The Effect of Rural Zoning on the Allocation of Land Use in Ohio

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American Agricultural Economics Association
Summer Meeting
Chicago
August 2001

Abstract

By incorporating the spatially arrangement of counties relative to each other, this paper uses a land use share model to investigate the possibility that the allocation of land use in one county could be influenced by not only the degree to which the county is zoned, but also the degree to which neighboring counties are zoned due to spillovers of zoning effects among neighboring counties. The estimation uses data on land use for 88 counties in Ohio.

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Introduction

Like many areas of the U.S., Ohio has witnessed a significant increase in urbanization rates within the last couple of decades. Ohio ranked in the top 10 among U.S. states in terms of the average annual rate of non-federal land developed for the periods 1982-1992 and 1992-1997. Given that Ohio's population is predicted to grow by 1.64% within the next 10 years and that the current rate at which land is converted to urban uses is five times the population growth rate, this fast-paced urbanization is expected to continue into the foreseeable future. Local governments in Ohio have offered several land use tools to influence the pattern and pace of land use change. Among these, zoning is the most basic land use tool. Although zoning is in widespread use, little is known of its overall effectiveness, particularly with regards to how it affects the allocation of land to different uses.

Conclusions from the theoretical and empirical literature on the effect of zoning are mixed. Some studies have concluded that zoning encourages urban sprawl by reducing settlement density in a metropolitan area and forcing people to move outside the area (Atkinson and Oleson, 1996; Bogart, 1998). Other research shows that land use patterns in cities without zoning are not substantially different from those in cities with zoning (Siegan, 1972). These conclusions differ partly because of different assumptions and different model structures. One of the main structural differences is whether one or several jurisdictions are modeled and whether the model is explicitly spatial.

By incorporating the spatially arrangement of counties relative to each other, this paper investigates the possibility that the allocation of land use in one county could be influenced by not only the degree to which the county is zoned, but also the degree to which neighboring counties are zoned. If local land markets are interdependent due to imperfect substitution of land among neighboring areas, then this suggests the possibility that zoning may restrict the supply of developable land in one county and consequently increase the amount of land converted in neighboring counties. In other words, the allocation of land uses for a given county might depend not only on the zoning within that county, but also on the extent to which zoning in neighboring counties may induce spillover effects by indirectly influencing the amount of land converted. Accounting for this possibility is important since the presence of such spillovers would provide a rationale for a regional governance approach to growth management.

A land use share model is developed and estimated using county-level data for 88 counties in Ohio on land use, zoning, and other socio-economic variables. In testing the zoning spillover hypothesis, we use different specifications of the neighborhood to gauge the extent of the potential spillovers for the zoning variables in the neighboring counties. This paper is organized as follows. First, an overview of Ohio rural zoning is presented. The next section reviews the findings on the effects of zoning in the literature. This is followed by the empirical model, data and variables, and empirical results. Conclusions are then drawn in the final section.

Ohio Rural Zoning[1]

In 1947, the Ohio General Assembly passed enabling legislation that allows cities, villages, counties, and townships to establish zoning. The methods and procedures to establish zoning are distinct. However, the content of a particular ordinance is the discretion of the people of the area. Ohio's law is very precise and detailed and is designed to involve the public in the zoning process.

Zoning regulation can be divided into two categories: unincorporated (rural) and municipal. Rural zoning concentrates on *township* and *county* zoning outside of municipalities (village, town, city). *Township* zoning is the responsibility of township trustees. *County* zoning falls into the jurisdiction of the county commissioners; *county* zoning may include all or any number of townships in the county under a uniform zoning text administered county-wide if the township so choose. All zoning issues are accepted or rejected by referendum. The vast majority of rural areas with zoning have used the township form.[2] It is possible that county administered zoning maybe more effective and efficient, but because of controversy and emotional feelings citizens often prefer to keep the decision making processes close to home and forego some of the economic efficiencies. Even with the county approach, rural zoning is either accepted or rejected by the majority vote in each township.

[1] Much of the discussion in this section is from Ohio State University Fact Sheets CDFS-300, CDFS-301, CDFS-304 and CDFS-305.

[2] Based on the records through November 1997, there are 604 townships that have enacted *township* rural zoning and 96 townships that have enacted *county* rural zoning. For the rest of 612 townships, 198 townships rejected rural zoning, 4 townships repealed township rural zoning, and 410 townships have no rural zoning.

The purpose of municipal zoning is to protect public health, safety, and general welfare. Township and counties, on the other hand, zone to protect “ the health, safety and morals” of the residents. There is no clear authority to zone on behalf of the general welfare in rural Ohio, thus townships and counties have been reluctant to enact ordinances that include districts exclusively for agriculture or open space, fearing legal challenge. Discussions of zoning by rural residents constantly provoke differences of opinion about what it can and cannot do. In 1947, the Ohio legislature gave counties and townships the legal authority to proceed with rural zoning as long as it was based upon a comprehensive plan. The legislation that created rural zoning is quite precise, but nonetheless misunderstandings can still occur. At its best, rural zoning can:

- assist community economic growth by helping reserve adequate and desirable sites for industrial and commercial users;
- protect the public's property from inconsistent or harmful uses;
- help keep rural areas from becoming dumping grounds for businesses which are trying to avoid municipal regulations;
- protect individual property owners from harmful or undesirable uses of adjacent property;
- provide orderly and systemic transition in land use that benefits all land uses through public hearing and local decisions;
- help prevent objections to normal and necessary farming operations which can take place when residential developments move into agricultural areas in an unplanned fashion;

- make a community more attractive by assisting the preservation of open space, unique natural resources, and natural terrain features;
- protect present and future industry from harassment by residential neighbors by informing residents where industry will be allowed to develop in an orderly fashion;
- serve as a tool to put into effect plans for future development;
- allow for important community decisions to be made within the community.

On the other hand, rural zoning cannot:

- change or correct past land uses;[3]
- prohibit farm buildings or farming decisions, such as crop or livestock selection;
- establish higher development standards than the community desires, such as a guarantee that its adoption will be followed by industrial, commercial, or tourism development;
- assure proper administration of the resolution, no matter how good it may be;
- assure that land uses will be permanently retained as assigned under the zoning resolution. Rezoning is possible in response to changing conditions and unanticipated opportunities;
- guarantee the structural soundness of buildings constructed in zoned districts. Zoning is not a building code.

As it can been seen from these statements, rural zoning in Ohio is not designed to prevent land from being converted to development use as long as the process occurs in an orderly fashion and harmless way. In other words, Ohio rural zoning is a development tool available to rural residents who what to participate in the growth and development of their area. Although it can not change or correct land use action in the past, it can serve as a guideline for development in the future. For this reason, we might expect it to have some influence on the allocation of land uses.

Hypothesized Effects of Zoning

Most of the economic literature on zoning has primarily focused on the effects of zoning on land *value* or *price*, e.g. Henneberry and Barrows (1990), Brownstone and De Vany (1991), McMillen and McDonald (1993), etc.[4] This approach seeks to identify whether the allocation of land has changed as a result of zoning by testing for price differentials, which would indicate that zoning does modify market outcomes by changing the expected return to specific land parcels. If zoning does not induce significant changes in the quantity of land allocated for various uses, land prices would be expected to remain constant, *ceteris paribus*.

One practical reason for using price as a measure of zoning effects is data availability. Data on sales transactions of houses, from which land values can be ascertained, are readily available from public records. On the other hand, land use data are limited in most areas of the U.S. For this reason, little empirical evidence exists of the effects of zoning on the amount, share, or rate of conversion to urban land uses.

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[3] The only exception is if a use is made "non-conforming". A nonconforming use can be eliminated if that use is voluntarily discontinued for two years or if more than one-half is destroyed by fire or natural disaster.

In what follows, we use county-level data for Ohio on land use shares, zoning, and other socio-economic variables to estimate the effects of zoning on the proportion of land use allocated to different uses within the county. In doing so, we are particularly interested in the possible spillover effects of one county's zoning on neighboring counties. Because zoning may affect the relative prices of different land parcels, it may alter residential choice behavior across the region. The importance of considering potential spatial spillovers of land use regulations has been noted and documented in the literature (Feitelson, 1993; Nelson, 1988). For example, Feitelson finds that price increases due to land use controls have repercussions beyond the regulated area for new and existing residents of the region. A critical issue in testing for potential spillovers is the relevant extent of the neighboring. We define four different neighborhoods and compare the robustness of the results across all four specifications. Detains are discussed in the next section.

The Empirical Model

One of the most common approaches to estimate the determinants of land use is the land use share model.[5] A logistic parameterization of the expected share P_{ik} is typically used to express the share equation:

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[4] For a complete literature review on the effects of zoning, see Pogodzinski and Sass (1991).
[5] For a review of these models, see Plantinga *et al*., 1999

$$(1) \qquad P_{ik} = \frac{e^{b_k' x_i}}{\sum_{s=1}^{k} e^{b_s' x_i}}$$

where i is county, k indexes land uses, X_i is a vector of explanatory variables, and $\boldsymbol{b}_k$ is a parameter vector to be estimated. The logistic specification in (1) bounds the expected shares between zero and one. The observed shares y_{ik} are the combination of the expected share, P_{ik}, and the error term ε_{ik}. The model is transformed by taking the logarithm of land use shares normalized on urban land use share (y_{i1}), which can be written as,

$$(2) \qquad ln(y_{ik} / y_{i1}) = \boldsymbol{b}_k' X_i$$

where k indexes agricultural(k = 2) , forest (k = 3) and other (k = 4) uses. Under this specification, the three log-share equations are estimated simultaneously. Theoretically, the seemingly unrelated regression (SUR) estimation should be employed because the disturbances in these different equations at a given time are likely to reflect some common unobservable or omitted factors, and hence could be correlated. Empirically, we used least square estimation for each of these three equation since we include the same set of explanatory variables for each equation.

Data and Variables

Much of the data used to estimate this mode were calculated from the 1992 *National Resources Inventory (NRI)*, a comprehensive nationwide assessment of land use conducted at 5-year intervals using systematic sampling procedure specifically designed to identify the areas of land in different uses. The *NRI* classifies land use as eleven categories, from which we aggregate as follows: "urban-small and large built-up" are defined as **urban use** in our model**;** "cropland" and "pastureland" as **agricultural use**; "forest land" as **forest use**; and the rest of the land not classified as one of the above as **other uses**. Additional data on population and agricultural profits are from the 1987 *Bureau of Economics Analysis* and the 1987 *Census of Agriculture*. Lastly, zoning data were collected by Ohio State University Extension[6] from records at the Secretary of State's office and through a survey of selected county planning agencies. The data were recorded through November 1997. Although there is a 5 years' differential between the zoning data and the land use shares data, the divergence does not impair the interpretation of the zoning in the model because almost no change in the zoning records occurred between 1992-97.

The explanatory variables in the vector *X* include (1) zoning variables, (2) access variables, (3) land quality, and (4) other variables. We discuss each of these in turn in what follows.

(1) Zoning variables:

In Ohio, rural zoning can be governed by township zoning boards or by county zoning boards, as decided by local referenda. The zoning approaches used by either are notably different, and thus may affect land use patterns differently. To capture the influence of these zoning differences in our model, we constructed two zoning variables

[6] We would like to thank Tim Pritchard for providing the zoning data.

as the proportions of land in each county that are in either zoning domain: township rural zoning (TRZ) or county rural zoning (CRZ).

In addition to these two zoning variables that focus within each county, two other zoning variables were created to capture the likely "spillover effects" on land use in counties driven by the degree to which neighboring counties are zoned. The two variables are i) a weighted average proportion of township rural zoning enacted in neighboring counties (WTRZ), and ii) a weighted average proportion of county rural zoning enacted in neighboring counties (WCRZ).

These weighted averages for neighboring counties were calculated based on the spatial relationship of counties to each other as specified using a spatial weight matrix. The spatial structure embodied in the spatial weight matrix is a maintained assumption; the structure is specified according to an *a priori* belief about the spatial pattern of the dependence -- in this case, the relevant neighborhood within which zoning spillovers are hypothesized to occur. However, the extent of the relevant neighborhood is an empirical question and one for which we do not have any additional data. In order to judge the robustness of the results to the assumption of the relevant neighborhood for this study, four spatial weight matrices were specified based on the following two widely used criteria: i) nearest neighbors, and ii) the degree of contiguity among neighbors. Details are listed in Table 1. After the weights were calculated, the elements of each row of matrices were normalized such that they sum to unity.

(2) Access variable:

The presence of a highway within a county is expected to affect the land use patterns as it could reduce the cost of access to nearest urban center. Consequently, it could encourage urban development; more land would be expected to allocate to urban use than either agricultural or forest use if a highway is present within a county. In this study, we used a dummy variable (HWAY), the presence of a highway in 1989 within each county, as the proxy for the accessibility characteristics.

(3) Land quality:

Land quality is constructed based on the measure of Land Capability Class[7](LCC) defined by USDA. There are eight classes in this construction; the lower the class, the fewer limitations for cultivation, thus, the higher is the land quality. Accordingly, LCC I and II represent land with physical characteristics best suited to crop production (USDA Soil Conservation Service, 1961). It is assumed that if a county has a large amount of high quality land best suited for crop production, then the agricultural share in the county will be higher, all else equal. Therefore, we used the amount of land in LCC I or II in log form (LN_LCC) as a measure for land quality. Furthermore, this variable can be used to account for some degree of within-county variation in land quality (Plantinga *et al*., 1999).

In addition to LN_LCC, average LCC for each county (AVLCC) is included to capture the possible heterogeneities of land quality among counties. The higher the value

[7] Land quality measures based on LCC are used in studies by Wu and Segerson (1995), Plantinga(1996), Hardie and Parks (1997), Miller and Plantinga(1999) and Plantinga *et al*.(1999).

of AVLCC, the lower is average land quality and therefore we would expect agricultural share in the county will be lower, all else equal.

(4) Other variables:

LN_URBAN: the amount of existing urban land within a county in 1987 is used as a proxy for conversion costs. Conversion costs will be lower in an area that is already partially converted to urban use, particularly if economies of scale exist (e.g. due to fixed costs incurred by building infrastructure to support initial urbanization). If this is the case, LN_URBAN is expected to have a positive effect on urban share in the county. One the other hand, LN_URBAN is expected to have negative effects on other land use shares, such as agriculture share, forest share.

LN_AVHOUV: average housing value in 1989 is used as a measure of the income spent on housing. This variable can serve as the surrogate for income, but could be a better measure since LN_AVHOUV represents the income appropriated to the spending on housing directly; that is, it could be a more direct measure than income if the focus is to differentiate urban land use with other uses.

PDEN: the population density of the county in 1987 is included as a proxy for urban land rents. It is commonly acknowledged that the allocations of land to urban, other nonfarm and nonforest uses are related to population density (Wall, 1981; Alig *et al*., 1990). Thus, we used population density to explain the share of land devoted to urban uses. It is expected that the higher the population density, more land will be allocated to urban uses.

LN_AGPROF: we include average estimated agricultural profit per county in 1987 to capture the opportunity costs of converting land from agriculture to an urban use. Since high agricultural profit gives farmers the incentive to keep land in agricultural use, LN_AGPROF is anticipated to have a positive effect on the share on agriculture use.

Empirical Results

Tables 2-5 present estimates of the model. The estimated coefficients can be interpreted as the percentage change in the share ratio y_k/y_1 for a one-unit change in the independent variable, where y_1 is urban land and y_k represents agricultural, forest, and "other" land use variables.

(1) The Effects of Zoning

From Table 2-5, the ratio of agricultural to urban use, $ln(y_2/y_1)$, is not significantly influenced by either township zoning (TRZ) or county zoning (CRZ). These coefficients are not significantly different from zero across all specifications of spatial weight matrices. One possible explanation for this result is that the rural zoning in Ohio is not designed to prevent conversion; it is more a matter of guiding development, and most local zoning assumes that when the demand is there, variance will be granted.

Contrary to the results that we found from the two zoning variables enacted within a county, three out of four specifications[8] show that the weighted average proportion of township rural zoning enacted in neighboring counties (WTRZ) has a negative and significant effect on the amount of agricultural relative to urban use in a county, including the specification with the highest adjusted R^2 (0.9634). These findings suggest that the degree of township rural zoning in neighboring counties has negative effects on the share ratios of agricultural use to urban use; in other words, it has positive effects on the amount of urban land use relative to agricultural use, all else equal. In spite of the spatial effects found in WTRZ, no such effect found in the weighted average proportion of county rural zoning enacted in neighboring counties (WCRZ) for the ratio of agricultural to urban use.

Alternatively, none of the zoning variables was found to have a significant effect on the land share of forest relative to urban land, $ln(y_3/y_1)$, suggesting that this ratio is not sensitive to either township zoning or county zoning, within the counties or from the neighboring counties.

(2) The Effects of other Explanatory Variables

Tables 2-5 also present the effects of other explanatory variables on the percentage change of the share ratio. The ratio of agricultural to urban use, $ln(y_2/y_1)$, is negatively and significantly influenced by LN_URBAN, our proxy for average conversion costs within the county, and population density within the county (PDEN). These coefficients

[8] Those are W^{12} in Table 3, W^{13} in Table 4, and W^{4} in Table 5, respectively.

are both negative and significantly different from zero at the 5% level across all specifications of spatial weight matrices. Average housing value (LN_AVHOUV) is also found to have a negative effect on this ratio; for the specification with the highest adjusted R^2 (0.9634) among four spatial weight matrices, the coefficient is significantly different from zero at the 10% level, indicating the increase of average housing value also is associated with a higher ratio of urban use to agricultural use. As expected, the coefficients on the average estimated profits from agriculture (LN_AGPROF) are all positive and significantly different from zero at the 5% level across all specifications of spatial weight matrices, indicating the opportunity cost of developing profitable agricultural lands.

In addition, the coefficients on LN_LCC and AVLCC are positive and negative, respectively, and they are all significantly different from zero at 5% level across specifications. Therefore, counties with larger amounts of high-quality agricultural land (LN_LCC) or with lower average LCC (i.e. higher land quality) (AVLCC) tend to have higher agricultural to urban ratios. Lastly, the presence of a highway (HWAY) is estimated to have a negative influence on the ratio of agriculture to urban use, but none of these estimates are significantly different from zero across the four different specifications.

Turning now to the other determinants of land use share of forest land relative to urban land, $ln(y_3/y_1)$, the coefficients on LN_URBAN and PDEN are both found to be negative and significantly different from zero at the 5% level across all specifications.

These results suggest that an increase in the amount of existing urban land or population density is related to a lower share ratio of forest use to urban use. LN_AVHOUV also has a negative effect on the ratios, although is not found to be significantly different from zero. Likewise, although the coefficients on LN_AGPROF are all positive, none are significantly different from zero. The insignificant result from LN_AGPROF is not surprising since this variable is more likely to influence agricultural use than forest use.

As for the effects of land quality on the ratio of forest to urban lands, the coefficients on LN_LCC and AVLCC are both positive, although the estimate is not significant for LN_LCC. Contrary to the results that we obtained in estimating the ratio of agricultural use to urban use, AVLCC has a positive and significant effect on the ratio of forest use to urban use. This result implies that counties with higher average LCC (i.e. lower land quality) tend to have higher ratios of forest to urban use. Given that forested land is often found on lands that are marginal in terms of agricultural productivity, the difference in this estimated effect across the normalized agricultural and forest land use shares is not surprising. Lastly, the coefficient on the presence of a highway (HWAY) is negative, but is not significantly different from zero across any of the four specifications.

Overall, the estimated coefficients appear reasonable. Those variables categorized as other variables, such as LN_URBAN and PDEN, seem to have more significant impact on the ratios than other categories do. In comparing the effect of a particular variable on these three ratios, we find that some variables have positive effects on the normalized share ratios of urban land across equations as well as specifications, such as

LN_URBAN, PDEN; others are more sensitive to one than others. For example, LN_AGPROF has positive effect on the ratios of agricultural use to urban throughout different spatial weight matrices, but it has inconclusive effects on the ratios of forest to urban as well as "others" to urban use. In addition, the two variables representing land quality, LN_LCC and AVLCC, have more significant influence on the ratio of agricultural use to urban use.

Conclusions

It cannot be said *a priori* whether zoning regulation will modify market outcomes or conform to them. Results from the land use share models regarding the role of zoning are mixed. We find that the proportion of land within a county that is zoned is not significant for either the agricultural or forest normalized land use share models. However, we do find that the proportion of neighboring township zoning is significant for the agricultural land use share model, although it is again insignificant in the forest land use share model. Therefore, rural zoning is not found to act as a constraint to the amount of urban land relative to agricultural and forest lands within a county, but does in some case generate a spillover effect across counties that results in a higher amount of urban land relative to agricultural land the higher the proportion of neighboring land that is zoned.

One possible explanation for why we find some evidence of a zoning spillover effect, but no evidence of zoning as a constraint within a county could have to do with the degree to which zoning policies within a county are endogenous vs. the relative exogeneity of zoning policies in neighboring counties. Residents within a county may have a fair amount of influence over the zoning policy within their own county and as a result, zoning within a county is not an exogenous constraint on the amount of urban land relative to undeveloped lands. On the other hand, residents within a county are likely to have little influence over the zoning policies of neighboring counties and therefore the proportion of land zoned in neighboring counties is viewed as an exogenous constraint on the amount of urban land relative to agricultural lands in neighboring counties. If the amount of land in neighboring counties that is zoned signals a potential constraint on the supply of urban land within the region, then this may spur the conversion of additional land to urban uses within a county. In other words, zoning spillovers arise due to residents' expectations over the exogeneity of zoning policies in the neighboring counties.

Alternatively, in light of the insignificance of most measures of zoning in the land use share models, we cannot rule out the case that this finding of a significant zoning spillover effect is spurious. In this case, we would conclude that zoning is not a constraint on the amount of urban land relative to either agricultural or forest lands and that there is no evidence of zoning spillovers among neighboring counties.

Table 1. Description of Spatial Weight Matrices

Spatial Weight Matrix	Description
(1) nearest neighbors contiguity	Nearest neighbors contiguity matrix based on Euclidean distance
W^{11}	Weight equals 1 if a county is within 5 nearest neighbors from the observed county, 0 otherwise
W^{12}	Weight equals 1 if a county is within 10 nearest neighbors from the observed county, 0 otherwise
W^{13}	Weight equals 1 if a county is within 15 nearest neighbors from the observed county, 0 otherwise
(2) degree of contiguity	Rook criterion
W^{2}	Weight equals 1 if share common boundaries, 0 otherwise

Notes: Spatial weight matrices (1) are carried out by SpaceState version 1.9 (Anselin, 1998). (2) is produced using ArcView 3.2 – SpaceStat Extension.

Table 2 Estimation Results for Land Use Share Models Based on Spatial Weight Matrix W^{11}

Explanatory Variables	$\ln(y_2 / y_1)$	$\ln(y_3 / y_1)$	$\ln(y_4 / y_1)$
CONSTANT	7.944 (3.838)**	1.773 (0.382)	9.503 (2.650)**
Zoning Variables			
TRZ	- 0.141 (- 1.052)	- 0.142 (- 0.474)	- 0.269 (- 1.162)
CRZ	- 0.123 (- 0.663)	- 0.212 (- 0.508)	- 0.665 (-2.066)**
WTRZ	- 0.419 (- 1.582)	0.013 (0.021)	0.620 (1.350)
WCRZ	0.014 (0.046)	- 1.084 (- 1.609)	0.773 (1.485)
Access Variable			
HWAY	- 0.018 (-0.252)	- 0.125 (-0.769)	0.096 (0.758)
Land Quality			
LN_LCC	0.230 (3.030)**	0.227 (1.331)	0.219 (1.659)*
AVLCC	- 0.224 (- 2.501)**	0.898 (4.466)**	0.079 (0.507)
Value-related Variables			
LN_URBAN	- 0.907 (-16.905)**	- 0.478 (-3.968)**	- 0.668 (-7.189)**
LN_AVHOUV	- 0.281 (- 1.516)	- 0.318 (-0.766)	- 0.539 (1.679)*
PDEN	- 0.004 (-6.606)**	- 0.003 (-2.488)**	- 0.003 (-3.373)**
LN_AGPROF	0.141 (2.348)**	0.105 (0.777)	- 0.177 (-1.704)*
Adjusted R^2	0.9605	0.8452	0.8183

Notes: 1. Subscripts on share refer to urban (k = 1), agriculture (k = 2), forest (k = 3), others (k = 4).
2. *t* -statistics are given in parenthesis. * denotes significant at 10%, ** denotes significant at 5%.

Table 3 Estimation Results for Land Use Share Models Based on Spatial Weight Matrix W^{12}

Explanatory Variables	$\ln(y_2 / y_1)$	$\ln(y_3 / y_1)$	$\ln(y_4 / y_1)$
CONSTANT	8.769 (4.418)**	1.846 (0.396)	8.741 (2.418)**
Zoning Variables			
TRZ	- 0.186 (- 1.529)	- 0.180 (- 0.632)	- 0.162 (- 0.731)
CRZ	- 0.121 (- 0.709)	- 0.368 (- 0.915)	- 0.502 (-1.611)
WTRZ	- 0.838 (- 3.058)**	0.588 (0.914)	0.119 (0.238)
WCRZ	- 0.120 (- 0.396)	- 0.617 (- 0.867)	0.411 (0.744)
Access Variable			
HWAY	- 0.058 (-0.806)	- 0.085 (-0.502)	0.074 (0.568)
Land Quality			
LN_LCC	0.186 (2.477)**	0.268 (1.520)	0.165 (1.204)
AVLCC	- 0.331 (- 3.548)**	1.031 (4.708)**	- 0.024 (- 0.144)
Value-related Variables			
LN_URBAN	- 0.902 (-17.493)**	- 0.489 (-4.041)**	- 0.655 (-6.978)**
LN_AVHOUV	- 0.282 (- 1.657)*	- 0.417 (-1.043)	- 0.398 (- 1.284)
PDEN	- 0.004 (-6.766)**	- 0.003 (-2.594)**	- 0.003 (-3.193)**
LN_AGPROF	0.147 (2.559)**	0.111 (0.816)	- 0.169 (-1.611)
Adjusted R^2	0.9634	0.8424	0.8136

Notes: 1. Subscripts on share refer to urban (k = 1), agriculture (k = 2), forest (k = 3), others (k = 4).
2. *t* -statistics are given in parenthesis. * denotes significant at 10%, ** denotes significant at 5%.

Table 4 Estimation Results for Land Use Share Models Based on Spatial Weight Matrix W[13]

Explanatory Variables	$\ln(y_2 / y_1)$	$\ln(y_3 / y_1)$	$\ln(y_4 / y_1)$
CONSTANT	8.164 (4.044)**	2.905 (0.620)	8.433 (2.360)**
Zoning Variables			
TRZ	- 0.191 (- 1.526)	- 0.188 (- 0.649)	- 0.149 (- 0.675)
CRZ	- 0.096 (- 0.558)	- 0.413 (- 1.031)	- 0.472 (-1.543)
WTRZ	- 0.790 (- 2.436)**	- 0.240 (-0.318)	0.530 (0.923)
WCRZ	- 0.300 (- 0.949)	- 0.562 (- 0.767)	0.409 (0.732)
Access Variable			
HWAY	- 0.048 (-0.654)	- 0.140 (-0.820)	0.097 (0.744)
Land Quality			
LN_LCC	0.255 (3.417)**	0.153 (0.884)	0.196 (1.487)
AVLCC	- 0.267 (- 2.932)**	0.842 (3.978)**	0.045 (0.279)
Value-related Variables			
LN_URBAN	- 0.920 (-17.434)**	- 0.478 (-3.901)**	- 0.653 (-6.990)**
LN_AVHOUV	- 0.288 (- 1.657)*	- 0.381 (-0.946)	- 0.412 (- 1.342)
PDEN	- 0.004 (-6.092)**	- 0.003 (-2.466)**	- 0.003 (-3.284)**
LN_AGPROF	0.153 (2.536)**	0.143 (1.015)	- 0.190 (-1.777)*
Adjusted R^2	0.9614	0.8381	0.8148

Notes: 1. Subscripts on share refer to urban (k = 1), agriculture (k = 2), forest (k = 3), others (k = 4).
2. *t* -statistics are given in parenthesis. * denotes significant at 10%, ** denotes significant at 5%.

Table 5 Estimation Results for Land Use Share Models Based on Spatial Weight Matrix W^4

Explanatory Variables	$\ln(y_2 / y_1)$	$\ln(y_3 / y_1)$	$\ln(y_4 / y_1)$
CONSTANT	7.889 (3.872)**	2.234 (0.481)	9.235 (2.645)**
Zoning Variables			
TRZ	- 0.139 (- 1.080)	- 0.187 (- 0.641)	- 0.272 (- 1.238)
CRZ	- 0.070 (- 0.405)	- 0.387 (- 0.983)	- 0.653 (-2.206)**
WTRZ	- 0.482 (- 2.124)**	0.192 (0.372)	0.925 (2.378)**
WCRZ	- 0.116 (- 0.411)	- 0.765 (- 1.189)	0.757 (1.565)
Access Variable			
HWAY	- 0.027 (-0.369)	- 0.109 (-0.664)	0.114 (0.922)
Land Quality			
LN_LCC	0.212 (2.764)**	0.233 (1.331)	0.312 (2.367)**
AVLCC	- 0.250 (- 2.818)**	0.935 (4.629)**	0.177 (1.168)
Value-related Variables			
LN_URBAN	- 0.907 (-17.054)**	- 0.475 (-3.923)**	- 0.676 (-7.426)**
LN_AVHOUV	- 0.250 (- 1.376)	- 0.386 (-0.933)	- 0.602 (- 1.931)*
PDEN	- 0.004 (-6.701)**	- 0.003 (-2.584)**	- 0.003 (-3.395)**
LN_AGPROF	0.141 (2.328)**	0.107 (0.790)	- 0.190 (-1.869)*
Adjusted R^2	0.9612	0.8431	0.8253

Notes: 1. Subscripts on share refer to urban (k = 1), agriculture (k = 2), forest (k = 3), others (k = 4).
2. *t* -statistics are given in parenthesis. * denotes significant at 10%, ** denotes significant at 5%.

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