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Space matters: the importance of amenity in planning metropolitan growth

Parvin Mahmoudi, Darla Hatton MacDonald, Neville D. Crossman, David M. Summers and John van der Hoek†

Most Australian capital cities require many 100,000s of additional dwellings to accommodate demographic change and population pressures in the next two or three decades. Urban growth will come in the form of infill, consolidation and urban expansion. Plans to redevelop environmental amenities such as parks and open green spaces are regularly being put forward to local councils and State governments. Maintaining parks and reserves represents one of the largest costs to local councils. To aid in the evaluation of some of the different propositions, we report the results of a spatial hedonic pricing model with fixed effects for Adelaide, South Australia. The results indicate that the private benefits of a close proximity to golf courses, green space sporting facilities, or the coast, are in the order \$0.54, \$1.58, and \$4.99 per metre closer (when evaluated at the median respectively). The historic Adelaide Parklands add \$1.55 to a property's value for each additional metre closer. We demonstrate how the estimated model could be used to calculate how local private benefits capitalized in property values change with changes in the configuration of a park.

Key words: hedonic pricing, water management and policy, spatial lag, fixed effects, open space, water restrictions.

1. Introduction

Australian cities are under pressure to expand in response to increased demands for urban living and changing household composition. Many Australian capital cities have long-term plans for urban development with the intent of guiding public policy and private investment towards sustainable development. These plans contain particular emphasis on the preservation of residential and environmental amenity (e.g. open space) from a broad perspective of human well-being and better livelihoods (State Government of Victoria 2010; Government of South Australia 2010). Setting aside and maintaining

† Parvin Mahmoudi is at the School of Economics, University of Adelaide, Adelaide, South Australia 5005, Australia. Darla Hatton MacDonald (email: Darla.Hattonmacdonald@csiro.au) is at CSIRO Ecosystem Sciences, PMB 2, Glen Osmond, South Australia 5064 and School of Management and Marketing, Charles Sturt University, Bathurst, New South Wales 2795. Neville D. Crossman and David M. Summers are at CSIRO Ecosystem Sciences, PMB 2, Glen Osmond, South Australia 5064. John van der Hoek is at the School of Mathematics and Statistics, University of South Australia, City West Campus, Adelaide, South Australia 5001, Australia.

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open space represents an opportunity cost to public authorities and private developers.

Existing long-term development plans provide a clear indication of the pressures to be placed on urban and peri-urban environments for more housing. For example, the New South Wales Government's (2010) strategy *Sydney Towards 2036* recognises the need for an additional 770,000 homes in Metropolitan Sydney by 2036, a third of which will be in outer Sydney and the remainder will be met via infill. The State Government of Victoria's (2010) *Melbourne 2030* long-term plan for Melbourne and the surrounding region forecasts a population of five million before 2030. A key feature of the plan is the need for an additional 600,000 new homes by 2030, with nearly 50 per cent in outer Melbourne. The Queensland Government (2009), in its *South East Queensland Regional Plan 2009–2031*, forecasts an additional 160,000 dwellings required for the Brisbane area by 2031. The Government of South Australia (2010) in its *30-year Plan for Greater Adelaide* forecasts the need for an additional 258,000 dwellings by 2040.

Urban development to accommodate the projected additional dwellings that are likely to be required in the coming two or three decades will involve increasing urban density via infill and consolidation and expansion of urban boundaries into peri-urban land. In the short term, placing a value on the economic benefits of residential and environmental amenity provides decision support to planners who are charged with evaluating the need for open space such as parks, reserves and wetlands within suburbs (Morancho 2003; Seidl *et al*. 2004; Cho *et al*. 2008; Sander and Polasky 2009; Tapsuwan *et al*. 2009; Poudyal *et al*. 2009; Bark *et al*. 2009, 2011). Local governments, who are primarily responsible for regulating urban development, need information on the value of open space if optimal public provision of these areas is to be achieved.

In this study, we examine the value of different environmental features using a generalised spatial hedonic price model with fixed effects developed by Lee and Yu (2010). Extending Kong *et al*. (2007), Seong-Hoon *et al*. (2008) and Bowman *et al*. (2009), we use real estate data, GIS data layers, remote sensing techniques and additional layers such as public transportation networks to build a geographically extensive and complex spatial data set to estimate the value of environmental amenities for a residential housing market. The result is a rich and extensive set of marginal implicit price estimates of the different structural housing, neighbourhood and amenity characteristics. We illustrate how these implicit price estimates could be used to support cost–benefit analysis of different public policies.

2. Description of the model

The hedonic pricing model is well established in the international economic literature (Rosen 1974; Freeman 2003 and Australian examples such as Fraser and Spencer 1998; Tapsuwan *et al*. 2009; Hansen 2009; Hatton

MacDonald *et al.* 2010; Neelawala *et al.* 2012). Taylor (2008) provides an overview of equilibrium conditions where a hedonic price function relates the equilibrium market price of a house P_h to its structural and lot characteristics S_h, environmental amenity EA_h, environmental dis-amenity ED_h and neighbourhood attributes N_h:

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

A buyer chooses a utility-maximising house given this price function. The model can be expanded to account for the possibility that the selling prices for properties in close proximity may be related (Samarasinghe and Sharp 2010). The spatial hedonic price model by means of spatial lag and spatial error can be expressed as:

$$\begin{aligned} Y_n &= \lambda W Y_n + [X_n| \quad Z_n] \begin{bmatrix} \beta \\ c \end{bmatrix} + U_n, \\ U_n &= \rho M U_n + V_n, n = 1, 2, \ldots, N \end{aligned} \tag{2}$$

where Y_n is a $n \times 1$ vector of the sales price of n houses. λ is the spatial autoregressive parameter. The matrix W in such models can be specified in different ways – usually based on distance or nearest neighbour. In our application, row i corresponds to house i and has only two non-zero elements $W_{ij_1} > 0$ and $W_{ij_2} > 0$ with $j_1 \neq i, j_2 \neq i$, representing the two closest neighbours to i. The values of W_{ij_1} and W_{ij_2} are proportional to the distances of j_1 and j_2 from i and sum to 1. X_n is a $n \times m$ factor matrix where m is the number of factors describing house i. These factors include the house and lot structural attributes, its proximity to the nearest environmental amenity such as a park or the beach, distance from the nearest environmental dis-amenity such as industry and other neighbourhood attributes. β is a $m \times 1$ parameter vector that describes the marginal prices of these factors. Z_n is a $n \times k$ matrix with k fixed spatial and time effects. c is a $k \times 1$ parameter that describes the marginal prices associated with spatial and time effects. The spatial fixed effects are binary variables for suburb location. The quarterly time binary variable controls for inflation effects over time. The inclusion of the suburb fixed effects in the price function addresses omitted variables when spatial effects are constant within suburbs (McMillen 2010).

Spatial autoregressive disturbances are introduced through U_n. Here ρ and M ($n \times n$ matrices) have similar structure to λ and W. V_n is a $n \times 1$ vector of independent and identically distributed error terms with zero mean and variance σ^2 (Gaussian assumptions).

By defining $S = S(\lambda) = I - \lambda W$ and $R = R(\rho) = I - \rho M$, assuming that S and R are invertible and using $U_n = R^{-1} V_n$ the reduced form of the spatial hedonic price model (Eqn 2) can be written as:

$$Y_n = S^{-1} X_n \beta + S^{-1} R^{-1} V \tag{3}$$

re-arranging

$$V_n = R(S Y_n - X_n \beta) \tag{3A}$$

where Y_n is normally distributed with a mean of μ_n and variance of Σ, which are defined as: $\mu_n = S^{-1}X_n\beta$ and $\Sigma = E[(S^{-1}R^{-1}V_n)(S^{-1}R^{-1}V_n)'] = \sigma^2 S^{-1} R^{-1}(R^{-1})'(S^{-1})'$.

3. Methodology

3.1. Study area

The focus of our study is the Adelaide metropolitan area (Figure 1). Governance of public open space is generally devolved to a local level except in instances where a property or area is heritage listed or covered by State legislation (i.e. natural resource management). The Adelaide metropolitan area is a product of many different socio-demographic, economic and planning trends over its history. Adelaide has a history of generous open space planning. Early settlement and land development in the metropolitan area has been influenced by the British notion of gardens and public spaces (Hutchings 2007). Social policies around home ownership and post-war immigration have also had a role in shaping the urban landscape. The result is a metropolitan area with distinct public amenity spaces. Linear Park, a set of linked park areas and bike trails bisects the Adelaide metropolitan area from the coast to Adelaide (described in more depth in Mugavin 2004). The extensive Adelaide Parklands, a 7.6 km^2 ring of park area, surrounds the Adelaide central business district. These parklands have come under increasing pressure for development associated with expanding existing sporting facilities (cricket/football grounds), temporary features such as motor car racing event, associated event parking and commercial facilities. Public policies debates around proposals to develop the Adelaide Parklands through the Adelaide Oval Redevelopment and Management Bill 2011 have become quite polarised (Hamilton 2011).

The variability of rainfall is now shaping the Australian urban landscape to a much greater extent than in the past. Water for the Adelaide metropolitan area is supplied by the surrounding Mount Lofty Ranges and the River Murray. Significant declines in rainfall across the Murray Darling Basin have lead to historical low levels of inflows to the River Murray over the last decade. While the Millennium Drought has broken, episodic drought and flooding is anticipated to continue with projected regional climatic forecasts suggesting overall less rainfall on average across south-eastern Australia (CSIRO 2008). The South Australian State government has responded to the Millennium Drought and climate projections by introducing infrastructure and policies to reduce demand in the short term and increase supply over the long term. Demand-side policies, such as water restrictions have been implemented and limit the timing of outdoor water use and/or the type of watering system such as sprinklers, drippers, hand-held hoses and buckets/watering cans. These sorts of bans impose costs on households by restricting when and how watering takes place to achieve water use reductions (Brennan *et al.* 2007; Grafton and Ward 2008).

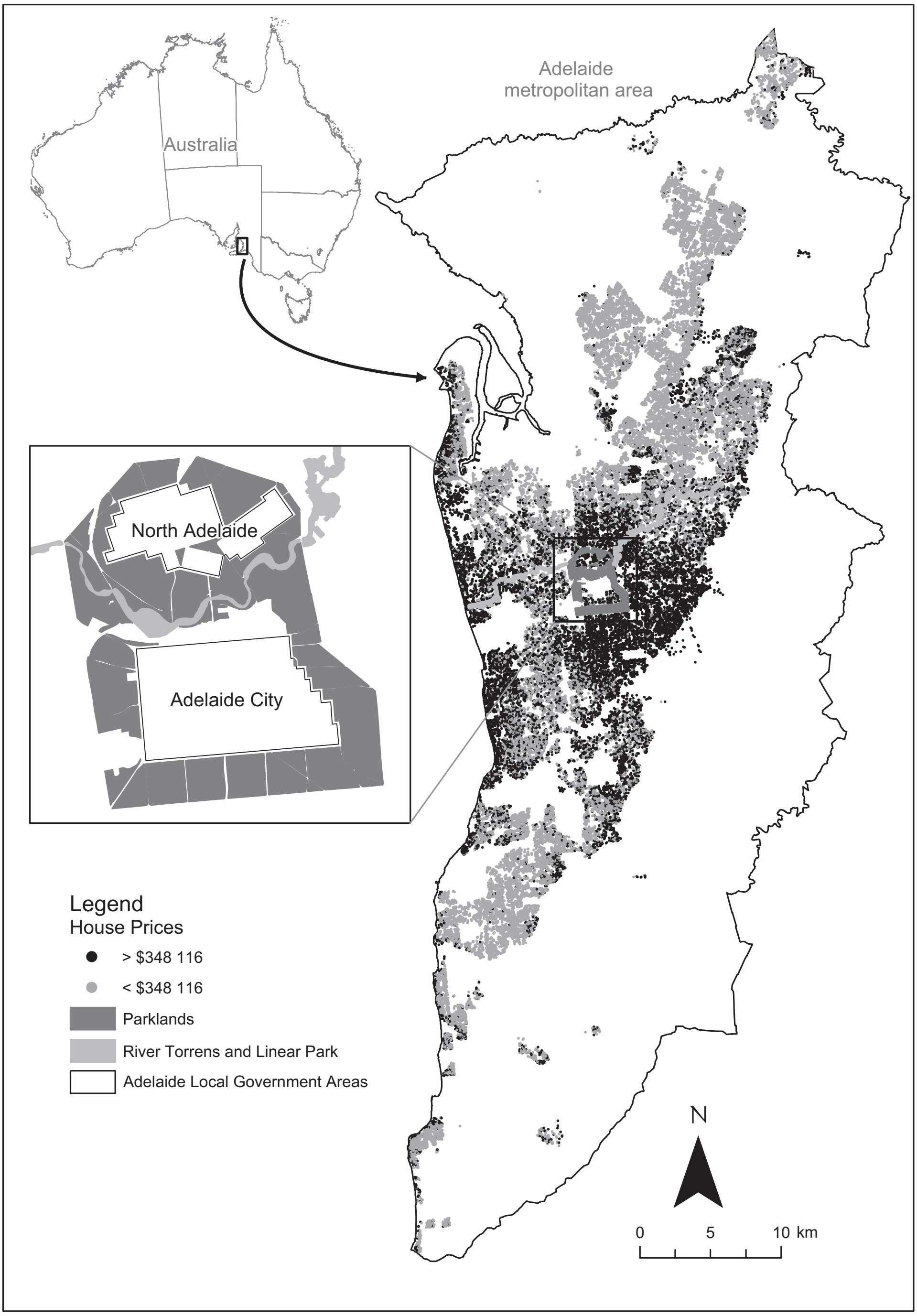

Figure 1 Study area including the central ring of parklands around the City of Adelaide and the Linear Park. Locations and sale prices of properties used in the hedonic model are also included. Note: Darker colour dots are properties whose transaction prices are above the sample mean of $348,166, and lighter colour dots are properties with sales prices below the sample mean.

From 2007 to 2009, household water restrictions were much more onerous than the restrictions on the watering of public open space. The tougher water restrictions imposed a rigid watering schedule on households, limiting households to using hand-held watering devices once a week on weekends during summer. Water restrictions on parks and public sports grounds allow watering with hand-held hoses any day (8pm to 8am) or sprinklers once a week between 8pm and 8am. The result is that many lawns on private property were brown and public open spaces tended to be greener.

A desalination plant has been built to increase metropolitan Adelaide's potable water supply (Wittholz *et al*. 2008). New reticulated pipe systems that supply recycled wastewater have been installed for some new urban development sites (Marks 2006). A recently completed pipeline system carries treated wastewater from the Glenelg sewage works to the Adelaide Parklands (Figure 1) for surface irrigation.

3.2 Data

Sales prices and housing attributes for private residential dwellings sold in the Adelaide metropolitan area were collected for the time period January 2005 to June 2008. The data were supplied by RP Data consisting of base data from the South Australian Valuer General and augmented with advertised market information (http://www.realestate.com.au). The sales information had to be cleaned for clearly erroneous entries or missing sales price information but the quality was generally quite high (anomalies <1 per cent). The spatial distribution of the sales is presented in Figure 1.

Private green area was mapped using atmospherically corrected, four band multispectral imagery collected with a Vexcel UltraCam digital camera in February 2006 by Aerometrex Pty Ltd (Kent Town, SA, Australia). Preprocessing of the image data included shadow removal to prevent dark areas around buildings being misclassified as vegetation. Shadows were removed by applying thresholds to eliminate pixels with low digital numbers (DN) in the infrared (75), red (50) and green (50) bands. A normalised difference vegetation index (NDVI) was then applied to classify areas of vegetation within the imagery using the equation:

$$\mathrm{NDVI} = \frac{(\mathrm{Infrared} - \mathrm{Red})}{(\mathrm{Infrared} + \mathrm{Red})} \tag{4}$$

Areas of photosynthetic green vegetation were isolated from other areas of high infrared and red contrast by applying thresholds (0.145 DN) to the NDVI outputs. The thresholds were determined by subjective visual assessment and comparison of aerial photography. An accuracy assessment applied to this classification reported a Kappa of 0.79, indicating 91.21 per cent prediction success using 143 independent validation sites. The amount of private green area within each sold property was then summarised for each residential property. This output was then joined to the data file of house sales.

Table 1 lists the data sets and descriptive statistics used in this study to describe amenities and dis-amenities of the residential environment, as well as neighbourhood variables that are likely to influence house prices. Data were sourced from various local and state government data custodians, assembled and merged using ARCGIS 9.3 (Esri Australia Pty Ltd., Brisbane Main Office, Brisbane, QLD, Australia). Each spatial data set was clipped to a 10 km buffer around the Adelaide metropolitan area defined by the Australian Bureau of Statistics (2006) Census of Population and Housing Adelaide Statistical Division to ensure the full influence of location is captured.

The area and location of all public open spaces, including the Adelaide Parklands and River Torrens Linear Park, reserves and national parks were assembled (Figures 1 and 2). Reserves and national parks were categorised according to the type of facilities available using online sources, street directories and a random sample of follow-up inspections. These facilities include sporting facilities, playground equipment and hiking trails. The Euclidean distance to the features within each of the spatial data sets in Table 1 was then calculated. The resultant raster surfaces describe, for every location in the study area, the straight line distance in metres to the nearest feature for every 10 m pixel in the study area. The centroids of sold properties were used to allocate the distance of each amenity, disamenity and neighbourhood variable to each property. Spatial distributions of environmental amenity and neighbourhood variables are presented in Figure 2 and 3, respectively.

Three sets of binary variables were created accounting for the quarter the property sold and the severity of the water restrictions. These binary variables can then be interacted with the distance to different public open spaces.

4. Estimation results

Models based on Equation (1) were systematically estimated by adding structural, lot and neighbourhood characteristics as well as environmental amenity variables.[1] Initial specifications of the model were estimated in Stata 10 and subjected to a Box-Cox test for functional form and a Ramsey F-test to arrive at the specification involving 65 variables in a double-log functional form with respect to the dependent variable and all the distance metrics to the attributes of environmental amenity. This formulation of the house, lot and neighbourhood characteristics is consistent with the approach in the

[1] Intermediate results are available from the authors upon request. We report only the spatial econometric model for the sake of brevity.

Table 1 Variable descriptions and descriptive statistics for the data in the estimation sample

Variable	Description	Median	Mean	Standard deviation	Min	Max
Dependent variable						
Price	Private residential dwelling sales price	\$300,000	\$348,166	\$193,247	\$62,000	\$3,840,000
Lot and house structural attributes – General						
Land area	Lot size in square metres	682 m^2	680 m^2	219 m^2	68 m^2	1904 m^2
Green area	Private green space (vegetation area front/back yards)	240 m^2	261 m^2	163 m^2	0 m^2	1880 m^2
Building size	Building area in square metres	133 m^2	148 m^2	53 m^2	80 m^2	1085 m^2
Bath	Number of bathrooms	1	1.38	0.55	1	6
Age	Age of house	33	37	27	0	160
Lot and house structural attributes – Condition (coded 1 for listed condition, otherwise 0)						
Excellent	Excellent condition	0	0.03	0.17	0	1
Good	Good condition	1	0.56	0.50	0	1
Average	Average condition	0	0.26	0.44	0	1
Fair	Fair condition	0	0.11	0.31	0	1
Poor	Poor condition	0	0.04	0.19	0	1
Very poor	Very poor condition	0	0.01	0.08	0	1
Lot and house structural attributes – Construction (coded 1 if listed construction present, otherwise 0)						
Pool	Swimming pool	0	0.09	0.29	0	1
Carport	Single carport	0	0.37	0.50	0	1
Double carport	Double carport	0	0.25	0.43	0	1
Garage	Single garage	0	0.49	0.50	0	1
Double garage	Double garage	0	0.09	0.28	0	1
Lot and house structural attributes – Construction (coded 1 if listed construction present, otherwise 0)						
Mansion	Mansion style house	0	0.0004	0.02	0	1
Brick wall	Brick construction	1	0.69	0.46	0	1
Freestone wall	Freestone construction	0	0.08	0.27	0	1
Block wall	Block construction	0	0.02	0.14	0	1
Bluestone wall	Bluestone, slate tile construction	0	0.02	0.14	0	1
Basket range stone wall	Basket range stone construction	0	0.01	0.10	0	1

Table 1 (*Continued*)

Variable	Description	Median	Mean	Standard deviation	Min	Max
Cement wall	Cement sheet, weatherboard or log construction	0	0.04	0.19	0	1
Iron wall	Iron wall construction	0	0.004	0.07	0	1
Rendered wall	Rendered wall construction	0	0.13	0.34	0	1
Galvanised iron roof	Galvanised iron roof construction	0	0.25	0.43	0	1
Imitation tile roof	Imitation tile roof construction	0	0.03	0.17	0	1
Shingle roof	Shingle roof construction	0	0.005	0.07	0	1
Tile roof	Tile roof construction	1	0.70	0.46	0	1
Other roof	Corrugated cement sheet, steel decking or slate roof construction	0	0.02	0.12	0	1
Environmental amenity – Area variable (area of the nearest reserve/national park with listed facilities)						
Area of reserve – garden	No facilities	4236 m^2	2.16 ha	5.87 ha	153 m^2	113.94 ha
Area of reserve – sport	Sporting facility only or sporting with other facilities	3.65 ha	7.21 ha	13.28 ha	638 m^2	83.80 ha
Area of national park – hiking	National park with hiking facility only	223.35 ha	271.75 ha	392.74 ha	3,286 m^2	1547.96 ha
Area of national park – sport	National park with sporting facility only or sporting with other facilities	700.76 ha	403.38 ha	328.23 ha	5.02 ha	859.12 ha
Area of waterbodies	Area of nearest lake/wetland/dam	2695 m^2	6.88 ha	26.12 ha	144 m^2	27.24 ha
Environmental amenity – Distance variable (distance to nearest reserve with listed facilities)						
Distance to linear park	Distance to the nearest section of Linear park	7.90 km	10.29 km	8.30 km	10 m	42.17 km
Distance to Adelaide parklands	Distance to the nearest section of the parklands that surround Adelaide CBD	10.74 km	12.29 km	8.60 km	36 m	42.93 km
Distance to reserve – garden	Park with no facilities	213 m	285.4 m	271.62 m	1 m	3.81 km
Distance to reserve – sport	Sporting facility only or sporting with other facilities	488 m	576.46 m	433.41 m	1 m	6.10 km
Distance to national park – hiking	National park with hiking facility only	4.28 km	5.49 km	4.23 km	10 m	19.47 km

Table 1 (*Continued*)

Variable	Description	Median	Mean	Standard deviation	Min	Max
Distance to national park – sport	National park with sporting facility only or sporting with other facilities	6.29 km	7.43 km	5.22 km	10 m	31.47 km
Distance to golf course	Golf course	2.44 km	2.73 km	1.82 km	10 m	10.70 km
Distance to water bodies	Lake/wetland/dam	1.27 km	1.43 km	869.5 m	1 m	4.40 km
Distance to coast	Coast	6.19 km	6.75 km	4.85 km	1 m	27.08 km
Environmental dis-amenity – Distance variable (distance to the nearest listed dis-amenity)						
Distance to fossil fuel generator	Fossil fuel generator	9.25 km	9.58 km	5.34 km	291 m	32.93 km
Distance to alternative generator	Alternative generator	9.25 km	10.31 km	5.48 km	222 m	28.46 km
Distance to industry	General industrial zone	2.01 km	2.45 km	1.86 km	1 m	9.96 km
Neighbourhood variable – Distance variable (distance to the nearest listed dis-amenity)						
Distance to interchange stop	Interchange stop (multiple at least every 15 minutes)	2.83 km	3.43 km	2.45 km	71 m	19.42 km
Distance to go zone bus stop	Bus available at least every 15 minutes	525 m	993.71 m	1.68 km	1 m	13.75 km
Distance to normal bus stop	Bus available every 30 minutes to an hour	234 m	424.91 m	975.74 m	1 m	10.39 km
Distance to private school	School run by private institution	951 m	1.09 km	657.38 m	10 m	8.62 km
Distance to public school	School run by the State Government	649 m	699.10 m	378.97 m	40 m	6.00 km
Distance to train line	Train line	2.62 km	3.40 km	3.00 km	10 m	19.63 km
Distance to main road	Main arterial road	234 m	277.60 m	206.90 m	1 m	1.70 km
Distance to commercial zone	Commercial zone	361 m	442 m	426.48 m	1 m	6.92 km
Neighbourhood variable – Census data (census tract level)						
Young	Percentage of population < 18 years old	22.6%	22.91%	5.35%	0%	41.13%
Income	Median household income per week	$987	$990	$293	$290	$2,639

Notes: Distances are measured from centroid of each property to the nearest boundary of each variable. All distance and area variables are measured in metres and square metres, respectively, for the purposes of the estimation.
Summary statistics are given for variables prior to transformation in any form and is based on estimation sample of 40,932 private residential dwellings sold in the Adelaide metropolitan area during January 2005 to June 2008. For simplicity, large numbers are reported in the larger unit.

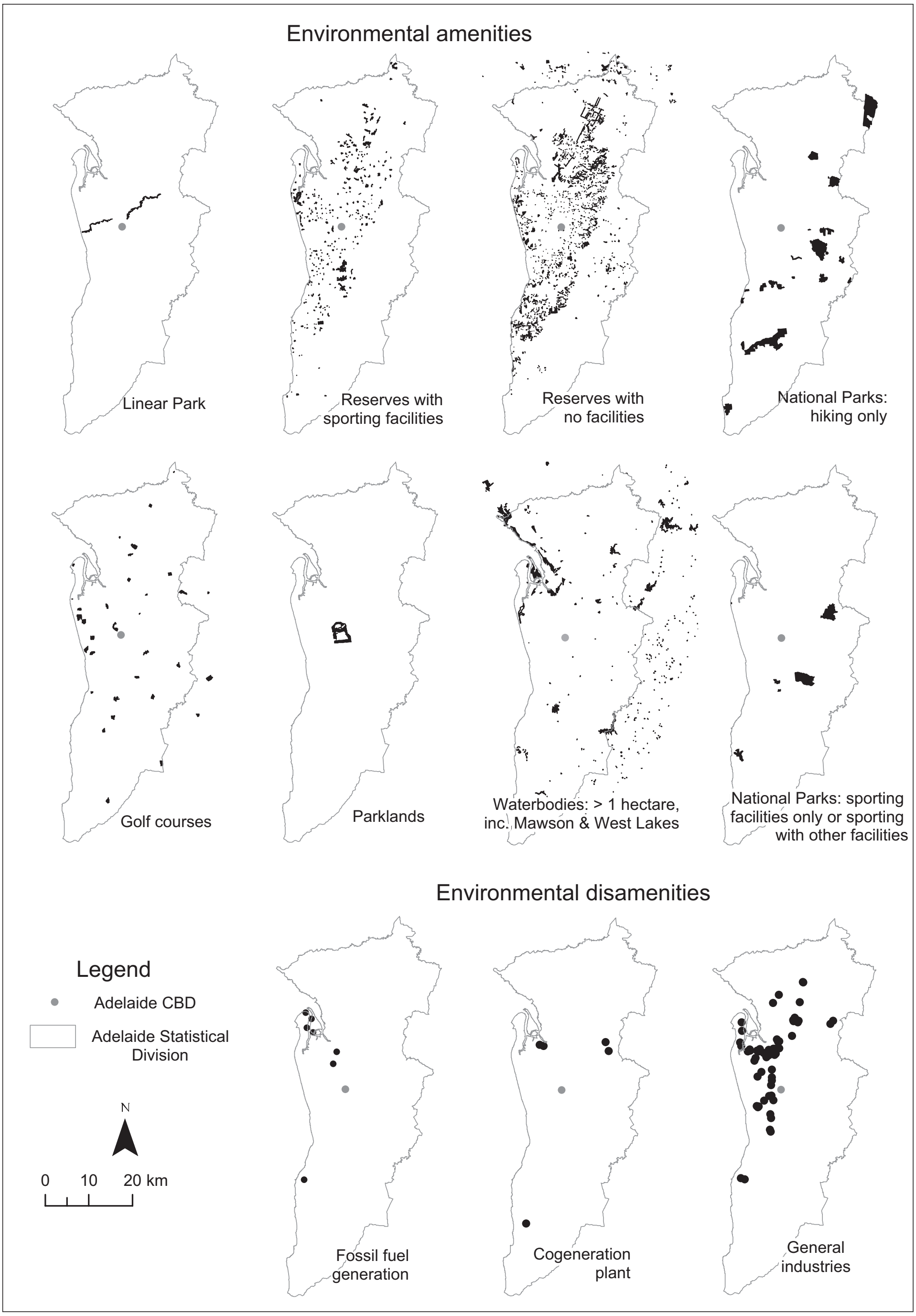

Figure 2 Location of environmental amenities and dis-amenities.

literature (Cropper *et al.* 1988; Taylor 2003). To make the interpretation of the interaction terms simpler, we normalised the covariates prior to estimation using the transformation by Anderson and West (2006):

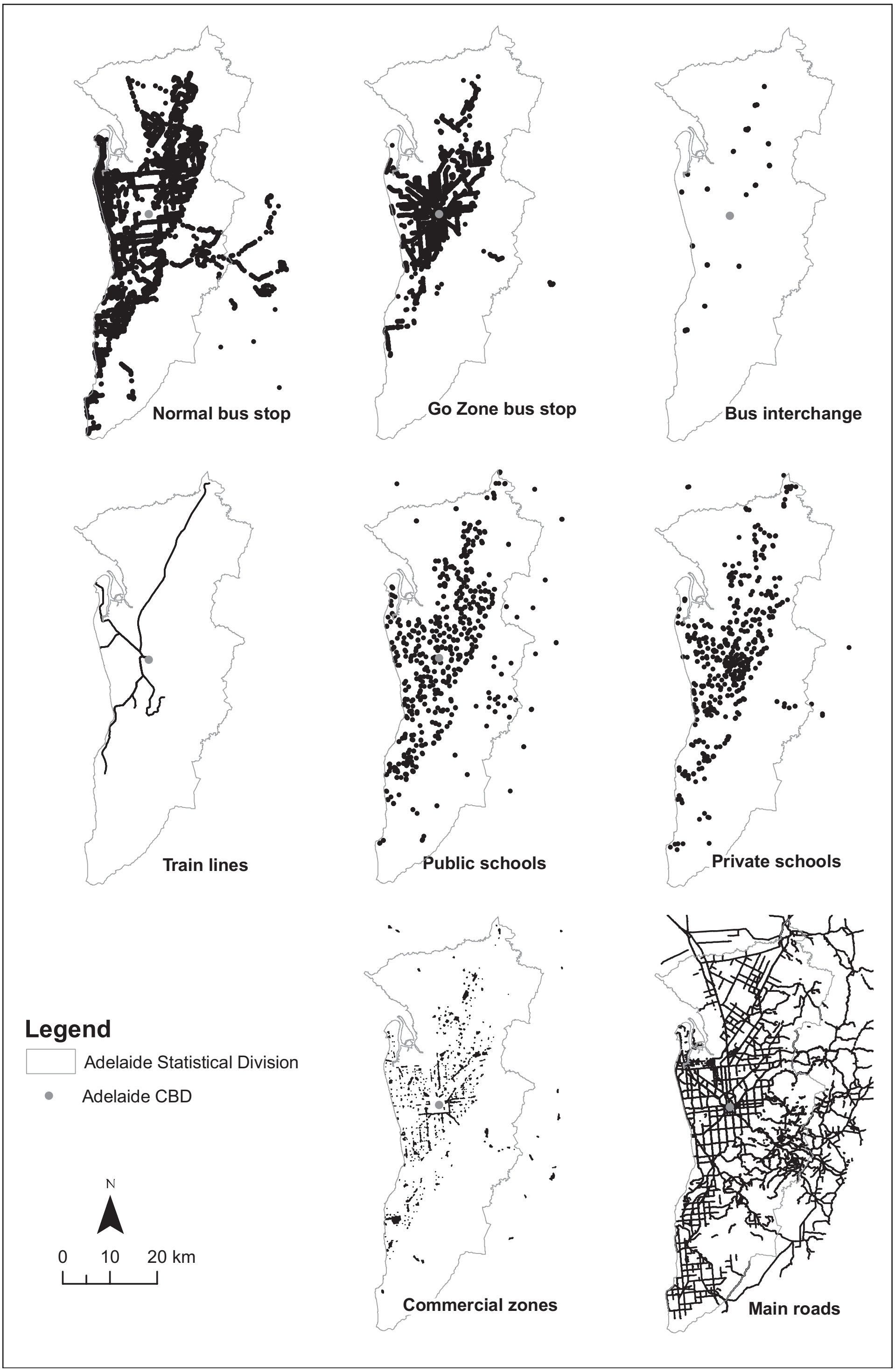

Figure 3 Location of neighbourhood variables.

$$A^* = (A - \bar{A})/\bar{A} \quad (5)$$

where A is the covariate vector prior to normalisation, and $\bar{A}$ is the sample median.

Ordinary least square estimates are potentially biased and inefficient if spatial dependence is ignored in the estimation process. Initially, a trend surface regression model of the natural logarithm of house prices indicates there is a quadratic trend suggested by the data using Geoda (Anselin 2005). The sign of the x coordinate is positive with its square term being negative, suggesting an increasing trend of house prices from west to east at a declining rate. The sign of the y coordinate is negative with its square term being positive, indicating a declining trend of house prices from south to north with an increasing rate. Moran's I of 0.75 is statistically significant at 1 per cent, which indicates strong spatial autocorrelation. Robust Lagrange Multiplier test statistics were used to investigate the existence of either spatial lag or spatial error or both. Testing suggests a spatial lag specification should be estimated. A set of fixed effects for each suburb across the Adelaide metropolitan area were developed to account for omitted variables that have no spill-over effects across spatial units of observations. Suburbs with few sales were merged with the most comparable adjoining suburbs based on crime statistics and median household income.

The estimated coefficients and the marginal impacts for attributes are presented in Table 2. The marginal impact or implicit price of any attribute is calculated using the partial derivative for the attribute of interest, the estimated coefficients from the hedonic pricing model and the appropriate median value or the reference category. The estimated implicit prices associated with all of the binary variables are calculated using $\exp(\hat{B} - \hat{V}(B)/2) - 1$, where $\hat{B}$ and $\hat{V}(B)$ are the estimated coefficient and variance for the binary variable, respectively (Halvorsen and Palmquist 1980).

5. Discussion

5.1. Lot and house structural attributes

Increasing land area and house size, as well as more bathrooms have a positive impact on the final selling price. An additional square metre of land area is associated with a price increase of $76 (2008 Australian $ used throughout) while controlling for all other characteristics of the house and lot that are available. An additional square metre of private green area increases sales price by about $17 for a median-sized property. The sales price rises by about $810 for every additional square metre of building area. An additional bathroom raises sales price by about $11,301. Finally, the sales price of the house falls by about $167 for every 1 year increase in its age. The existence of a swimming pool attracts a premium of $15,295. The estimated marginal prices of a double garage, a double carport, a single

Table 2 Estimation results

Dependent variable: ln price variables	Coefficient	Standard error	Estimated marginal impacts (AU$)
Lot and house structural attributes – General			
Land area	0.000382***	0.000022	76
Land area^2	0.000000***	0.000000	–
Land area × green area	0.000055***	0.000021	–
Building size	0.003311***	0.000092	810
Building size^2	−0.000002***	0.000000	–
Bath	0.037670***	0.001907	11,301
Age	−0.010056***	0.000302	−167
Age^2	0.000187***	0.000006	–
Age^3	−0.000001***	0.000000	–
Lot and house structural attributes – Condition			
Excellent	0.078307***	0.005864	23,492
Good	0.034978***	0.002262	10,493
Fair	−0.026847***	0.002905	−8,054
Poor	−0.061847***	0.005003	−18,554
Very poor	−0.095013***	0.011250	−28,504
Lot and house structural attributes – Outside features			
Pool	0.050994***	0.002689	15,298
Single garage	0.014606***	0.001754	4,382
Double garage	0.027316***	0.002593	8,195
Single carport	0.009947***	0.001725	2,984
Double carport	0.023110***	0.001992	6,933
Lot and house structural attributes – Construction			
Mansion	0.231965***	0.067077	69,590
Freestone wall	0.042659***	0.003356	12,798
Block wall	−0.011968**	0.005164	−3,590
Bluestone wall	0.039276***	0.005690	11,783
Basket range wall	0.023940***	0.006382	7,182
Cement wall	−0.050149***	0.004994	−15,045
Iron wall	−0.080052***	0.013745	−24,016
Rendered wall	0.015010***	0.002458	4,503
Imitation tile roof	−0.018807***	0.005093	−5,642
Shingles roof	−0.033554***	0.010444	−10,066
Tile roof	0.006822***	0.002138	2,047
Other roof	0.006585	0.007439	1,975
Environmental amenity			
ln (Distance to Linear Park)	−0.009231***	0.002984	−0.35
ln (Distance to Adelaide Parklands)	−0.055547***	0.006546	−1.55
Distance to road × ln (Distance to Adelaide Parklands)	−0.001699***	0.000221	–
ln (Distance to reserve – Garden)	0.000919	0.000857	1.29
Area of reserve – Garden × ln (Distance to reserve – garden)	−0.000046***	0.000010	–
ln (Distance to reserve – sport)	−0.002565**	0.001168	−1.58
Area of reserve – sport × ln (Distance to reserve – sport)	0.000053	0.000046	–
ln (Distance to reserve – sport) × water restrictions	0.003306	0.002169	–
ln (Distance to reserve – sport) × Tougher water restrictions	−0.003663**	0.001814	–
ln (Distance to national park – hiking)	0.006061***	0.002246	0.42

Table 2 (*Continued*)

Dependent variable: ln price variables	Coefficient	Standard error	Estimated marginal impacts (AU$)
Area of national park – hiking × ln (Distance to national park – hiking)	0.000182	0.000081	–
ln (Distance to national park – sport)	0.026128***	0.003245	1.25
Area of national park – sport × ln (Distance to national park – sport)	0.001057*	0.000585	–
ln (Distance to national park – sport) × water restrictions	−0.006150***	0.002237	–
ln (Distance to national park – sport) × Tougher water restrictions	−0.011519***	0.002023	–
ln (Distance to golf)	−0.004391**	0.001874	−0.54
ln (Distance to water bodies)	−0.001838	0.001550	−0.43
Area of water bodies × ln (Distance to water bodies)	0.000008	0.000017	–
ln (Distance to coast)	−0.102808***	0.003829	−4.99
Environmental disamenity			
ln (Distance to fossil fuel generator)	0.047608***	0.005855	1.54
ln (Distance to alternative generator)	0.026390***	0.005200	0.86
ln (Distance to industry)	0.022345***	0.001416	3.34
Neighbourhood attributes			
ln (Distance to interchange stop)	−0.007327***	0.002751	−0.78
ln (Distance to go zone bus stop)	0.000357	0.001254	0.20
ln (Distance to normal bus stop)	0.001946*	0.001086	2.49
ln (Distance to private school)	0.000453	0.001520	0.14
Young × ln (Distance to private school)	−0.009175**	0.004023	–
Income × ln (Distance to private school)	−0.000282	0.003611	–
ln (Distance to public school)	0.005541***	0.001415	2.56
Young × ln (Distance to public school)	0.002785	0.004317	–
Income × ln (Distance to public school)	0.014695**	0.003841	–
ln (Distance to train line)	0.009705***	0.001778	1.11
ln (Distance to main road)	0.020441***	0.001996	26.21
ln (Distance to commercial zone)	0.004132***	0.000983	3.43
Fixed effects			
Interest rate	−0.003403	0.007257	−1,021
Quarter property sold × Interest rate	Significant*** except 1st* and 2nd quarters 2005**		
Suburb fixed effects	Significant*** except Noarlunga Downs and Smithfield		
Constant	10.087970***	0.130511	–
Spatial autoregressive parameter (λ)			0.1023***
R^2			0.8990
No. of observations			40,923

***Estimated coefficient is significant at $\alpha = 1\%$, **$\alpha = 5\%$ and *$\alpha = 10\%$.

garage and a single carport are approximately \$8,195, \$6,933, \$4,382 and \$2,984, respectively.

5.2. Environmental amenities

The marginal impact of different environmental amenities including open spaces across the Adelaide metropolitan area is summarised in Table 2. The marginal impact is a non-linear function of the selling price, the relevant distance metric and any interaction terms. The marginal impact is calculated by differentiating Equation (1) with respect to the distance to a particular amenity and substituting the appropriate selling price, the estimated coefficient(s), interaction term and the distance metric.

Publicly provided open spaces such as reserve areas, the Adelaide Parklands and sporting fields confer private benefits to nearby homeowners. A negative coefficient on a distance metric indicates that the selling price is increasing as the distance from the feature decreases. The estimated coefficient on proximity to the nearest segment of Linear Park is negative and significant at $\alpha = 1$ per cent indicating that price increases by \$0.35 for a property 1 m closer (calculated at the median for all continuous variables). The impact of the historical multi-use Adelaide Parklands is more complicated. The Adelaide Parklands surround the central business district and in turn are surrounded by main roads. The normalised proximity to the nearest main road is interacted with proximity to Parklands to distinguish between the price effects of the Parklands and main roads. Overall, the price increases by about \$1.55 for every metre closer the property is to the nearest part of the Parkland. The estimated coefficient is significant at $\alpha = 1$ per cent.

Proximity to the nearest reserve with no facilities is positive but not significant (Table 2). However, the interaction term between proximity to a reserve without any facilities and its size is negative and significant at $\alpha = 1$ per cent. The distance to a national park with hiking trails interacted with park size is positive and significant (at $\alpha = 1$ per cent). This suggests that national parks with hiking trails are not regarded as amenities. National parks with trails for walking may detract from the final selling price because they remain in a natural, unmanaged state throughout the year presenting a heightened fire danger owing to dense native vegetation as well as a pestilence risk (e.g. eastern brown snake). Thus households may choose to drive to these areas rather than live nearby. Proximity to the nearest reserve with sporting facilities is negative and significant at $\alpha = 5$ per cent. For every metre closer the property is to this feature raises sales price by about \$1.58 (Table 2). The estimated coefficient on the interaction term between distance to the nearest reserve with sporting facility and its size is positive and not significant.

With water restrictions, there may be additional private benefits to irrigated public open spaces. There is potential for households to substitute between private green space and sporting ovals as ovals are generally well-watered and maintained open spaces while tougher water restrictions have lead to browning of lawns and gardens on private lands. To test for evidence of substitution, proximity to the nearest reserve or national park with a sporting facility (which are watered more regularly) is interacted with one of two binary variables for presence of water restrictions and tougher water restrictions. This interaction term is negative and significant (at α = 5 per cent) only with the tougher water restrictions. This suggests that some substitution may be occurring as water restrictions increase in severity. With tougher water restrictions, the marginal price for proximity to the nearest reserve with sporting facility rises by about $3.80 per metre closer. Interaction terms on distance to and area of national parks with sporting facilities were created and the estimated coefficients are positive and significant. However when distance to the national park with sporting facilities is interacted with water restrictions variables, the estimated coefficients are negative and significant at α = 1 per cent.

The estimated coefficients for distances to golf courses and the coast are negative and significant at α = 5 per cent and α = 1 per cent, respectively. The sales price increases by about $0.54 for every metre closer a property is to a golf course. Proximity to the coast (Adelaide's sandy recreational beaches) adds $4.99 for every metre closer the property is to the beach when evaluated at the median.

5.3. Environmental dis-amenities

All the estimated coefficients for distances from the environmental dis-amenities are positive and significant at α = 1 per cent (Table 2). When evaluated at the median, property values decrease by $0.86, $1.54 and $3.34, respectively, for every metre closer the property is to the nearest alternative fuel generator, fossil fuel generator and general industrial zone.

5.4. Neighbourhood variables

Many of the proximity metrics for public transportation are positive and not significant (Go Zone bus stops with higher frequency bus schedules) or are positive but significant at α = 10 per cent indicating a detracting quality to the attribute (normal bus stops or train lines, Table 2). Adelaide is a car-dominated city with <5 per cent of employed people using public bus transport to get to work. Proximity to the nearest private and public school are also estimated. Private schools are an amenity in the areas where the percentage of population <18 years old is higher. Public schools across the Adelaide metropolitan area are not an amenity as the coefficient for proximity to the nearest public school is positive and significant at α = 1 per cent.

5.5. Suburb fixed effects

A series of fixed effects were used to capture any remaining neighbourhood characteristics for which there is presently limited or no available data. Davoren Park, the suburb with the lowest median selling price, was used as the reference. The residual value that might be attributed to each suburb was calculated and mapped in Figure 4. A strong geographical clustering of higher valued suburbs is situated around the Adelaide Parklands and the eastern suburbs. These suburbs have traditionally commanded a premium over and above all the characteristics of the house, lot and environmental amenity of the surrounding area.

5.6. A practical policy example

An example will help demonstrate how this research can be used in a practical policy setting. For example, a local Council may look at the potential to expand a small pocket park into a larger space through the purchase of a number of properties to create larger better equipped facilities. The zone of benefit around the park can be calculated using the partial derivative of the hedonic price function:

$$\frac{\partial P}{\partial \,\text{distance to small reserve}} = \left(Bi \frac{P * \text{area of small reserve}}{\text{distance to small reserve}} \right) \tag{6}$$

To illustrate, a small pocket park in the southern suburbs across of the Adelaide metropolitan area was selected. In this hypothetical example, the pocket park was increased in size from the 4000 m^2 to 1 ha by removing adjoining houses. The marginal impact on each property within a kilometre of the improved park has been calculated using Equation (6) and presented in Figure 5. The sum of capitalised private benefits associated with a pocket park expanding from 4000 m^2 to a 1 ha is \$950,000 ceterius paribus. Expanding the pocket park to 2 ha or 3 ha has been calculated as \$2.5 M and \$4.5 M, respectively, in private benefits capitalised in land values. Owing to the nonlinear nature of the equations, the benefits of environmental amenities to adjoining properties is relatively high and declines rapidly as distance increases. For a newly created 3 ha park, adjoining property might increase by \$27,000, but the increased value declines to \$552 by 1000 m.

6. Conclusions

In this study, a first-stage hedonic analysis of private residential home transaction data from the Adelaide metropolitan area is conducted to estimate the implicit values associated with residential amenities, such as open spaces and industrial dis-amenities. To estimate these values, it was necessary to collect

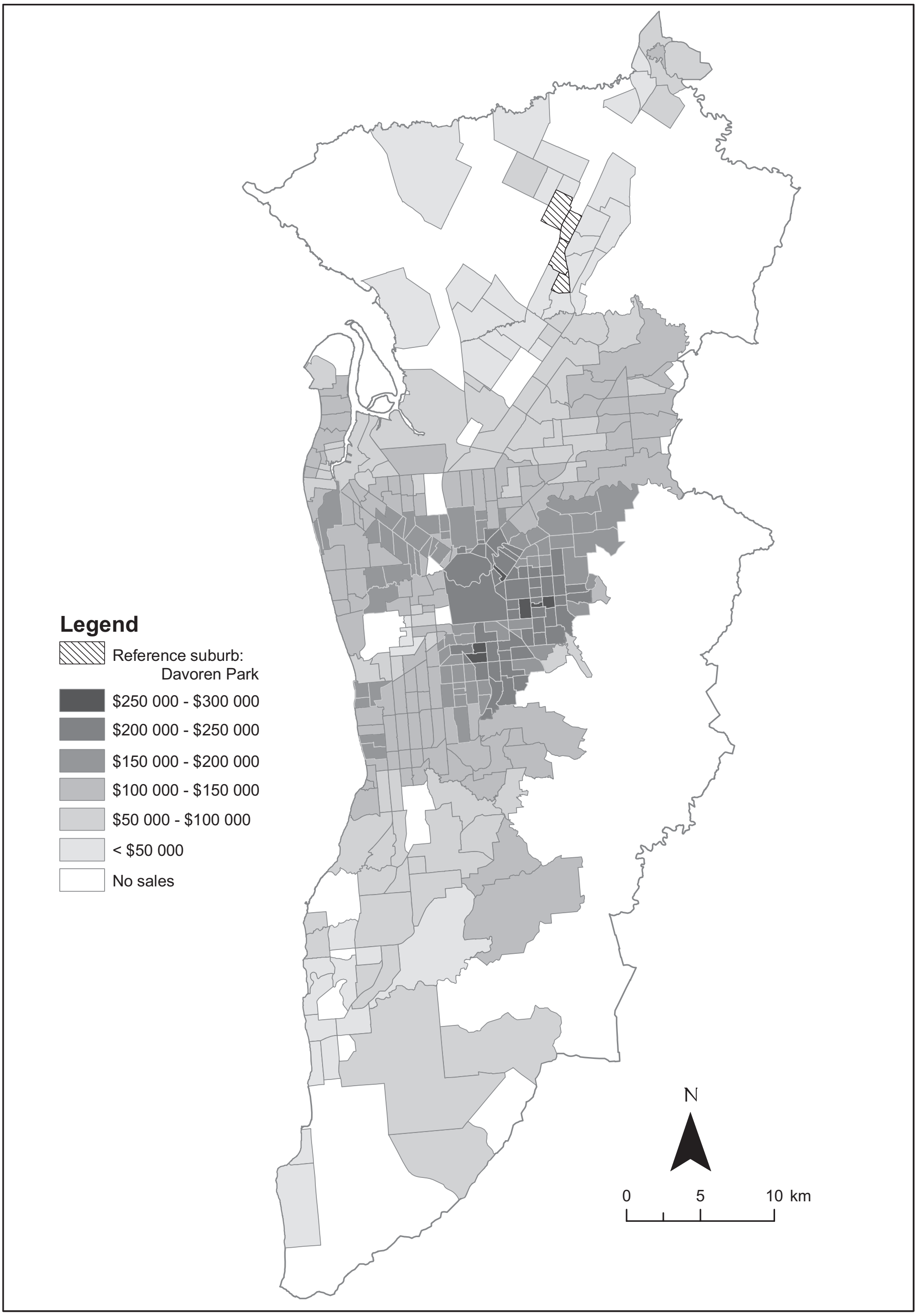

Figure 4 Map of fixed effects over the Adelaide metropolitan area.

and assemble extensive data sets on final selling prices of single-family residential houses, and all the attributes associated with the house, lot and neighbourhood across the entire metropolitan area. Local fixed effects are also

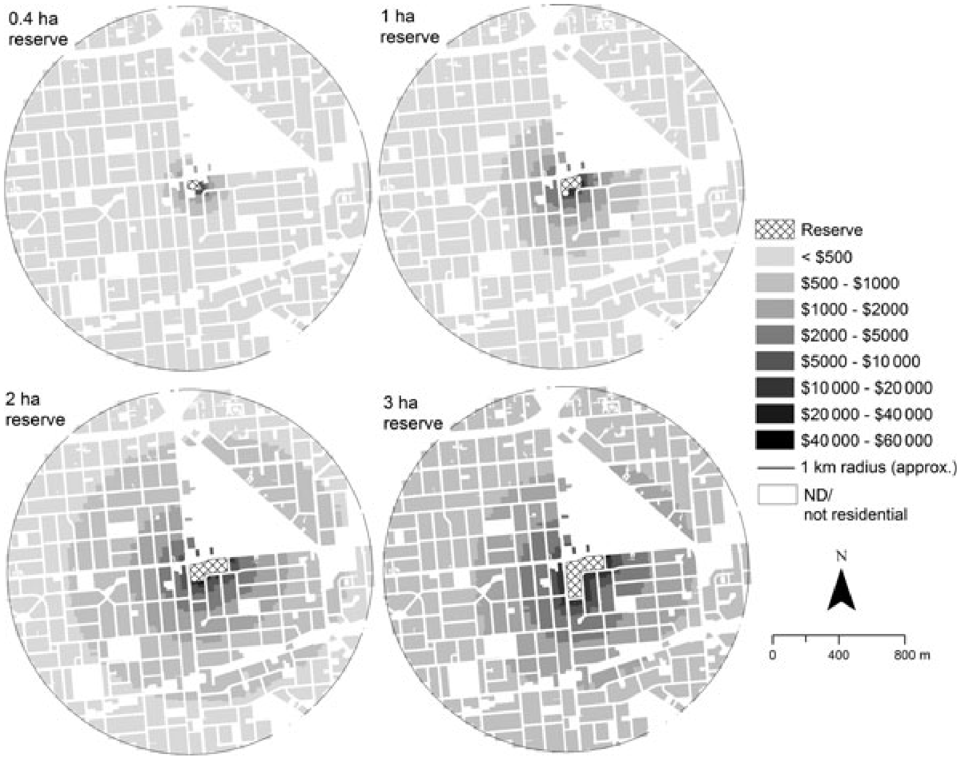

Figure 5 Marginal impact of expanding a pocket park.

included in the model to control for any remaining neighbourhood characteristics.

Our modelling has also identified how households may alter behaviour in response to sustainability-related public policies. For instance, under tougher water restrictions used to reduce water consumption, some substitution between private green space and sporting ovals may be occurring. Reserves with sporting ovals are watered more frequently, and our analysis suggests households may be willing to pay more to live closer to these areas. Further our results suggest that nature reserves that are not watered and not managed are not an amenity that households were willing to pay more to live near. We speculate that this may be due to the brown, dry landscape, the risk of fire and the risk posed by snakes. There are implications here for long-term planning of urban infill and expansion. The current climate of reduced water availability and policy focus on reducing urban water consumption has created an additional economic imperative to protect and provide open spaces that are managed and maintained, particularly through regular watering.

Our research provides information required to evaluate the benefits of protecting existing open space and the provision of new open spaces as part of the planning and regulation processes needed to support long-term urban growth plans. We have provided an illustration of how the modelling results could be used in a practical policy application. A local Council might want to evaluate the benefits from changing the configuration of small pocket park. The benefit of expanding a pocket park from 0.4 ha to 1 ha resulted in $0.9 M in private benefits being capitalised in property values ceterus paribus. For a given proposal, a developer or a Council could in turn evaluate the suite of economic costs of acquiring the land (in our stylised example, existing houses), and a comprehensive analysis of the cost and benefits would reveal the types of open space developments and redevelopments that are likely to yield positive net benefits. Future research could focus on testing the magnitude of substitution between public and private space with a second stage analysis and optimising land use configuration. There is also scope to examine the contribution of open spaces to local tax bases.

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