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Open space, residential property values, and spatial context

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Abstract

We use hedonic analysis of home transaction data from the Minneapolis–St. Paul metropolitan area to estimate the effects of proximity to open space on sales price. We allow the effects of proximity to vary with demographic and location-specific characteristics and include fixed effects to control for observed and unobserved neighborhood characteristics. We find that the value of proximity to open space is higher in neighborhoods that are dense, near the central business district, high-income, high-crime, or home to many children. Using the metropolitan area's average value may substantially overestimate or underestimate the value of open space in particular neighborhoods.

JEL classification: Q15; Q21; Q26
Keywords: Open space; Hedonic; Home values; Fixed effects; Geographic Information Systems (GIS)

1. Introduction

Urban populations in the United States have an established trend of decentralization. The average population density for major metropolitan statistical areas fell by more than ten percent between 1982 and 1999 (Glaeser and Kahn, 2004). As cities grow at their peripheries, planners and developers increasingly weigh the tradeoff between developing and preserving open space. Although development can help satisfy a growing population's need for additional housing and commercial space, open areas provide a number of benefits, including opportunities for recreation, pleasing views, or simply the absence of negative externalities associated with

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development (Irwin, 2002). Open space may also provide various ecological benefits, such as wildlife habitat or improved water quality. To make appropriate decisions regarding the provision of these public goods and to design more effective zoning and land-use regulation policies, city and regional planners need to know precisely how their residents value open areas. Such information may also help real estate developers design more desirable residential communities and profit by limiting development (Heal, 2001).

This paper attempts to unravel the many factors that determine the amenity value of open space in urban housing markets. In a competitive housing market prospective homebuyers will bid up the prices of homes with desirable surroundings, thereby capitalizing in property values externalities generated by proximity to open space. We use hedonic analysis of home transaction data from the Minneapolis–St. Paul metropolitan area (Twin Cities) to estimate the effects on home value of proximity to neighborhood parks, regional, state, and federal parks and natural areas (henceforth defined as special parks), golf courses, and cemeteries. We use geographic information systems (GIS) software to derive proximity measures from regional land use data. Importantly, we allow the effects of proximity to depend on amenity size, population density, income, and other covariates believed to influence the value of open space. In addition to controlling for home structural attributes and other environmental amenities, we include local fixed effects to control for neighborhood characteristics, geographic location, and omitted spatial variables.

A large and growing literature estimates the effects of open space on residential property values.[1] Several recent studies measure the distance to different types of nearby open areas and find that home value increases with proximity and that the effect varies by type (Bolitzer and Netusil, 2000; Lutzenhiser and Netusil, 2001; Smith et al., 2002). Other recent studies measure the total quantity of surrounding open space (Acharya and Bennett, 2001) and often distinguish broadly between protected open space, such as public parks and land under conservation easement, and developable open space, such as privately owned agricultural land (Irwin and Bockstael, 2001; Irwin, 2002; Geoghegan, 2002; Geoghegan et al., 2003). This distinction is relevant because the effect of open space on home value reflects both current amenities and expected future changes. These studies find that preserved open space surrounding a home increases home value, while developable open space has a lesser, insignificant, or negative effect on home value. Cheshire and Sheppard (1995, 1998) distinguish between publicly accessible and inaccessible open space in two English cities. They find that these areas have roughly equal value in one city, while only accessible open space increases home value in the other.

In addition to varying by open space type, we might expect the amenity value of open space to depend on a home's location and surroundings. For example, escaping to a park is probably more valuable in the dense clutter of the central city than in the relatively wide-open suburbs. Indeed, Geoghegan et al. (1997) find that the amenity value of open space first rises and then falls as distance to the central business district (CBD) increases. Distance to the CBD may only proxy, however, for other variables that determine the value of open space. Cheshire and Sheppard

[1] A number of studies use hedonic analysis to estimate the amenity value of particular types of open space, such as golf courses (Do and Grudnitski, 1995), neighborhood parks (Weicher and Zerbst, 1973; Espey and Owusu-Edusei, 2001), greenbelts (Correll et al., 1978; Lee and Linneman, 1998), forest areas (Tyrväinen and Miettinen, 2000), and wetlands (Doss and Taff, 1996; Mahan et al., 2000; Earnhart, 2001). Other studies use alternative methods: Schultz and King (2001) use aggregate census data to estimate the effects of open space on average home values; Breffle et al. (1998) employ survey methods to estimate the willingness to pay to preserve undeveloped land; Riddel (2001) models the dynamic effects of an open space purchase on housing and labor markets. See McConnell and Walls (2005) for a review of open space valuation studies that use survey and property value methods.

(1998), for example, estimate a demand system for housing attributes and find that demand for open space rises with income.[2]

This paper explores more thoroughly than any previous paper we are aware of how the amenity value of open space in a metropolitan area depends on a home's location and neighborhood characteristics. We consider how the effects of proximity to open space vary with amenity size, private lot size, population density, distance to the CBD, income levels, crime rates, and neighborhood age composition.[3] Additionally, we control for unobserved neighborhood characteristics with local fixed effects. Our sample area and dataset are significantly larger than those in previous open space studies that include such effects (Espey and Owusu-Edusei, 2001; Do and Grudnitski, 1995). We are therefore able to specify our fixed effects at a finer geographic scale to control more effectively for correlated omitted variables.

We find that the sales price of an average home increases with proximity to neighborhood parks, special parks, and golf courses. These results are sensitive to the inclusion of local fixed effects: when we replace our fixed effects with a large number of observable control variables we find that being close to a neighborhood park decreases the sales price of an average home.

The effects of proximity to open space vary widely with neighborhood characteristics and location. Using the metropolitan area's average effects may therefore overestimate or underestimate the value of open space in particular neighborhoods by a substantial margin. For example, the value of proximity to neighborhood parks and special parks falls as distance to the CBD increases and rises with population density and income. The benefits of proximity to neighborhood parks are higher in neighborhoods with more children, while being close to special parks grants higher benefits in neighborhoods with fewer children. Proximity to parks is more valuable in high-crime areas, indicating that these amenities may buffer against the negative effects of high crime rates on sales prices. The benefits of proximity to golf courses and cemeteries also depend on neighborhood characteristics and location.

The remainder of this paper is divided into four sections. Section 2 discusses our econometric model, Section 3 describes our data sources and provides descriptive statistics, Section 4 presents the results of our econometric estimation, and Section 5 concludes.

2. Econometric model

Using standard hedonic theory (Rosen, 1974) we define a home h by its structural attributes S_h, neighborhood characteristics and location N_h, and environmental amenities A_h. Given an existing

[2] Geoghegan et al. (2003) and Cheshire and Sheppard (1995) estimate separate hedonic functions for different jurisdictions and speculate that differences in the amenity value of open space may be related to jurisdiction income levels and quantities of open space. Garrod and Willis (1992) find that the demand for broadleaf cover of nearby woodland increases with homeowner age, income, and the number of children in the household. Acharya and Bennett (2001) find that the value of land use diversity depends on population density. Studies in the local public goods literature find that government spending on parks (Bergstrom and Goodman, 1973; Borcherding and Deacon, 1972; Pack and Pack, 1978; Perkins, 1977; Santerre, 1985) or the quantity of locally owned public open space (Bates and Santerre, 2001) increases with income. Santerre (1985) finds that spending on parks decreases as distance to the CBD increases, while Bergstrom and Goodman (1973) find evidence that spending increases with population density and age.

[3] Geoghegan et al. (1997) allow the value of open space to depend on distance to the CBD but do not consider other factors. Cheshire and Sheppard (1998) estimate demand for open space as a function of implicit prices but not the amenity value of open space as a function of location and neighborhood characteristics. Their demand system could be inverted to yield the amenity value of open space as a function of the quantity of open space consumed, income, and the consumption levels of a number of home structural and neighborhood characteristics; they do not undertake this analysis.

stock of homes, housing market equilibrium is characterized by a hedonic price function, which relates the market price of a home P_h to its attributes:

$$P_h = f(S_h, N_h, A_h), \tag{1}$$

and each homebuyer having chosen her utility-maximizing home given this price function. Differentiation of the hedonic price function with respect to a particular attribute yields the marginal implicit price of that attribute, which equals the homebuyer's marginal willingness to pay.[4]

Econometric specification and estimation of the hedonic price function poses a number of potential problems. Irwin and Bockstael (2001) formalize two specific problems associated with the measurement of open space values. First, because the uses of neighboring parcels of land are interdependent, the quantity of privately owned, developable open space that surrounds a home is endogenous to home value. This issue is not of great concern here because the public parks, golf courses, and cemeteries in our sample generally are preserved permanently as open spaces. Second, because property values determine residential development, unobserved variables that affect home value will be correlated with the quantity of surrounding open space. If these variables are omitted, OLS estimates are biased. This is true even for public open space; indeed, Bates and Santerre (2001) show that public provision depends on private land values. Although several studies use an instrumental variables approach to deal with these sources of bias (Irwin and Bockstael, 2001; Irwin, 2002; Geoghegan et al., 2003), our large and geographically detailed data set allows us to control for potential omitted spatial variables using local fixed effects.

Theory has little to say about the functional form of the hedonic function. Graphical inspection of the relationship between sales price and key explanatory variables in our data, such as square footage, clearly suggested a log–log functional form. We tried estimating flexible-form models with Box–Cox transformations of the dependent and independent variables but were unable to reject a log–log relationship. We therefore estimate a hedonic function of the following form:

$$\ln P_{hi} = \boldsymbol{\alpha}'\ln \boldsymbol{X}_{hi} + \boldsymbol{\beta}'\boldsymbol{Y}_{hi} + \sum_{a\in A} \ln d_{a,hi}[\lambda_a + \theta_a s_{a,hi} + \boldsymbol{\gamma}_a{}'\boldsymbol{Z}_{hi}] + \delta_i + \varepsilon_{hi}, \tag{2}$$

where: P_{hi} is the sales price of home h in block group i; $\boldsymbol{X}_{hi}$ is a vector of continuous home structural characteristics; $\boldsymbol{Y}_{hi}$ is a vector of dichotomous home structural characteristics and month-of-sale dummy variables; $\boldsymbol{\alpha}$ and $\boldsymbol{\beta}$ are parameter vectors to be estimated; A is the set of environmental amenities; $d_{a,hi}$ is the distance to the nearest amenity of type a, and $s_{a,hi}$ is its size; $\boldsymbol{Z}_{hi}$ is a vector of covariates expected to influence the value of proximity to amenities; λ_a, θ_a, and $\boldsymbol{\gamma}_a$ are two parameters and a parameter vector to be estimated for each a; δ_i is a block group fixed effect; and ε_{hi} is a random error term.

The elasticity of sales price with respect to distance to amenity type a is given by:

$$\frac{\partial \ln P_{hi}}{\partial \ln d_{a,hi}} = \lambda_a + \theta_a s_{a,hi} + \boldsymbol{\gamma}_a{}'\boldsymbol{Z}_{hi}. \tag{3}$$

[4] Rosen (1974) suggests a second-stage analysis, wherein estimated marginal implicit prices are regressed on a vector of demand variables to identify willingness to pay. We do not undertake such an analysis here, as Palmquist (1992) shows that marginal prices sufficiently measure total benefits in the case of localized externalities. Several open space studies undertake a second-stage analysis and estimate demand (Garrod and Willis, 1992; Cheshire and Sheppard, 1998; Cheshire and Sheppard, 2002). See Palmquist (1991), Sheppard (1999), and Freeman (2003) for surveys of hedonic theory and methods.

When this elasticity is negative sales price falls as distance increases, so proximity to the amenity has a positive effect on home value. The elasticity in Eq. (3) depends on amenity size and the covariates in vector $\boldsymbol{Z}_{hi}$, which includes variables expected to influence the value of open space. We predict that the amenity value of proximity to open space will be higher for large amenities. Large private lots will likely substitute for nearby open spaces and therefore diminish the value of proximity. We expect that the value of escaping to an open space will be higher in dense surroundings. Driving is more common in the suburbs, so the value of being within walking distance of a park should fall as distance to the CBD increases. Theory suggests that high income households will be willing to pay more for proximity to open space. Households in high crime areas may be reluctant to venture outdoors, and parks may serve as focal points for criminal behavior, so the value of proximity will likely be lower in those areas. Finally, we expect the retired and families with young children to benefit from proximity to open space more than the middle-aged.

We enter these covariates linearly, as linear covariates perform better than logged covariates and yield similar conclusions as quadratic covariates. When an element of $\boldsymbol{\gamma}_a$ is negative, an increase in the corresponding element of $\boldsymbol{Z}_{hi}$ makes proximity to amenity a more valuable.

Previous studies find that neighborhood characteristics, such as income levels and distance to the CBD, affect home value directly. We control for the direct effects of neighborhood characteristics, location, and potential omitted variables with approximately 1800 census block group fixed effects. These fixed effects have several limitations. First, if block groups overlap perceived neighborhood boundaries then problems with unobserved neighborhood characteristics may persist. On the other hand, if block groups are nested within perceived neighborhoods then our estimates may be inefficient.[5] Second, our fixed effects may fail to control for omitted variables that affect a single property or small number of properties. Lastly, our fixed effects do not control for potential unobserved covariates that determine the value of open space. We attempted to control for potential omitted covariates but subsequently were unable to estimate the covariate interactions with precision.

Finally, our measures of distance to the nearest amenities may fail to account for more distant but potentially important areas. Several recent studies address this issue by measuring the total quantity of open space surrounding a home within a given distance (Cheshire and Sheppard, 1995; Irwin and Bockstael, 2001; Irwin, 2002; Geoghegan, 2002) or at multiple scales (Acharya and Bennett, 2001; Geoghegan et al., 1997; Geoghegan et al., 2003). Homes in the same census block group often have the same overall pattern of surrounding land use, however. Distance to the nearest open space is therefore a reasonable proxy given our inclusion of block group fixed effects.

3. Data

Table 1 lists the variables that we use to estimate Eq. (2), while Table 2 presents descriptive statistics for the data in our estimation sample. These data come from several sources. Our 1997 single-family home sales price and structural data come from Regional Multiple Listing Service of Minnesota, Inc., and we locate these homes using GIS address data from The Lawrence Group

[5] Gibbons and Machin (2003) use a distance-weighted smoothing function to control for spatial effects prior to estimation. This approach avoids the problem of choosing arbitrary neighborhood boundaries but requires assumptions regarding the choice of smoothing function and its parameters.

Table 1
Variable names and definitions

Variable name	Definition	Location in Eq. (2)
Dependent variable		
SALESPRICE	Home sales price ($1997)	$\ln P_{hi}$
Home structure		
LOTSIZE	Lot size (acres)	$\ln \boldsymbol{X}_{hi}$, $\boldsymbol{Z}_{hi}$
SQUAREFEET	Finished square feet	$\ln \boldsymbol{X}_{hi}$
BATHROOMS	Number of bathrooms	$\ln \boldsymbol{X}_{hi}$
AGE	Age of home	$\ln \boldsymbol{X}_{hi}$
FIREPLACE	Equals 1 if home has fireplace; 0 otherwise	$\boldsymbol{Y}_{hi}$
MONTH[m]	Equals 1 if sold in month m = Jan–Dec; 0 otherwise	$\boldsymbol{Y}_{hi}$
Amenity distance		
DIST_NPARK	Distance to neighborhood park (meters)	$\ln d_{a,hi}$
DIST_SPARK	Distance to special park (meters)	$\ln d_{a,hi}$
DIST_GOLF	Distance to golf course (meters)	$\ln d_{a,hi}$
DIST_CEMETERY	Distance to cemetery (meters)	$\ln d_{a,hi}$
DIST_LAKE	Distance to lake (meters)	$\ln d_{a,hi}$
DIST_RIVER	Distance to river (meters)	$\ln d_{a,hi}$
Amenity size		
SIZE_NPARK	Size of neighborhood park (acres)	$s_{a,hi}$
SIZE_SPARK	Size of special park (acres)	$s_{a,hi}$
SIZE_GOLF	Size of golf course (acres)	$s_{a,hi}$
SIZE_CEMETERY	Size of cemetery (acres)	$s_{a,hi}$
SIZE_LAKE	Size of lake (acres)	$s_{a,hi}$
Neighborhood (covariates)		
DENSITY	Persons per square mile	$\boldsymbol{Z}_{hi}$
CBD	Distance to CBD (meters)	$\boldsymbol{Z}_{hi}$
INCOME	Median household income ($1990)	$\boldsymbol{Z}_{hi}$
CRIME	Number of reported serious crimes per 1000 people	$\boldsymbol{Z}_{hi}$
UNDER18	Percent of population less than 18 years old	$\boldsymbol{Z}_{hi}$
OVER65	Percent of population aged 65 years and older	$\boldsymbol{Z}_{hi}$

Note: Table lists and defines the variables that we use to estimate Eq. (2). The third column indicates location of each variable in Eq. (2). Note that lot size appears both linearly as a covariate and in its logged form as a direct determinant of home value.

(TLG). We focus on transactions within urbanized areas of the Twin Cities in an effort to minimize possible complications associated with large tracts of privately owned, undeveloped land (Irwin and Bockstael, 2001). We omit approximately nine percent of these observations because of missing or implausible data, which reduces our estimation sample to 24,862 transactions.[6] Fig. 1 maps the locations and sales prices of the homes in our estimation sample.

We compute the age of each home in 1997 based on its year of construction. We derive lot size for most homes by multiplying lot length by lot width, though some transaction records provide

[6] Of these omitted observations, approximately 80% lacked lot size data, 17% lacked square footage data, 6% lacked age data, 2% lacked bathrooms data, and less than 1% lacked sales price, crime, or census demographic data. Detailed data procedures are available upon request.

Table 2
Summary statistics

Variable	Mean	Standard deviation	Minimum	Maximum
SALESPRICE	142,322.00	98,300.05	1,000.00	4,300,000.00
LOTSIZE	0.33	0.73	0.01	45.00
SQUAREFEET	1863.13	890.66	99.00	35,000.00
BATHROOMS	2.10	0.90	1.00	9.00
AGE	38.00	28.63	1.00	148.00
FIREPLACE	0.50	0.50	0.00	1.00
DIST_NPARK	468.67	616.42	1.00	28,932.72
DIST_SPARK	2265.40	1705.78	1.00	15,882.51
DIST_GOLF	2036.66	1215.32	1.00	23,427.33
DIST_CEMETERY	5102.96	4623.22	1.00	24,119.25
DIST_LAKE	1313.20	1209.47	1.00	30,684.93
DIST_RIVER	5822.94	4073.83	35.03	19,342.36
SIZE_NPARK	27.08	43.58	0.06	671.66
SIZE_SPARK	1025.34	1871.39	9.02	8601.17
SIZE_GOLF	134.58	85.24	12.91	575.96
SIZE_CEMETERY	55.32	75.26	2.84	455.27
SIZE_LAKE	154.79	570.03	0.07	5793.59
DENSITY	4025.71	3187.65	18.90	29,104.70
CBD	14,514.22	8383.18	1181.49	38,945.76
INCOME	43,132.67	13,992.09	4999.00	150,001.00
CRIME	39.89	19.98	0.00	220.00
UNDER18	27.08	7.67	0.00	54.74
OVER65	9.30	7.92	0.00	73.47

Note: Table is based on estimation sample of 24,862 home transactions in the Twin Cities during 1997. See Table 1 for variable definitions. Summary statistics are given for variables prior to logarithmic transformation or normalization. See text for details.

acreage values directly. For observations with irregularly shaped lots we estimate acreage using the lot dimensions provided. We include month-of-sale dummy variables to control for potential seasonality in sales prices.

The neighborhood covariates come from a variety of sources. We locate the CBD of Minneapolis and the CBD of St. Paul using TLG street data and calculate the distance from each home to the nearest CBD. Our population density, median income, and age composition variables come from the 1990 U.S. Census block group data. We obtain crime data for Minneapolis and St. Paul city neighborhoods from the Minneapolis and St. Paul police departments and crime data for suburban municipalities from the Minnesota Department of Public Safety. These data record the number of serious crimes, such as thefts and assaults, that were reported during 2000 for each city neighborhood and suburban municipality. We calculate crime rates using these data and population estimates from the 2000 U.S. Census.

Finally, we use 2001 land use data from TLG to calculate the distance from each home to the nearest neighborhood park, special park, golf course, and cemetery, as well as the distance to the nearest lake and major river. In addition to these measures of proximity, we record the sizes of the nearest neighborhood park, special park, golf course, cemetery, and lake. We define special parks as national, state, and regional parks, arboretums, nature centers, natural areas, and wildlife refuges, in order to distinguish these areas from neighborhood parks, which generally are more urbanized and provide fewer recreational opportunities and natural amenities. Our land use data do not allow us to consider other types of open space amenities, such as vacant lots or university

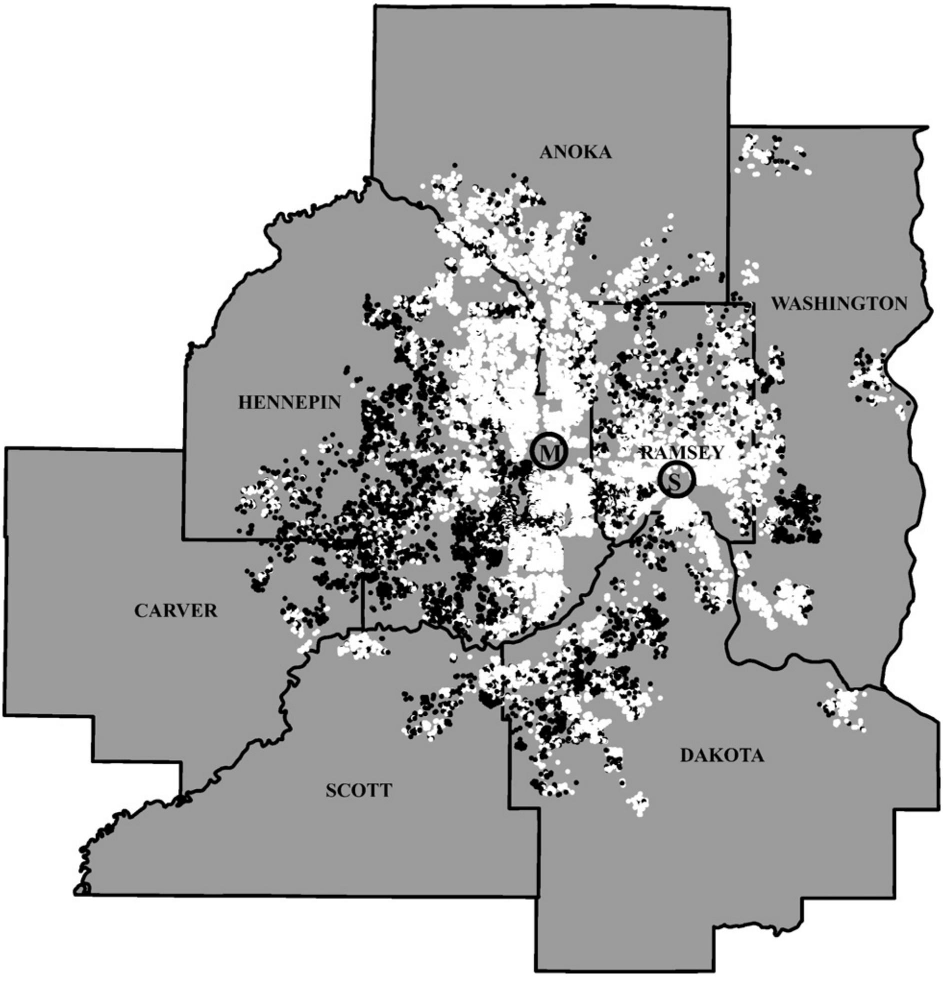

Fig. 1. Locations and values of homes in estimation sample. Note: Figure is based on the estimation sample of 24,862 single-family home transactions in the Twin Cities during 1997. Black dots are homes whose sales prices exceeded the sample mean of $142,322; white dots are homes with sales prices below the mean. Circles labeled “M” and “S” identify the central business districts of Minneapolis and St. Paul, respectively. County names are given in caps. For a sense of scale, downtown Minneapolis is 8 miles from downtown St. Paul.

campuses, and we do not consider potentially relevant distinctions within our broad categories. Fig. 2 maps the locations of the open space amenities in our study area.

4. Estimation and results

In order to simplify interpretation of the amenity coefficients we normalize the covariates prior to estimation according to the following linear transformation:

$$Z^*_{hi} = (\boldsymbol{Z}_{hi} - \bar{Z})/\bar{Z}, \tag{4}$$

where $\boldsymbol{Z}_{hi}$ is the covariate vector prior to normalization and $\bar{Z}$ is its sample mean. We normalize the amenity size variables analogously. We then estimate Eq. (2) using the standard fixed effects

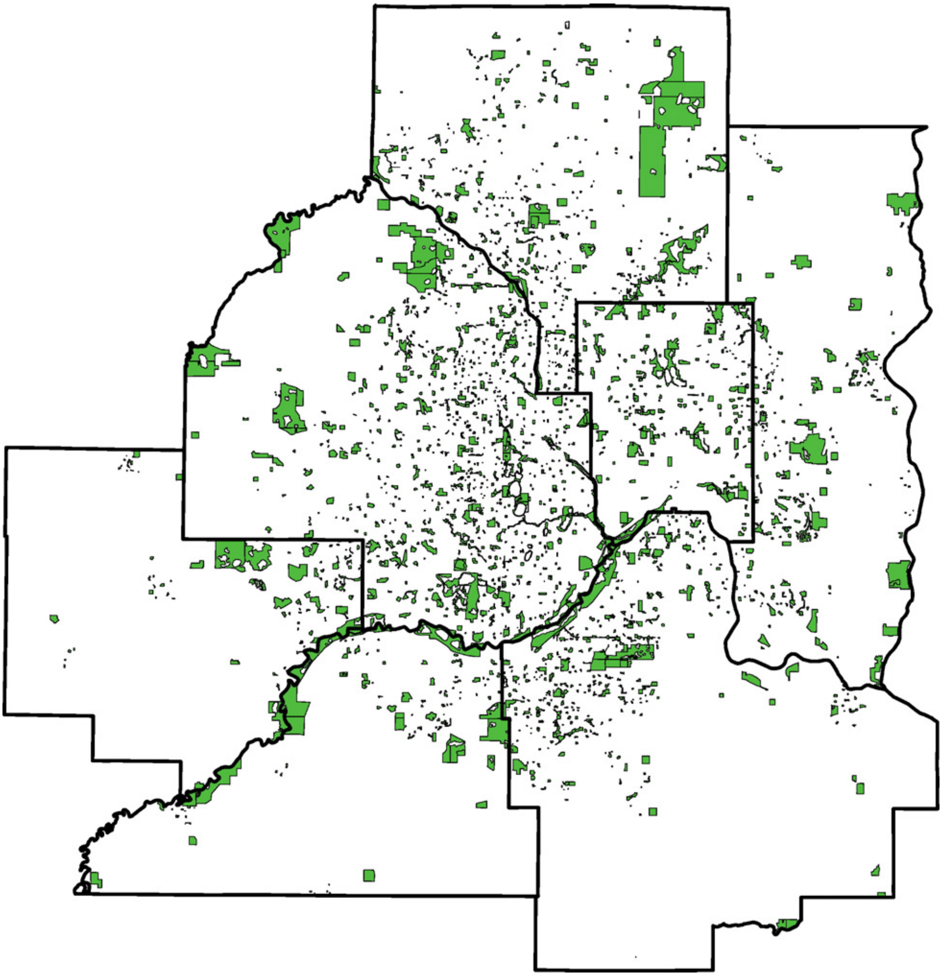

Fig. 2. Locations of open space areas. Note: Figure shows the locations of 2174 open spaces within the Twin Cities, including 1825 neighborhood parks, 152 special parks, 153 golf courses, and 44 cemeteries.

estimator, which takes the difference of each variable from its block group mean and then applies OLS. Table 3 presents the results.

The estimated coefficients for the home structural characteristics are all highly significant with the expected signs and reasonable magnitudes. Sales price rises by about 0.50% for every one percent increase in square footage, 0.08% for every one percent increase in the number of bathrooms, and 5% with the addition of a fireplace.[7] Sales price falls by about 0.13% for every one percent increase in the age of a home. Finally, sales price rises by about 0.09% for every one percent increase in lot size, assuming the home is located an average distance from each amenity.[8]

[7] The estimated percent effect of a fireplace on sales price is $e^{\{\eta - V(\eta)/2\}} - 1$, where η is the coefficient estimate for the fireplace dummy variable and $V(\eta)$ is its estimated variance (Halvorsen and Palmquist, 1980; Kennedy, 1981).

[8] The effect of lot size depends on amenity distance because lot size appears in the covariate vector $\boldsymbol{Z}_{hi}$.

We now turn to the amenity distance coefficients. Given our normalization of the covariates the elasticity in Eq. (3) becomes:

$$\frac{\partial \ln P_{hi}}{\partial \ln d_{a,hi}} = \lambda_a + \theta_a s^*_{a,hi} + \boldsymbol{\gamma}_a' \boldsymbol{Z}^*_{hi}, \tag{5}$$

which simplifies to

$$\frac{\partial \ln P_{hi}}{\partial \ln d_{a,hi}} = \lambda_a \tag{6}$$

for an amenity of average size and a home with average covariate characteristics. We can therefore interpret each amenity distance coefficient in Table 3 directly as the elasticity of sales price with respect to amenity distance for a home with average characteristics. The value of an average home increases with proximity to neighborhood parks, special parks, lakes, and rivers, with benefits ranging from a low of 0.0035% of sales price for every one percent decrease in the distance to the nearest neighborhood park, to a high of 0.0342% for every one percent decrease in the distance to the nearest lake. These effects are statistically significant at or near the 1% level. Sales price also rises with proximity to the nearest golf course and falls the closer a home is to the nearest cemetery, though these effects are of substantially lower magnitude and statistical significance.

For a sense of the importance of these effects in dollar terms, halving the distance to the nearest neighborhood park increases the sales price of an average home by about 0.173% or $246. This translates into an annualized benefit of about $20, assuming a 30-year time horizon and an interest rate of 7.6%, which Freddie Mac reports was the average rate for a 30-year fixed-rate mortgage in 1997. Similar calculations indicate that halving the distance to the nearest special park increases the sales price of an average home by about $1790, or about $142 per year.

According to the positive coefficient on the amenity size interaction for neighborhood parks, an increase in the size of the nearest neighborhood park makes the elasticity of sales price with respect to distance more positive.[9] In other words, the amenity value of proximity to a neighborhood park falls as park size increases. The interaction effect is small, however, and the unexpected sign may be caused by some omitted disamenity associated with large parks, such as increased noise or traffic flow. As expected, the amenity value of proximity to special parks rises with amenity size, though this interaction effect is also small and only statistically significant at the 13% level.

As expected, the amenity value of proximity to neighborhood parks falls as distance to the CBD increases and rises with population density, income, and the fraction of the population under age 18. Surprisingly, this value rises with crime rates, though this interaction effect is not statistically significant. As expected, the amenity value of proximity to special parks rises with population density and income and falls as distance to the CBD increases, though the latter effect is statistically insignificant. Again, the amenity value of proximity to special parks rises with crime rates, so it appears that both types of parks buffer against the negative effects of crime.

Surprisingly, our estimates suggest that the amenity value of proximity to special parks is higher for homes with large private lots, indicating that special parks and private lots are complements. Alternatively, Parsons (1990) shows theoretically that the per-acre price of land should be independent of lot size, which implies that purchasers of large lots pay for both the amenity benefits they receive as

[9] This and all subsequent interaction effects are statistically significant at or below the 5% level, unless otherwise noted.

Table 3
Estimation results

Variable	Coefficient	Standard error
Ln(LOTSIZE)	0.0979	0.0036
Ln(SQUAREFEET)	0.4974	0.0055
Ln(BATHROOMS)	0.0825	0.0045
Ln(AGE)	−0.1335	0.0019
FIREPLACE	0.0454	0.0030
Ln(DIST_NPARK)	−0.0035	0.0014
Ln(DIST_SPARK)	−0.0252	0.0035
Ln(DIST_GOLF)	−0.0060	0.0039
Ln(DIST_CEMETERY)	0.0084	0.0076
Ln(DIST_LAKE)	−0.0342	0.0039
Ln(DIST_RIVER)	−0.0273	0.0099
SIZE_NPARK ·Ln(DIST_NPARK)*	0.0004	0.0002
SIZE_SPARK ·Ln(DIST_SPARK)*	−0.0003	0.0002
SIZE_GOLF ·Ln(DIST_GOLF)*	0.0001	0.0006
SIZE_CEMETERY ·Ln(DIST_CEMETERY)*	−0.0002	0.0003
SIZE_LAKE ·Ln(DIST_LAKE)*	0.0002	0.0001
LOTSIZE ·Ln(DIST_NPARK)*	−0.0001	0.0004
LOTSIZE ·Ln(DIST_SPARK)*	−0.0027	0.0008
LOTSIZE ·Ln(DIST_GOLF)*	−0.0002	0.0008
LOTSIZE ·Ln(DIST_CEMETERY)*	0.0013	0.0007
LOTSIZE ·Ln(DIST_LAKE)*	−0.0037	0.0007
LOTSIZE ·Ln(DIST_RIVER)*	0.0040	0.0008
DENSITY ·Ln(DIST_NPARK)*	−0.0060	0.0028
DENSITY ·Ln(DIST_SPARK)*	−0.0165	0.0062
DENSITY ·Ln(DIST_GOLF)*	0.0165	0.0068
DENSITY ·Ln(DIST_CEMETERY)*	−0.0064	0.0078
DENSITY ·Ln(DIST_LAKE)*	−0.0016	0.0073
DENSITY ·Ln(DIST_RIVER)*	0.0143	0.0165
CBD ·Ln(DIST_NPARK)*	0.0125	0.0034
CBD ·Ln(DIST_SPARK)*	0.0093	0.0078
CBD ·Ln(DIST_GOLF)*	0.0139	0.0057
CBD ·Ln(DIST_CEMETERY)*	−0.0009	0.0134
CBD ·Ln(DIST_LAKE)*	−0.0471	0.0065
CBD ·Ln(DIST_RIVER)*	0.0139	0.0148
INCOME ·Ln(DIST_NPARK)*	−0.0117	0.0052
INCOME ·Ln(DIST_SPARK)*	−0.0290	0.0094
INCOME ·Ln(DIST_GOLF)*	0.0153	0.0098
INCOME ·Ln(DIST_CEMETERY)*	0.0211	0.0198
INCOME ·Ln(DIST_LAKE)*	−0.0350	0.0115
INCOME ·Ln(DIST_RIVER)*	−0.1489	0.0375
CRIME ·Ln(DIST_NPARK)*	−0.0037	0.0032
CRIME ·Ln(DIST_SPARK)*	−0.0177	0.0081
CRIME ·Ln(DIST_GOLF)*	−0.0034	0.0067
CRIME ·Ln(DIST_CEMETERY)*	−0.0067	0.0085
CRIME ·Ln(DIST_LAKE)*	0.0287	0.0077
CRIME ·Ln(DIST_RIVER)*	−0.0054	0.0092
UNDER18 ·Ln(DIST_NPARK)*	−0.0155	0.0069
UNDER18 ·Ln(DIST_SPARK)*	0.0238	0.0151
UNDER18 ·Ln(DIST_GOLF)*	0.0038	0.0136
UNDER18 ·Ln(DIST_CEMETERY)*	−0.0010	0.0278
UNDER18 ·Ln(DIST_LAKE)*	0.0872	0.0167

(continued on next page)

Table 3 (*continued*)

Variable	Coefficient	Standard error
UNDER18 ·Ln(DIST_RIVER)*	0.1817	0.0455
OVER65 ·Ln(DIST_NPARK)*	−0.0016	0.0023
OVER65 ·Ln(DIST_SPARK)*	0.0030	0.0041
OVER65 ·Ln(DIST_GOLF)*	0.0136	0.0046
OVER65 ·Ln(DIST_CEMETERY)*	0.0063	0.0085
OVER65 ·Ln(DIST_LAKE)*	−0.0173	0.0057
OVER65 ·Ln(DIST_RIVER)*	0.0124	0.0155
MONTH DUMMIES		*Significant*
BLOCK GROUP FIXED EFFECTS		*Significant*
Number of observations		24,862
R-squared		0.8781
R-squared within block groups		0.6009

Note: Results are based on data for single-family home transactions in the Twin Cities during 1997. Dependent variable is log of sales price. Estimation method is OLS implicitly controlling for block group fixed effects. * indicates variable has been transformed according to Eq. (4) prior to estimation. See Tables 1 and 2 for variable definitions and descriptive statistics, respectively. See text for details.

well as the benefits that would have accrued to additional homeowners were the lot subdivided further. The interaction between special park distance and private lot size may be picking up this effect, though the results of our attempts to explore this issue further were inconclusive. The unexpected sign on this interaction term could instead reflect some omitted covariate that is correlated with lot size.

These interactions can have profound implications for the valuation of parks in particular neighborhoods. For example, in neighborhoods that are twice as dense as average the amenity value of proximity to neighborhood parks is nearly three times higher than average, while the value of special parks is two-thirds higher than average. Likewise, in neighborhoods that are twice as wealthy as average the amenity value of neighborhood parks is more than four times higher than average, while the value of special parks is more than two times higher than average.

Because population density, neighborhood income, and the other covariates vary across the metropolitan area, so too will the value of open space. We use Eq. (5) and the coefficient estimates in Table 3 to calculate for each home the elasticity of sales price with respect to amenity distance. Fig. 3 shows that the amenity value of proximity to neighborhood parks and special parks varies widely and is highest near the CBDs of Minneapolis and St. Paul. Fig. 4 and Table 4 quantify this variation, which is substantial. Consistent with the amenity distance coefficients in Table 3, the value of proximity to special parks is higher on average than the value of neighborhood parks. Fig. 4 and Table 4 suggest that sample mean effects may underestimate or overestimate the amenity value of open space in particular neighborhoods by a substantial margin, however. Although the estimated amenity value of proximity to parks is negative for a large number of homes, recall that our coefficient estimates reflect the value of open space relative to other homes in the same census block group. Therefore, it is possible that residents living at these locations would prefer to live farther away from open space while still deriving benefits from its general proximity.

The coefficients on other covariate interactions reveal a number of intriguing relationships. As expected, the amenity value of proximity to golf courses falls as distance to the CBD increases. This value falls, however, as population density increases, perhaps due to congestion, and falls as the fraction of the population age 65 and older increases, indicating that the middle-aged benefit more from proximity to golf courses than individuals of retirement age. We do not have a compelling explanation for why the value of proximity to golf courses falls as incomes increase,

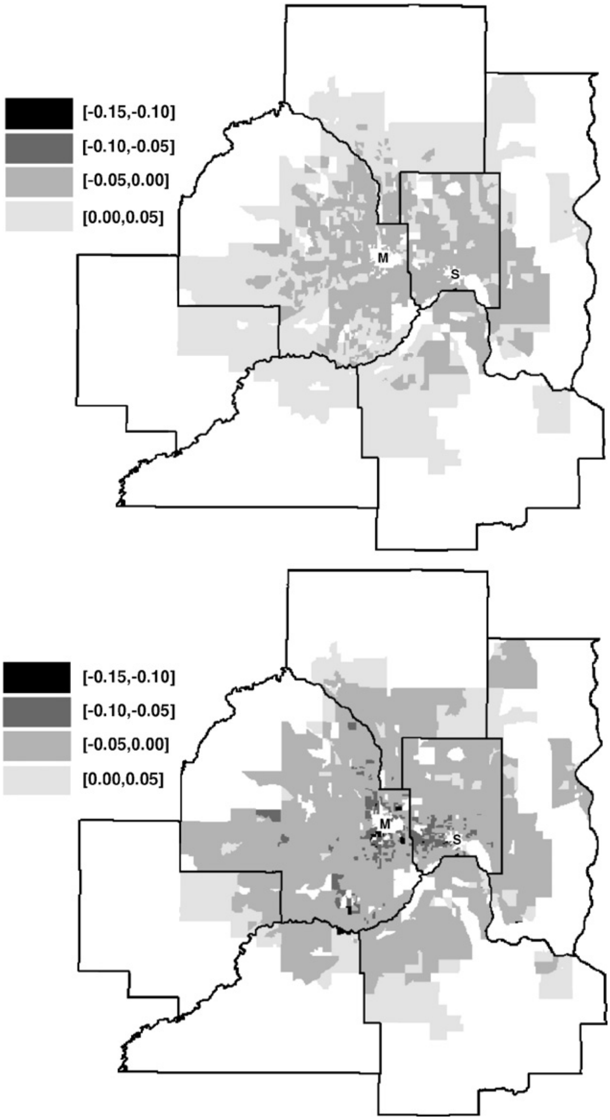

Fig. 3. Spatial variation of elasticity effects: neighborhood parks and special parks. Note: Figures show elasticities of sales price with respect to distance to neighborhood parks (top) and special parks (bottom). Shading reflects average estimated elasticity by block group. White areas indicate rural or nonresidential block groups that contain no homes from our estimation sample.

though the interaction effect is only statistically significant at the 12% level. As expected, the amenity value of proximity to cemeteries falls as private lot size increases.

Surprisingly, the amenity value of proximity to lakes falls as lake size increases, though large lakes may be associated with noisier watercraft activity, and the interaction effect is only statistically significant at the 7% level. The amenity value of proximity to lakes rises with lot size, distance to the CBD, income, and the fraction of the population age 65 and older, and falls as

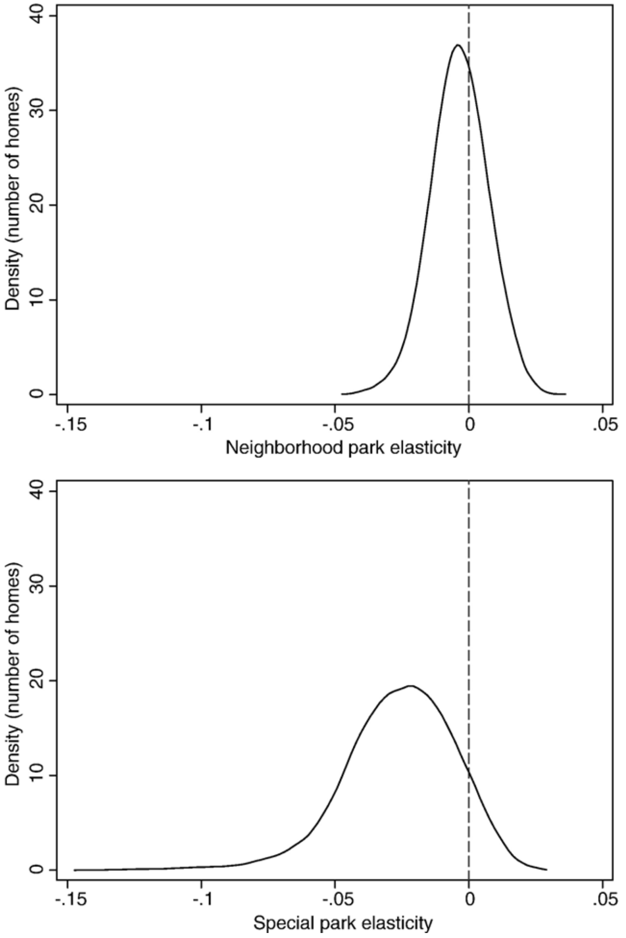

Fig. 4. Distribution of elasticity effects: neighborhood parks and special parks. Note: Figures show variation in elasticity of sales price with respect to distance to parks. Estimated elasticity is positive for 36% of homes in the case of neighborhood parks and 10% of homes in the case of special parks. Distributions are estimated using a non-parametric kernel density estimator. Distribution for special parks omits 11 observations that have elasticities less than −0.15. See Table 4 for characteristics of distributions.

crime rates and the fraction of the population under age 18 increase. Finally, the amenity value of proximity to major rivers rises with income and falls as private lot sizes and the fraction of the population under age 18 increase.

We also estimate Eq. (2) with a large number of neighborhood control variables in place of the block group fixed effects.[10] Although the amenity distance coefficients increase in statistical significance, we find that proximity to neighborhood parks and major rivers decreases the sales price of an average home. Likewise, the covariate interactions increase in statistical significance but many have unexpected signs. These results suggest that it is important to control explicitly for

[10] We include controls for income, density, race, age, home ownership rates, distance to the CBD, school quality, crime rates, distance to major highways, and distance to major shopping centers. Regression results are available upon request.

Table 4
Characteristics of distributions of amenity distance effects

Amenity	Mean	Percentiles				
		10	25	50	75	90
Neighborhood park	−0.0035	−0.0157	−0.0099	−0.0035	0.0029	0.0095
Special park	−0.0260	−0.0502	−0.0382	−0.0244	−0.0118	−0.0013
Golf course	−0.0059	−0.0192	−0.0144	−0.0078	0.0015	0.0099
Cemetery	0.0007	−0.0177	−0.0096	0.0006	0.0100	0.0193
Lake	−0.0340	−0.0805	−0.0573	−0.0367	−0.0141	0.0153
River	−0.0244	−0.0936	−0.0559	−0.0243	0.0083	0.0415

Note: Table presents characteristics of distributions of estimated elasticities of sales price with respect to amenity distance. Elasticities were calculated according to Eq. (5) using coefficient estimates in Table 3. See Fig. 4 for kernel density estimates of distributions for neighborhood parks and special parks.

omitted spatial variables in hedonic open space studies that use data from complex urban housing markets.

5. Conclusion

We use hedonic analysis of home transaction data from the Twin Cities to estimate the effect of proximity to open space on sales price. We consider several types of open space, including neighborhood parks, special parks, golf courses, and cemeteries. Importantly, we allow the effects of proximity to depend on population density, income, and other covariates believed to influence the value of open space amenities. In addition, we control for neighborhood characteristics and potential omitted spatial variables using local fixed effects.

Our results yield two important insights. First, the effect of open space on sales price depends on a home's location and neighborhood characteristics. Broadly speaking, urban residents in dense neighborhoods near the CBD place substantial value on proximity to open space, while suburban residents do not appear to value open space as highly. For example, in neighborhoods that are twice as dense as average, the amenity value of proximity to neighborhood parks is nearly three times higher than average, while the amenity value of special parks is two-thirds higher. Reliance on estimates of amenity benefits for the average home in a metropolitan area therefore will overestimate or underestimate dramatically values to homes in particular neighborhoods, and results from studies that focus on city preferences should not be used to draw implications for suburban planning.

Instead, our results suggest that planners and developers need to consider spatial context when providing or protecting open space public goods and designing zoning and land-use regulation policies. In addition to varying by neighborhood density, the effect of open space on home values also depends on income. In neighborhoods that are twice as wealthy as average the amenity value of neighborhood parks is more than four times higher than average, while the amenity value of special parks is more than two times higher. Crime rates also affect open space values, as neighborhood and special parks both appear to buffer against the negative effects of crime. In addition, families with children value neighborhood parks more highly than the middle-aged, whereas the opposite is true for special parks.

Second, unobserved neighborhood characteristics, if uncontrolled for, can lead to biased estimates for observed characteristics. For example, when omitting local fixed effects we find that proximity to a neighborhood park decreases the sales price of an average home. Researchers estimating the value of open space should take care to use data and empirical specifications that allow inclusion of such fixed effects at a fine geographic scale.

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