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Seong-Hoon Cho, Dayton M. Lambert, and Roland K. Roberts

ABSTRACT. *A two-rate property tax (TPT) imparts different tax rates on land and structures. A hypothetical TPT is evaluated as an instrument to promote open space preservation. The potential TPT effects on open space equilibrium levels were compared with simulated equilibrium levels reflecting the TPT policy shock. Ex ante results suggest that equilibrium open space levels were positively displaced following a revenue-neutral tax policy on land. About 76% of the households valued open space more following a land value tax rate of 9.04%, which suggests that households in certain locations are likely to support programs or policies preserving open space.* (JEL Q58, R11)

I. INTRODUCTION

Rapid population and economic growth in Tennessee has increased residential demand for land at the cost of sprawl and leap-frog development. The Knoxville Tennessee metropolitan statistical area (MSA) is one of the top 10 fastest growing metropolitan areas in the United States (*Knoxville News Sentinel* 2008). This kind of growth has raised concerns about its potential negative impacts on public goods, including the loss of amenity benefits from farmland and open space, as well as higher costs of infrastructure and community services. Adverse consequences of sprawling development patterns have encouraged local policymakers and nongovernmental activists to turn to urban and suburban open space conservation as potential countermeasures (Irwin, Bell, and Geoghegan 2003).

One type countermeasure is a "smart growth" policy, which refers to development initiatives that protect open space and farmland, revitalize communities, keep housing affordable, and provide alternative transportation choices (International City/County Management Association 2007).[1] Compact development, a key component of most smart growth policies, has the objective of conserving open space by targeting preservation of farmland and other critical environmental areas (Environmental Protection Agency 2007). Local governments have incorporated smart growth principles to preserve open space.

Smart growth initiatives have involved various instruments to preserve open space, including zonal territorial policies (e.g., zoning and growth boundary) and acquisition policies (e.g., conservation easements, purchase of and transfer of development rights, government purchases of land for parks, and similar initiatives). Some communities in the South, including the Knoxville MSA, that have committed to preserve open space continue to struggle with policy implementation (Cho and Roberts 2007).

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[1] The International City/County Management Association (2007) has laid out 100 policies and guidelines for communities to realize smart growth. The mechanisms include zoning, building design, transfer of development rights, purchase of development rights, multimodal transportation systems, and the land value tax. We addressed only the land value tax in this study.

Policy implementation in the South is particularly challenging because many of the policy instruments are often viewed as an infringement on the property rights that are sacrosanct to many. Thus, there is a need for alternative instruments, other than zonal and acquisition types of policies, to promote open space preservation.

Land value taxation is a potential policy tool. First proposed by the American social economist Henry George in the nineteenth century, land value taxation is an ad valorem tax where only the value of land itself is taxed (George 1896; Post 1915). The base of a land value tax is the "highest and best use" of the land in a parcel. Taxing land at a higher rate than buildings on a parcel or structural improvements to buildings is a potential policy tool to promote compact development because (1) this taxing promotes greater economic incentive to develop land where land values are higher—such as around existing infrastructure and amenities, (2) development becomes more profitable due to the reduction in the tax rate on building values, and (3) this taxing discourages development in areas distant from infrastructure where land values and taxes are low (e.g., Brueckner 1986; Brueckner and Kim 2003; Case and Grant 1991; Mills 1998; Nechyba 1998; Oates and Schwab 1997; Skaburskis 1995). Such taxing schemes have been referred to as a two-rate or a split-rate property tax.[2] Hereafter, this taxation scheme is referred to as the two-rate property tax (TPT).

Most residential real estate property taxes in the United States are collected as a percentage of total assessed property values, which are usually a taxable portion of the appraised value of land and the structures on them.[3] Because the total assessed value of a property is the sum of the assessed worth of land and structures, land and structure values are weighted equally, producing a single property tax rate. Taxation of buildings, structures, or land improvements allegedly discourages site improvement by reducing the economic return from such improvements (Mathis and Zech 1982). The taxation of buildings, structures, or land improvements raises the perceived cost of improvements. Thus, the land owner can reduce the tax burden by designing development projects that use relatively more land than improvements. This reaction leads to lower than optimal densities and forces the city to spread more than it would under an "ideal" tax weighting system between land and improvements (Skaburskis and Tomalty 1999).

Some researchers have investigated the effects of a TPT on housing. Brueckner (1986) analyzed the long-run impacts of a TPT on the level of improvements, the value of land, and the housing price. Turnbull (1988) and Anderson (1986) showed that land improvement and different types of property taxes affect the speed and capital intensity of development. Oates and Schwab (1997) explored the impact of TPT reform on economic development in Pittsburgh. Despite the potential advantages of the TPT in promoting compact development, only a handful of U.S. municipalities have implemented such tax schemes. Among those are Pittsburgh and a score of towns in Pennsylvania. Pittsburgh's experience with the TPT is inconclusive, but some small towns experienced increased construction in their centers after implementation (Bourassa 1990; Oates and Schwab 1997).

This research evaluates the TPT as a potential smart growth policy to induce open space preservation. Spatial forecasts of how a TPT affects the equilibrium amounts of open space enjoyed by homeowners in neighborhoods are generated. Equilibrium levels of open space are observed around house sales transactions. This assumes sales transaction decisions, including areas of surrounding open space, represent market equilibrium conditions. Spatial econometric modeling and ex ante simulations measure deviations from equilibrium levels of open space in neighbor-

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[2] If the tax on building values is eliminated, the resulting property tax is referred to as a site-value or land-value tax.

[3] The rate is expressed in mills, where one mill is one-tenth of a cent ($0.001).

hoods following the introduction of a TPT. The spatial process model captures the interactions between agents across the housing market. Ex ante simulations generate forecasts to compare the status quo land policy to hypothetical TPT scenarios. Therefore, the simulations we use are an exercise in equilibrium displacement, measuring deviations from a status quo distribution of open space. While it is difficult to discern any supply or demand schedule from equilibrium displacement, income effects due to changes in the prevailing tax policy and displacement of open space from initial equilibrium levels are clearly related.

II. CONCEPTUAL BACKGROUND

Equilibrium displacement of open space levels following implementation of a TPT suggests (1) changes in willingness to pay for open space or (2) changes in supply and demand for new properties with different amounts of open space and other attributes. With increased willingness to pay for open space, individuals may be more inclined to support and participate in smart growth policies geared toward preserving open space. For example, some households may be more willing to pay into a fund designed to preserve open space by purchasing development rights. In this case, promoting compact development following implementation of a TPT will more likely succeed in areas where the marginal willingness to pay for open space is higher. Alternatively, changes in supply and demand of new properties are constrained by supply flexibility and occupier mobility, at least in the short term. Thus, in this study, we analyze the short-run impacts of a TPT on deviations from open space equilibrium levels implying changes in willingness to pay for open space.

Changes in the TPT tax burden on open space equilibrium levels occur through changes in net income after taxes. After-tax net income increases, remains unchanged, or decreases depending on the increase in the amount of tax paid on the value of land ($\Delta\tau_{\mathrm{L}}$) relative to the decrease in the amount of tax paid on the value of the structure ($\nabla\tau_{\mathrm{S}}$). If $\Delta\tau_{\mathrm{L}} > \nabla\tau_{\mathrm{S}}$, the tax burden increases and net income falls. If $\Delta\tau_{\mathrm{L}} < \nabla\tau_{\mathrm{S}}$, the tax burden decreases and net income increases. If $\Delta\tau_{\mathrm{L}} = \nabla\tau_{\mathrm{S}}$, the tax burden and net income remain unchanged. The effect on willingness to pay for open space decreases, remains unchanged, or increases if the tax burden increases, remains unchanged, or decreases, respectively. This premise is empirically tested using the ex ante simulations that measure deviations from open space equilibrium levels following the TPT.

III. EMPIRICAL MODEL

Extending the theoretical framework of the simultaneous relationship between open space and housing price (Irwin and Bockstael 2001; Geoghegan, Lynch, and Bucholz 2003; Walsh 2007), we hypothesize that open space equilibrium levels observed around house sales transactions and corresponding house prices are explained by the following system of equations:

$$\begin{pmatrix} y_i^{\mathrm{o}} \\ y_i^{\mathrm{p}} \end{pmatrix} = \begin{pmatrix} & \gamma_o^{\mathrm{p}} y_i^{\mathrm{p}} & +\boldsymbol{\delta}_o' \mathbf{X}_i^{\mathrm{o}} + \bar{\tau}\cdot(L_i + S_i)\delta_o^{\mathrm{t}} \\ \gamma_p^{\mathrm{o}} y_i^{\mathrm{o}} & & +\boldsymbol{\delta}_p' \mathbf{X}_i^{\mathrm{p}} + \bar{\tau}\cdot(L_i + S_i)\delta_p^{\mathrm{t}} \end{pmatrix}$$
$$= \begin{pmatrix} e_i^{\mathrm{o}} \\ e_i^{\mathrm{p}} \end{pmatrix}, \qquad [1]$$

where y_i^{o} is the natural log of the equilibrium amount of open space in the neighborhood of house i, y_i^{p} is the natural log of the equilibrium price of house i, e is a random disturbance term for house i with

$$E\begin{pmatrix} e_i^{\mathrm{o}} \\ e_i^{\mathrm{p}} \end{pmatrix} = \begin{pmatrix} 0 \\ 0 \end{pmatrix}, \text{ and } \operatorname{cov}(e_i^{\mathrm{o}}, e_i^{\mathrm{p}}) = \begin{bmatrix} \sigma_{oo} & \sigma_{op} \\ \sigma_{po} & \sigma_{pp} \end{bmatrix}.$$

Open space and housing price are hypothesized to be endogenous (Irwin and Bockstael 2001; Geoghegan, Lynch, and Bucholz 2003; Walsh 2007). Exogenous variables hypothesized to explain open space in the neighborhood of house i are contained in $\mathbf{X}^{\mathrm{o}}$, including structural attributes of the house, distance measures to amenities (i.e., lakes, parks) or disamenities (e.g., railroads). Spatial fixed effects in $\mathbf{X}^{\mathrm{o}}$ and $\mathbf{X}^{\mathrm{P}}$

include the average American College Testing (ACT) score for the school district where the house is located, and city and planning boundaries, that is, an urban growth boundary and a planned growth area (see Table 1 for the complete list). The variable $\bar{\tau}\cdot(L_i^{\mathrm{A}}+S_i^{\mathrm{A}})$ is the prevailing property tax rate on the assessed (A) value of land (L) and structures (S) ($\bar{\tau} = 2.69\%$ for Knox County, Tennessee) times the assessed value of land and structures at location i.[4] Exogenous instruments explaining the housing price are in $\mathbf{X}^{\mathrm{p}}$, including socioeconomic variables from census-block groups, for example, vacancy rate and unemployment rate. The census-block-group variables are unique instruments for the hedonic housing price equation. $\gamma_o^{\mathrm{p}}, \gamma_p^{\mathrm{o}}, \delta_o^{\mathrm{t}}, \delta_p^{\mathrm{t}}$ are scalar parameters, and $\boldsymbol{\delta}_o, \boldsymbol{\delta}_p$ are conformable parameter vectors.

Given consistent estimates of the parameters in the system of equations ($\boldsymbol{\delta}_o, \boldsymbol{\delta}_p$) and an unbiased and efficient procedure to forecast the amount of open space in the neighborhood and housing price, $\bar{\tau}$ can be varied to test ex ante hypotheses about how neighborhood open space equilibrium levels change following new tax policies. The objective is to gain insight into where a TPT will be most successful in increasing the amount of open space in neighborhoods, given a spatially heterogeneous housing market.

Defining Open Space Equilibrium

Assuming the distribution of housing transactions represents the market equilibrium, the amount of open space in the household's immediate neighborhood is also at equilibrium. To define the amount of open space in the immediate neighborhood for individual households, open space was aggregated in different size buffers for each housing sales transaction. There are no clear guidelines in the literature regarding optimal buffer sizes identifying open space area in neighborhoods (e.g., McConnell and Walls 2005). For example, Geoghegan, Lynch, and Bucholz (2003) used two buffers: a 100-m radius around the property and a 1,600-m radius. Acharya and Bennett (2001) also used a 1,600-m buffer. Nelson et al. (2004) used 0.1-mi, 0.25-mi, and 1.0-mi buffers, and Irwin (2002) used a 400-m buffer. Lichtenberg, Tra, and Hardie (2007) used buffers of 0.5, 1, and 2 mi. Because results may be sensitive to buffer size change, 0.2-, 0.5-, 1-, 2-, and 5-mi radius buffers were used in this study in a sensitivity analysis.

There are three classifications of open space in the study area: (1) developed open space, (2) forest open space, and (3) agricultural open space. Aggregating across these widely divergent types of open space to arrive at a single metric introduces generic inconsistency. Forest open space is used in this study. Agricultural land and developed open space were not used because the study area contains very little agricultural land, and developed open space tracts represent a wide variety of environments, including large-lot single-family housing units, parks, and golf courses. The major open space category in the area is forest land. In addition, the city of Knoxville has been promoting sustainable forest management as green space conservation, for example, the Knoxville–Knox County Comprehensive Park, Recreation, and Greenways Plan (MPC 2008). Forest areas in multiple buffer sizes were estimated as the cumulative areas of the pixels defined as "forest area" inside the buffers, given the land use definitions from the National Land Cover Database (NLCD). The NLCD classifies 30-m by 30-m pixels into 21 mutually exclusive land use categories. "Forest area" was defined by classifying each pixel into one of three categories: deciduous forest, evergreen forest, and mixed forest.

Determining Hypothetical Tax Rates Based on the TPT

Tax rates on assessed land values were determined using a simple optimization

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[4] In Knoxville, appraisers analyze all real estate sales and develop common units of comparison and corresponding values for structures and land jointly. They review similarities and differences among the properties to arrive at a uniform assessed value for the structures and land of a particular property.

procedure to simulate the effects of a hypothetical TPT on equilibrium amounts of open space. The key constraint in the optimization procedure ensured that the sum of the tax revenues collected from all house locations following a change in the hypothetical scenarios was equal to the sum of the existing (i.e., status quo) property tax revenue. The purpose of the constraint was to determine a hypothetical TPT scenario that was tax revenue neutral compared to the existing property tax scheme.

Let $R_i = \bar{\tau}_L L_i^A + \bar{\tau}_S S_i^A$, where R is the municipal government's revenue from property taxes on the assessed (A) value of land (L) and structures (S) at house i, and $\bar{\tau}$ is the existing property tax rate (percent). This equation depicts the existing property tax scheme (i.e., the baseline case) in which the tax rates on the assessed values of land and structures are identical (i.e., $\bar{\tau} = \bar{\tau}_L = \bar{\tau}_S = 2.69\%$ for Knox County). The annual aggregate tax revenue for the county from assessed land and associated structures is $R^* = \sum_{i=1}^{N} R_i$. Suppose a hypothetical TPT scenario placed more emphasis on the assessed value of land by decreasing the tax rate on structures by α percent. The revenue collected at property i is then $\tilde{R}_i = \bar{\tau}_L L_i^A + \alpha \bar{\tau}_S S_i^A$, where $\alpha \in [0,1]$, with lower levels of α reflecting greater emphasis on taxing the assessed value of land relative to structures. When α decreases and $\bar{\tau}_S$ remains at the existing tax rate (2.69%), $\bar{\tau}_L$ must increase for the TPT scenario to be revenue neutral.

Consider the following optimization problem that constrains the aggregate of the tax revenue under the hypothetical TPT scenario to be identical to the existing property tax (EPT) scheme:

$$\max_{\tau_L \in [0,1] | \alpha = \alpha^*} Z = 0, \text{ subject to}$$

$$\underbrace{\sum_{i=1}^{N} [\tau_L L_i^A + \alpha \bar{\tau} S_i^A]}_{\text{hypothetical TPT}} = \underbrace{\bar{\tau} \sum_{i=1}^{N} [L_i^A + S_i^A]}_{\text{EPT}}, \qquad [2]$$

where $\bar{\tau} = 2.69\%$ in the EPT scheme. For each level of α we choose, the optimization problem finds a new level of τ_L that satisfies the tax revenue neutrality constraint. The optimization problem is conditional on the selected values of α^*. The justification for requiring tax revenue neutrality is that it may not be practical or politically feasible to raise or lower total tax revenue.

We simulate the hypothetical TPT scenario using four levels of $\alpha^* \in [0.25, 0.50, 0.75, 0.95]$. Given equation [2], these levels of α^* generated assessed tax rates on land value of $\tau_L \in [3.32\%, 5.86\%, 9.04\%, 12.21\%]$. To simulate the effect of a particular TPT scenario, we rescaled tax revenue at the ith location by the new tax rates on land ($\tau_L L_i^A$) and structures ($\alpha^* \bar{\tau} S_i^A$). Given consistent parameter estimates of the open space equation, we forecast deviations from the equilibrium open space levels by replacing the observed tax rate at location i with the simulated values, holding other location factors constant.

General Moment Estimation of the SARAR(1,1)

Most studies use a spatial process model going back to that of Whittle (1954), in which an endogenous variable is specified to depend on spatial interactions between cross-sectional units plus a disturbance term. The interactions are modeled as a weighted average of nearby cross-sectional units, and the endogenous variable comprising the interactions is usually referred to as a spatially lagged variable. The weights, grouped in a matrix identifying neighborhood connections, form the distinctive core of spatial process models. The model is termed a spatial autoregressive lag model (Anselin and Florax 1995). Whittle's first-order spatial autoregressive lag model (SAR[1]) was popularized and extended by Cliff and Ord (1973, 1981), who distinguished models in which the disturbances followed a spatial autoregressive process.

The general model contains a spatially lagged endogenous variable, as well as spatially autoregressive disturbances in addition to exogenous variables, and is called a spatial autoregressive model with autoregressive (AR) disturbance of order

TABLE 1
VARIABLE NAMES, DEFINITIONS, AND DESCRIPTIVE STATISTICS

Variable	Unit	Definition	Mean	Std. Dev.
Dependent variables				
Housing price	\$	Housing sale price	131,866.80	97,522.70
Open space	ft^2	Area of forest land within a buffer of 0.2 mi drawn around each house sale transaction	423,932.00	523,717.00
Structural variables				
Finished area	ft^2	Total finished square footage of house	1,945.87	946.59
Lot size	ft^2	Total parcel square footage	24,900.77	43,354.21
Age	year	Year house was built subtracted from 2001	27.60	21.93
Brick		Dummy variable for brick siding (1 if brick, 0 otherwise)	0.26	0.44
Pool		Dummy variable for swimming pool (1 if pool, 0 otherwise)	0.05	0.21
Garage		Dummy variable for garage (1 if garage, 0 otherwise)	0.65	0.48
Bedroom		Number of bedrooms in house	3.06	0.63
Stories		Height of house in number of stories	1.35	0.48
Fireplace		Number of fireplaces in house	0.72	0.56
Quality of construction		Dummy variable for quality of construction (1 if excellent, very good, or good, 0 if average, fair, or poor, as rated by the tax assessors' office)	0.36	0.48
Condition of structure		Dummy variable for condition of structure (1 if excellent, very good, or good, 0 if average, fair or poor, as rated by tax assessors' office)	0.75	0.43
Census-block-group variables				
Vacancy rate	ratio	Vacancy rate for census-block group in 2000 (ratio of vacant housing units to total housing units of any type)	0.06	0.03
Unemployment rate	ratio	Unemployment rate for census-block group in 2000 (ratio of unemployed to the labor force, age 16 or older)	0.04	0.03
Travel time to work	minutes	Average travel time to work for census-block group in 2000	22.56	3.32
Housing density	houses/acre	Housing density for census-block group	1.10	1.03
Distance variables				
Distance to CBD	ft	Distance to the central business district	45,130.90	20,651.22
Distance to greenway	ft	Distance to nearest greenway (a mostly contiguous vegetated pathway developed for recreation, pedestrian, and bicycle uses)	7,977.45	5,516.14
Distance to railroad	ft	Distance to nearest railroad track	7,014.59	5,541.91
Distance to sidewalk	ft	Distance to nearest sidewalk	3,127.94	4,291.76

table continued on following page

TABLE 1
(Continued)

Variable	Unit	Definition	Mean	Std. Dev.
Distance to park	ft	Distance to nearest park among 42 municipal parks	8,726.11	5,640.44
Park size	$10^3 \times ft^2$	Size of nearest park	1,451.58	4,152.37
Distance to golf course	ft	Distance to nearest golf course	10,717.38	4,906.00
Distance to water body	ft	Distance to nearest stream, lake, river, or other water body	8,493.86	5,837.99
Size of water body	$10^3 \times ft^2$	Size of nearest water body	18,600.00	37,900.00
Spatial fixed-effect variables				
Knoxville		Dummy variable for city of Knoxville (1 if Knoxville, 0 otherwise)	0.34	0.47
Flood		Dummy variable for 500-year floodplain (1 if stream protection area, 0 otherwise)	0.01	0.10
Interface		Dummy variable for rural-urban interface (1 if census-block group of mixed rural-urban housing, 0 otherwise)	0.23	0.42
Urban growth area		Dummy variable for urban growth boundary (1 if urban growth area, 0 otherwise)	0.08	0.27
Planned growth area		Dummy variable for planned growth area (1 if planned growth area, 0 otherwise)	0.43	0.50
ACT score		Average composite score of American College Test by high school district	20.69	1.40
Real estate market/tax variable				
Season		Dummy variable for season of sale (1 if April through September, 0 otherwise)	0.55	0.50
Property tax	$	Amount of tax paid on the assessed value of land and structures	789.11	627.86

(1,1) (SARAR) (Anselin 1988; Kelejian and Prucha 2006); $\mathbf{y} = \rho\mathbf{W}_1\mathbf{y} + \mathbf{X}\boldsymbol{\beta} + \mathbf{e}$, $\mathbf{e} = \lambda\mathbf{W}_2\mathbf{e} + \mathbf{u}$, $\mathbf{u} \sim \text{iid}(\mathbf{0}, \boldsymbol{\Omega})$, where $\mathbf{W}_1$ and $\mathbf{W}_2$ are (possibly identical) nonstochastic, positive definite, exogenous matrices defining interrelationships between spatial units, and $E[\mathbf{uu}'] = \boldsymbol{\Omega}$. The reduced-form version is $\mathbf{y} = \mathbf{A}^{-1}\mathbf{X}\boldsymbol{\beta} + \mathbf{A}^{-1}\mathbf{B}^{-1}\mathbf{u}$; $\mathbf{A} = (\mathbf{I} - \rho\mathbf{W}_1)$, $\mathbf{B} = (\mathbf{I} - \lambda\mathbf{W}_2)$, where ρ is the spatial lag regressive term and λ is the spatial error autoregressive term. Spatial process models can be estimated using maximum likelihood, but researchers more frequently use generalized method of moments or instrumental variable procedures because these approaches relax the usual assumptions required by maximum likelihood. The approach taken here extends Kelejian and Prucha's (2004) system estimator to an estimator robust to unspecified forms of heteroskedasticity recently suggested by Arraiz et al. (2008).[5]

Forecasting Open Space and Housing Price

This research applies Kelejian and Prucha's (2007) procedure for generating forecasts from the SARAR(1,1) equation system to facilitate comparisons between the observed property tax scheme (the baseline) and counterfactual TPT scenarios. The

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[5] We thank Dr. R. J. G. M. Florax for providing the ARAR(1,1) code in R.

estimator is efficient because it incorporates information about the correlation between the spatially lagged dependent variable and the error term. Kelejian and Prucha demonstrated why two "intuitive predictors" (estimates are denoted by the symbol ^) are suboptimal.

$$\hat{\mathbf{y}} = \hat{\mathbf{A}}^{-1}\mathbf{X}\hat{\boldsymbol{\beta}} \text{ (e.g., the reduced-form equation)} \tag{3}$$

and

$$\hat{\mathbf{y}} = \hat{\rho}\mathbf{W}\mathbf{y} + \mathbf{X}\hat{\boldsymbol{\beta}} \text{ (e.g., the structural equation).} \tag{4}$$

These candidate estimators are generally inefficient because they ignore information about lag and error correlation between cross-sectional units.

To motivate the spatial predictor used here, consider the reduced-form single-equation SARAR(1,1) model, $\mathbf{y} = \mathbf{A}^{-1}\mathbf{X}\boldsymbol{\beta} + \mathbf{B}^{-1}\mathbf{A}^{-1}\mathbf{u}$. The following assumptions are applied: $\mathbf{u} \sim (0, \sigma_\varepsilon^2 = n^{-1}\mathbf{e}'\mathbf{e}\boldsymbol{\Psi}^u), \mathbf{y} \sim (\mu_y, \sigma_e^2\boldsymbol{\Psi}^y)$, with $\mu_y = \mathbf{A}^{-1}\mathbf{X}\boldsymbol{\beta}$; $\boldsymbol{\Psi}^u = \mathbf{B}^{-1}\mathbf{B}^{-1}$; and $\boldsymbol{\Psi}^y = \mathbf{A}^{-1}\boldsymbol{\Psi}^u\mathbf{A}^{-1}$ (Kelejian and Prucha 2007). Rewrite the usual SARAR(1,1) model for location i: $y_i = \rho w_{i.}\mathbf{y} + \boldsymbol{\beta}'\mathbf{x}_i + u_i$, and $u_i = \lambda w_{i.}u_i + e_i$, where "$i.$" is the ith row of the respective matrices. An efficient predictor applied in this research is[6]

$$\hat{y}_i = \hat{\rho} w_{i.}\mathbf{y} + \hat{\boldsymbol{\beta}}'\mathbf{x}_i + \text{var}(w_{i.}\mathbf{y})^{-1}\text{cov}(e_i, w_{i.}\mathbf{y})w_{i.}[\mathbf{y} - \hat{\mathbf{A}}^{-1}\mathbf{X}\hat{\boldsymbol{\beta}}], \text{ with} \tag{5a}$$

$$\text{cov}(e_i, w_{i.}\mathbf{y}) = \hat{\sigma}_\varepsilon^2 \hat{\sigma}_{i.}^u \hat{\mathbf{A}}^{-1} w_{i.}', \left(\hat{\sigma}_{i.}^u \text{ is the } i\text{th row of } \hat{\boldsymbol{\Psi}}^u, \hat{\sigma}_\varepsilon^2 = n^{-1}\hat{\mathbf{e}}'\hat{\mathbf{e}}\right), \text{ and} \tag{5b}$$

$$\text{var}(w_{i.}\mathbf{y}) = \hat{\sigma}_\varepsilon^2 w_{i.}\hat{\mathbf{A}}^{-1}\hat{\boldsymbol{\Psi}}^y\hat{\mathbf{A}}^{-1}w_{i.}'. \tag{5c}$$

Therefore, in addition to the structural part of the model in [5a], the second term provides information about the covariance between location i and its j neighbors.

This single-equation predictor is extended to the hedonic system. In doing so, the endogeneity associated with open space and housing price, as well as the endogeneity arising from neighborhood dependence, is jointly determined. The resulting reduced-form set of equations ensures that policy shocks are exogenous. The following steps modify the single-equation predictor to accommodate the simultaneous nature of the system. Given consistent estimates of the SARAR(1,1), housing price (HP), and open space (OS) equations, we have

$$\mathbf{y}_n^{\text{OS}} = \hat{\rho}^{\text{OS}}\mathbf{W}_n\mathbf{y}_n^{\text{OS}} + \hat{\gamma}^{\text{OS}}\mathbf{y}_n^{\text{HP}} + \mathbf{X}_n^{\text{OS}}\hat{\boldsymbol{\beta}}^{\text{OS}}, \text{ and} \tag{6a}$$

$$\mathbf{y}_n^{\text{HP}} = \hat{\rho}^{\text{HP}}\mathbf{W}_n\mathbf{y}_n^{\text{HP}} + \hat{\gamma}^{\text{HP}}\mathbf{y}_n^{\text{OS}} + \mathbf{X}_n^{\text{HP}}\hat{\boldsymbol{\beta}}^{\text{HP}}, \tag{6b}$$

where n denotes sample size. Moving the endogenous variables to the left-hand side, including the endogenous spatially lagged dependent variables,

$$\hat{\mathbf{A}}_n^{\text{OS}}\mathbf{y}_n^{\text{OS}} - diag_n(\hat{\gamma}^{\text{OS}})\mathbf{y}_n^{\text{HP}} = \mathbf{X}_n^{\text{OS}}\hat{\boldsymbol{\beta}}^{\text{OS}}, \quad \hat{\mathbf{A}}_n^{\text{OS}} = (\mathbf{I}_n - \hat{\rho}^{\text{OS}}\mathbf{W}_n), \text{ and} \tag{7a}$$

$$\hat{\mathbf{A}}_n^{\text{HP}}\mathbf{y}_n^{\text{HP}} - diag_n(\hat{\gamma}^{\text{HP}})\mathbf{y}_n^{\text{OS}} = \mathbf{X}_n^{\text{HP}}\hat{\boldsymbol{\beta}}^{\text{HP}}, \quad \hat{\mathbf{A}}_n^{\text{HP}} = (\mathbf{I}_n - \hat{\rho}^{\text{HP}}\mathbf{W}_n). \tag{7b}$$

Applying some matrix algebra yields the following reduced-form system:

$$\begin{pmatrix} \hat{\mathbf{y}}_n^{\text{OS}} \\ \hat{\mathbf{y}}_n^{\text{HP}} \end{pmatrix} = \begin{pmatrix} \hat{\mathbf{A}}_n^{\text{OS}} & -diag_n(\hat{\gamma}^{\text{OS}}) \\ -diag_n(\hat{\gamma}^{\text{HP}}) & \hat{\mathbf{A}}_n^{\text{HP}} \end{pmatrix}^{-1} \times \begin{pmatrix} \mathbf{X}_n^{\text{OS}} & {}_{k_{\text{HP}}}0_n \\ {}_{k_{\text{OS}}}0_n & \mathbf{X}_n^{\text{HP}} \end{pmatrix} \begin{pmatrix} \hat{\boldsymbol{\beta}}^{\text{OS}} \\ \hat{\boldsymbol{\beta}}^{\text{HP}} \end{pmatrix}, \tag{8a}$$

where subscripts indicate conformable matrices. In compact notation, [8a] is rewritten as

$$\hat{\mathbf{Y}}_{\text{R}} = \hat{\mathbf{G}}^{-1}\mathbf{X}\hat{\boldsymbol{\beta}}, \tag{8b}$$

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[6] Out of the five estimators studied by Kelejian and Prucha, the estimator applied here ranked second in terms of mean squared error performance. The "preferred" estimator is more efficient than the estimator applied in this study only when lag and error dependencies are simultaneously "large," for example, both around |0.9|. However, as the error autoregressive term approaches zero and the lag autoregressive term approaches |1.0|, the mean squared error of the estimator applied here and the preferred estimator are similar. In this study, the preferred estimator was not applied because of the computational time needed to construct this estimator, and the simultaneity of the system. See Kelejian and Prucha (2007) for details.

with the subscript R denoting the reduced-form equation. Equation [8b] is the analogue of the single-equation SAR reduced-form model, including additional endogenous regressors (equation [3]).

In terms of the hedonic system, the structural equation component of [5a] must take into consideration the endogeneity of housing price in the open space equation, and vice versa. Moving the endogenous housing price and open space variable to the left-hand side, rearranging terms, and then using matrix algebra,

$$\begin{pmatrix} \hat{\mathbf{y}}_n^{\mathrm{OS}} \\ \hat{\mathbf{y}}_n^{\mathrm{HP}} \end{pmatrix} = \begin{pmatrix} \mathbf{I}_n & -diag_n(\hat{\gamma}^{\mathrm{OS}}) \\ -diag_n(\hat{\gamma}^{\mathrm{HP}}) & \mathbf{I}_n \end{pmatrix}^{-1} \times \begin{pmatrix} \mathbf{W}\mathbf{y}^{\mathrm{OS}} & \mathbf{X}_n^{\mathrm{OS}} & {}_1 0_n & {}_{k_{\mathrm{OS}}} 0_n \\ {}_1 0_n & {}_{k_{\mathrm{HP}}} 0_n & \mathbf{W}\mathbf{y}^{\mathrm{HP}} & \mathbf{X}_n^{\mathrm{HP}} \end{pmatrix} \begin{pmatrix} \hat{\rho}^{\mathrm{OS}} \\ \hat{\boldsymbol{\beta}}^{\mathrm{OS}} \\ \hat{\rho}^{\mathrm{HP}} \\ \hat{\boldsymbol{\beta}}^{\mathrm{HP}} \end{pmatrix}. \quad [9a]$$

Equation [9a] is the analogue of equation [4]. With [8b] and [9a] in hand, the forecast estimator is constructed for each equation following [5a]. The forecasting equations facilitate ex ante comparisons between predicted values generated under the observed status quo property tax scheme and the hypothetical two-rate property tax scenarios.

Neighborhood Identification

Thiessen polygons were used to identify neighborhood contiguity. This effectively turns the spatial representation of the sample from points into polygons, which are related to notions of spatial market areas (Anselin 1988). The elements of the contiguity matrix were interacted with an n by n matrix containing a continuous (exponential) decay function in each position. The resulting matrix therefore discounts the influence of sales transactions between more distant neighbors. The elements of the combined matrix were $\tilde{w}_{ij} = (w_{ij} > 0)\exp(-d_{ij})$, where d_{ij} = Euclidean distance between locations i and j, and $w_{ij} = 1$ if i and j were neighbors. The final matrix was row standardized. The average number of neighbors was 5.7, and the minimum and maximum eigenvalues (e) of the combined weighting matrix were -0.62 and 1, respectively. These values set the bounds for the AR lag and error parameters as $[e_{\min}^{-1}, e_{\max}^{-1}] = [-1.61, 1]$ (Anselin 1988).

IV. STUDY AREAS AND DATA

Housing sales transactions from Knox County, Tennessee, were the basic unit of observation. The Knox MSA consists of rapid and slow housing growth regions. Recently, low-density sprawl in western Knox County has been driven by newer houses on smaller lots for residents including commuters to Oak Ridge National Laboratory, high-tech firms associated with the laboratory, the University of Tennessee, and the central business district (Cho and Roberts 2007). Specifically, typical single-family houses in the town of Farragut in western Knox County are newer (by 9 years), in lower-density areas (by 0.6 houses per acre), and on smaller lots (by 2,409 ft^2) relative to the rest of Knox County.[7]

Five GIS data sets were used: individual parcel data, satellite imagery data, census-block group data, boundary data, and environmental feature data. Individual parcel data (sales price, lot size, and structural information) and boundary data (high school district and jurisdiction boundaries) were obtained from county offices. The individual parcel data were from the Knoxville, Knox County, Knoxville Utilities Board Geographic Information System (KGIS 2007) and the Knox County Tax Assessor's Office. The boundary data are from the Knoxville–Knox County Metropolitan Planning Commission (MPC 2006).

Data are for single-family house sales during 2001 in Knox County. There were 3,466 observations after eliminating those with missing information. Land cover information is from Landsat 7 imagery for 2001. The classified National Land Cover

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[7] The numbers were calculated using parcel data that were updated in 2005 (KGIS 2007).

Database (NLCD) from the multiresolution land characteristics consortium (NLCD 2001) included the GIS map used in the analysis to identify forest open space in the study area. Forest open space area was determined by classifying NLCD pixels into three categories dominated by trees generally greater than 5 m tall, and greater than 20% of total vegetation cover. The categories included "deciduous forest" (more than 75% of the tree species shed foliage simultaneously in response to seasonal change), "evergreen forest" (more than 75% of the tree species maintain their leaves all year), and "mixed forest" (neither deciduous nor evergreen species are greater than 75% of total tree cover.).

Environmental feature data, including water bodies and golf courses, are from the Environmental Systems Research Institute Data and Maps 2004 (ESRI 2004). Information from census-block groups, for example, housing density, unemployment rate, and vacancy rate, were assigned to houses located within the boundaries of the block groups. Based on Public Chapter 1101, lands outside the city of Knoxville and the town of Farragut were classified as the urban growth area (UGA), planned growth area (PGA), and rural area (MPC 2006) (Figure 1).[8] Shape files identifying the UGA and PGA were obtained from the MPC (2006).

V. RESULTS

Regression Results

Regression results using multiple-sized buffers suggest that the property tax is statistically significant at the 5% level for forest open space within 0.2-mi radius buffers. However, the property tax variable was not associated with forest open space when the system was estimated with the 0.5-, 1-, 2-, and 5-mi radius open space buffers. This finding suggests that changes in property tax schemes have significant effects on the amount of forest open space decision only in immediate neighborhoods. For estimating and predicting open space levels following implementation of a TPT, regression results for the housing price and open space equation using a 0.2-mi radius buffer are presented in Table 2. The adjusted R^2 values for the housing price and open space equations are 0.75 and 0.59, respectively. The spatial lag (ρ) and error autocorrelation (λ) parameters were significant in both equations. A Breusch-Pagan (1979) Lagrange multiplier (LM) value for cross-equation residual correlation was too small to reject at the 5% level (LM = 2.85, $df = 1$). Therefore, the open space and housing price equations were estimated separately.

Despite the theoretical background and literature about the potential endogeneity between open space and housing price, open space was not significant in the housing price equation, and housing price was not significant in the open space equation. The result is in contrast to other findings, for example, those of Irwin and Bockstael (2001) and Cho, Poudyal, and Roberts (2008). A two-stage least-squares model assuming homoskedasticity and no autoregressive dependence using the same model specification produced a significant open space coefficient in the housing price equation at the 10% level and a significant housing price coefficient in the open space equation at the 1% level.[9] Apparently, concomitantly modeling heteroskedasticity and spatial error and lag processes seems to make a difference in this particular case.

All statistically significant coefficients of the structural variables in the housing price equation are consistent with expectations. Newer houses and houses with larger finished areas, larger lots, more fireplaces, brick siding, pools, garages, better con-

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[8] The rural areas include land conserved (or set aside) for farming, recreation, and other nonurban uses. The UGA is reasonably compact but adequate to accommodate the entire city's expected growth for the next 20 years, and the PGAs are large enough to accommodate urban growth expected to occur in unincorporated areas over the next 20 years (MPC 2006).

[9] These estimates are available by request.

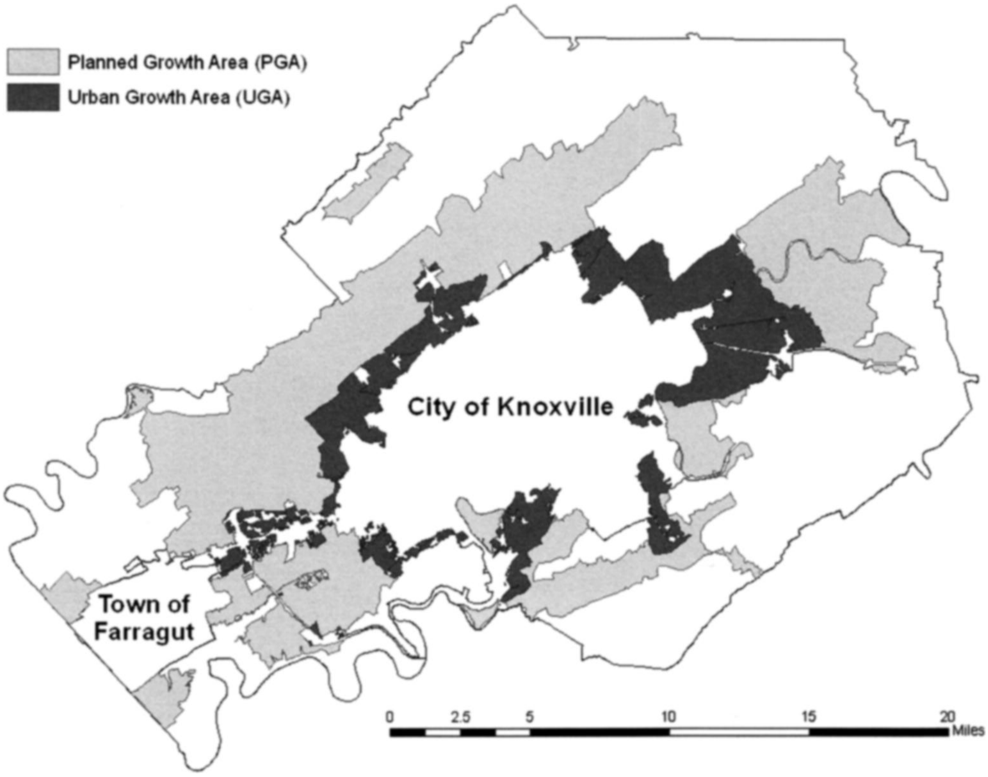

FIGURE 1
Knoxville, Farragut, Urban Growth Area (UGA), and Planned Growth Area (PGA)

struction quality, and better structural conditions are valued higher. Only one of the four census-block group variables is statistically significant at the 1% level. Neighborhoods with lower housing densities tend to have relatively more expensive houses. The negative relationship between housing density and housing price corroborates previous findings of stronger preferences for lower density housing by high-income households (Skaburskis 2000; Gordon and Richardson 1998; Cho and Roberts 2007).

Significant coefficients of the distance variables in the housing price equation show that closeness to the central business district, greenways, and water bodies is valued. The size of the nearest park is also positively associated with housing price. The effect of property taxes on housing price is positive and significant at the 1% level, but the effect is negative and significant at the 5% level in the open space equation. The positive association found between housing price and property tax was anticipated, because property taxes are higher for properties with higher assessed value.

In the open space equation, 8 of the 11 structural variables were significant at the 5% level (lot size, age, brick, pool, garage, fireplace, quality of construction, and condition of structure). Persons living in newer houses, houses with larger lots, more fireplaces, a garage, no brick siding, no pool, lower quality of construction, and lower condition of structure have more open space. Households located near larger water bodies

TABLE 2
ESTIMATES OF THE GMM-SARAR(1,1) SPATIAL PROCESS MODEL

	Housing Price	Open Space
Variable	Coefficient (St. Err.)	Coefficient (St. Err.)
Intercept	4.505 (0.356)***	−0.488 (11.572)
ln (Housing price)		0.433 (1.416)
ln (Open space)	−0.002 (0.001)	
Structural variables		
ln (Finished area)	0.499 (0.027)***	−0.103 (0.998)
ln (Lot size)	0.036 (0.012)***	0.637 (0.203)***
Age	−0.004 (0.000)***	−0.024 (0.000)**
Brick	0.055 (0.013)**	−0.771 (0.348)**
Pool	0.073 (0.027)***	−0.198 (0.617)***
Garage	0.069 (0.011)***	0.022 (0.327)***
Bedroom	0.007 (0.011)	−0.125 (0.272)
Stories	0.071 (0.014)	0.194 (0.374)
Fireplace	0.020 (0.010)**	0.044 (0.280)***
Quality of construction	0.122 (0.012)***	−0.107 (0.418)***
Condition of structure	0.100 (0.013)***	−0.107 (0.399)***
Census-block-group variables		
Vacancy rate	−0.268 (0.170)	
Unemployment rate	−0.327 (0.201)	
Travel time to work	−0.001 (0.002)	
Housing density	−0.014 (0.009)***	
Distance Variables		
ln (Dist. to CBD)	−0.054 (0.023)**	−0.302 (0.440)
ln (Dist. to greenway)	−0.020 (0.006)***	−0.108 (0.187)
ln (Dist. to railroad)	−0.003 (0.005)	0.053 (0.150)
ln (Dist. to sidewalk)	−0.002 (0.006)	0.086 (0.131)
ln (Dist. to park)	−0.004 (0.007)	0.022 (0.196)
ln (Park size)	0.017 (0.006)***	0.062 (0.120)
ln (Dist. to golf course)	0.002 (0.014)	−0.015 (0.294)
ln (Dist. to water body)	−0.016 (0.009)*	−0.107 (0.165)
ln (Size of water body)	−0.001 (0.002)	0.021 (0.050)***
Spatial fixed-effect variables		
Knoxville	0.045 (0.026)*	−0.122 (0.544)**
Flood	−0.025 (0.037)	0.603 (1.017)
Interface	−0.004 (0.019)	0.446 (0.347)***
Urban growth area	0.023 (0.026)	0.156 (0.549)
Planned growth area	0.038 (0.020)*	−0.228 (0.385)
ACT score	0.000 (0.007)	−0.147 (0.161)
Real estate market/tax variables		
Season	0.042 (0.010)***	−0.050 (0.270)
Property tax	0.050 (0.010)***	−0.431 (0.001)**
ρ	0.281 (0.027)***	0.991 (0.028)***
λ	−0.100 (0.049)*	−0.152 (0.069)**
Adj. R^2	0.746	0.591

*, **, *** Statistical significance at the 10%, 5%, and 1% levels.

have more open space, suggesting that water bodies may complement open space.

The negative and positive effects for households in the city boundary of Knoxville and in the rural-urban interface, respectively, suggest that relatively more open space is available outside the city boundary in the rural-urban interface. An increase in property taxes is negatively associated with open space. The negative effect of property taxes on the open space level suggests that open space is a normal good; willingness to pay for open space decreases as disposable income decreases with higher property taxes.

Comparison of Housing Prices and Open Space under the EPT and the TPT Scenarios

Predicted baseline housing prices were moderately correlated across Knox County (Moran's $I = 0.35$, $P = 0.002$), as were the predicted open space levels (Moran's $I = 0.14$, $P = 0.002$) (Figure 2)[10]. The empirical distributions of the predicted baseline housing prices and open space levels were not statistically different from any of the four distributions simulated under the TPT scenarios (Kolomogorov-Smirnoff two-sample test, $P > 0.05$ for all comparisons). Of the 3,466 observations, the housing price increased from the equilibrium level for 1,117 houses (32%), and open space level increased from the equilibrium level for 2,644 households (76%) following a shift from an existing property tax to a land value tax rate of 9.04%. The remainder of housing prices decreased from the equilibrium level (68% of houses), and open space levels decreased from the equilibrium level (24% of households).

As expected, housing prices gradually increase as the weighted tax burden on land increased and the weighted tax burden on structures decreased. For example, the mean difference between the predicted baseline housing price and the housing price predicted under the TPT with a simulated land value tax rate of 9.04% (with $\alpha^* = 0.5$, or a 50% decrease from the weight placed on structures in the existing tax scheme) is \$445 (0.35% of the mean value of the predicted baseline housing price). Given a rate on land value of $\tau_{\mathrm{L}}^* = 9.04\%$, the mean difference between the predicted baseline open space level and the open space level forecasted following the policy shock is 4,400 ft^2 (0.89% of the mean value of predicted baseline open space level) (Table 3).

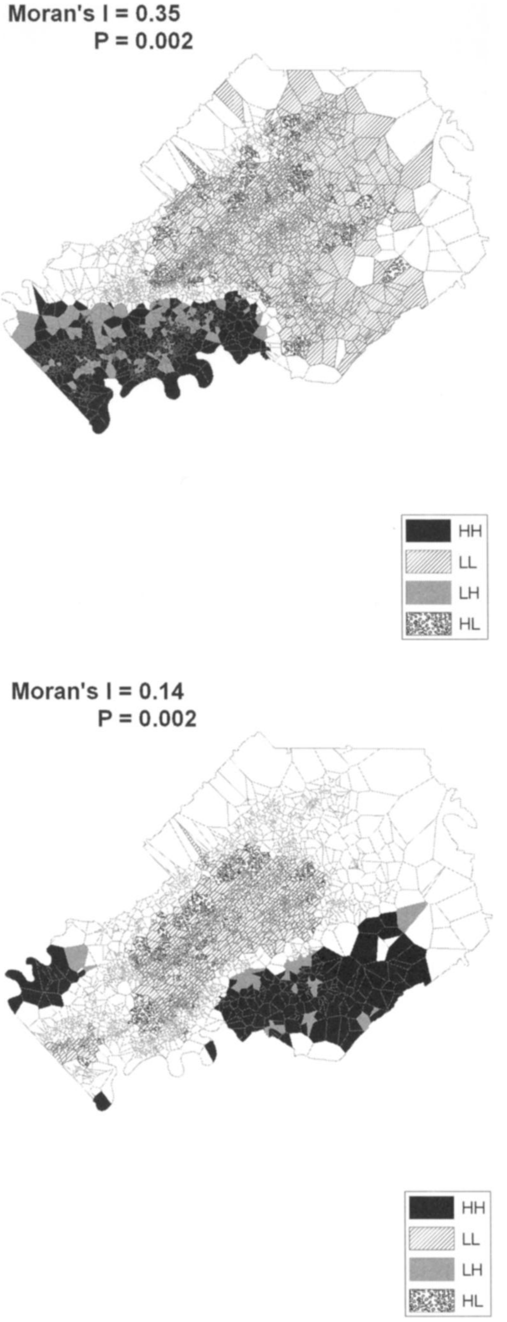

FIGURE 2
Local Indices of Spatial Association for Predicted Housing Price (upper) and Open Space Level (lower)

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[10] HH, locations with high values with similar neighbors; LL, locations with low values with similar neighbors; LH, locations with low values with high-value neighbors; HL, locations with high values with low-value neighbors.

TABLE 3

Difference between Base and Predicted Housing Price and Open Space under a Scenario with a 9.04% Assessed Land Value Tax Rate

	Housing Price ($)		Open Space (ft^2)	
Region	Mean Difference	Difference from Mean of Entire County	Mean Difference	Difference from Mean of Entire County
Entire county	444.8***	—	4,400.4	—
Farragut	830.2***	385.4*	24,515.9***	20,115.5**
Knoxville	186.0***	−258.8***	−10,385.9*	−14,786.3**
Urban growth area	417.1**	−27.8	8,766.5	4,366.0
Planned growth area	568.0***	123.2	−2,717.6	−7,118.0

*, **, *** Statistical significance at the 10%, 5%, and 1% levels, respectively, using a paired *t*-test.

Housing prices in the town of Farragut are projected to experience the highest increase in value, with an average increase of $830. The mean differences between base and predicted housing prices are $385 higher in Farragut and $259 lower in Knoxville than the mean difference observed over the entire county (Table 3). The differences are significant at the 10% level (paired *t*-test). The amount of open space in the town of Farragut is projected to experience the greatest increase of 24,516 ft^2. The mean of the difference between base and predicted open space levels is an addition 20,116 ft^2 in Farragut, and 14,786 ft^2 less in Knoxville than the mean difference for the entire county (Table 3). The differences are significant at the 5% level.

Housing prices and open space in the households' immediate neighborhood (0.2-mi buffer) increase or decrease following the implementation of a TPT, depending on a property's ratio of land-to-structure values. This ratio varies from house to house, and so does the impact of the TPT. While the distributions between the existing and two-rate tax rates of the entire county were not significantly different from each other ($P >$ 0.05, Kolmogorov-Smirnoff test), the tax burden for some individuals increased, but for others it decreased. The simple correlation analysis between the housing price impacts following the 9.04% tax rate scenario on land value and the ratio of assessed land value to total assessed value is $r = 88\%$, whereas the correlation between this ratio and changes in open space level is $r = -46\%$. These simple correlations suggest that, following the implementation of a TPT, households residing in areas with higher land-to-structure value ratios would have higher demand for housing. Therefore, one might expect an increase from the equilibrium housing price following a policy that places more weight on land in the total assessment of property value. At the same time, those households would experience decreases from the open space equilibrium level.

Local indices of spatial association (Anselin 1995) between the typical property tax baseline and the 9.04% tax rate on land value scenario are presented in Figure 3.[11] The global pattern of the impacts exhibit positive (but weak) spatial autocorrelation for housing prices (Moran's $I = 0.02$, $P =$ 0.03) and for open space levels (Moran's $I =$ 0.02, $P = 0.03$). Also, it may be that the policy shocks are relatively localized and that the spatial feedback/feed-forward effects of policy changes on housing price and open space level die out quickly. This finding suggests that houses experiencing relatively large increases in housing price and open space levels following implementation of the 9.04% tax rate on land value are surrounded by houses that also experienced increases. Clusters of positive spatial open space autocorrelation were observed

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[11] See note 10 for abbreviations.

in western Knox County surrounding the town of Farragut, where predicted housing prices exhibit positive spatial correlation (Figure 1). In contrast, clusters of open space exhibiting negative autocorrelation are evident in Knoxville, where predicted housing prices are negatively correlated.

Sixty-four percent of households (768 of 1,193 households) experiencing greater tax burdens following the 9.04% tax rate hike on land value also experienced a decreases from the initial open space equilibrium level surrounding the site, suggesting that individuals at these locations were less willing to pay for open space under the new tax scheme. Thirty-six percent of households (425 of 1,193 households) with greater tax burdens after the 9.04% tax rate on land value experienced increases in open space from initial equilibrium levels. Households in areas with positive deviations from the initial equilibrium levels were more willing to pay for open space following the new tax scheme.

Of the households whose tax burden decreased following the TPT, 98% (2,219 of 2,273 households) were in locations where simulated open space levels were higher than initial open space equilibrium levels. Households located in these areas had a higher willingness to pay for open space. The deviation of open space from the initial equilibrium level decreased for the remaining 2% of these households. Households where the simulated open space level was lower than the initial starting point before the policy shock were less willing to pay for open space.

Overall, open space levels increase relative to the initial equilibrium levels following the 9.04% policy shock for 76% of the households (2,644 of 3,466). Among the households with positive deviations from the initial open space equilibrium level, 84% (2,219 of 2,644) had lower tax burdens and greater net income after the new tax scheme. In this case, there appears to be some evidence favoring the premise that willingness to pay for open space will increase if the tax burden decreases.

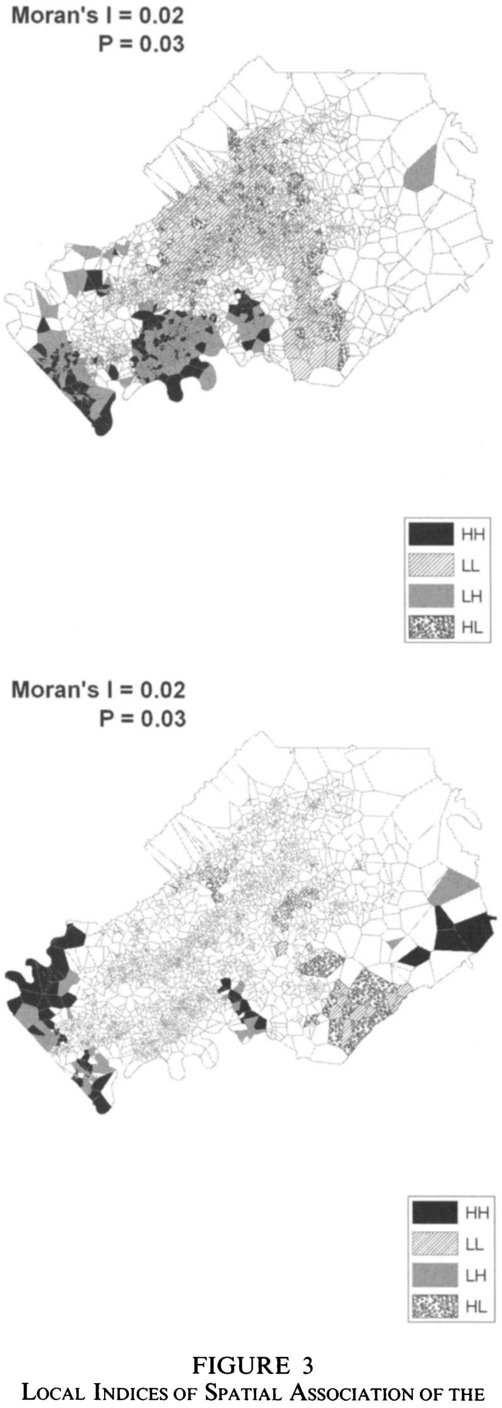

FIGURE 3
LOCAL INDICES OF SPATIAL ASSOCIATION OF THE DIFFERENCE BETWEEN PREDICTED HOUSING PRICE AND SIMULATED HOUSING PRICE (UPPER) AND THE DIFFERENCE BETWEEN PREDICTED OPEN SPACE AND SIMULATED OPEN SPACE (LOWER) UNDER AN ASSESSED LAND VALUE TAX RATE OF 9.04%

VI. CONCLUSIONS

Some communities that have committed to preserve open space using zonal and acquisition types of policies continue to struggle with policy implementation. This research evaluates a TPT as an alternative instrument to promote open space preservation. The potential effect of a hypothetical TPT on open space equilibrium levels was compared with simulated equilibrium levels following a tax policy shock.

Ex ante results suggest that the policy effects of a TPT are spatially heterogeneous with respect to open space levels and housing prices. Therefore, a TPT with a sliding scale may be useful for targeting locations to mitigate the potentially negative effects of sprawl by encouraging open space preservation. In particular, the impact on open space is greater in areas where housing prices are generally higher in and around the town of Farragut in western Knox County. These houses are typically newer are located in low-density but rapidly developing areas, and the lots are generally smaller in these areas that serve as "bedroom" communities.

Equilibrium open space levels were augmented following a revenue-neutral tax policy on land. About 76% of the households valued open space more following a land value tax rate of 9.04%, which suggests that households in certain locations are likely to support programs or policies preserving neighborhood open space. For example, households in these locations are more likely to approve new spending for more open space preservation following policies that placed more emphasis on taxing land relative to building or structural improvements. Therefore, under the TPT scheme, promoting compact development by encouraging open space preservation may succeed.

We applied a procedure that extends the most recent treatment of heteroskedastic-robust spatial process models to estimate a SARAR(1,1) spatial process model. There are few hedonic studies that use spatial process models for ex ante policy analysis. To our knowledge, most hedonic studies attempting ex ante policy analysis using regression results from spatial process models have omitted the spatial dependence between the response variable and disturbances in their forecasts. Our analysis attempted to narrow this gap in the spatial econometrics literature as applied to hedonic housing price studies.

The insignificance of open space in the housing price equation and housing price in the open space equation was somewhat unexpected. This could be related to the variable constructed to proxy open space. For example, how individuals define and value open space may represent open space levels more accurately than the measure used in this study, that is, the value of forest open space within a 0.2-mi radius buffer around properties using a hedonic framework. Such information typically requires primary survey data collection. McConnell and Walls (2005) reviewed the findings from the stated preference methods using survey data. They summarized specific dollar estimates of willingness to pay for open space of specific types within different ranges in other locations. For example, Bergstrom, Dillman, and Stoll (1985) estimated willingness to pay to preserve farmland from development in South Carolina as $9 to $16 per household per year. Rosenberger and Walsh (1997) estimated willingness to pay to preserve western ranchland from development in Colorado as $86 to $144 per household per year. Johnston et al. (2001) estimated willingness to pay to preserve farmland from development in Suffolk County, New York, as $40 to $162 per household per acre per year. Clearly, willingness to pay for open space varies depending on the questions posed to respondents and the type of area considered to be "open space." Ideally, we would supplement the NLCS data defining open space with primary survey data reflecting willingness to pay in Knoxville, Tennessee, but this is beyond the current analysis and left for future research.

Finally, the simulation analysis may be subject to the Lucas critique. The implicit assumption is that the estimated reduced-form parameters in the empirical model do not change when the local government changes land tax rates. Lucas (1976) pointed out that substantive change in government policies may induce people to reoptimize. This analysis considered only a single cross section of housing transactions in a limited area. Without ex post information about how individuals may (or may not) change their housing location decisions following the shocks implemented in this analysis, it is difficult to imagine how the Lucas critique can be put to the empirical test. Testing whether home owners "reoptimize" following a change in government policy would require a dynamic panel of transaction data collected after the introduction of a new tax policy. We leave this for future research.

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