Journal of Agricultural and Applied Economics, 38,2(August 2006):287–298

Estimating Effects of an Urban Growth Boundary on Land Development

Seong-Hoon Cho, Zhuo Chen, Steven T. Yen, and David B. Eastwood

This study estimates the effects of an urban growth boundary (UGB) on land development decisions in Knox County, TN, using a heteroscedastic probit model. With combined effects of increased land development within the city boundary and decreased development within the UGB and the neighboring town of Farragut after the implementation of UGB, the UGB of Knox County has been successful in urban revitalization within the city boundary and discouraging urban sprawl. These UGB impacts may be related to the city government having the right to annex land parcels within the UGB without consent of land owners.

Key Words: heteroscedastic probit, land development, urban growth boundary

JEL Classifications: C35, Q24, R52

The smart growth policy glossary of the Environmental Protection Agency (EPA) defines an urban growth boundary (UGB) as "a mapped line that separates land on which development will be concentrated from land on which development will be discouraged or prohibited." It further states that, "typically, facilities and services necessary for urban development are provided within the boundary, while service extensions outside the boundary are restricted." The objectives of UGBs are summarized in six categories (Staley, Jefferson, and Mildner): (1) preserve open space and farmland; (2) minimize the use of land generally by reducing lot sizes and increasing residential densities; (3) reduce infrastructure costs by encouraging urban revitalization, infill, and compact development; (4) clearly separate urban and rural areas; (5) ensure the orderly transitions of land from rural to urban uses; and (6) promote a sense of unified community. UGBs have become one of the hottest planning tools in the nation. More than 100 cities and counties have adopted a form of UGB (Staley, Jefferson, and Mildner). They are increasingly seen as the growth management tool of choice by local communities because they offer potential solutions for urban sprawl and the preservation of farmland and open space with higher intensity of investment and development in restricted areas.

As a part of Tennessee's Growth Policy Act, effective since 1998, all counties and the cities within them are required to collaborate

---

Seong-Hoon Cho, Steven T. Yen, and David B. Eastwood are, respectively, assistant professor, associate professor, and professor at the Department of Agricultural Economics, the University of Tennessee. Zhuo Chen is a Preventive Effectiveness postdoctoral fellow at the Center for Disease Control and Prevention, and a visiting scholar at the Chicago Center of Excellence in Health Promotion Economics, the University of Chicago.

The authors thank William M. Park, Christopher D. Clark, and Frank O. Leuthold for helpful comments. Thanks are also due to Tim Kuhn and Gretchen Beal of Knoxville/Knox County Metropolitan Planning Commission and Keith G. Stump of Knoxville–Knox County–Knoxville Utilities Board geographic information system for providing urban growth boundary, school district, and sales data.

in defining UGBs. Its passage was considered a dramatic and unexpected move by the state legislature (Porter). The City of Knoxville adopted a UGB in January 2001. Following Oregon and Washington, Tennessee is one of only three states that have adopted statewide policies mandating creation of UGBs for local governments. Oregon adopted growth management legislation in 1973, and Portland adopted growth boundaries in 1979. Washington passed the Growth Management Act in 1990, with Clark County introducing a UGB in 1995.

Despite the popularity of UGBs, there have been unintended consequences, as well as failures, in meeting the aforementioned objectives. Portland, OR, has proven to be an excellent case study for examining the intended and unintended effects of a UGB, since the area is considered to demonstrate the most sophisticated and comprehensive attempt to implement a UGB. However, evaluation of Oregon's UGB was not started until the 1990s mainly because the state had not developed a program to collect data for systematic analysis. Despite the data limitations, a substantial body of research has emerged that evaluates the UGB of Portland, OR. Some studies support the conclusion that Portland's UGB has effectively slowed down urban sprawl and increased residential density (e.g., Kline and Alig; Nelson and Moore; Patterson). Others have drawn more skeptical conclusions, arguing that growth management had no impact or only insignificant impacts on growth (e.g., Bae; Jun; Richardson and Gordon). Empirical analyses have also found contradictory results about unintended consequences of UGBs mainly with respect to the effects on housing prices. Downs reported that market demand, instead of the boundary, is the primary driver of housing prices. Cho, Wu, and Boggess and Phillips and Goodstein concluded differently, arguing that UGBs have created upward pressure on housing prices. Chan found that UGBs had raised housing prices in the San Francisco Bay area.

Although UGBs were mandated in Tennessee in 1998, to date there have been no systematic analyses to estimate their impacts. An analysis of the effects of Knoxville's UGB system on land development decisions provides the first study of the state-mandated program. Because UGBs in Tennessee are a state-mandated program in which all cities are linked to a state-wide growth management system, Knoxville's experience may reflect what has occurred throughout the state. The objective of the study is to estimate the effects of a UGB on land development decisions by examining the relationship among time of the adoption, location of UGB in Knoxville/Knox County, and the probabilities of land development. It is achieved with the use of a land parcel data set that provides the relevant variables and allows us to overlay census-block groups. In estimating the relationships, a probit model is used with correction for heteroscedastic errors caused by sizes and values of parcels, which are the common causes of heteroscedasticity in the literature (Dubois; Fletcher, Gallimore, and Mangan; Goodman and Thibodeau). A homoscedastic probit model is also estimated for comparison.

Statistical Model

To explain the binary outcome (y_i) for land development we use the probit model, characterized by

$$(1) \qquad y_i = \begin{cases} 1 & \text{if } x_i'\beta + u_i > 0 \\ 0 & \text{if } x_i'\beta + u_i \leq 0, \end{cases}$$

where x_i is a vector of explanatory variables for observation i and β is a conformable parameter vector. The error term u_i is assumed to be normally distributed with zero mean and standard deviation σ_i. To accommodate variation in the error standard deviation σ_i, the paper uses a model of multiplicative heteroscedasticity, which is a very flexible model that could reduce to many other useful formulations (Greene, p. 232). We parameterize the error standard deviation σ_i as a multiplicative function of exogenous variables z_i with corresponding parameter vector γ such that (see, e.g., Harvey)

$$(2) \qquad \sigma_i = \exp(z_i'\gamma)$$

Denote the univariate standard normal cumulative distribution function as $\Phi(\cdot)$. Then, it follows from Equations (1) and (2) that the probability of land development is

$$\text{(3)} \quad \Pr(y_i = 1) = \Phi[x_i'\beta/\exp(z_i'\gamma)].$$

The sample likelihood function for an independent sample can be constructed with the probability (Equation 3) and its complement, that is,

$$\text{(4)} \quad L = \prod_{y_i=0} \{1 - \Phi[x_i'\beta/\exp(z_i'\gamma)]\} \times \prod_{y_i=1} \Phi[x_i'\beta/\exp(z_i'\gamma)].$$

Maximum-likelihood estimation is carried out by maximizing the likelihood function (Equation 4). To examine the effect of explanatory variables on the probability of land development, we calculate the marginal effects. This is done by differentiating the probability (Equation 3) with respect to a common variable in x_i and z_i, say $w_{ij} = x_{ij} = z_{ij}$:

$$\text{(5)} \quad \frac{\partial \Pr(y_i = 1)}{\partial w_{ij}} = \phi\left(\frac{x_i'\beta}{\exp(z_i'\gamma)}\right)\frac{\beta_j - (x_i'\beta)\gamma_j}{\exp(z_i'\gamma)},$$

where $\phi(\cdot)$ is the probability density function of the univariate standard normal. In the numerator of the second fractional term on the right-hand side of Equation (5), only the first (second) term appears if w_{ik} appears only in x_i (z_i).

The model presented above reduces to the special case of the homoscedastic probit model when $\gamma = 0$, in which case the standard deviation is $\sigma_i = 1$ and the probability of land development is $\Phi(x_i'\beta)$, with which the likelihood function (Equation 4) can be simplified accordingly. Because the heteroscedastic and homoscedastic probit models are nested, selection between the two models can be done by regular means, e.g., likelihood-ratio (LR) test.

Two dummy variables were created to capture the impacts of UGB before and after its implementation within and outside of the UGB area. A dummy variable indicating within and outside a half-mile buffer area just outside of the Knoxville city limits was created to capture the spillover effect of economic development within the city (see Figure 1). A dummy variable indicating within and outside a small city, Farragut, also within the county was created to capture the effect of land development on a nearby Knoxville city (see Figure 1). Interaction terms between the dummy variable indicating pre-UGB and post-UGB periods and the dummy variables indicating the areas of UGB, Knoxville, Farragut, and the half-mile buffer were created to capture the impacts of UGB in these areas.

Variable definitions are in Table 1. *TUGB* is one for land plots developed after the implementation of UGB in January 2001 (i.e., 2001–2004) and zero otherwise. *TUGB* × *LUGB* represents an interaction term between the dummy variable indicating post-UGB implementation period and the dummy variable indicating within the UGB area. *TUGB* × *KNOXVL* represents an interaction term between the dummy variable indicating post-UGB implementation period and the dummy variable indicating within the Knoxville. *TUGB* × *FARRGT* is to capture the spillover effects of land development by the UGB in neighboring Farragut. *TUGB* × *BUFFER* represents an interaction term between the dummy variable indicating post-UGB implementation period and the dummy variable indicating within a half-mile buffer area outside of Knoxville.

Previous studies have found that natural logarithms of the monetary value, distance, and size variables fit models better than a simple linear form because the transformation captures the declining effect of these variables (Bin and Polasky; Iwata, Murao, and Wang; Mahan, Polasky, and Adams). Consequently, natural logarithms of monetary value, distance, and size-related variables are used in the model.

Data

Our dataset contains information about housing parcels within Knox County from the Knoxville–Knox County–Knoxville Utilities Board's geographic information system

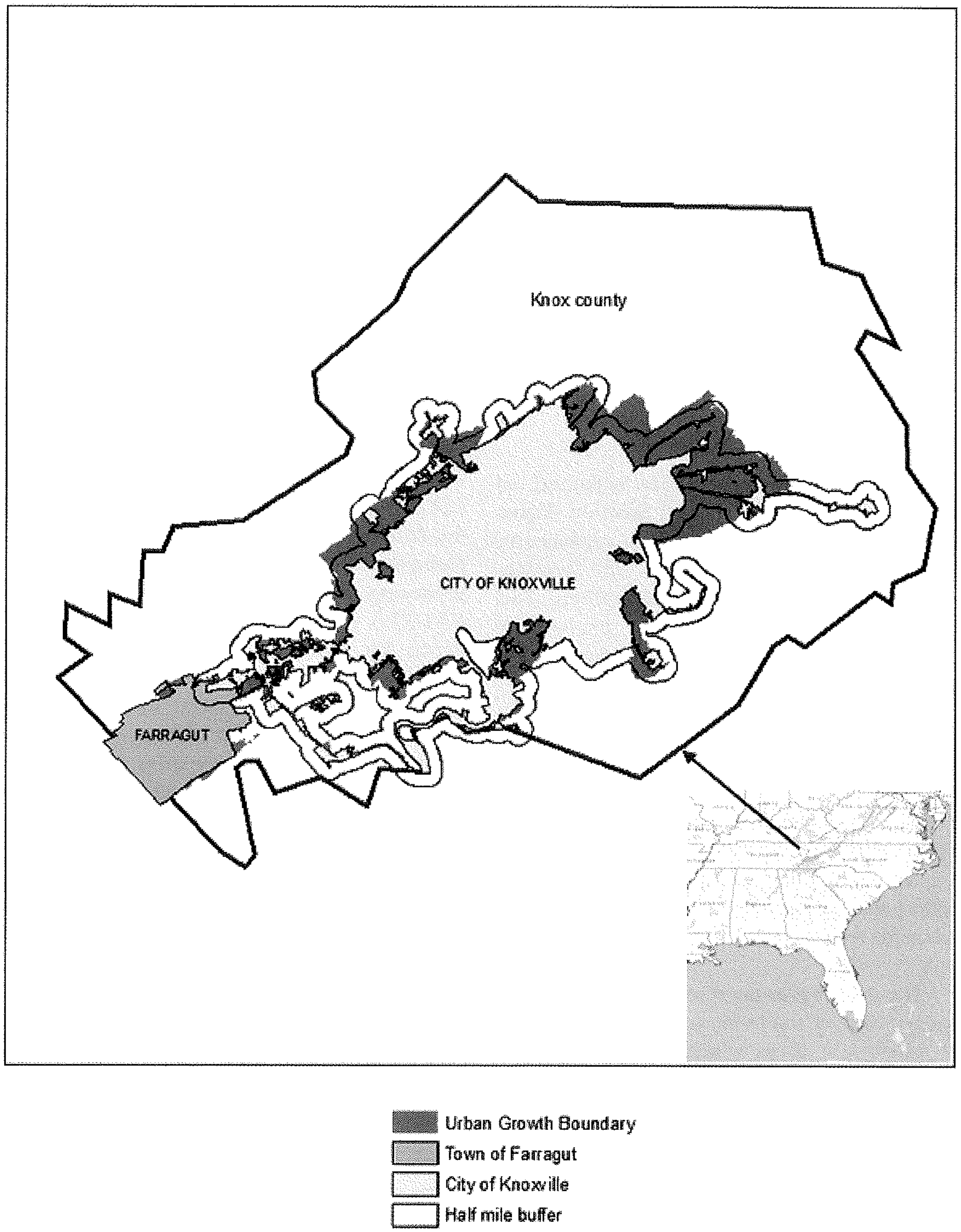

Figure 1. Urban Growth Boundary and a Half-Mile Buffer at Knox County

(KGIS) and 2000 long form data of census-block groups. The county adopted the UGB system in January 2001. Thus, the data include parcels developed during an 8-year period starting from 4 years before the UGB was initiated in January 2001 and parcels that were not developed by the end of December 2004. Parcels classified as single family, condo units,

Table 1. Names and Definitions of Variables

Variable	Description
Dependent variable	
DEV	Dummy variable for developed parcel (1 if land use for the parcel is defined as single family, condo units, planned development, and other residential, 0 otherwise)
Parcel variables	
LOTSQFT	Lot square footage
VALUE	Appraised value of land parcel per square foot
Census block group variables	
POPDNS	Population density per square mile in 2000
TRAVEL	Average travel time to work in 2000 (in minutes)
PCINC	Per capita income in 2000
UNEMP	Unemployment rate in 2000
VACANT	Vacancy rate in 2000
Jurisdiction and high school district variables	
KNOXVL	Dummy variable for City of Knoxville (1 if Knoxville, 0 otherwise)
FARRGT	Dummy variable for Town of Farragut (1 if Farragut, 0 otherwise)
BEARDEN	Dummy variable for Bearden High School District (1 if Bearden, 0 otherwise)
CARTER	Dummy variable for Carter High School District (1 if Carter, 0 otherwise)
CENTRL	Dummy variable for Central High School District (1 if Central, 0 otherwise)
DOYLE	Dummy variable for Doyle High School District (1 if Doyle, 0 otherwise)
FULTON	Dummy variable for Fulton High School District (1 if Fulton, 0 otherwise)
GIBBS	Dummy variable for Gibbs High School District (1 if Gibbs, 0 otherwise)
HALLS	Dummy variable for Halls High School District (1 if Halls, 0 otherwise)
KARNS	Dummy variable for Karns High School District (1 if Karns, 0 otherwise)
POWELL	Dummy variable for Powell High School District (1 if Powell, 0 otherwise)
WEST	Dummy variable for West High School District (1 if West, 0 otherwise)
Distance variables	
DOWNTN	Distance in feet to downtown Knoxville
WATER	Distance in feet to nearest water body
GOLF	Distance in feet to nearest golf course
GREEN	Distance in feet to nearest greenway
RAIL	Distance in feet to nearest railroad
INTERST	Distance in feet to nearest interstate highway
GSMNP	Distance in feet to Great Smoky Mountains National Park
Urban growth boundary variables	
TUGB	Dummy variable for timing of Urban Growth Boundary (1 if sold after UGB, 0 otherwise)
LUGB	Dummy variable for house within Urban Growth Boundary (1 if UGB, 0 otherwise)
BUFFER	Dummy variable for house within a half mile buffer outside of city of Knoxville (1 if buffer, 0 otherwise)

planned residential development, and other residential use that were built during the 1997–2004 period are treated as developed. Parcels classified as unused and in agriculturally related use were considered undeveloped. The 2000 long form data at census-block group level were merged with the parcel data.[1] The long form data were created in GIS form

[1] The use of the 2000 census data implicitly assumes that the socioeconomic characteristics of census-block groups over the 1997–2004 time period are constant.

by a private data provider, GeoLytics. Distance measurements using GIS were added to the data.

Parcel data include assessed land value and size of the parcel. All the assessed values were the values determined by the Knox County tax assessors' office at the end of 2004. There were 234 census-block groups in Knox County. The 2000 census-block group data provided population density, average travel time to work, unemployment rate, per capita income, and home vacancy rate measures. Distance calculations were made using the shape files of various location variables from Data and Maps 2004, ArcGIS 9, and geographic data from the Environmental System Research Institute, Redlands, CA. KGIS also provided shape files of high school districts, Knoxville, Farragut, and the UGB area. Spatial joining of these shape files and shape files of the parcel data was processed using ArcMap. The high school, jurisdiction, and UGB dummy variables were created using ArcMap as well.

After cleaning up the parcel data (deleting missing observations, unreasonably low appraised value of land parcels below $1,000, and unreasonably small parcel sizes below 100 square feet), there were 31,916 housing observations used for the estimation. Summary statistics are presented in Table 2. Among 31,916 parcels, 34% or 10,817 were developed. The average appraised value for the land parcels was $1.2 per square foot with a maximum of $220 per square foot. For the entire sample, the typical parcel was 55,477 square feet. For developed parcels it was 29,088 square feet, and for undeveloped parcels it was 68,996 square feet. The average vacancy rate was 7%, average travel time to work was 23 minutes, typical per capita income was $26,639, and mean unemployment rate was 4.5%.

Results

The heteroscedastic probit model was estimated by maximum likelihood, using lot square footage and appraised value of land parcel per square foot to accommodate the error heteroscedasticity. Results are presented in Table 3, and results for the homoscedastic probit model are in the appendix. Based on results (likelihood values) of the heteroscedastic and homoscedastic models, a likelihood-ratio test suggests rejection of the homoscedastic probit model at the 1% significance level. Pseudo R^2s (Wooldridge, p. 465) indicate that the heteroscedastic model is slightly better than the homoscedastic model in terms of goodness of fit and explanatory power. Percentages of correct predictions (Wooldridge, p. 465) also show that the heteroscedastic model is preferred. Unless stated otherwise, the discussions in this section are based on the heteroscedastic probit model.

Marginal effects of continuous variables were evaluated at the sample means, whereas marginal effects of dummy variables were evaluated for discrete changes in dummy variables from 0 to 1. The positive and statistically significant coefficient of *TUGB* suggests that land parcels had a 4.7% greater probability of development after the implementation of UGB than before. The positive and significant coefficient of the *LUGB* suggests that land parcels within the boundary of UGB were 2.9% more likely to be developed than the land parcels in Knox County excluding Knoxville and the UGB area.

However, we cannot conclude based on these two variables that the increase in the likelihood of the development was due to the implementation of UGB. UGB's positive locational effect (being right outside city boundary) was captured by the positive and significant coefficient of *BUFFER*. The negative and significant coefficients of *TUGB* × *LUGB* and *TUGB* × *FARRGT* indicate that a land parcel was 6.6% and 12.8% less likely to be developed within the boundaries of UGB and Farragut during the 4 years after UGB implementation. The opposite sign of the coefficient of *TUGB* × *LUGB* from the signs of the coefficients of *TUGB* and *LUGB* suggests the effect of *TUGB* × *LUGB* was affected by time and location. On the other hand, the positive and significant coefficient of *TUGB* × *KNOXVL* indicates that a typical land parcel was 27.1% more likely to be developed within the bound-

Table 2. Summary Statistics of the Variables

Variable	Mean	Std. Dev.	Min.	Max.
Dependent variable				
DEV	0.339	0.473	0.000	1.000
Parcel variables				
LOTSQFT (1,000)	55.477	15.063	0.100	7,839.413
VALUE	1.210	1.937	0.003	220.000
Census-block group variables				
POPDNS (1,000)	1.228	1.103	0.969	21.133
TRAVEL	22.611	3.944	10.000	34.000
PCINC (1,000)	23.639	10.980	4.437	81.373
UNEMP	0.045	0.043	0.000	0.520
VACANT	0.072	0.037	0.000	0.280
Jurisdiction and high school district variables				
KNOXVL	0.309	0.462	0.000	1.000
FARRGT	0.047	0.213	0.000	1.000
BEARDEN	0.099	0.299	0.000	1.000
CARTER	0.074	0.262	0.000	1.000
CENTRL	0.080	0.272	0.000	1.000
DOYLE	0.110	0.312	0.000	1.000
FULTON	0.056	0.229	0.000	1.000
GIBBS	0.082	0.274	0.000	1.000
HALLS	0.071	0.257	0.000	1.000
KARNS	0.105	0.306	0.000	1.000
POWELL	0.064	0.246	0.000	1.000
WEST	0.089	0.286	0.000	1.000
Distance variables				
DOWNTN (1,000)	43.866	22.842	0.773	104.820
WATER (1,000)	9.361	6.832	0.003	38.949
GOLF (1,000)	12.425	6.009	0.302	42.617
GREEN (1,000)	9.194	6.919	0.006	42.617
RAIL (1,000)	7.595	6.755	0.001	43.478
INTERST (1,000)	11.041	9.940	0.002	58.105
GSMNP (1,000)	120.655	22.308	61.084	187.213
Urban growth boundary variables				
TUGB	0.129	0.335	0.000	1.000
LUGB	0.100	0.300	0.000	1.000
BUFFER	0.224	0.417	0.000	1.000

ary of Knoxville during the 4 years after UGB implementation. The three interaction coefficients imply that UGB significantly decreased land development within the UGB boundary and neighboring Farragut while it significantly increased land development within Knoxville. The increased land development within Knoxville leads to the inference that the UGB was successful for urban revitalization within the city boundary. On the other hand, the decreased land development within the UGB and neighboring Farragut suggests that the UGB was also successful in discouraging urban sprawl outside of the city boundary.

The marginal effects of the variables used in the heteroscedasticity equation (Equation 2) (i.e., lot size and appraised value of land) are both positive and statistically significant at the

Table 3. Maximum-Likelihood Estimation of Heteroscedastic Probit Model

	Coefficient		Marginal Effect	
Variable	Estimate	S.E.	Estimate	S.E.
INTERCEPT	−87.112***	24.588		
Parcel variables				
ln *LOTSQFT*†	−1.117***	0.274	0.0005***	0.004
ln *VALUE*†	9.392***	1.247	0.217***	0.006
Census-block group variables				
POPDNS (1,000)	0.865***	0.210	0.020***	0.000
TRAVEL	0.081	0.051	0.002**	0.001
ln *PCINC*†	−10.350***	1.525	−0.010***	0.015
UNEMP	−22.465***	5.043	−0.508***	0.095
VACANT	−13.098***	4.774	−0.296***	0.104
Jurisdiction and high school district variables				
KNOXVL‡	−0.691	0.659		
FARRGT‡	−4.128***	1.073	−0.087***	0.018
BEARDEN‡	0.462	0.676		
CARTER‡	−7.462***	1.356	−0.147***	0.013
CENTRL‡	−2.763***	0.840	−0.060***	0.015
DOYLE‡	−0.587	0.903		
FULTON‡	1.041	0.751		
GIBBS‡	−4.354***	1.071	−0.092***	0.017
HALLS‡	−5.151***	1.148	−0.107***	0.017
KARNS‡	−1.920**	0.760	−0.042***	0.015
POWELL‡	−1.380	0.899		
WEST‡	0.277	0.726		
Distance variables				
ln *DOWNTN*†	8.184***	1.138	0.004***	0.013
ln *WATER*†	1.902***	0.324	0.005***	0.004
ln *GOLF*†	2.004***	0.410	0.004***	0.007
ln *GREEN*†	0.591***	0.205	0.001***	0.004
ln *RAIL*†	0.602***	0.166	0.002***	0.003
ln *INTERST*†	1.348***	0.237	0.003***	0.004
ln *GSMNP*†	4.569***	1.909	0.001**	0.042
Urban growth boundary variables				
TUGB‡	2.009***	0.602	0.047***	0.013
LUGB‡	1.255**	0.604	0.029**	0.014
BUFFER‡	4.150***	0.717	0.097***	0.012
TUGB × *LUGB*‡	−3.088**	1.315	−0.066***	0.025
TUGB × *KNOXVL*‡	10.825***	1.636	0.271***	0.023
TUGB × *FARRGT*‡	−6.458***	1.864	−0.128***	0.027
TUGB × *BUFFER*‡	1.024	1.004		
Error terms				
ln *LOTSQFT*	0.285***	0.014		
ln *VALUE*	0.279***	0.016		
Pseudo R^2	0.2513			
% of correct predictions	77.3			

Notes: Log-likelihood is −15,306.42. Standard errors were calculated from the heteroscedasticity-consistent covariance matrix.
† Marginal effect of the natural log variables, which were divided by mean values of the respective variables.
‡ Marginal effect of discrete changes in dummy variables. Only significant marginal effects are shown in the table.
* Statistically significant at the 10% level.
** Statistically significant at the 5% level.
*** Statistically significant at the 1% level.

1% level.[2] An increase of 1,000 square feet of lot size increases the estimated probability of development by 0.5%. An increase in appraised value of $1 per square feet increases the estimated probability of development by 21.7%.

The marginal effects of census-block group variables are all statistically significant at the 5% level. Evaluated at the average population density, an increase of 1,000 people per square mile increased the estimated probability of development by 2%. An increase of travel time to work by 10 minutes increased the estimated probability of development by 2%. *TRAVEL* was expected to represent ease of access to work, but the positive coefficient may reflect the congestion and noise associated with center of business district (CBD) where people travel to work. It also suggests that developments in recent years had patterns of sprawl, that is, areas away from CBD were more likely to be developed. An increase in average per capita income in the area by $1,000 decreased the estimated probability of development by 1%. This negative effect of income on probability of development may be explained by the fact that people with higher incomes may have preferred to have more open space (e.g., Howell-Moroney). Thus, the probability of land development should be lower for an area with a greater number of people with higher incomes (stronger preference for open space). A 1% increase in the vacancy rate decreased the estimated probability of development by roughly 0.3%. The higher vacancy rate represents lower housing demand, which was translated into lower housing supply that lowered the probability of land development.

Six out of 12 marginal effects of jurisdiction and high school district variables are statistically significant at the level of 1%. The probability of development decreased by 9% if the parcels were in Farragut versus outside. Although the majority of recent rapid growth of the county occurred in portions of west Knox County where Farragut is located (see Figure 1), there was a greater number of parcels not developed in Farragut compared with other areas. The probability of land development was lower if the parcel was in the Carter, Central, Gibbs, Halls, and Karns high school districts. These significant and negative coefficients of high school district dummy variables are interesting and need further study.

All the distance variables are positive and statistically significant, at least at the level of 5%. The positive coefficient for distance to downtown, and thus the negative effect of a parcel in the central city, may be explained by the fact that downtown Knoxville was mostly developed and fewer parcels remained undeveloped within and closely around the downtown area. An increase in distance from any water bodies by 1,000 feet (or 0.19 miles) increased the probability of development by 0.5%. The negative effect of being closer to water bodies may be explained by the fact that some regions closer to water bodies are floodplain areas where flood hazards were high and less likely to be developed. Distances of 1,000 feet (or 0.19 miles) from any golf course, greenway, railroad, interstate highway, and Great Smoky Mountains National Park (GSMNP) increased the probability of development by 0.4%, 0.1%, 0.2%, 0.3%, and 0.1%, respectively. Positive coefficients for golf course, greenway, and GSMNP are rather counterintuitive and need further study. Railroad and interstate highway coefficients reflect the noise and disamenities associated with being closer to railroad and interstate highway.

Conclusions

The effects of the UGB on land development decisions in Knoxville and Knox County were estimated. Results suggest that the UGB has impacted land development in different directions in different areas. Land parcels were less likely to be developed within the UGB area after UGB implementation. One of the reasons for the decreasing land development within

[2] Interestingly, the probit estimates without adjusting for heteroscedastic errors (see Appendix) show that the marginal effect of lot size is negative and statistically significant at the 5% level. Knowing that the error terms of lot size and assessed value are both significant, the negative marginal effect of lot size probably is misleading and likely caused by misspecification of the homoscedastic errors.

UGB area may be related to the fact that the city government had the right to annex land parcels within the UGB boundary without the consent with land owners. This feature of UGB apparently was a negative factor for land development within UGB because annexation by the city meant paying a city property tax.

On the other hand, land parcels were found to be more likely to be developed within the boundary of Knoxville after UGB implementation. The following is an explanation for the positive impact of UGB on land development within city boundary. Although land ownerships within city boundary require paying extra city property tax, the positive amenities, such as more services provided by the city, may have compensated for the extra cost of living in the city. There may have been a lower uncertainty factor due to living within city boundary versus living within the UGB. Households within the UGB and outside Knoxville had uncertainty about whether they would be annexed and have to pay extra property tax, but within the city boundary they were certain to pay extra tax. It may be that households disliked the uncertainty factor and chose rather to pay extra property tax and enjoy positive amenities along with it.

Land parcels were less likely to be developed in Farragut during the four years after UGB implementation. This spillover effect of UGB may be related to the fact that land development within Knoxville during the same period of time increased. Considering the fact that the county area is fixed, development in one local area may indicate decreased development in another local area.

Combining increased land development within city boundary and decreased development within UGB area and neighboring Farragut, the UGB of Knox County seems to be successful in urban revitalization within the city boundary and discouraging the urban sprawl. This result may be surprising given the UGB has been adopted in Knox County for a relatively short time period and UGBs are usually considered long-term growth management tools, often established for 15- or 20-year periods (Staley, Jefferson, and Mildner). It is also generally believed by local experts that the line drawn for the UGB may not be closely tied to the development of the area because the UGB boundary in Knoxville was drawn in response to not only concerns over sprawl, but also to the fallout from local annexation battles. The interests in local annexation battles may not be relevant to the purpose of the UGB as a growth management tool. Despite this local belief and the relatively short period of UGB, the uncertainty of paying an extra city property tax might be a substantial deterrent to housing development.

References

Bae, C. "Cross-Border Impacts of Growth Management Programs: Portland, Oregon, and Clark County, Washington." *17th Pacific Regional Science Conference.* Portland, OR, June 30–July 4, 2001.

Bin, O., and S. Polasky. "Effects of Flood Hazards on Property Values: Evidence Before and After Hurricane Floyd." *Land Economics* 80(2004): 490–500.

Chan, S. "Drawing the Line: The Effect of Urban Growth Boundaries on Housing Prices in the San Francisco Bay Area." Working Paper, Public Policy Center, Stanford University. 2004.

Cho, S., J. Wu, and W.G. Boggess. "Measuring Interactions among Urban Development, Land Use Regulations, and Public Finance." *American Journal of Agricultural Economics* 85(2003):988–99.

Downs, A. "Have Housing Prices Risen Faster in Portland Than Elsewhere?" *Housing Policy Debate* 13(2002):7–31.

Dubois, P. "Moral Hazard, Land Fertility and Sharecropping in a Rural Area of the Philippines." *Journal of Development Economics* 68(2002):35–64.

EPA. *Smart Growth Policies Glossary.* Internet site: http://cfpub.epa.gov/sgpdb/glossary.cfm?type=strategy (accessed July 20, 2005).

Fletcher, M., P. Gallimore, and J. Mangan. "Heteroscedasticity in Hedonic House Price Model." *Journal of Property Research* 17(2000):93–108.

Goodman, A.C., and T.G. Thibodeau. "Age-Related Heteroscedasticity in Hedonic House Price Equations." *Journal of Housing Research* 6(1995):25–42.

Greene, W. *Econometric Analysis.* Upper Saddle River, NJ: Prentice Hall, 2003.

Harvey, A. "Estimating Regression Models with

Multiplicative Heteroscedasticity." *Econometrica* 44(1978):461–65.

Howell-Moroney, M. "What Are the Determinants of Open-Space Ballot Measures? An Extension of the Research." *Social Science Quarterly* 85(2004):169–79.

Iwata, S., H. Murao, and Q. Wang. "Nonparametric Assessment of the Effects of Neighborhood Land Uses on the Residential House Values." *Advances in Econometrics: Applying Kernel and Nonparametric Estimation to Economic Topics,* Volume 14. T.B. Fomby and R.C. Hill, eds. Greenwich, CT: JAI Press, 2000.

Jun, M. "The Effects of Portland's Urban Growth Boundary on Urban Development Patterns and Commuting." *Urban Studies* 41(2004):1333–48.

Kline, J., and R. Alig. "Does Land Use Planning Slow the Conversion of Forest and Farm Lands?" *Growth and Change* 30(1999):2–22.

Mahan, B.L., S. Polasky, and R.M. Adams. "Valuing Urban Wetlands: A Property Price Approach." *Land Economics* 76(2000):100–13.

Nelson, A.C., and T. Moore. "Assessing Urban Growth Management: The Case of Portland, Oregon, the USA's Largest Urban Growth Boundary." *Land Use Policy* 10(1995):293–302.

Patterson, J. "Urban Growth Boundary Impacts on Sprawl and Redevelopment in Portland, Oregon." Working Paper, University of Wisconsin—Whitewater, 1999.

Phillips, J., and E. Goodstein. "Growth Management and Housing Prices: The Case of Portland, Oregon." *Contemporary Economic Policy* 18(2000):334–44.

Porter, D.R. *Tennessee's Growth Policy Act: Purposes, Implementation, and Effects on Development.* Chicago, IL: National Association of Realtors, 2002. Internet site: http://www.realtor.org/SG3.nsf/files/tengrowthpol.pdf/$FILE/tengrowthpol.pdf (Accessed June 9, 2005).

Richardson, H.W., and P. Gordon. "Portland and Los Angeles: Beauty and the Beast." *17th Pacific Regional Science Conference.* Portland, OR, June 30–July 4, 2001.

Staley, S.R., G.E. Jefferson, and C.S. Mildner. *A Line in the Land: Urban-growth Boundaries, Smart Growth, and Housing Affordability.* Policy Study 263. Washington, DC: Reason Public Policy Institute, 1999.

Wooldridge, J.M. *Econometric Analysis of Cross Section and Panel Data.* Cambridge, MA: MIT Press, 2002.

Appendix. Maximum-Likelihood Estimation of Homoscedastic Probit Model

	Coefficient		Marginal Effect	
Variable	Estimate	S.E.	Estimate	S.E.
INTERCEPT	−9.424***	1.429		
Parcel variables				
ln *LOTSQFT*†	−0.024**	0.011	−0.0001**	0.004
ln *VALUE*†	0.625***	0.013	0.174***	0.004
Census-block group variables				
POPDNS (1,000)	0.076***	0.013	0.026***	0.000
TRAVEL	−0.001	0.003		
ln *PCINC*†	−0.599***	0.040	−0.202***	0.013
UNEMP	−1.884***	0.310	−0.635***	0.104
VACANT	−1.546***	0.310	−0.521***	0.104
Jurisdiction and high school district variables				
KNOXVL‡	−0.078*	0.042	−0.026*	0.014
FARRGT‡	−0.311***	0.053	−0.095***	0.015
BEARDEN‡	0.001	0.040		
CARTER‡	−0.315***	0.052	−0.097***	0.014
CENTRL‡	−0.075	0.050		
DOYLE‡	0.119**	0.057	0.041**	0.020
FULTON‡	0.138**	0.057	0.048**	0.020
GIBBS‡	−0.161***	0.057	−0.052***	0.018
HALLS‡	−0.271***	0.060	−0.085***	0.017
KARNS‡	−0.084*	0.045	−0.028*	0.015
POWELL‡	−0.018	0.057		
WEST‡	0.151***	0.047	0.053***	0.017
Distance variables				
ln *DOWNTN*†	0.641***	0.037	0.005***	0.012
ln *WATER*†	0.100***	0.011	0.004***	0.004
ln *GOLF*†	0.141***	0.019	0.004***	0.006
ln *GREEN*†	0.043***	0.012	0.002***	0.004
ln *RAIL*†	0.037***	0.009	0.002***	0.003
ln *INTERST*†	0.111***	0.010	0.003***	0.004
ln *GSMNP*†	0.410***	0.115	0.001***	0.039
Urban growth boundary variables				
TUGB‡	0.095***	0.032	0.033***	0.011
LUGB‡	0.077**	0.036	0.026**	0.013
BUFFER‡	0.306***	0.030	0.108***	0.013
TUGB × *LUGB*‡	−0.229***	0.077	−0.072***	0.022
TUGB × *KNOXVL*‡	0.807***	0.063	0.308***	0.024
TUGB × *FARRGT*‡	−0.319***	0.085	−0.097***	0.023
TUGB × *BUFFER*‡	0.079	0.060		
Pseudo R^2	0.2392			
% of correct predictions	76.9			

Note: Log-likelihood is −15,552.16.
† Marginal effect of the natural log variables, which were divided by mean values of the respective variables.
‡ Marginal effect of discrete changes in dummy variables. Only significant marginal effects are shown in the table.
* Statistically significant at the 10% level.
** Statistically significant at the 5% level.
*** Statistically significant at the 1% level.