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Demand for urban tree cover: A two-stage hedonic price analysis in California

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ABSTRACT

This research seeks to use extensive home sale and socioeconomic data, coupled with urban tree cover data to identify the influence of urban trees on house values, estimate the demand for urban trees and ultimately calculate the welfare change of forest loss in California, with a two-stage hedonic price model. In the first stage model, we detected spatial dependence using the Lagrange-Multiplier Robust tests and found significant spatial correlations in house prices for each of five California counties. Our identification strategy relies on flexibly controlling for unobserved spatial effects by using the Spatial Lag Model (SAR) to get consistent estimates of urban tree cover. The SAR model solves the problem by establishing the spatial weight matrix to incorporate the neighboring house price. In the second stage, we then used market segmentation to identify the demand parameters by collecting data from five geographic markets, assuming that residents in each market share common preference structures. Consequently, the first-stage analysis provides evidence of positive effect of tree cover on home values, which is robust with different specifications. We further found that the estimated own price elasticity of demand for tree cover within each parcel was − 0.075, suggesting an inelastic demand curve.

1. Introduction

Since Rosen (1974) first provided a theoretical framework for the hedonic price model, a large amount of research has been carried out to value environmental amenities, including hazardous waste sites (Brasington and Hite, 2005; Greenstone and Gallagher, 2008), air quality (Kim et al., 2003; Chay and Greenstone, 2004), and open space (Irwin and Bockstael, 2001; Klaiber and Phaneuf, 2010; Abbott and Klaiber, 2010). The impact of forest amenities on house sale prices has also been widely examined with the hedonic price framework in the environmental and land use economics literature. Many of these studies have focused on solving specific econometric issues associated with the hedonic price model, especially with respect to functional form (Cropper et al., 1988; Tyrvainen and Miettinen, 2000), parameter identification (Brown and Rosen, 1982; Bartik, 1987; Bishop and Timmins, 2015), and benefit analysis (Kim et al., 2003). In terms of benefit estimation, most of the previous studies have used Rosen's (1974) first stage hedonic price model to estimate the marginal effect of forest amenities on home values and provide a wide range of estimates about whether trees increase the value of a home, but only few have conducted non-marginal change analysis due to the difficulty in identifying demand parameters in the second stage (Netusil et al., 2010). Non marginal change refers as any change that is large enough to affect individual's willingness to pay at the margin (Bishop and Timmins, 2015).

Given that many policies or environmental impacts likely cause non marginal changes, it is of great use to estimate actual demand curves in order to estimate welfare impacts. To address the question of non-marginal changes in tree cover, this study develops a two-stage hedonic price model and utilizes a series of specifications to assess the influence of urban trees on house values and then estimate the demand for urban trees in California. The first stage hedonic price model is used to derive marginal implicit prices for attributes of interest (e.g. Garrod and Willis, 1992; Powe et al., 1995; Tyrvainen and Miettinen, 2000; Kong et al., 2007; Netusil et al., 2010; Sander et al., 2010); the second stage instruments marginal implicit prices to estimate the demand curve and to implement welfare analysis (Poudyal et al., 2009; Netusil et al., 2010). The consistent parameter identification in the first stage hedonic model is of great importance to the parameter identification of the demand curve in the second stage.

In this research, we combined parcel data, tree cover data, socioeconomic data, and other relevant data files together to form the final

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Table 1
Definition and source of data.

Variable name	Variable definition	Mean
Price	House price after prices adjusted for inflation (in 2003 dollars)	451,071.8
Tree %	% of parcel covered by trees (Area tree cover/lot area)	5.0
Lot size	Size of house lot in 1000 m^2	17.0
Area of house	Size of the house structure in thousands of square feet (1000 ft^2)	1.7
Fire place	Whether it is a fireplace	0.6
Age	Year that the house was sold minus the year that the house was built	35.3
Condition	Auditor's assessment of the condition and upkeep of a house	6.4
Bedrooms	The number of bedrooms	3.1
Bathrooms	The number of bathrooms (including half bathrooms)	2.1
Garage	Dummy variable indicates the presence of the garage	0.6
Pool	Dummy variable indicates the presence of the pool	0.1
CBG % Black	Percentage of Black population in a Census Block Group	1.6
CBG % White	Percentage of White population in a Census Block Group	79.3
CBG % Hispanic	Percentage of Hispanic population in a Census Block Group	20.4
Total Respiratory Risk	Total respiratory risk measured by toxic air releases. Higher number = more risk.	5.8
Average slope	Steepness of the lot on which a house is built. Higher number = higher slope.	4.7
Average elevation	Elevation of the lot on which a house is built. Higher number = higher elevation.	116.7
Average annual rainfall	Average annual precipitation in inch	33.3
Soil permeability	The ability of a soil to transmit water or air.	14.8
Available water capacity	The quantity of water that the soil is capable of storing for use by plants	0.2
Soil erodibility	Quantifies the susceptibility of soil particles to detachment and movement by water	0.3
Vol. water content of soil	Represents the fraction of the total volume of soil that is occupied by the water contained in the soil	14.9
Population change	Rate of change in county level population from 1990 to 2000	13.8
Median household income	Census tract level median household income in 1990	53,131.4
Median household age	Census block level median household income in 2000	37.3
Year sold	The year the house is sold	451,071.8
Tract	The tract the house is located in	5.0

dataset. In the study of first stage model to estimate the benefits of urban trees, one identification issue is that of spatial spillovers, whereby the price of house i is likely to be influenced by neighboring house prices, and neighboring house prices may be correlated with the percentage of tree cover in the i_{th} parcel. If the neighboring house price has been omitted, the percentage of tree cover in this parcel tends to be highly correlated with the error term (the neighboring house price falls into the errors), thus resulting in an endogeneity problem, which causes biased estimation results. In other words, higher tree cover can be used to predict house price, but house price may also predict tree cover. Under these circumstances, the percentage of tree cover within each parcel is associated with the unobservables that contribute to the house price. Failure to diagnose and correct such spatial autocorrelation may lead to inefficiently estimated coefficients and even a failure of consistency. This paper tested spatial dependence using Lagrange-Multiplier Robust tests and found significant spatial correlations in house prices for each of five California counties. Our identification strategy relies on flexibly controlling for unobserved spatial effects by using the spatial autoregressive lag model (SAR) to get consistent estimates of urban tree cover. The SAR model solves the problem by establishing the spatial weight matrix to incorporate the neighboring house price.

In the second stage demand estimation, the main problem is identification of demand parameters. Since the same information is used for the two stages, demand cannot be identified from the hedonic alone. We used market segmentation to identify the demand parameters by collecting data from five geographically distinct markets, assuming that residents in each market share common preference structures. In this study, market segments consist of five California counties: Sonoma, Napa, Shasta, Placer, Los Angeles. To address price endogeneity in the second stage, we instrumented the implicit prices to estimate the demand for urban tree cover. We first estimated the implicit price of urban tree cover for each county and obtained the five different coefficients for the relationship between urban tree cover and house price. Then we calculated the implicit price for each observation and instrumented implicit prices with the variables of population change and county dummies. Finally, the data were pooled to estimate the demand curve.

As a result, the estimated own price elasticity of demand for tree cover within each parcel was -0.075, suggesting an inelastic demand curve. Then we conducted welfare analysis and the results suggested that consumer surplus decreased by $247.62 per household if assuming the 20% reduction (3.97%) of the current average tree cover (4.96%).

This paper fills a gap in the literature by estimating the demand curve of urban tree covers in California. Most previous studies only focus on the first stage marginal price estimation. Estimation of the demand curve for urban tree cover is significant because it is necessary to measure the benefits of non-marginal changes in urban tree cover. We also make a contribution by using spatial econometrics to address the issue of omitted variable bias.

2. Study area and data

The five counties in the study have relatively large numbers of houses and therefore have a sufficient number of house transactions for statistical analysis. Furthermore, the five counties were chosen to be in different regions, and thus have different markets and climate conditions. House characteristics differ substantially across the five counties.

Parcel data were purchased from ParcelQuest, a California based firm that collects and consolidates parcel data, including house sales and physical characteristics of homes. The purchased parcel data included shape files and other files with house transaction prices and characteristics. All transaction house prices were deflated to $2003.

Data about the tree canopy for each parcel was calculated using a program called eCognition. In this study, traditional Remote Sensing methods were first tested and were unsuccessful in separating lawns from trees as both reflected highly in green and especially in near-infrared. Therefore, eCognition software was used which incorporates Geographic Object Based Image Analysis (GeOBIA) methods. Then the tree layer was intersected with parcel layer in a GIS to produce a layer that yielded the area of tree cover for each parcel analyzed.

Other variables were added to the dataset. Fire hazard data, year 2000 US Census socioeconomic data at Census Block Group Level, 2005 USEPA National-Scale Air Toxics assessments for environmental risk data at census tract level, and the SSURGO soil attribute data were also