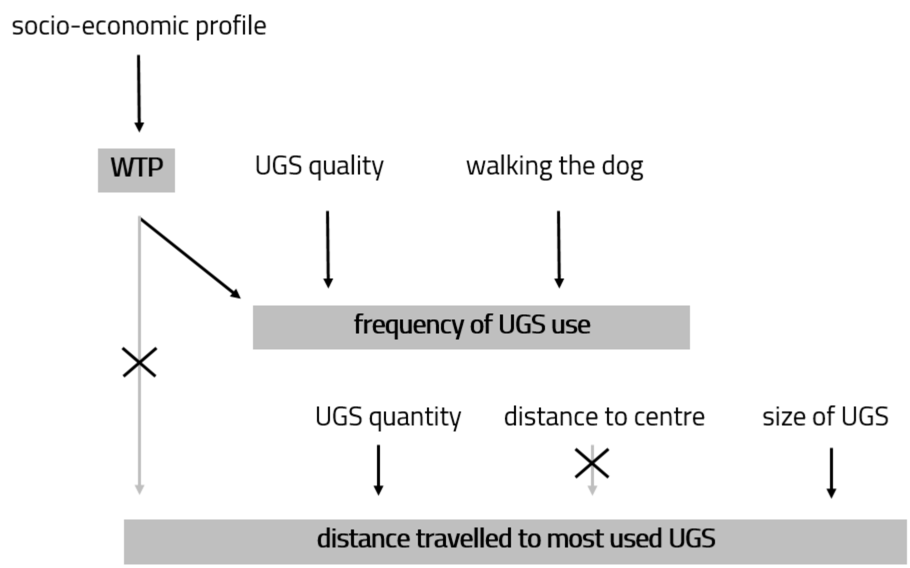

Figure 3: The Figure depicts the three-step modelling approach with the three dependent variables (grey boxes) i) respondents' willingness to pay for UGS (WTP), ii) the frequency of UGS use and iii) the distance which respondents travel to their most used UGS. Black arrows indicate the factors that significantly influence each of the dependent variables.

4.2. Relation between trade-offs of housing space and UGS, frequency of use and distance to most used UGS

4.2.1. Willingness to trade-off housing space for UGS (WTSH)

From urban economic theory we expect respondents who value housing space to live further away from the centre. At the same time, suburban residents also value proximity to green spaces (private or public). As expected, we find a significant urban-suburban gradient effect: compared to residents living less than 1km away from the city hall, suburban residents are significantly less likely to trade-off housing space for UGS (Table B.3). We conclude on a pure urban-suburban effect and no significant effect of perceived quality of UGS near locations.

Socio-economic characteristics influence the trade-off as expected from urban theory (Brueckner et al., 1999). Respondents of the group "medium" have the highest probability to be strongly in favour of the trade-off, while the groups "low" and "young/student" are less likely. This could be explained by the "medium" groups likely having children and, thus, searching public places to spend time outside (e.g. Lo & Jim, 2010); while "low" groups, that is mainly retired residents, value housing space since they spend more time at home. "High" groups, however, are associated with a surprisingly high probability of not being willing to trade off housing for UGS space.

4.2.2. Frequency of UGS use

WTSH explains significantly why respondents are more likely to visit UGS at least on a monthly basis (Table B.4). To explain daily visits, however, the provision of local UGS (quantity and perceived quality) and the main reason to use UGS (in this case walking the dog) are significant. Respondents who stated no willingness to trade off housing for UGS space (most likely low income groups and students) are the ones most likely to never/seldom visit UGS. Locations with less than 5% UGS are less likely to encourage UGS usage more than once per week. Good perceived quality of UGS raises the relative probability of daily UGS use. In sum, these results suggest that respondents use UGS seldom because their valuation of UGS is low rather than due to a lack of provision of UGS.

4.2.3. Distance to most used UGS

We find that the trade-off between housing and UGS space has no significant influence on the distance travelled to the most used UGS. The quality and quantity of UGS provision and the size of the most used UGS significantly explain the distance. A provision of less than 1% explains in particular why respondents travel further to use UGS (around the 0.7 quantile); effects of low provision on small (<0.4 quantile) and large (>0.8 quantile) distances are lower (Figure C.2). This non-linearity suggests an underlying self-selection by respondents on their residential location. Conversely, as the satisfaction with local UGS quality decreases, respondents travel further to use UGS. No significant urban-suburban effect is observed.

Figure 4 summarises the findings from the three-step modelling approach using WTSH. The willingness to trade off has a significant urban-suburban structure after controlling for socio-economic variation.

4.3. Relation between substitution of private for public green space, frequency of use and distance to most used UGS

4.3.1. Willingness to substitute private for public green space (WTSG)

Interestingly, respondents who are satisfied with the quality of UGS nearby their residential location are more likely to trade off private with public green space (Table B.5). Although we find that satisfaction with local UGS quality is generally higher in suburban locations, the urban-suburban gradient alone does not explain the preference significantly. "Low" groups have the lowest probability to be in favour of such a trade-off, while all other groups are less

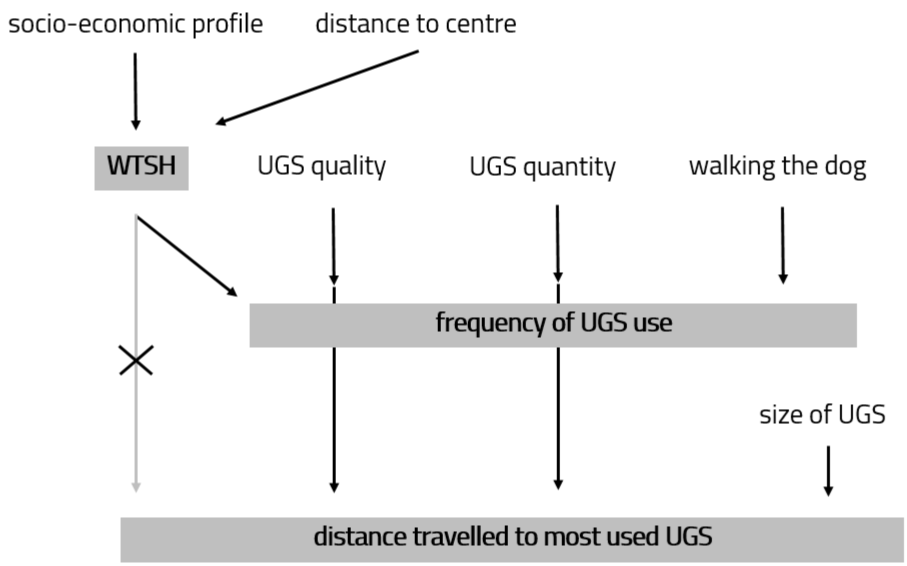

Figure 4: The Figure depicts the three-step modelling approach with the three dependent variables (grey boxes) i) respondents' willingness to trade off housing for public urban green space (WTSH), ii) the frequency of UGS use and iii) the distance which respondents travel to their most used UGS.

likely to reject. This is contradictory to Talen (2010) who finds that UGS can substitute for private green space for apartment dwellers but not for owners of houses with private gardens.

4.3.2. Frequency of UGS use

We do not find a significant effect of substitutability of private for public green space on the frequency of use (Table B.6). Instead, a low quantity of UGS around residential locations is associated with a higher probability of fewer visits to UGS. This suggests that substitutability of private for public green space is a weak indicator of frequency of use since green spaces fulfil different functions at different levels (private vs. public).

4.3.3. Distance to most used UGS

Although the trade-off between private and public green space does not influence the frequency, it does influence the distance travelled. Strong WTSG significantly reduces the distance travelled, in particular at large quantiles (Figure C.3). This suggests that people who are the most willing to trade private UGS for public ones are the ones who use the closest ones as if the public space was a continuity of the private place. Since the substitutability was shown to partly depend on the perceived quality of nearby UGS, qualitative provision of UGS can lead to a reduction in travel distance to use UGS. This indirect relation also suggests that the economic value of UGS is already considered in the choice of residential location.

The quantity of UGS provided around residential locations affects the distance travelled (especially around the 0.7 quantile). Thus, an indifference towards the spatial distribution of UGS is associated with respondents who travel further to use UGS. The constraint of UGS quantity and proximity explains why respondents travel further, despite again the size of the UGS which acts as a wide-range pull-factor. However, the non-linear effect of UGS quantity indicates underlying endogenous effects, that is residential sorting.

Figure 5 summarises the findings from the three-step modelling approach using WTSG. Substitution effects vary across socio-economic profiles and are dependent on locational aspects (perceived quality of local UGS). Attitudes as well as characteristics of the residential environment significantly influence patterns of UGS use.

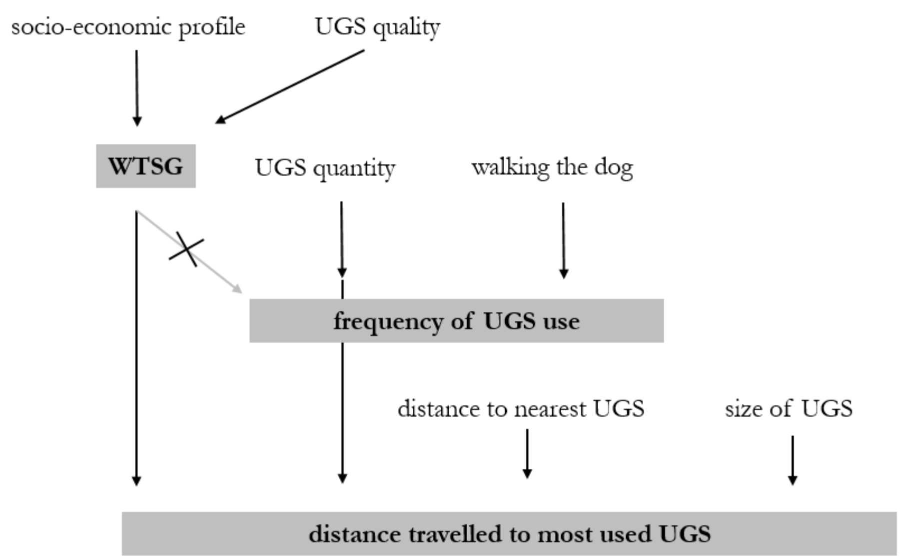

Figure 5: The Figure depicts the three-step modelling approach with the three dependent variables (grey boxes) i) respondents' willingness to private for public green space (WTSG), ii) the frequency of UGS use and iii) the distance which respondents travel to their most used UGS. Black arrows indicate the factors that significantly influence each of the dependent variables.

5. Discussion

Our analysis shows that there exist complex interdependencies and non-linear effects with regards to the valuation and the use of UGS. Those interdependencies require a careful consideration and generalisation from other cases before designing urban planning strategies. In this section, we highlight our main findings, pertaining to (i) attitudes and (ii) use of UGS, and confront them against empirical evidence obtained from other cases in the literature.

5.1. Explaining attitudes towards UGS

Our study highlights the importance of differentiating between the role of socio-economic background and spatial aspects to understand residents' attitudes.

Socio-economic profiles influence attitudes. Compared to other studies that look separately at single socio-economic criteria, we have retrieved socio-economic profiles. Our results indicate that these profiles influence attitudes towards UGS. More precisely, highly educated, full-time employed people from all age groups (i.e. indirectly higher income groups) are more likely to express strong positive attitudes (WTP, WTSH, WTSG) than older, retired and less educated respondents (i.e. indirectly lower income groups). This is a rejoinder to Sander & Zhao (2015) and Jim & Chen (2006) who respectively find an increase in WTP with income, and with income and age. We depart partially from Lorenzo et al. (2000) who find an influence of income on WTP, but not of age or education, and depart more strongly from Tyrväinen &

Väänänen (1998) who find no association between WTP and income. This suggests different influences of socio-economic profiles across attitudes.

Local UGS provision explains attitudes towards UGS. We have found that willingness to substitute private for public green space increases with the perceived quality of local UGS. This follows, for instance, Balram & Dragićević (2005); Ambrey & Fleming (2014); Brander & Koetse (2011) who find that attitude towards green may also be influenced by the spatial environment surrounding an individual. Since low income groups are in our study associated with the lowest probability to substitute private green for public green space, our results suggest that low income people living in a poor quality UGS neighbourhood would be least likely among all groups to substitute private for public green space. From discussion with the respondents we can derive the assumption that the people with the most vulnerable socio-economic status are the ones who are the most afraid to loose private property in favour of public space. Thus, precarity of the economic situation is a potential explanation.

Respondents of our survey in Brussels, who already have satisfactory quantity and quality of UGS around their home location, tend to value UGS more. On these grounds, we can conclude that respondents (who were able to) already took the UGS distribution into consideration when choosing their residential location. This goes in the direction of Brueckner's theory (1997) which states that the relative location of different income groups depends on the spatial patterns of amenities within cities.

Public and private green play different roles. We do not find explicit compensatory effects as suggested, for instance, by Maat & de Vries (2006) who test whether someone living in a less green environment would value UGS more. Dehring & Dunse (2006) show that the value given to public UGS varies according to the property type households live in. Tu et al. (2016) find that preferences are heterogeneous due to private garden ownership. Talen (2010) finds that apartment dwellers would more likely substitute private green space for UGS than owners of homes who likely have a private garden. Our results rather suggest that public and private green space differ in the ecosystem services they provide and are only partly substitutable. Like Barbosa et al. (2007) we find that wealthier households are more likely to make such a trade-off, but show that socio-economic background alone does not explain such preferences.

Housing space trade-off depends on centrality. A willingness to trade off private housing space for public space exists and is directly controlled by the urban-suburban structure. In contrast, a willingness to pay or substitute private green for more UGS is not related to centrality. To the best of our knowledge this centrality effect has not been tested earlier as such. It suggests that when dealing with green space substitution issues, bundling housing and garden consumptions within a single spatial good as is usually the case in urban economics is not relevant.

5.2. Explaining patterns of UGS use

Our analysis suggests that neither UGS provision nor attitudes alone can explain the frequency of UGS use or the distance travelled to use UGS; in fact, both need to be considered in conjunction.

Weekly use relates to attitudes while local provision matters for daily use. We find that attitudes (WTP and WTSH) explain whether someone uses UGS frequently, while the provision of UGS (quantity, quality and proximity) explains in particular the daily use of UGS. This second finding is in line with Tyrväinen & Miettinen (2000); Maat & de Vries (2006) who find that availability of UGS tends to increase the use of UGS.

Non-linear proximity effects on travel distance to UGS. In addition, we find that local provision of UGS has no linear effect on the distance to the most used UGS. Lack of provision, therefore, does not univocally lead to larger travelled distances to UGS, but might indicate indifference to the spatial distribution of UGS relative to someone's home location.

Lanzendorf (2000) shows that residents in low-density neighbourhoods comprising detached houses with gardens travel shorter distances than residents in a more urbanized neighbourhood in Cologne. According to Van Herzele & Wiedemann (2003) respondents use UGS at different distances from their home based on the functional levels of UGS. In Brussels, respondents travel further to use larger UGS as also found by Giles-Corti et al. (2005) in Perth. Moreover, we find that they travel further in case they express preferences towards private rather than public green space or because of a lack of provision near their home location. In addition, less frequent UGS use is associated with visits of UGS further from residential locations.

Willingness to substitute private green influences travel distance to UGS. The willingness to substitute private green is the only attitude dimension that significantly explains the distance to the most used UGS. In fact, the stronger the willingness is, the shorter is the maximum distance travelled, that is the less people travel across the city to use UGS. Since the substitution effect also reflects the satisfaction with the quality of local UGS we conclude that the residential location is by choice in proximity to high quality UGS.

No spatial heterogeneity of use beyond residential sorting. Although the quantity of UGS is obviously higher in the North-West and South-East of Brussels, we do not find spatial patterns in stated attitudes, frequency of use or distance travelled to use UGS. This is likely due to the careful consideration of survey locations with well assorted respondent groups.

Shafer et al. (2013) show that access and opportunity to use UGS depend on households' socio-economic status and location. Ernstson (2013) find that UGS is disproportionally available to a subset of the urban population. In Brussels, either or both socio-economic status and location only indirectly influence the use of UGS through residential sorting.

No explicit urban-suburban differences in use and travel distance. We do not observe an explicit urban-suburban effect in our econometric analysis. Distance to the centre itself does not explain the use and distance to UGS significantly. However, there is residential sorting along the urban-suburban gradient. The quantity and perceived quality of UGS as well as the housing/UGS trade-off are also subject to an urban-suburban gradient. Respondents who live further away from the centre are generally more satisfied with the quality of UGS and have a larger share of UGS nearby than those closer to the centre. Results suggest that attitudes towards UGS partly underlie the location choice of our respondents.

6. Conclusion

Urban green spaces provide benefits to the urban population. These benefits do not accrue equally to all residents because the use of green space depends on their socio-economic characteristics, residential location and attitude towards green space and their complex interdependencies.

We have quantified residents' attitudes towards UGS in Brussels and their influence on patterns of UGS use while controlling for socio-economic aspects and the urban-suburban gradient.

We have provided evidence that both socio-economic and locational aspects influence residents' attitude towards UGS and patterns of UGS use. Attitudes towards UGS expressed in monetary terms, as a trade-off with housing space or as a substitution with private green, are all explained by socio-economic characteristics. The effect of residential location varies across these dimensions. In addition, we have seen that attitudes add to locational and socio-economic effects to explain frequency of use and travel distance to UGS.

Our results contribute still rare empirical findings for a European city. We corroborate previous studies in the role of local UGS provision on UGS use but show that attitudes are key factors to be taken into account for understanding use. Moreover, attitudes themselves are impacted by socio-economic and locational variables.

Although this research is limited in its scope, our results suggest that a spatially equal distribution of UGS would not necessarily provide benefits to all residents. Our findings rather call for the provision of strategically distributed high quality UGS which meets user preferences and can, thus, reduce the need for private green space and steer both the use of UGS and residential choices.

Future research should aim at an inter-city comparison for further generalization by replicating the analysis based on the same survey conducted also in other European cities. Our results also stress the need for theorizing and comprehensively addressing endogenous and non-linear effects between residential choice and UGS practice. In particular, we revealed interdependencies between the various explanatory factors, which highlights the need to better understand how residential preferences and constraints impact residential sorting, hence observed differences in UGS use. Future research should be carefully designed to account for the revealed interdependencies between attitudes, socio-economic and locational variables and the use of UGS. Without measured evidence and trade-offs, planning recommendations may well lead to inappropriate UGS locations and imbalances in use and benefits in the longer term after relocations and differences in monetary power across households.

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Appendix

A. Socio-economic profiles

Table A.1: Share [%] of observations per socio-economic profile and total numbers N .

Response	*Socio-economic profile*				*Total*
	low	student	medium	high	
N	63	191	160	106	520
Age					
<25	0.00	84.21	3.27	0.57	61
25-35	1.03	14.04	40.52	40.34	146
35-45	2.06	1.75	21.57	30.68	96
45-55	10.31	0.00	18.30	26.70	94
55-65	36.08	0.00	15.69	1.14	64
>65	50.52	0.00	0.65	0.57	59
Diploma					
Primary	23.71	10.53	10.46	2.27	50
Secondary	47.42	57.89	43.79	11.93	181
University	28.87	31.58	45.75	85.80	289
Household size					
Single	51.55	19.30	28.10	3.98	115
2	41.24	14.04	30.07	24.43	147
3 or 4	4.12	33.33	28.10	55.11	177
5 or 6	1.03	29.82	9.15	14.77	65
>6	2.06	3.51	4.58	1.70	16
Occupation					
At home	90.72	8.77	40.52	1.70	171
Parttime	4.12	15.79	13.73	11.36	56
Student	0.00	68.42	0.65	0.57	47
Working	5.15	7.02	45.10	86.36	246
Nationality					
European	84.54	64.91	75.16	86.93	418
Non-European	15.46	35.09	24.84	13.07	102

B. MLR models

Table B.1: Predicted probabilities of willingness to pay for UGS (WTP) and model coefficients. Predicted probabilities for all categories are reported in each first row; below coefficients based on the listed reference levels; standard errors in brackets.

	Dependent variable: WTP			
	Less	Equal	More	Much More
	(1)	(2)	(3)	(4)
Socio-economic profile				
low	0.12	0.36	0.36	0.16
young/student	0.09	0.20	0.26	0.42
		−0.115	0.028	1.345**
		(0.624)	(0.615)	(0.626)
medium	0.05	0.22	0.43	0.29
		0.376	1.040**	1.504***
		(0.516)	(0.502)	(0.545)
high	0.04	0.20	0.46	0.30
		0.539	1.378***	1.801***
		(0.532)	(0.517)	(0.558)
Constant		1.070***	1.070***	0.223
		(0.335)	(0.335)	(0.387)
Akaike Inf. Crit.				1,198.961
Prediction accuracy				0.43
Note:				*p<0.1; **p<0.05; ***p<0.01

Table B.2: Predicted probabilities of frequency of UGS use and model coefficients. Predicted probabilities for all categories are reported in each first row; below coefficients based on the listed reference levels; standard errors in brackets.

	Dependent variable: frequency of use				
	Never/Seldom	Monthly	Weekly	Several	Daily
	(1)	(2)	(3)	(4)	(5)
Willingness to pay					
Less	0.30	0.10	0.18	0.25	0.17
Equal	0.15	0.13	0.32	0.28	0.12
		0.977	1.242^{**}	0.772	0.361
		(0.757)	(0.609)	(0.576)	(0.656)
More	0.08	0.17	0.08	0.31	0.11
		1.941^{***}	1.974^{***}	1.578^{***}	0.942
		(0.739)	(0.607)	(0.571)	(0.645)
Much More	0.11	0.13	0.11	0.29	0.17
		1.264^{*}	1.538^{**}	1.045^{*}	1.017
		(0.755)	(0.612)	(0.579)	(0.646)
Walking the dog					
No	0.11	0.15	0.11	0.29	0.11
Yes	0.09	0.07	0.09	0.19	0.48
		−0.515	−0.480	−0.246	1.672^{***}
		(0.704)	(0.591)	(0.581)	(0.540)
Strong satisfaction quality					
No	0.15	0.17	0.17	0.29	0.10
Yes	0.09	0.13	0.13	0.34	0.16
		0.249	0.719^{**}	0.571^{*}	0.993^{***}
		(0.366)	(0.321)	(0.324)	(0.377)
Constant		-1.224^{*}	−0.858	−0.474	-1.338^{**}
		(0.705)	(0.572)	(0.532)	(0.612)
Akaike Inf. Crit.					1,469.119
Hosmer-Lemeshow test		X-squared = 18.207, df = 28, p-value = 0.9208			
Prediction accuracy					0.34
Note:					*p<0.1; **p<0.05; ***p<0.01

Table B.3: Predicted probabilities of willingness to substitute housing space for UGS (WTSH) and model coefficients. Predicted probabilities for all categories are reported in each first row; below coefficients based on the listed reference levels; standard errors in brackets.

	Dependent variable: WTSH		
	Not at all	Somewhat	Strongly
	(1)	(2)	(3)
Distance to centre			
< 2 km	0.26	0.30	0.44
2-4km	0.34	0.25	0.42
		−0.478	−0.323
		(0.338)	(0.309)
4-6km	0.44	0.18	0.38
		-1.076^{***}	-0.667^{**}
		(0.374)	(0.326)
>6km	0.33	0.23	0.43
		−0.520	−0.281
		(0.658)	(0.575)
Socio-economic profile			
low	0.48	0.14	0.38
young/student	0.34	0.34	0.32
		1.207^{***}	0.178
		(0.447)	(0.399)
medium	0.27	0.22	0.51
		0.970^{**}	0.885^{***}
		(0.387)	(0.295)
high	0.34	0.27	0.38
		0.967^{***}	0.357
		(0.364)	(0.285)
Constant		−0.635	0.118
		(0.394)	(0.325)
Akaike Inf. Crit.			1,103.116
Hosmer-Lemeshow test	X-squared = 7.8527, df = 14, p-value = 0.8969		
Prediction accuracy			0.47
Note:	*p<0.1; **p<0.05; ***p<0.01		

Table B.4: Predicted probabilities of frequency of UGS use and model coefficients. Predicted probabilities for all categories are reported in each first row; below coefficients based on the listed reference levels; standard errors in brackets.

	Dependent variable: frequency of use				
	Never/Seldom	Monthly	Weekly	Several	Daily
	(1)	(2)	(3)	(4)	(5)
Substitution housing space					
Not at all	0.20	0.11	0.28	0.25	0.15
Somewhat	0.05	0.19	0.39	0.30	0.06
		1.950***	1.717***	1.572***	0.488
		(0.550)	(0.495)	(0.505)	(0.611)
Strongly	0.09	0.15	0.30	0.31	0.16
		1.116***	0.870**	1.028***	0.834**
		(0.423)	(0.358)	(0.362)	(0.402)
Share of UGS within 441m					
>15%	0.09	0.14	0.18	0.40	0.19
5-15%	0.08	0.16	0.35	0.27	0.13
		0.182	0.739	−0.306	−0.294
		(0.576)	(0.535)	(0.505)	(0.547)
1-5%	0.14	0.13	0.35	0.26	0.11
		−0.603	0.173	−0.930*	−1.047**
		(0.555)	(0.506)	(0.475)	(0.527)
<1%	0.12	0.15	0.31	0.34	0.09
		−0.277	0.237	−0.475	−1.093
		(0.823)	(0.756)	(0.725)	(0.905)
Walking the dog					
No	0.11	0.15	0.33	0.30	0.11
Yes	0.09	0.08	0.18	0.20	0.45
		−0.438	−0.432	−0.190	1.628***
		(0.708)	(0.593)	(0.584)	(0.542)
Strong satisfaction w. quality					
No	0.14	0.18	0.28	0.30	0.10
Yes	0.09	0.13	0.35	0.29	0.15
		0.088	0.622*	0.398	0.787**
		(0.376)	(0.328)	(0.332)	(0.383)
Constant		−0.416	−0.328	0.527	−0.301
		(0.567)	(0.518)	(0.479)	(0.536)
Akaike Inf. Crit.					1,455.472
Hosmer-Lemeshow test					X-squared = 28.628, df = 32, p-value = 0.638
Prediction accuracy					0.38
Note:					*p<0.1; **p<0.05; ***p<0.01

Table B.5: Predicted probabilities of willingness to substitute private for public green space (WTSG) and model coefficients. Predicted probabilities for all categories are reported in each first row; below coefficients based on the listed reference levels; standard errors in brackets.

	Dependent variable: WTSG		
	Not at all	Somewhat	Strongly
	(1)	(2)	(3)
Satisfaction w. UGS quality			
Not at all	0.40	0.18	0.42
Somewhat	0.32	0.29	0.39
		0.696^{*}	0.111
		(0.402)	(0.332)
Very	0.33	0.19	0.49
		0.232	0.304
		(0.382)	(0.296)
Socio-economic profile			
low	0.51	0.15	0.35
young/student	0.36	0.24	0.49
		1.174^{**}	0.991^{**}
		(0.479)	(0.395)
medium	0.30	0.23	0.48
		0.981^{***}	0.846^{***}
		(0.379)	(0.294)
high	0.33	0.22	0.45
		0.847^{**}	0.690^{**}
		(0.369)	(0.283)
Constant		-1.568^{***}	-0.572^{*}
		(0.430)	(0.323)
Akaike Inf. Crit.			1,024.443
Hosmer-Lemeshow test			X-squared = 4.048, df = 10, p-value = 0.9452
Prediction accuracy			0.47
Note:			*p<0.1; **p<0.05; ***p<0.01

Table B.6: Predicted probabilities of frequency of UGS use and model coefficients. Predicted probabilities for all categories are reported in each first row; below coefficients based on the listed reference levels; standard errors in brackets.

	Dependent variable: frequency of use				
	Never/Seldom	Monthly	Weekly	Several	Daily
	(1)	(2)	(3)	(4)	(5)
Substitution private green					
Not at all	0.14	0.14	0.35	0.24	0.14
Somewhat	0.10	0.17	0.34	0.32	0.09
		0.568	0.346	0.646	−0.092
		(0.501)	(0.438)	(0.451)	(0.546)
Strongly	0.12	0.15	0.27	0.31	0.16
		0.218	−0.077	0.417	0.297
		(0.406)	(0.347)	(0.357)	(0.401)
Share of UGS					
>15%	0.01	0.14	0.18	0.39	0.20
5-15%	0.09	0.16	0.35	0.26	0.14
		0.251	0.763	−0.289	−0.281
		(0.567)	(0.526)	(0.498)	(0.542)
1-5%	0.17	0.14	0.34	0.25	0.11
		−0.547	0.086	−0.987**	−1.183**
		(0.538)	(0.491)	(0.462)	(0.517)
<1%	0.12	0.16	0.30	0.33	0.09
		0.027	0.356	−0.324	−1.032
		(0.798)	(0.732)	(0.704)	(0.888)
Walking the dog					
No	0.12	0.16	0.33	0.29	0.11
Yes	0.09	0.08	0.17	0.20	0.46
		−0.411	−0.391	−0.137	1.713***
		(0.700)	(0.584)	(0.578)	(0.537)
Constant		0.152	0.616	1.072**	0.428
		(0.516)	(0.474)	(0.443)	(0.489)
Akaike Inf. Crit.					1,475.706
Hosmer-Lemeshow test					X-squared = 10.559, df = 24, p-value = 0.9918
Prediction accuracy					0.38
Note:					*p<0.1; **p<0.05; ***p<0.01

C. Quantile models

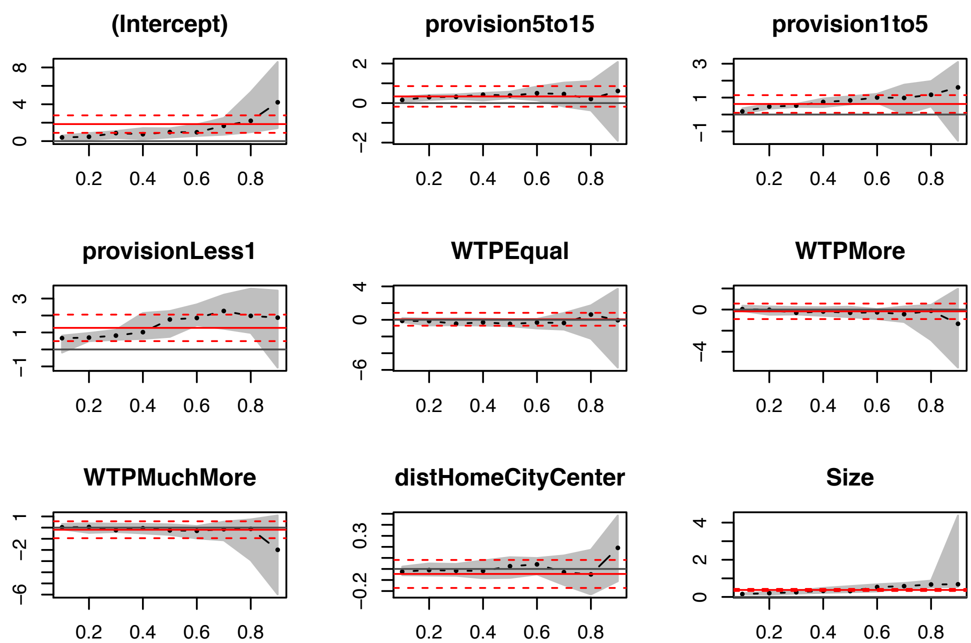


Figure C.1: Quantile regression analysis explaining the distance respondents travel to visit their most used UGS (network walking distance in km) with WTP. A UGS provision of less than 1% (p-value<0.01), between 1-5% and the size of the UGS are significant (both p-value<0.001).

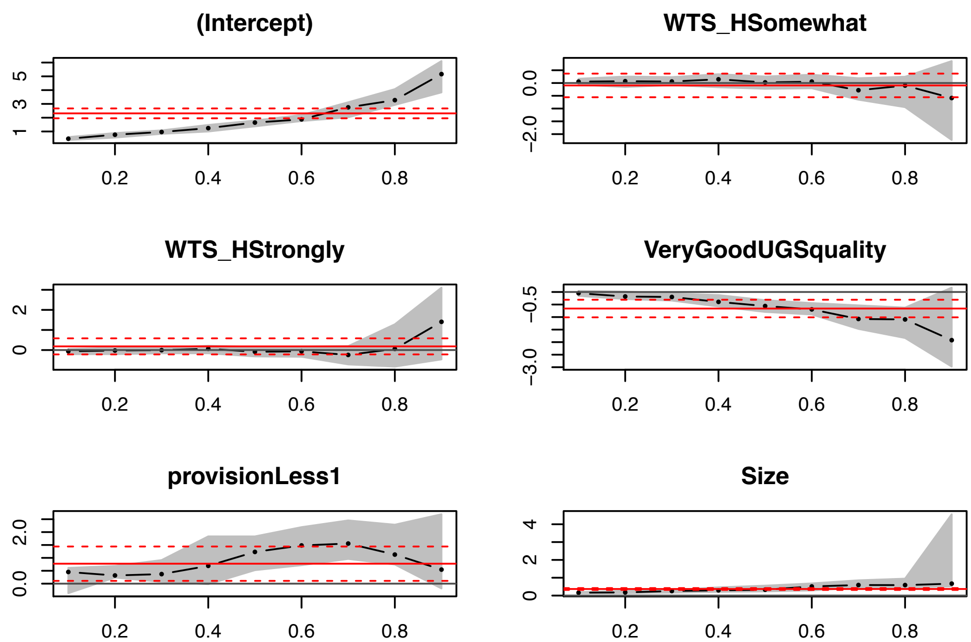


Figure C.2: Quantile regression analysis explaining the distance respondents travel to visit their most used UGS (network walking distance in km) with WTSH. A UGS provision of less than 1%, strong satisfaction with the quality of nearby UGS and the size of the UGS are significant with p-value<0.001.

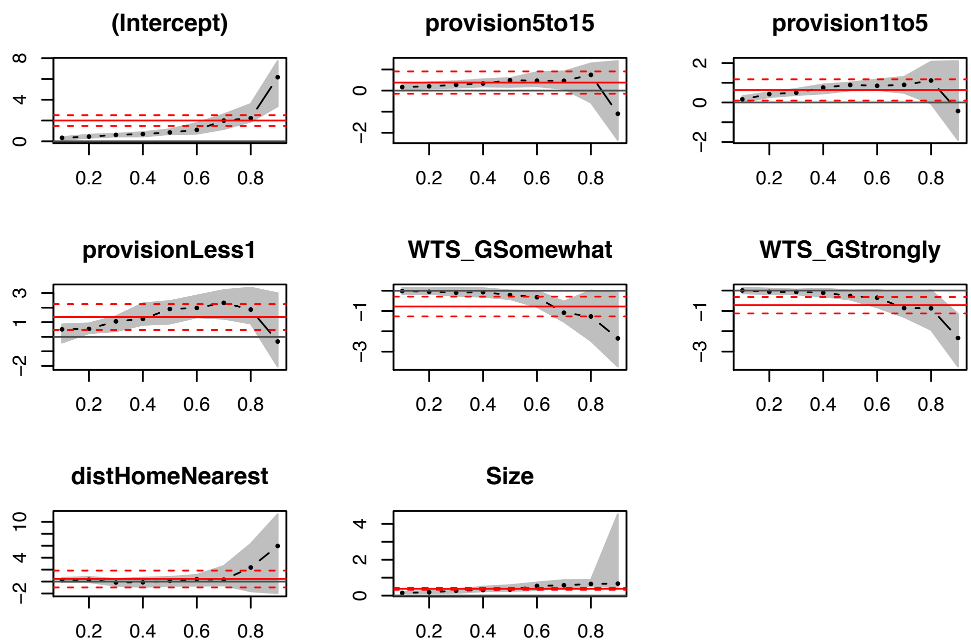
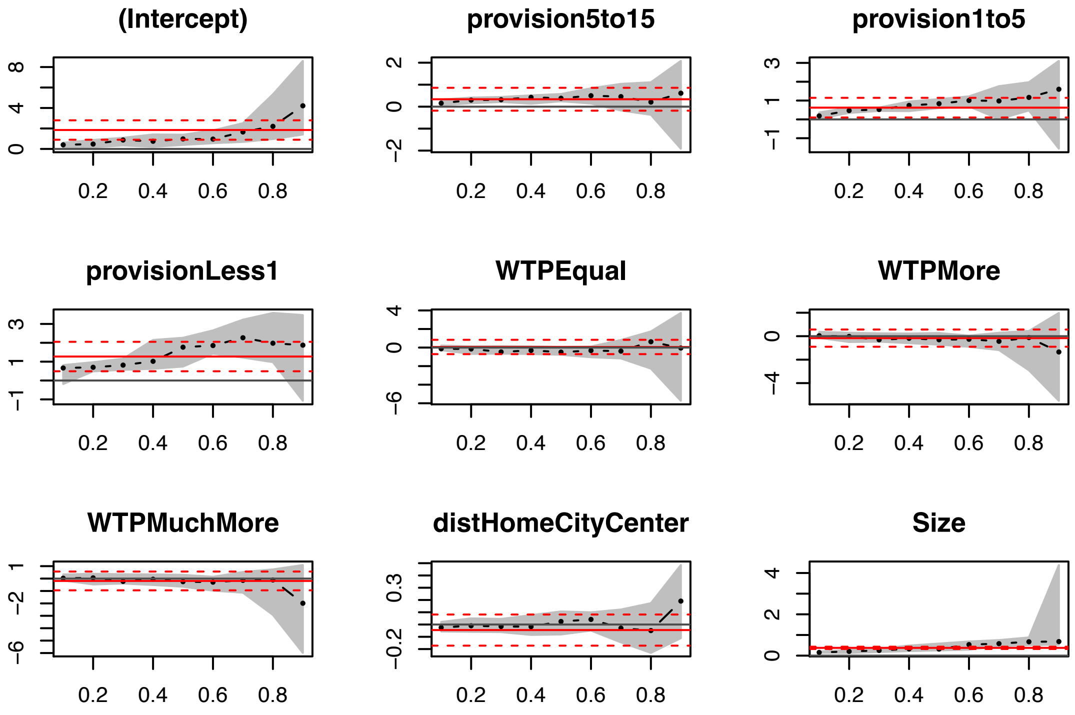
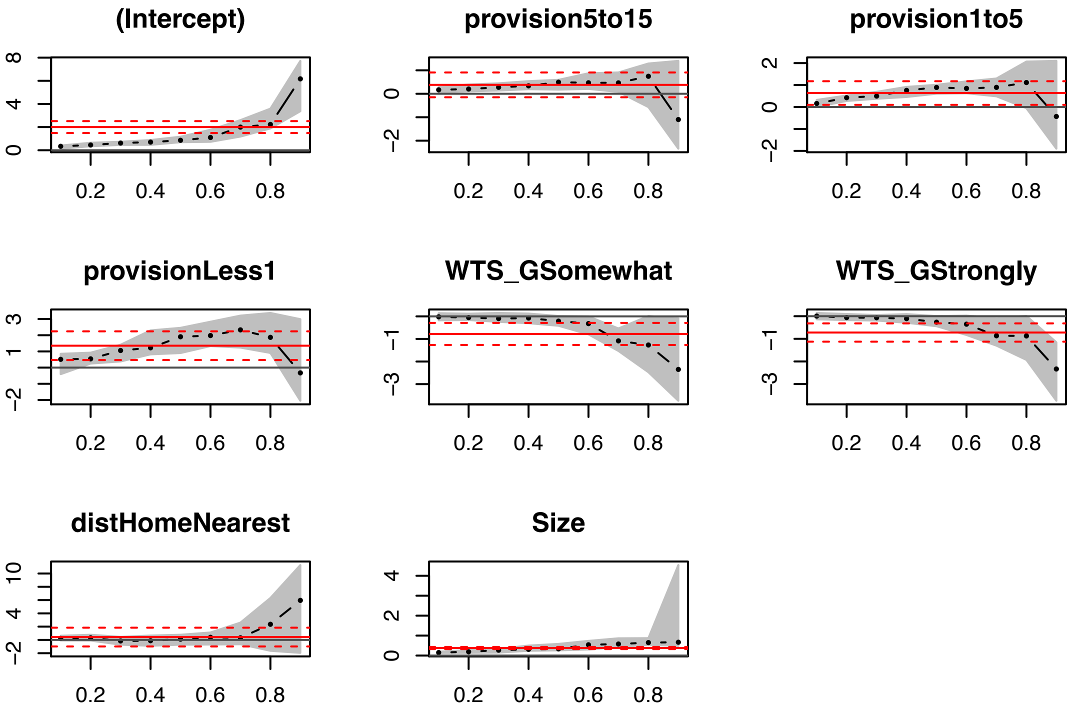
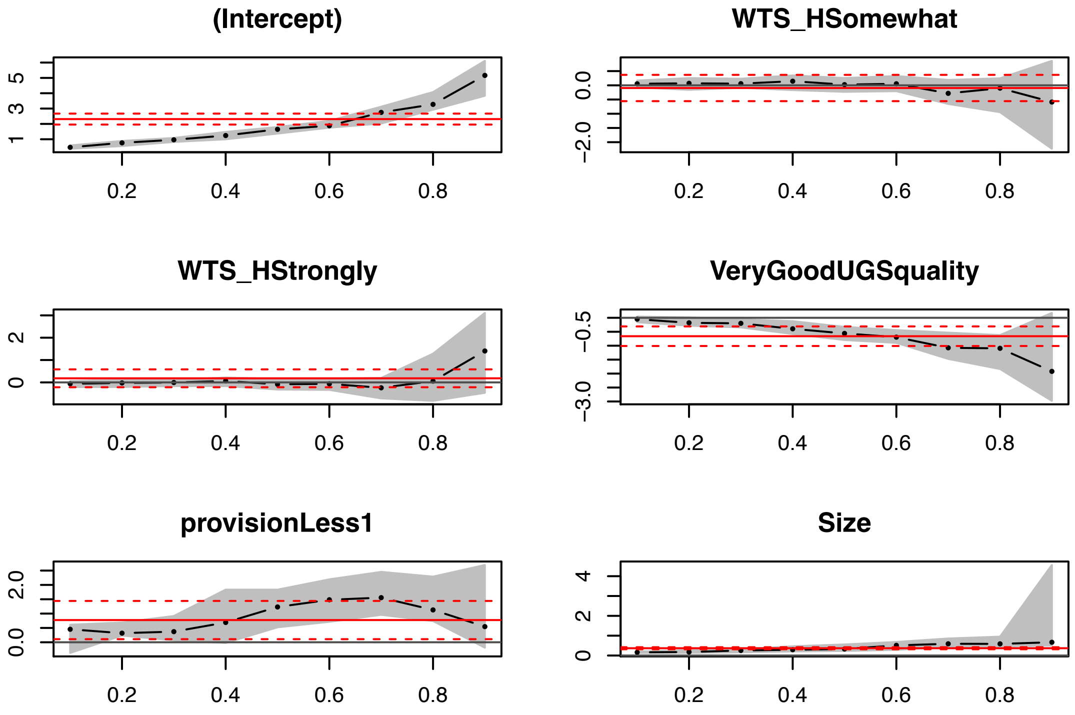


Figure C.3: Quantile regression analysis explaining the distance respondents travel to visit their most used UGS (network walking distance in km) with WTSG. UGS provision, willingness to substitute private for public UGS space, the distance to the nearest UGS and the size of the UGS are significant.


(Intercept)
provision5to15
provision1to5
provisionLess1
WTPEqual
WTPMore
WTPMuchMore
distHomeCityCenter
Size
0.2
0.4
0.6
0.8



(Intercept)
provision5to15
provision1to5
provisionLess1
WTS_GSomewhat
WTS_GStrongly
distHomeNearest
Size
0.2
0.4
0.6
0.8



(Intercept)
WTS_HSomewhat
WTS_HStrongly
VeryGoodUGSquality
provisionLess1
Size
1
3
5
0.0
−2.0
0
2
−0.5
−3.0
0.0
2.0
0
2
4
0.2
0.4
0.6
0.8