Ecological Economics 186 (2021) 107067

Contents lists available at ScienceDirect

Ecological Economics

journal homepage: www.elsevier.com/locate/ecolecon

Methodological and ideological options

Valuing urban green amenities with an inequality lens

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ARTICLE INFO

Keywords:
Ecosystem services
Hedonic analysis
Green amenities
Natural capital accounting
Distributional effects

ABSTRACT

Considering rapid urbanization worldwide, concern is growing that the resulting loss of green space affects welfare negatively. This study assesses how implicit prices of green amenities differ across apartments in different price groups to assess distributional impact of urban green amenities. Additionally, the paper proposes adjustments to enhance the standard hedonic model and increase comparability of estimates across study areas. Sales data for 6614 apartments in the suburbs of Stockholm, Sweden, an area that is relatively more prone to land conversion, were combined with GIS data on green urban areas and assessed in a simple log-linear model and quantile regression model. The results suggest that forested area even in a in a city with abundant green areas, have an impact on apartment prices. The price effect of green amenities differs strongly across both categories of 'green area' such as parks and forests, as well as, between the mean and the ends of the distribution of apartment prices. The proposed adjustments and results could be of use to other study areas.

1. Introduction

Urban ecosystem services are held to contribute to health and well-being (European Commission, 2015) and public policy seemingly gives unprecedented attention to biodiversity's contribution to welfare, such as in the G7-meeting and World Economic Forum. Simultaneously, the consideration of how environmental status has varying effect across groups of the population gains traction in policy. The emerging environment-inequality debate seems to largely suggest that the environment-inequality nexus is not complete without attention to distributional effects, of not only market, but non-market environmental amenities (Ernstson, 2013).[1]

Urban ecosystems contribute to health and wellbeing through multiple ecosystem services, including cultural ecosystem services such as recreation (European Commission, 2015, Fisher et al., 2009). However urban ecosystems vary in effectiveness to deliver ecosystem services, calling for a focus on appropriate spatial consideration and level of analysis (de Groot et al., 2010). Moreover, urban ecosystem services which are distributed unevenly and with different quality across space, have equity implications across households with different socio-economic characteristics (Geneletti et al., 2019, Nyelele and Kroll, 2020). Recent literature highlights the need to shed more light on the link between urban ecosystems and their distributional impacts with appropriate scale and granularity of analysis, at both the community and household level (Cortinovis et al., 2018).

The hedonic approach has been amply applied to value urban green amenities. (See Brander and Koetse, 2011 and Perino et al., 2014 respectively for systematic reviews of American and British case studies). Nevertheless, previous studies have mostly focused on the hedonic pricing of the proximity of urban green spaces (e.g. e.g., Fernandez et al., 2018 and Votis, 2017). Other measures include the area or the share of environmental amenity within a certain distance from the housing (Belcher and Chisholm, 2018; Saphores and Li, 2012); an interaction variable for area of and distance to the closest park or greenspace (Fernandez and Bucaram, 2019; Mahmoudi et al., 2013); gravity index consisting of distance weighted area of all green space (Pandit et al., 2014); and area or proportion of green space (or other environmental amenities) within multiple concentric buffers (Abbott and Klaiber, 2010; Sander et al., 2010). It is generally held that features such as direct view to green areas are highly valued (Lo and Jim, 2012). Therefore, for some apartments located near green areas immediate proximity could be the valuable characteristic.

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[1] E.g., health costs or productivity losses caused by air pollution.

https://doi.org/10.1016/j.ecolecon.2021.107067
Received 2 July 2020; Received in revised form 31 March 2021; Accepted 6 April 2021
Available online 2 May 2021

Because the functioning of the real estate market is relevant for policy, the findings by hedonic analysis are used by policy makers to shape policy. For example, whether and where to use regulation or the tax base to invest in public green areas: high implicit prices of certain green space, such as neighborhood parks, may warrant policies focusing on such areas (e.g., by conditioning housing development permits on the creation of nearby public neighborhood parks). However implicit prices from models focusing on average sales prices may ignore preferences of different income groups, and lead to policy that disregards equity concerns.

Natural Capital Accounting[2] aims to bring locally estimated values to a regional or national scale and has emerged as a way to represent nature's contribution to people in statistics underpinning policy making (see e.g., Hein et al., 2020). A notable such initiative is the United Nations System of Environmental Economic Accounting (SEEA). Recent developments of its SEEA Experimental Ecosystem Accounting explore how hedonic analysis can be used to represent the value of urban green amenities. Hedonic analysis complies with the transaction price convention of Natural Capital Accounting, However there are also challenges such as double counting, not least when hedonic analysis is used in combination with travel-cost models since both methods may account for value of proximity to green space for the same individual (Barton et al., 2015). Another challenge is non-representation of preferences amongst those not living in the area.

Heterogeneity of apartment prices is an important question addressed in this paper, to assess whether green spaces have different hedonic prices for properties with different values. Previous studies using the quantile regression hedonic model to this end include Fernandez and Bucaram (2019) who found that the effect of e.g., proximate volcanic parks in Auckland, New Zealand, had a highly varied effect on apartment prices across price segments. A recent study for Poland found support for that some urban green areas are a luxury good (Łaszkiewicz et al., 2019). China represents a different context, with a study of Shanghai finding that homeowners acquire preferential private urban green areas while renters are left with the publicly provided areas (Xiao et al., 2017).

Admittedly, proximity is an imperative property of urban green spaces that is likely to be capitalized into house prices. Yet, preferably there would be a more comprehensive measurement of the monetary value of per unit area of urban green spaces. Our approach seeks to enrich the currently thin evidence base in this regard, through measuring the hedonic prices of per unit area of green spaces surrounding each residential property. Several models with different radii of the buffer are compared (as in Saphores and Li, 2012). Moreover, the effect of distance may be linear or non-linear. Using buffers addresses this challenge, because it allows the capture of distance effects that fluctuate in a non-linear way across different distance bands. For example, it could be that only absolute proximity matters, where this would not be accurately captured by a linear approximation to distance effects.

Previous studies for the Stockholm municipality area have highlighted the positive preferences people have for urban green space and nature (e.g., Bokalders and Block, 2014). However the only study to our knowledge that aims to establish the relationship statistically (Spacescape, 2011) found no relationship between green space or nature, and apartment prices, respectively. This was attributed to the abundance of green space in Stockholm. To this end, the analysis uses a two-fold strategy: Firstly, an extremely short distance band is added. An advantage with this approach is that it is easily scalable to be used e.g., in national level Natural Capital Accounts, which is a secondary purpose of this study to explore. Secondly, to shed light on the magnitude of differences in preferences for urban green space, a standard quantile regression approach is applied to the city of Stockholm. Sweden and Stockholm are often portrayed as having low income differences and generous spending in public amenities. Indeed, Stockholm is abundant in green public space. While the inner city of Stockholm may more resemble that picture, we focus on the outer-Stockholm area which is socially more mixed as well as under greater pressure to convert land into built environment.

While the main aim of the paper is not to inform Natural Capital Accounting, we hold that the analysis can contribute also to such use and to other efforts building on the scaling up and/or transfer of study area findings from hedonic analysis to a larger/other geographical area (region, country).

The next section introduces hedonic pricing and the econometric focus of this study, followed by the methodology section outlining the model and data. The empirical analysis section presents the results, which are discussed and concluded in the final section.

2. Econometric model

Hedonic pricing is a long-standing approach for the valuation of environmental amenities. It assumes that house prices depend on features of the property per se, such as its age and floor area, as well as location-specific characteristics, such as environmental amenities and the distance to the city center (Bishop et al., 2020). For instance, a house surrounded by picturesque green spaces is likely to have a price premium compared to another house without any green spaces in its close proximity, other conditions being equal. Therefore, regressing house prices on these factors would reveal their individual effects on house prices, which can be regarded as these factors' implicit prices or their value capitalized into house prices. The conventional hedonic price model (Rosen, 1974) takes the form:

$$ln\ V = \alpha + \Sigma i\ \beta i\ Xi + \varepsilon \tag{1}$$

where selling price (V) is expressed in logged form, α is a constant term, βi is the regression coefficient for the ith housing characteristic (Xi) which captures the implicit price, and ε is the residual error term.

Regression analysis in hedonic studies commonly focus on the mean of the distribution, expressed as $E(y|X)$, where the expectation (E), of the left-hand side variable (y), is conditional on the right-side variable X. However as highlighted by Koenker and Hallock (2001) and Mosteller and Tukey (1977), this risks ignoring information that is important for interpreting the results, which is occurring at other percentage points of the distribution than at the mean. Quantile regression models extends the analysis to any part of the distribution of the left-hand side variable, expressed as any conditional quantile $Q\ y\ (\tau|X)$ and offer a more complete understanding of the relationship between the explanatory and the dependent variables. This is done by computing not one but several different regression curves, for different percentage points of the distributions. A proportion τ (or 100τ %) of the values of the left-side variable are up to (lower or the same as) the quantile estimate at the X value. One property of quantile models is that they do not build on assumptions about the distribution of the error term. Minimizing the sum of weighted absolute values of the error term produces the estimates (Koenker, 2005). For mathematical explanations of quantile regression, see e.g., Koenker (2005) and Lingxin and Naiman (2007).

Quantile models are used in marketing research to reveal information about high-value customers, in financial research to shed light on atypical but influential fluctuations in stock value, and more recently, in hedonic analysis of property markets (Zietz et al., 2007). Early applications of quantile regressions include ecological studies (Ydenberg and Dill, 1986). In the present study, examples include small tracts of relatively untouched forest, which may not generally affect property values in the area, but rather for apartments in the immediate proximity, or, by certain income groups.

It is to be observed that, the hedonic approach will give a

[2] See UN Statistics, accessed on March 23, 2020: https://seea.un.org/home/Natural-Capital-Accounting-Project

Table 1
Explanation of the variables included in the regression analysis.

Variable name	Variable specification
P: Price	
Ln sales price of apartment	Adjusted sales price: log of purchase price plus fee adjustment (SEK. 1 SEK aprox. = 0.1 EUR)
S: Structural characteristics (apartment, and building holding the apartment)	
Living area	Surface area (m^2)
New production	1 = the building is newly constructed, 0 = else
L: Location within the market	
Distance center	Distance to the center of Stockholm (m.)
Distance metro	Distance to nearest metro station (m.)
E: Environmental characteristics	
For all five variables below: Green area as a percentage of the total area, within each distance band (20 m., 50 m., 200 m., 500 m., 1000 m. radius from each individual apartment in the data set).[b]	
City park	Park at open plaza.
Neighborhood parks	Group variable for neighborhood parks.
Multiuse parks	Group variable for multiuse parks.
Nature	Group variable for nature areas except for'Forested area'.
Forest	Forest.
Other	
Month	Binary variables representing the month that the apartment was sold. January is chosen as reference variable against which the other month-variables are compared.
Congregation	Binary variables for the congregations in the sample.[a]

[a] Congregation is a geographical unit for small areas in cities in Sweden commonly used for administrative purposes. As reference variable against which to compare all the congregation dummies is the area of Skärholmen and Hässelby which has the lowest median income (approx. EURO 18000). Income data were not available for the households. Instead, data were extracted for median income of each apartment's census area (250*250 m), and the data added for all the apartments within the congregation.

[b] City Parks, e.g., the park named Lugnets park; Neighborhood parks e.g., Midsommarparken; Multiuse parks e.g., Årstafältet; Nature areas e.g., Södra Vinterviksparken; Forest e.g., Årstaskogens strand.

conservative estimate of the value of green spaces because the unit of analysis is apartments sold. Thereby, the sample consists of those living in the area, ignoring by-passers, and only those who own their flats, ignoring renters. Another source of underestimation is that spatial correlation between green areas decrease the explanatory power by increasing standard errors (Brander and Koetse, 2011).

3. Model specification and data

3.1. Basic model

Following function (1), the relationship below is to be estimated:

$$P = f\ (S, L, E) \tag{2}$$

Where price P depends on standard hedonic variables in a vector of structural characteristics (S) of the apartment and the building the apartment is in, location within the market (L) including the distance to the city center and transport, as well as environmental characteristics (E) which is a vector of different types of urban green spaces. Additionally a quantile version of the spatial auto correlation model was used to account for spatial endogeneity, estimated using the two-stage instrumental variable estimation method suggested by Kim and Muller (2004) to address the endogeneity issues associated with spatial lags (Zietz et al., 2007).

The outer-Stockholm area is used for this study because, in general, Stockholm city green spaces are rather well protected. In contrast, conversion pressure of urban green areas is much higher in suburban areas of Stockholm and therefore they are of greater policy interest (Region Stockholm, 2017).

Table 2
Summary statistics of the variables included in the regressions (Statistics for the middle-distance band, 200 m. is displayed. Summary statistics for all five distance bands are available upon request).

Variable	Mean	Std. Dev.	Min	Max
P: Price				
Ln sales price of apartment	14.605	0.319	13.006	15.897
S: Structural characteristics				
Living area	61.997	20.831	17	180
New production	0.064	0.246		
L: Location within the market				
Distance to center	7202.335	2609.128	3440	15,547
Distance to metro	624.840	549.583	13	2905
E: Environmental characteristics				
City park	0.0006	0.010	0	0.214
Neighborhood parks	0.0115	0.021	0	0.163
Multiuse parks	0.001	0.011	0	0.217
Nature	0.024	0.030	0	0.176
Forest	0.012	0.052	0	0.588
Month of sale				
February	0.084	0.278		
March	0.102	0.303		
April	0.095	0.294		
May	0.099	0.299		
June	0.097	0.297		
July	0.044	0.205		
August	0.079	0.271		
September	0.104	0.306		
October	0.092	0.289		
November	0.085	0.279		
December	0.042	0.201		
Congregation [a]				
Bromma	0.123	0.328		
Brännkyrka	0.096	0.295		
Enskede-årsta	0.135	0.342		
Farsta	0.086	0.280		
Hägersten	0.130	0.337		
Skarpnäck	0.131	0.337		
Spånga-kista	0.105	0.307		
Vantör	0.083	0.276		
Vällingby	0.031	0.174		
Västerled	0.038	0.193		

$N = 6300$ apartments.

3.2. Price (P) and structural characteristics (S)

Data for price and structural characteristics were purchased from the private company Mäklarstatistik. The sales data represent close to all sales of housing in the suburban part of the Stockholm Municipality (see Tables 1 and 2 for explanation of the variables and summary statistics, respectively). The dataset includes a large number of variables representing structural characteristic which are of interest to the main clients of Mäklarstatistik, which are real estate companies. However only a few of the variables are complete across the apartments and therefore suitable for statistical analysis. The year 2010 was chosen to allow a sufficiently long lag after the data for Environmental characteristics (E), which is for the year 2008. The conversion of green space in Stockholm has been relatively low for the past two decades; hence, the two-year lag should not be too long for studying the association between green areas and apartment prices. For the same reason the analysis should be relevant for today's land use policy.

The price variable was adjusted to reflect the value and not only the price of the apartment. In Sweden, ownership of an apartment usually consists of a share in a co-op of an apartment building. The value to the buyer of such an apartment is represented by two financial components: the upfront purchase price of the apartment and the monthly fee paid to the co-op. The monthly fee consists of maintenance costs for the building and the capital cost of the co-op. To compute this value, one could attempt to compute the net present value of future expenditures on fees.

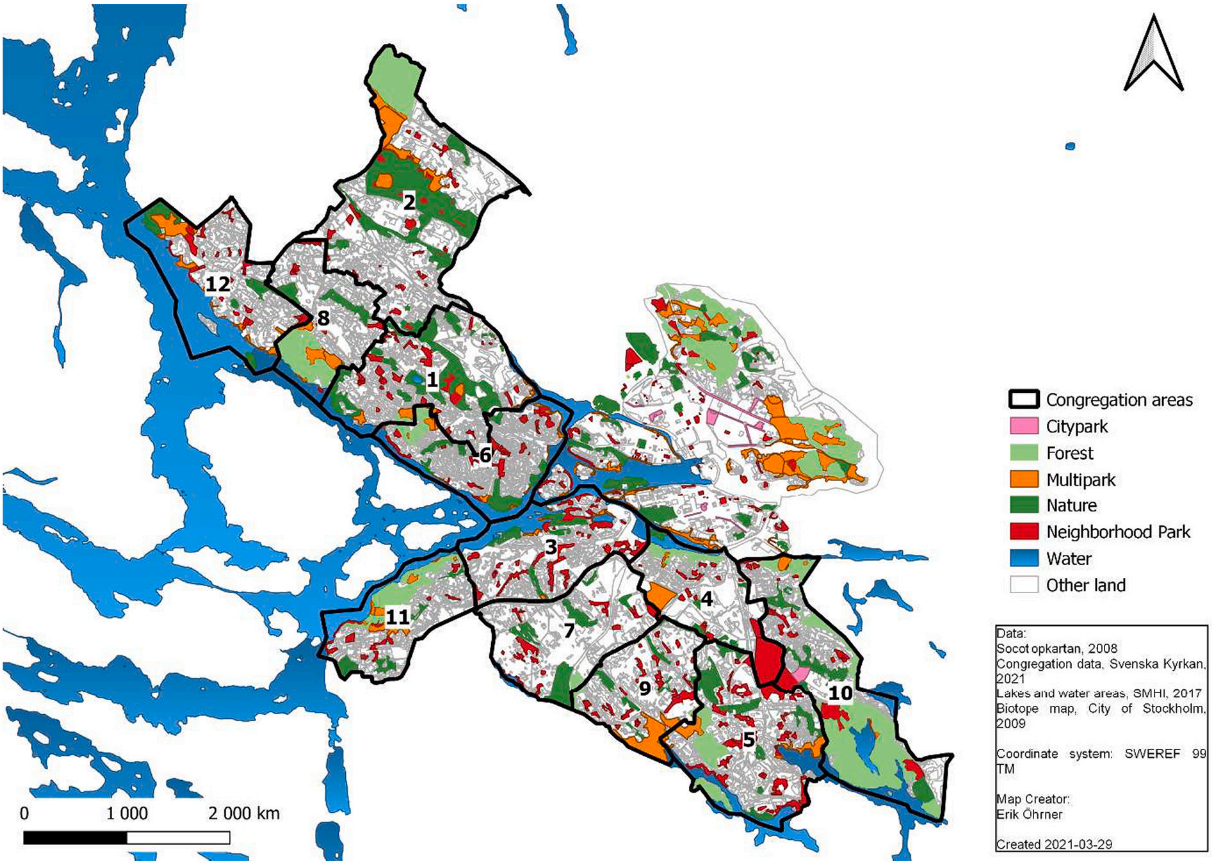

Fig. 1. Outer Stockholm area included in the regression analysis, by land use and congregation [a] (Stockholm City is the mapped area without black borderline).

However this approach has several challenges, such as assessing the expected ownership time of an apartment. The link between ownership time and hedonic price is complex to estimate because that relationship depends on socio-demographic characteristics of individual households.[3] Therefore we suggest, to our knowledge, a new adjustment which is obtained by first estimating the elasticity between the co-op fee and the price of the apartment. Additionally, the proposed adjustment enables us to straightforwardly compare hedonic results across both owned apartments and co-op apartments. The resulting metric facilitates comparisons and possibly value transfer of hedonic values across different sites, including internationally.

The weight that buyers give to the fee in their purchase decision is obtained through a two-stage approach. The apartment's fee is first regressed on the standard determinants used in the hedonic model. Thereafter the regression function is re-arranged by moving the coefficient for fee to the left- hand side (i.e., weighted purchase price$_i$ = price for apartment$_i$ + coefficient for fee * fee for the apartment). Thereby the coefficient, the effect that the fee has on the purchase price, is used as a measure for the weight that the fee has in the purchase decision. The new dependent variable expresses the lower bound of the buyers' preference for the apartment (the upper bound being unknown, because the buyer will, on average, pay the market price and not more).[4] To represent three categories of relatively low-, middle- and high price ranges for apartments, the model is deployed on the 25th, 50th and 75th percentiles of sales prices, respectively.[5]

Standard hedonic variables for structural characteristics from the literature are used, i.e., apartment size and a variable for apartments in newly constructed buildings since they have been shown to strongly affecting sales prices in Stockholm (Bjellerup and Majtorp, 2019).

3.3. Location within the market (L)

Distance to city center and to nearest subway are included as standard variables from the hedonic literature with an expected negative effect on apartment prices. Binary variables for the congregation where the apartment is located are used to control for heterogeneity across sublocalities in the study area (Bjellerup and Majtorp, 2019). These dummies control for such fixed effects pertaining to location which may otherwise confound the effect of the explanatory variables on sales prices.

3.4. Environmental characteristics (E)

The study area of Stockholm is characterized by its geological feature of several large land areas and abundant surface water. To some less extent the study area shares the features of the inner city, with city planning characterized by efforts to create connectivity between islands.

[3] E.g., Hjalmarson and Hjalmarson (2009) found that higher-income households relatively more consistently account for their real ownership time when valuing houses.

[4] A Box-Cox regression was used to test for the correct specification of the green space variables since they are new to the literature. The test of Box-Cox specification showed to be non-significant, and therefore the untransformed form of those variables is used.

[5] The models are estimated with robust estimators with standard errors that are asymptotically valid even under heteroscedasticity and misspecification, following Machado et al. (2011).

Table 3
Land use in Stockholm Municipality (year 2008)[a].

Urban green space	Ha.
Forest	2094
Citypark	75
Multipark	1032
Nature	1942
Neighborhood park	1219
Total green areas	6363

Source: Own elaboration based on Stockholm Sociotope map obtained from the Stockholm Munitipality.
[a] Stockholm municipality includes both Stockholm City and the study area which is outer Stockholm.

Outer Stockholm has abundant green areas. Data for the environmental characteristics were obtained from the Stockholm Sociotope provided by the Stockholm Municipality environmental office.[6] The data, for the year 2008, are produced for planning purposes by the municipality. The Stockholm Sociotope Map builds on stated preferences for different characteristics of neighborhoods, with a uniquely large set of pre-categorized green spaces and other urban characteristics, with highly detailed GIS data. The pre-categorized types of green space are based on interviews with Stockholm inhabitants, who identify distinct qualities of urban green areas. These spaces are then categorized into 22 types of so-called sociotopes. While a 'biotope' refers to the physical-ecological environment (e.g., a forest, cows in a meadow, etc.), a 'sociotope' adds the uses of, or values that, people attribute to this place (e.g. trees which symbolize vitality, a setting resembling a valued cultural element, etc.). The shape file maps 1182 polygons for so called 'sociotopes', within all open space in the Stockholm Municipality (Fig. 1). The minimum size of these sociotope polygons is 5000 sqm. Exceptionally, sociotopes down to 1000 sqm are included.

[a] Congregations: 1.Bromma, 2.Spånga-Kista, 3.Hägersten, 4. Enskede, 5.Farsta, 6.Västerled, 7.Brännkyrka, 8.Vällingby, 9.Vantör, 10. Skarpnäck, 11.Skärholmen, 12.Hässelby.

Source: Authors own creation based on the data listed in the figure.

Previous studies (e.g., Palmquist, 2005) have highlighted the need to complement the way people's perceptions are integrated into hedonic modeling. For example, Daams et al. (2016) uses primary data for stated perceptions of green areas, detailed by each specific location. The present study extends on the data approach of Daams et al. by using data with a more comprehensive set of green space categories. Moreover, the low cost of these data facilitates scaling up to the regional level.

To seek to improve on previous studies, a strategy was designed to assess both scarcity value (controlling for the general abundance of green areas around the apartment) and green space areas in the immediate proximity of the apartments, by the use of different distance bands. To determine the categories of green space to analyze in the regressions, the literature was surveyed, and inputs were sought from city planners in the countries included in this broader research project, resulting in five categories (Table 3 illustrates the highly mixed land use of the Stockholm municipality): City parks, are located mostly in business areas and in mixed areas for business, residential and other uses. Neighborhood parks, located near built areas, are used for relaxation, often has a green surface, and have low background noise. This category includes: Park blocks, which are very small neighborhood parks, serving as a green oasis with seats for relaxation, and garden plots, which are small gardens with planted flowers. Multiuse parks are both grassy parks and beach parks, which are aimed for leisure activities such as strolling and swimming. Nature areas include managed and unmanaged nature of different sizes, rivers and lakes, mountain parks (most of the park consists of rock surface and slopes) and landscape parks (multi-shape parks, with open fields and forest which constitute a clear feature in the city scape, often with water contact) as well as nature parks (park with much remaining original nature). The Forest category represents relatively unmanaged forest.[7]

A longer distance band of 5000 m. was excluded due to information from the literature and from city planners that this distance was less of a policy concern, due to the high abundance of green areas in the study area. Instead a 50 m. band was added to account for immediately proximate green areas. Apartments with a direct view to green spaces are likely to have a premium price. However such data was not available. Instead, as a rough proxy, a very short distance band of 20 m. was used. By inspecting GIS maps we concluded that a distance band of 20 m. is long enough to capture immediate green areas visible from the apartment, while short enough to exclude many other nearby buildings that could potentially block the view to those green areas.[8] Previous studies show mixed results for green amenity values for the area of and distance to green space (e.g., in Sander et al., 2010 the effect varied non-linearly across multiple concentric buffers), and rather inconclusive results across income levels (see e.g., the most comprehensive contribution to our knowledge, in Fernandez and Bucaram, 2019). To try to enhance the analysis, data with high spatial resolution and unusually high thematic detail for green space were obtained from the County of Stockholm. The variables are converted from area (m2) to percentage of that area to the total area of the buffer, to enable to interpret spatial decay.[9]

Proximity to surface water is a highly priced characteristic for apartments in some areas of Stockholm (Spacescape, 2011), and such areas (lakes and rivers) abound in the area, meaning that prices for apartments near water will to a large extent be dominated by water proximity rather than other characteristics, such as green areas. To eliminate this confounding effect, all apartments closer than 300 m to water were eliminated from the data using GIS analysis.[10] Binary variables for month of sale and congregation were included to control for seasonality in sales prices, and for heterogeneity across localities, respectively.

4. Results

For means of exposition the results for the log-linear OLS model and the full results of the quantile regression are placed in s Table A1 and Table A2, respectively. The regression results from the quantile regression of the spatial auto correlation model (Appendix B, Table A3: highly resemble those in the standard models. We found no substantial consequences of spatial autocorrelation, and therefore opted to focus on the standard quantile regression models. As can be seen (Figure A1:), the vast majority (98%) of the correlation coefficients are within the range (−0.2, 0.2), which does not seem to suggest substantial multicollinearity. We note that the OLS results are similar to the quantile regression results for the 50th percentile, while they differ in levels to the results of the 25th and 75th percentile. Below we interpret the results for the intersect between area and distance of green areas, and, quantiles of apartment prices, respectively (Table 4 and Fig. 2). R-squared for the fit of the model is relatively high (76.3 to 79.8 across the 15 regressions: regressions for five different

[6] A revised map is available for the year 2014. The 2008 version is used in this analysis due to budgetary reasons. The reason is that the map needs to match timewise with the other main dataset for this analysis, on housing prices. Housing data for 2014 is obtainable only for a price beyond the budget of this analysis.

[7] Cemeteries were excluded from the analysis due to their ambiguous effect on sales prices.

[8] While a more ad-hoc analysis, case-by-case, would provide higher accuracy of view to green space, we hold that our approach with a set distance is more tractable to scaling up, for purposes of natural capital accounting.

[9] Because one additional square meter of green area will have less effect in a 10,000 m. radius than in a 20 m. radius, using percentages facilitates the interpretation of the coefficients.

[10] This distance range was determined from visual inspection of GIS maps of the outer Stockholm study area. Starting from the shore and proceeding in a right angle inland-wards, the 300-m range captured most apartments with direct water view.

Table 4
Regression results for the association of environmental characteristics (E) with adjusted sales price of apartments (by distance band and for the 25th, 50th and 75th percentile of sales prices).

Variable	20 m.	50 m.	200 m.	500 m.	1000 m.
q 0.25					
City park	−3.259**	−1.065**	−0.776**	−0.678	−7.52***
Neighborhood parks	0.294	0.305	0.679*	1.906*	2.606
Multiuse parks	1.383***	−0.568	−0.379	−0.610	−1.111*
Nature	−0.056	0.012	−0.158	−1.125*	−0.775
Forest	0.192	0.155**	0.240***	0.174*	0.099
q 0.5					
City park	−6.443***	−1.653***	−1.166***	−1.323**	−10.104***
Neighborhood parks	0.270	0.349*	0.539	1.533*	1.999
Multiuse parks	0.714*	0.797*	−0.659*	−0.657	−1.514*
Nature	−0.011	0.022	−0.134	−0.652	−0.275
Forest	0.111**	0.105	0.148**	0.109	−0.005
q 0.75					
City park	−9.973***	−2.28***	−1.599	−1.659***	−12.535***
Neighborhood parks	0.190	0.275	0.360	0.752	0.534
Multiuse parks	0.277	0.208	−0.951	−1.276***	−2.198***
Nature	0.051	0.142	0.032	−0.441	0.006
Forest	−0.028	0.117	0.091*	0.100	0.061

* $p < .05$; ** $p < .01$; *** $p < .001$. $N = 6300$. Standard errors adjusted for 313 clusters by postal code.

distance bands, for each of the regressions with different quantiles (3); 0,78 to 0,8 for the OLS regressions); However it is generally advised to interpret this measure cautiously in quantile regressions.[11].)

The predictors for the structural characteristics (S) of apartments are statistically significant, across all distance bands and all quantiles, and behave as expected in accordance with the literature: The conditional distribution of the response (sales price) increases with the predictor for the size of the apartment. Apartments in newly constructed buildings are associated with a price premium. Likewise, the two variables for location in the market (L) behave as expected and in line with the literature. Apartments located further away from the city center of Stockholm have a relatively lower price. Prices are higher the nearer they are to the nearest metro station. The binary variables representing the month in year 2010 in which the apartment was sold controls for inflation. As expected, their coefficients increase throughout the year, with the last months having a statistically significant effect through all three percentiles.

Recalling from the method section, two aspects of green amenities are assessed: if and to what extent sales prices are influenced by, firstly, the size of surrounding green space (i.e., the area-unit measure that is necessary for Natural Capital Accounting); and secondly, the apartment's distance to green amenities (following classic hedonic theory). Additionally, assessing green urban amenity variables across distance bands allows to identify if and to what extent there is non-linearities in the relationship between green spaces and sales prices. For ease of exposition, the variables are first interpreted for: the center-percentile and for the middle-distance band relative to the number of distance bands, i.e., 200 m., for each green area category,[12] and thereafter by the effects across quantiles of sales prices. Because of the emerging nature of the metric used in this study for area and for different distance bands, the point estimates should be seen as illustrative.

The area of city parks is associated with a negative effect on sales prices, which is statistically significant for all five distance bands. For the middle-distance band, 200 m., a 1% increase in city park area is associated with negative 1.2% of sales price. As for the distance effect of the association between area and sales price: The estimates first decrease by distance until 500 m and then notably increase at 1 km. (all in absolute terms). The negative sign is consistent with studies finding that City parks can be perceived as a negative amenity by those living close to them (pers. comm. Magnus Rothman[13]). As for the functional form of the distance effect (i.e., the difference across distance bands) to the combined distance-area measure, the pattern is not clear. The initial spatial decay effect appears consistent with that City parks in outer-Stockholm are frequently perceived as noisy and even unsafe (pers. comm. Peter Wiborn[14]) which is consistent with some of the findings elsewhere (Troy and Morgan Grove, 2008; Groff and McCord, 2012; Troy et al., 2012).

However the reason why park size would have a higher negative effect in the 1000 m. band remains to be understood, although U-shaped patterns have been found in other study areas for other than urban green amenities (e.g., Liao and Yang, 2012). That result represents a similar pattern of non-linearity across distance as shown by, e.g., Fernandez and Bucaram (2019). We recall earlier attribution of lacking statistical results to the high abundance of green space in Stockholm (Spacescape, 2011). Possibly the measure for the distance-area intersect is associated with higher influence of confounders at longer distances.

For the second green space category, neighborhood parks, the effect of area is positive and statistically significant for distance bands 50 and 500 m. The positive sign is consistent with that neighborhood parks are primarily meant to serve the proximate community. One additional percentage of such park area within 50 m. (interpreting this band because the middle band, 200 m. is not statistically significant) is positively associated with sales prices by 0.3%. The distance effect is consistent for all distance bands (statistically significant for the three shortest bands) and increase by distance. The reason to an inverse spatial decay of the distance-area measure is unclear. Possibly, while neighborhood parks have a positive effect on prices, they may be perceived as an amenity of secondary priority, next to other amenities such as stores and restaurants (pers. comm. Magnus Rothman[15]).

The area of multi-use parks is positively associated with sales price for the closer distance bands and is statistically significant (for four out of five distance bands). For example, one additional percent of multiuse parks within 200 m. is negatively associated with sales prices by 0.6%. The coefficient is rather similar for the 20 m. and 50 m. bands, where after the coefficient declines to the extent that the sign shifts to negative. The reasoning for the area effect is unclear but could possibly be similar as for neighborhood parks: in the outer city area studied here, multi-use parks, such as large fields of grass, can indeed be very large. It is possible

[11] The Parente-Santos Silva test for intra-cluster correlation (Parente and Santos Silva, 2013) indicated correlation. Therefore, the standard errors were computed following Parente and Santos Silva (2016) which allows for intra-cluster correlation, in our case by clustering by the apartments' postal code.

[12] Additionally, the 200 m. band has relatively many statistically significant variables and thereby enables clear inter-variable comparisons.

[13] Environmental Planning Unit at Stockholm City, Sep 4, 2019.

[14] Environmental Planning Unit at Stockholm City, Sep, 2019.

[15] Environmental Planning Unit at Stockholm City, Sep 4, 2019.

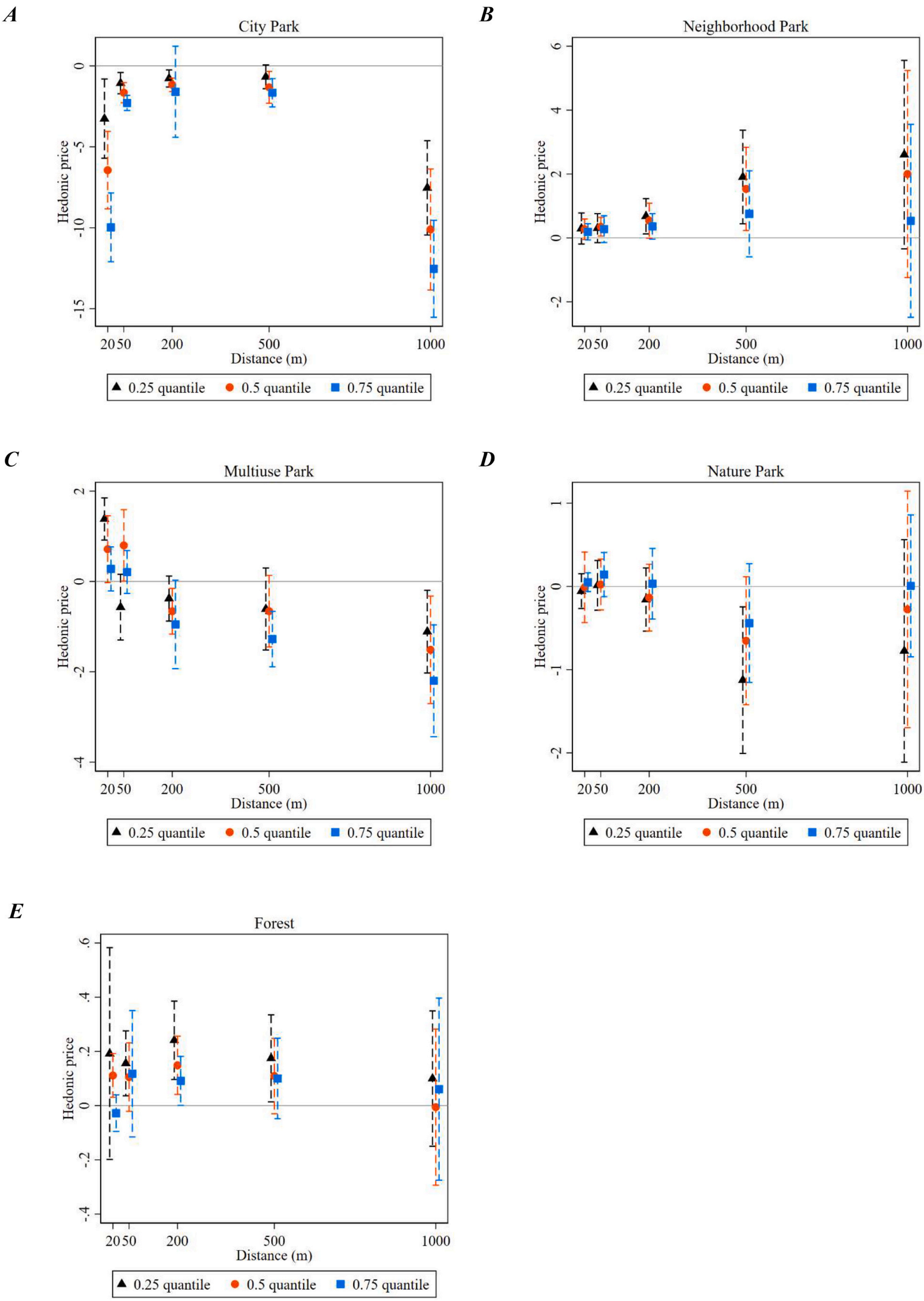

Fig. 2. Regression results.
Note: symbols represent point estimates and dashed lines represent 95% confidence intervals.

that they are perceived to crowd-out other services that are valued for households in the study area.

The area of green space classified as natural areas displays a negative result (except for at the 50 m. band), with an increasingly negative effect across the distance bands, but is not statistically significant. There could be several reasons why the effect of nature areas differs to the effect of forested land. One reason may be that area is perceived differently between the two, as a function of how the different green areas are used. A possibility is that forested land is a place to go to for a somewhat longer time. Instead, nature areas, such as those covered here, offer well-being not so much as a function of the size of the area, but rather, the existence of any natural space. In contrast, in the area of the remaining category, forest has a positive association with sales price, and is statistically significant (for two out of five distance bands). For example, one additional percent of forest area within 200 m. increases the sales price with 0.1%. The effect is rather stable across the distance bands. We note that the forest category has the most stable effect across the distance bands compared to all the green area categories.

We note that the results for the 25th, 50th and 75th percentile differ. The 25th and 50th percentile has higher explanatory power for green space. This difference accrues to those green spaces that have a positive not negative price effect (both neighborhood parks and forests). Assuming that the apartment price goes with household income, this would suggest that proximity and the size of neighborhood parks and forests have a stronger price effect on relatively lower-price apartments than other apartments. This seems to run against common wisdom that green amenities represent a luxury good (see, e.g., Chadourne et al. 2013), being relatively higher valued by high-income than other households. However the results refer to only the relative levels of the hedonic prices of green space (relative to total apartment prices), not the absolute levels, since the estimates are derived from log-linear models. Moreover, Fernandez and Bucaram (2019) highlights non-linearity of the linkage between apartment prices and green space across quantiles and across the distance and area of green space, respectively. As such, our results reiterate that the understanding of how perceptions about green space vary across price quantiles is still emerging.

5. Discussion and concluding remarks

Conventional hedonic models assess only mean values of prices. This paper relaxes that constraint by using the quantile regression to shed light on implicit prices of green urban amenities across categories of apartment prices, to approximate distributional impacts of urban green areas. The study contributes to the literature on valuation of urban green amenities not only by providing one of only few hedonic studies of Scandinavia; the study also proposes adjustments of the conventional specification of the hedonic model to increase comparability of hedonic studies across locations and countries (that is, the adjustment of the dependent variable to account for co-op fees); a simple yet new attempt to control for view from the apartment in a context of abundant green areas which else risk masking the effect of green amenities on hedonic prices (a distance band designed to capture view from the apartment); and the use of pre-existing original data with unusual level of granularity and which is based on stated preferences.

Previous studies examining the effect of urban green space on sales prices have found mixed results, not least for forests, and, across quantiles of apartment prices. Because the understanding of how people's perceptions for urban green areas translates into property prices is still emerging, we recall that our study proposes modifications rather than reliable point estimates. For example, Barton et al. (2015) call for a more granular approach to hedonic analysis, including interaction effects. We note that our results are consistent with previous studies for the conventional hedonic variables and align to previous studies on urban green amenities by highlighting that, e.g., City parks can indeed be a negative amenity, and that neighborhood parks and relatively unmanaged forested land tend to have a positive effect on apartment prices.

Previous hedonic studies of urban green amenities in Stockholm and Oslo (Spacescape, 2011; Barton et al., 2015) found no statistically significant effects of several types of green areas on housing prices. This was attributed to particulars of the case study context, notably, abundance of green areas. However possibly because of our proposed adjustments to the hedonic model, we identified a positive association between forested land and apartment prices even in this case study area which is abundant with green areas. This result may be of interest for urban planning processes which tend to have a highly local scope, paying less attention to the regional scale with the risk of undervaluing forest patches located between building projects which consequently risk being disregarded (pers. Comm. Bette Lundh-Malmros[16]).

Our results show that implicit prices for especially some of the green area categories differ across price quantiles, which we hold to highlight the need to address distributional aspects of green amenities. In our study, forested land is one such category. Because of such distributional effects, from a public welfare and inequality lens, policymakers may need to assure that the information guiding their decision represents the preferences for green amenities for all income groups, including those living in rented apartments. There seems to be a need for future studies to go more in depth regarding the factors that influence how urban ecosystem services can contribute to a more equitable outcome. The quantile regression framework with the proposed adjustments seem to be a straightforward way to approximate such distributional effects and could possibly be of use in Natural Capital Accounting, even without census data which may be difficult to obtain in many countries.

Others, beyond those owning apartments or living in the area, have preferences for urban amenities, which highlights another angle of distributional effects of urban planning. Moreover, we want to caution that the distributional aspect of implicit prices for green areas is likely to differ across locations with different ratios of owned (i.e., the data for this study) to rented apartments, aspects such as quality of green areas, as well as subcategories of green space. For example, City parks are likely to have a relatively large number of by-passers, many of whom are likely to appreciate the green space they offer. Moreover, City parks are often surrounded by a relatively low share of private housing to commercial buildings. Therefore, the hedonic estimate for City parks can be thought to be particularly conservative concerning the general public's preferences. In contrast, the number of persons appreciating Neighborhood parks may be lower, despite that the share of private housing is likely to be larger. Arguably for this category, the estimate is less conservative. Multiuse parks and Natural areas are e.g., likely to have a relatively lower share of non-residents appreciating them as compared with Neighborhood parks.

Finally, the results re-open the question about how to consider results in hedonic studies, which, in this case, are those that seek to shed light on the value of urban green areas. Apartments with certain characteristics increase disproportionally in value during a housing boom, such as newly constructed apartments (SvD, 2011). The results show that several of the urban green areas have relatively higher implicit prices for lower-priced in contrast to higher-priced apartments. This reminds that valuation studies conducted in booming and down-turn housing markets, respectively, need to be interpreted differently, with equity implications for how valuation studies inform long term urban planning decisions concerning green areas.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

This paper is an output of the Ecosystem Services Accounting for

[16] Environmental Unit of Region Stockholm, Sep. 13, 2016.

Development (ESAfD) project, funded by the Swedish International Development Cooperation Agency (SIDA, grant number NV-05230-14, 2013) and implemented together by the Environment for Development (EfD) initiative and the Swedish Environment Protection Agency. We are grateful to Catarina Silveira who conducted interviews, and to useful feedback on early ideas and manuscripts received from the entire ESAfD team; at the Third Annual Meeting of the Policy and Technical Experts Committee (PTEC) of the World Bank (2014); and in project meetings with the World Bank Wealth Accounting and the Valuation of Ecosystem Services (WAVES). Ulrika Egero, Ecologist at Stockholm City, provided helpful suggestions on urban ecology. We are also indebted to Dr. Ian Brown (Stockholm University) for valuable suggestions on the GIS work, and to Hernán De Angelis (Swedish EPA) for help to processing the GIS data.

Appendix A

Table A1
OLS regression results of adjusted sales price of apartments. By distance band (Outer Stockholm, year 2010).

	Model 16	Model 17	Model 18	Model 19	Model 20
	20 m.	50 m.	200 m.	500 m.	1000 m.
	b/se	b/se	b/se	b/se	b/se
S: Structural characteristics					
Living area	0.013***	0.013***	0.013***	0.013***	0.013***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
New production	0.088***	0.087***	0.078**	0.068*	0.064*
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
L: Location within the market					
Distance metro	−0.000***	−0.000***	−0.000***	−0.000***	−0.000***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Distance centre	−0.000	−0.000	−0.000	−0.000	−0.000
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
E: Environmental characteristics					
City park	−7.671***	−1.743***	−1.258***	−1.372**	−10.315***
	(1.08)	(0.24)	(0.22)	(0.51)	(1.61)
Neighborhood parks	0.319*	0.361*	0.488*	1.214	1.522
	(0.14)	(0.14)	(0.24)	(0.67)	(1.33)
Multiuse parks	0.730**	0.143	−0.541	−1.059**	−1.904***
	(0.25)	(0.58)	(0.39)	(0.39)	(0.55)
Nature	0.059	0.174	−0.012	−0.724	−0.446
	(0.13)	(0.17)	(0.25)	(0.40)	(0.58)
Forest	0.138*	0.162**	0.213**	0.181*	0.116
	(0.06)	(0.05)	(0.07)	(0.09)	(0.14)
Month					
February	−0.003	−0.003	−0.002	0.001	0.003
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
March	0.001	0.001	0.003	0.003	0.005
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
April	−0.002	−0.003	−0.003	−0.002	0.003
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
May	−0.012	−0.012	−0.010	−0.009	−0.009
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
June	−0.002	−0.003	−0.001	0.001	0.000
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
July	−0.014	−0.016	−0.011	−0.008	−0.006
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
August	0.025*	0.025*	0.025*	0.024*	0.029**
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
September	0.025*	0.024*	0.025*	0.025*	0.032***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
October	0.036***	0.035***	0.037***	0.038***	0.036***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
November	0.041***	0.041***	0.041***	0.042***	0.046***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
December	0.041***	0.040**	0.041***	0.040**	0.044***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Congregation					
Bromma	0.073	0.074	0.078	0.091	0.134*
	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)
Brännkyrka	−0.155*	−0.155*	−0.150*	−0.142*	−0.086
	(0.07)	(0.07)	(0.07)	(0.07)	(0.06)
Enskede-årsta	−0.072	−0.072	−0.066	−0.075	0.029
	(0.08)	(0.08)	(0.08)	(0.08)	(0.07)
Farsta	−0.015	−0.017	−0.013	0.010	0.026
	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)
Hägersten	−0.002	−0.000	0.011	0.027	0.089
	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)
Skarpnäck	−0.048	−0.047	−0.040	−0.024	0.081

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Table A1 (*continued*)

	Model 16	Model 17	Model 18	Model 19	Model 20
	20 m.	50 m.	200 m.	500 m.	1000 m.
	b/se	b/se	b/se	b/se	b/se
	(0.08)	(0.08)	(0.07)	(0.07)	(0.07)
Spånga-kista	−0.073	−0.073	−0.077	−0.065	−0.025
	(0.05)	(0.06)	(0.05)	(0.05)	(0.05)
Vantör	−0.203**	−0.204**	−0.198**	−0.181**	−0.114
	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)
Vällingby	0.066	0.067	0.064	0.069	0.091
	(0.05)	(0.05)	(0.05)	(0.06)	(0.05)
Västerled	0.127	0.128	0.139	0.155*	0.221**
	(0.08)	(0.08)	(0.08)	(0.08)	(0.07)
Constant	14.303***	14.297***	14.273***	14.265***	14.139***
	(0.11)	(0.11)	(0.10)	(0.11)	(0.11)
R-sqr	0.777	0.778	0.780	0.786	0.795

* $p < .05$; ** $p < .01$; *** $p < .001$. Standard errors in parenthesis, adjusted for 313 clusters by postal code. n = 6300.

Table A2
Quantile regression results of adjusted sales prices for apartments. By distance band and for the 25th, 50th and 75th percentile of sales prices (Outer Stockholm, year 2010).

	Models 1,2,3	Models 4,5,6	Models 7,8,9	Models 10,11,12	Models 13,14,15
	20 m.	50 m.	200 m.	500 m.	1000 m.
	b/se	b/se	b/se	b/se	b/se
Q 0.25					
S: Structural characteristics					
Living area	0.012***	0.012***	0.012***	0.012***	0.012***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
New production	0.144***	0.143***	0.135***	0.120***	0.119***
	(0.03)	(0.03)	(0.02)	(0.03)	(0.03)
Distance metro	−0.000***	−0.000***	−0.000***	−0.000***	−0.000***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Distance centre	−0.000*	−0.000*	−0.000**	−0.000**	−0.000*
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
E:Environmental characteristics					
City park	−3.260**	−1.065**	−0.776**	−0.678	−7.530***
	(1.25)	(0.39)	(0.30)	(0.37)	(1.49)
Neighborhood parks	0.295	0.306	0.679*	1.907*	2.606
	(0.25)	(0.23)	(0.28)	(0.74)	(1.49)
Multiuse parks	1.383***	−0.569	−0.379	−0.611	−1.111*
	(0.24)	(0.37)	(0.26)	(0.45)	(0.47)
Nature	−0.057	0.012	−0.158	−1.126*	−0.775
	(0.11)	(0.15)	(0.19)	(0.45)	(0.68)
Forest	0.192	0.156**	0.241***	0.175*	0.100
	(0.20)	(0.06)	(0.07)	(0.08)	(0.13)
Constant	14.343***	14.338***	14.317***	14.310***	14.208***
	(0.09)	(0.09)	(0.09)	(0.07)	(0.08)
February	−0.005	−0.006	−0.005	0.002	0.002
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
March	−0.008	−0.009	−0.007	−0.005	−0.007
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
April	−0.005	−0.006	−0.001	0.000	−0.005
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
May	−0.012	−0.013	−0.009	−0.006	−0.013
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
June	−0.021	−0.018	−0.015	−0.013	−0.022*
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
July	−0.018	−0.020	−0.013	0.002	−0.011
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
August	0.019	0.015	0.012	0.016	0.013
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
September	0.030*	0.026	0.023	0.025	0.030**
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
October	0.037**	0.034**	0.039**	0.044***	0.039***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
November	0.039**	0.040***	0.046***	0.044***	0.043***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
December	0.049***	0.047**	0.043**	0.046**	0.043***
	(0.01)	(0.02)	(0.02)	(0.02)	(0.01)
Congregation					

(*continued on next page*)

Table A2 (*continued*)

	Models 1,2,3	Models 4,5,6	Models 7,8,9	Models 10,11,12	Models 13,14,15
	20 m.	50 m.	200 m.	500 m.	1000 m.
	b/se	b/se	b/se	b/se	b/se
Bromma	0.098	0.099	0.096	0.122**	0.142**
	(0.05)	(0.05)	(0.05)	(0.04)	(0.05)
Brännkyrka	−0.153	−0.153	−0.155	−0.134*	−0.103
	(0.09)	(0.09)	(0.08)	(0.06)	(0.08)
Enskede-årsta	−0.063	−0.060	−0.064	−0.078	−0.001
	(0.07)	(0.07)	(0.07)	(0.06)	(0.06)
Farsta	0.045	0.043	0.033	0.073	0.071
	(0.05)	(0.05)	(0.05)	(0.04)	(0.05)
Hägersten	0.010	0.011	0.014	0.033	0.074
	(0.06)	(0.05)	(0.06)	(0.04)	(0.05)
Skarpnäck	−0.034	−0.033	−0.034	−0.004	0.067
	(0.06)	(0.06)	(0.07)	(0.05)	(0.05)
Spånga-kista	−0.001	−0.005	−0.022	−0.004	0.014
	(0.06)	(0.05)	(0.05)	(0.05)	(0.06)
Vantör	−0.160**	−0.161**	−0.166**	−0.138***	−0.112*
	(0.05)	(0.05)	(0.05)	(0.04)	(0.05)
Vällingby	0.155**	0.152**	0.138**	0.149***	0.153**
	(0.06)	(0.05)	(0.05)	(0.04)	(0.05)
Västerled	0.075	0.077	0.087	0.113*	0.151**
	(0.06)	(0.06)	(0.06)	(0.05)	(0.05)
R-sqr	0.764	0.765	0.767	0.772	0.784
Q 0.5					
S: Structural characteristics					
Living area	0.013***	0.013***	0.013***	0.013***	0.013***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
New production	0.110***	0.110***	0.105***	0.092**	0.087**
	(0.03)	(0.02)	(0.03)	(0.03)	(0.03)
Distance metro	−0.000***	−0.000***	−0.000***	−0.000***	−0.000***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Distance center	−0.000**	−0.000**	−0.000**	−0.000*	−0.000
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
E:Environmental characteristics					
City park	−6.443***	−1.654***	−1.167***	−1.324**	−10.105***
	(1.41)	(0.32)	(0.21)	(0.49)	(1.91)
Neighborhood parks	0.270	0.349*	0.539	1.533*	1.999
	(0.16)	(0.15)	(0.28)	(0.66)	(1.66)
Multiuse parks	0.715*	0.798*	−0.660*	−0.657	−1.515*
	(0.34)	(0.37)	(0.26)	(0.40)	(0.61)
Nature	−0.011	0.023	−0.135	−0.653	−0.276
	(0.22)	(0.15)	(0.20)	(0.39)	(0.73)
Forest	0.111**	0.105	0.149**	0.109	−0.006
	(0.04)	(0.06)	(0.05)	(0.07)	(0.15)
Month					
February	0.003	−0.001	0.006	0.004	0.006
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
March	0.006	0.005	0.008	0.004	0.001
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
April	−0.001	−0.001	−0.002	−0.006	−0.002
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
May	−0.000	0.001	0.001	−0.007	−0.002
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
June	0.005	0.003	0.009	−0.001	0.001
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
July	−0.006	−0.007	0.006	−0.002	0.006
	(0.02)	(0.02)	(0.01)	(0.02)	(0.01)
August	0.038***	0.037***	0.038***	0.034**	0.033**
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
September	0.037***	0.035***	0.040***	0.029**	0.032***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
October	0.056***	0.053***	0.057***	0.048***	0.048***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
November	0.064***	0.063***	0.062***	0.054***	0.058***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
December	0.057***	0.057***	0.059***	0.057***	0.054***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Congregation					
Bromma	0.011	0.012	0.003	0.037	0.078
	(0.12)	(0.12)	(0.08)	(0.07)	(0.08)
Brännkyrka	−0.190	−0.190	−0.201*	−0.190**	−0.129
	(0.13)	(0.12)	(0.08)	(0.07)	(0.09)

(*continued on next page*)

Table A2 (*continued*)

	Models 1,2,3	Models 4,5,6	Models 7,8,9	Models 10,11,12	Models 13,14,15
	20 m.	50 m.	200 m.	500 m.	1000 m.
	b/se	b/se	b/se	b/se	b/se
Enskede-årsta	−0.150	−0.150	−0.154	−0.143	−0.029
	(0.14)	(0.14)	(0.10)	(0.08)	(0.11)
Farsta	−0.048	−0.046	−0.050	−0.007	0.004
	(0.12)	(0.11)	(0.07)	(0.06)	(0.07)
Hägersten	−0.093	−0.091	−0.089	−0.053	0.019
	(0.14)	(0.13)	(0.09)	(0.08)	(0.11)
Skarpnäck	−0.106	−0.105	−0.110	−0.073	0.033
	(0.14)	(0.14)	(0.09)	(0.08)	(0.11)
Spånga-kista	−0.088	−0.087	−0.099	−0.068	−0.032
	(0.11)	(0.11)	(0.07)	(0.06)	(0.06)
Vantör	−0.246*	−0.247*	−0.254***	−0.217**	−0.158
	(0.12)	(0.12)	(0.08)	(0.07)	(0.09)
Vällingby	0.046	0.049	0.033	0.051	0.077
	(0.11)	(0.11)	(0.07)	(0.07)	(0.07)
Västerled	0.012	0.013	0.015	0.051	0.128
	(0.14)	(0.14)	(0.09)	(0.08)	(0.12)
Constant	14.424***	14.422***	14.404***	14.380***	14.222***
	(0.17)	(0.17)	(0.12)	(0.12)	(0.17)
R-sqr	0.773	0.774	0.776	0.782	0.792
Q 0.75					
S: Structural characteristics					
Living area	0.014***	0.014***	0.014***	0.014***	0.014***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
New production	0.069***	0.069***	0.063**	0.056*	0.051*
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
L: Location within the market					
Distance metro	−0.000***	−0.000***	−0.000***	−0.000***	−0.000***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Distance center	−0.000	−0.000	−0.000	−0.000	−0.000
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
E:Environmental characteristics					
City park	−9.973***	−2.287***	−1.599	−1.660***	−12.535***
	(1.08)	(0.24)	(1.43)	(0.47)	(1.53)
Neighborhood parks	0.191	0.275	0.360	0.753	0.535
	(0.13)	(0.21)	(0.21)	(0.68)	(1.54)
Multiuse parks	0.278	0.208	−0.951	−1.276***	−2.198***
	(0.26)	(0.26)	(0.51)	(0.31)	(0.63)
Nature	0.051	0.142	0.032	−0.441	0.006
	(0.05)	(0.14)	(0.22)	(0.36)	(0.44)
Forest	−0.028	0.118	0.091*	0.100	0.061
	(0.05)	(0.12)	(0.05)	(0.07)	(0.17)
Month					
February	0.002	0.001	0.004	−0.001	−0.000
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
March	0.002	0.002	0.004	0.001	0.008
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
April	−0.007	−0.007	−0.003	−0.010	0.000
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
May	0.005	0.007	0.007	0.001	0.008
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
June	0.006	0.005	0.007	0.005	0.006
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
July	0.009	0.009	0.012	0.007	0.007
	(0.01)	(0.02)	(0.01)	(0.01)	(0.01)
August	0.025*	0.027*	0.026*	0.023	0.029**
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
September	0.037**	0.038**	0.040**	0.032**	0.043***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
October	0.044**	0.043**	0.044***	0.034**	0.043***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
November	0.058***	0.057***	0.058***	0.055***	0.058***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
December	0.059***	0.062***	0.062***	0.046***	0.053***
	(0.02)	(0.02)	(0.02)	(0.01)	(0.01)
Congregation					
Bromma	0.008	0.012	0.023	0.032	0.058
	(0.11)	(0.11)	(0.09)	(0.07)	(0.06)
Brännkyrka	−0.168	−0.168	−0.164	−0.169*	−0.123*
	(0.11)	(0.11)	(0.09)	(0.07)	(0.06)
Enskede-årsta	−0.139	−0.136	−0.123	−0.120	−0.022

(*continued on next page*)

Table A2 (*continued*)

	Models 1,2,3	Models 4,5,6	Models 7,8,9	Models 10,11,12	Models 13,14,15
	20 m.	50 m.	200 m.	500 m.	1000 m.
	b/se	b/se	b/se	b/se	b/se
	(0.13)	(0.13)	(0.11)	(0.09)	(0.07)
Farsta	−0.081	−0.086	−0.078	−0.065	−0.059
	(0.10)	(0.10)	(0.08)	(0.06)	(0.06)
Hägersten	−0.073	−0.070	−0.053	−0.031	0.013
	(0.12)	(0.12)	(0.10)	(0.08)	(0.07)
Skarpnäck	−0.089	−0.086	−0.074	−0.055	0.026
	(0.13)	(0.13)	(0.11)	(0.09)	(0.07)
Spånga-kista	−0.105	−0.106	−0.109	−0.103	−0.069
	(0.10)	(0.10)	(0.08)	(0.06)	(0.05)
Vantör	−0.243*	−0.243*	−0.231*	−0.220**	−0.156*
	(0.11)	(0.11)	(0.10)	(0.07)	(0.07)
Vällingby	0.013	0.013	0.012	0.022	0.050
	(0.11)	(0.12)	(0.10)	(0.08)	(0.06)
Västerled	0.055	0.054	0.073	0.090	0.149
	(0.12)	(0.13)	(0.11)	(0.09)	(0.08)
Constant	14.364***	14.359***	14.323***	14.304***	14.202***
	(0.17)	(0.16)	(0.14)	(0.12)	(0.11)
R-sqr	0.767	0.769	0.771	0.777	0.787

* $p < .05$; ** $p < .01$; *** $p < .001$. Standard errors in parenthesis, adjusted for 313 clusters by postal code. $n = 6300$.

Appendix B. Regression results from quantile regression of the spatial auto correlation model

This is a brief summary of the regression results of the quantile version of the spatial auto correlation model:

$$Q[P_i|X_i, q] = X_i\beta_q + \rho_q \sum_j W_{ij}P_j + \varepsilon$$

where P_i represents the price of apartment *i*, X_i refers to a vector of explanatory variables as specified in Eq. 2 in the paper, and W_{ij} denotes the spatial weight matrix between apartment *i* and its neighboring apartment *j*.

The model was estimated using the two-stage instrumental variable estimation method suggested by Kim and Muller (2004) to address the endogeneity issues associated with spatial lags (Zietz et al., 2007). In the first stage, predicted values of $\sum_j W_{ij}P_j$ were obtained from a quantile regression model which regressed $\sum_j W_{ij}P_j$ against X_i and $\sum_j W_{ij}X_j$. The second stage is a quantile regression model which regressed P_i against X_i and the predicted values of $\sum_j W_{ij}P_j$. The same quantile was used for both stages. The standard errors and statistical significance were derived using bootstrapping. The estimation was undertaken in R (McMillen, 2015). W_{ij} is exogenously specified, where each apartment *j* within a threshold distance of apartment *i* is given equal weight, and more distant apartments receive a weight of zero. The threshold distance was set to be 0.05. As a reference point, we calculated the maximum Euclidean distance between apartments within each congregation using their geographic coordinates:

$$distance_{max} = \sqrt{(longitude_{max} - longitude_{min})^2 + (latitude_{max} - latitude_{min})^2}$$

and this maximum distance ranges from 0.05 to 0.11 across congregations Table A3.

Table A3
Spatial quantile regression estimates for the association of environmental characteristics (E) with adjusted sales price of apartments (by distance band and for the 25th, 50th and 75th percentile of sales prices).

Variable	20 m.	50 m.	200 m.	200 m.	500 m.	1000 m.
q 0.25						
City park	−3.227	−1.077***	−0.738***	−0.738***	−0.709***	−7.447***
Neighborhood parks	0.313*	0.318**	0.635***	0.635***	1.867***	2.704***
Multiuse parks	1.383	−0.563	−0.387**	−0.387**	−0.594***	−1.079***
Nature	−0.059	−0.039	−0.202	−0.202*	−1.140***	−0.781***
Forest	0.217*	0.156**	0.244***	0.244***	0.174***	0.089
ρ_q	−0.003*	−0.003*	−0.003*	−0.003*	−0.002	−0.002
q 0.5						
City park	−6.502	−1.682***	−1.161***	−1.161***	−1.323***	−9.994***
Neighborhood parks	0.278**	0.375***	0.541***	0.541***	1.543***	2.140***
Multiuse parks	0.746	0.840	−0.654***	−0.654***	−0.639***	−1.490***
Nature	−0.010	0.023	−0.141	−0.141	−0.664***	−0.296
Forest	0.053	0.069	0.150***	0.150***	0.106***	0.020
ρ_q	−0.003**	−0.003**	−0.003***	−0.003***	−0.003**	−0.003*
q 0.75						
City park	−9.977***	−2.288***	−1.615***	−1.615***	−1.634***	−12.532***
Neighborhood parks	0.183	0.238	0.357***	0.357***	0.806***	0.528
Multiuse parks	0.280	0.203	−0.951*	−0.951*	−1.272***	−2.196***
Nature	0.048	0.142*	0.042	0.042	−0.446***	0.004
Forest	−0.055	0.119	0.090**	0.090**	0.099**	0.057
ρ_q	−0.001	−0.001	−0.002	−0.002	−0.001**	−0.001
Times of bootstrapping	50	100	100	1000	100	100

* $p < .05$; ** $p < .01$; *** $p < .001$. $N = 6300$.

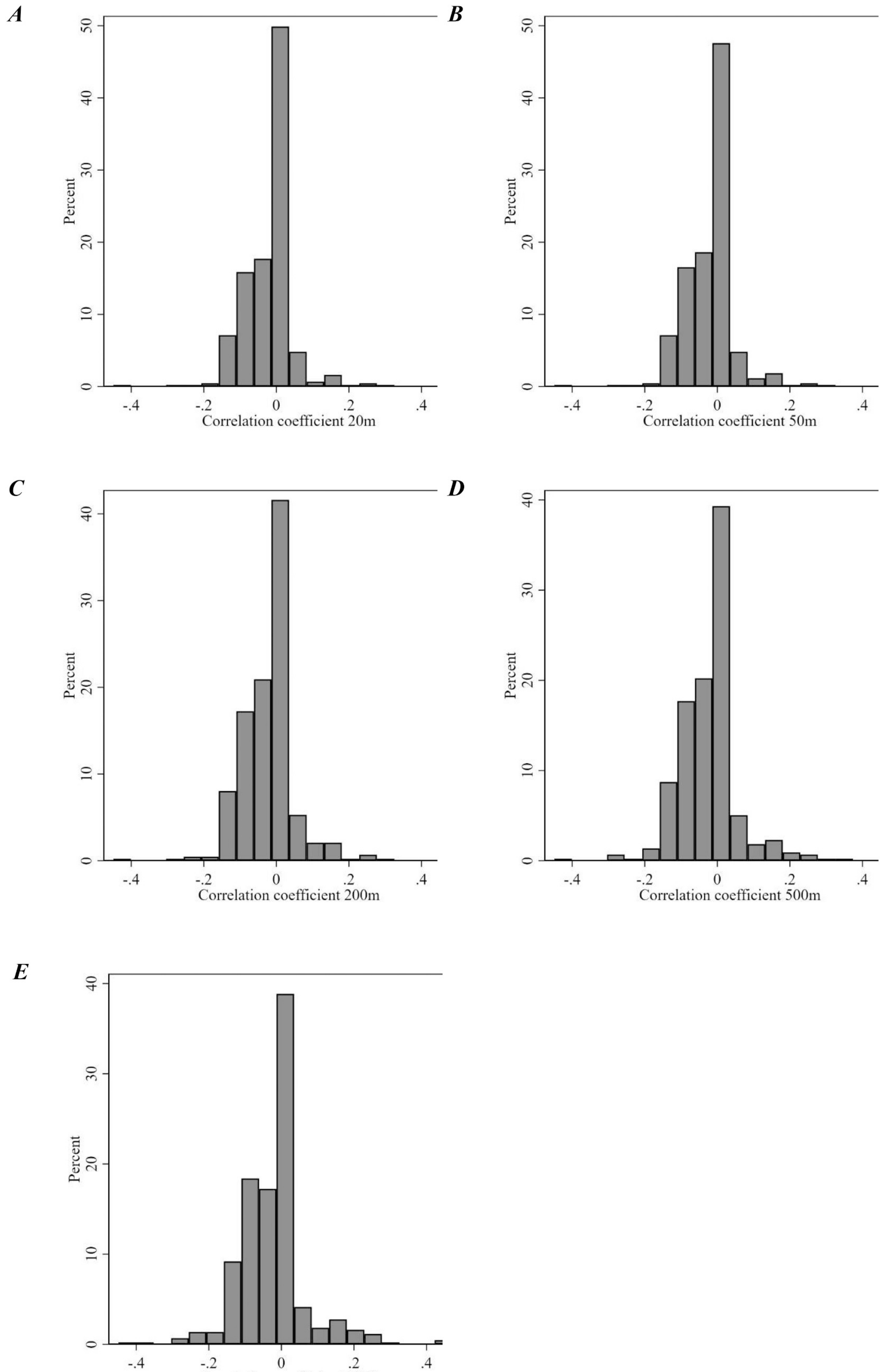

Fig. A1. Histograms of the correlation coefficients between the explanatory variables included in the regressions.

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