Analysis of the Effects of Large Lot Zoning

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Abstract

This study extends a test for the presence of binding zoning, originally developed to be applied across many adjacent jurisdictions, so that it can be applied within a single jurisdiction. This study also demonstrates how to carry out this test in the presence of spatially correlated OLS residuals by using a mixed effects model whose coefficients are estimated using the maximum likelihood technique. The study examines twenty years of land sales data from a Midwestern county containing two adjacent cities surrounded by rural areas. A thirty-five-acre acre, minimum lot size in the rural area is found to be binding; while a 9,000 square foot minimum lot size in the cities is found to be not binding.

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Introduction

This study expands on an overlooked empirical test for binding large lot zoning by extending its application from multiple to a single jurisdiction using a mixed effects model. Originally the test was developed to apply across many jurisdictions, each with a different minimum lot-size zoning ordinance. In this study, the theory is extended to make the test applicable within a single jurisdiction. The empirical model is also extended to include the possibility of spatially correlated residuals.

Peterson (1974) explains that zoning ordinances can have three separate effects on land values. First, municipalities may engage in fiscal zoning in an effort to increase the per capita tax base or reduce the demand for municipal services. Fiscal zoning can lower the property tax rate for any given set of municipal services. This tax price-edge is likely to be capitalized into higher land values. Second, zoning can limit the ways in which a parcel of land can be developed. If the profit maximizing use of a parcel of land is prohibited by a zoning ordinance, the value of the parcel will be adversely affected. Third, externality zoning will affect a parcel's value by limiting the type of externalities to which the parcel is exposed. This sort of zoning will enhance the value of the parcel.

In the aggregate, the effect of zoning on land values is not clear. The fiscal and externality effects tend to enhance land values, while the land-use constraint effect can lower land values. Peterson (1974) shows that one can focus on the land-use constraint effect of large lot zoning by examining the sales of land zoned for a particular use, such as single-family, for the presence of a binding zoning constraint.

Zoning ordinances are not always binding constraints. Just because a large-lot zoning ordinance places a limit on the minimum lot size in a community, it does not automatically make that ordinance binding. Specifically, zoning laws are not binding if they (1) do not inhibit the efficient combination of land and other factors in the production of buildings and (2) do not inhibit the efficient allocation of land among competing uses. On the other hand, if a zoning ordinance does inhibit the free market outcome, then that ordinance is binding. This study examines only large-lot zoning.

Zoning is a difficult phenomenon to measure, much less test whether it is or is not binding. Probably the oldest way of capturing the effects of zoning is to use a series of dummy variables representing each zoning category. For example, Jud (1980), Mark and Goldberg (1986) and Nicholas (1981) capture the effects of zoning by using as many as seven dummy variables. But some researchers have developed more innovative ways to measure zoning. For example, Shlay and Rossi (1981) and Rolleston (1987) developed an index-of-restrictiveness measure to capture the effects of zoning. This index is based on a weighted sum of the percentages of land zoned at varying degrees of restrictiveness. McMillen and McDonald (2002) look at zoning as an aggregate quantity restriction. But restrictiveness models are not useful for testing whether or not a large lot zoning ordinance is binding. Using an interesting model that examines the impact of zoning on employment and population density, Frew, Jud and Wingler (1990) report that zoning in Greensboro, North Carolina has a substantial impact on the shape of urban density functions. But the Frew, Jud and Wingler model is not designed for the study of the effect of zoning on land values.

Fortunately, tests for binding zoning have been conducted by others. These tests focus on large lot zoning because it constitutes a form of zoning that is often assumed to be binding, and because it appears to be an attempt by a city to exclude undesirable residents. Using housing sales aggregated by census tract across various metropolitan areas, Hamilton (1978) concludes that zoning is binding. Fischel (1980) performs the same test within metropolitan areas and finds that zoning is not binding. Using individual sales of single-family houses, some built on land zoned single-family and some built on land zoned multi-family, Maser, Riker and Rosett (1977) and Peterson (1974) also come to opposite conclusions. It could be that zoning is binding in some areas and not others. Also, the fiscal and externality effects of zoning might outweigh the land-use constraint effect.

White (1988) shows that tests for the presence of a binding zoning ordinance using sales of single-family homes are inherently biased. Presumably, land zoned for multi-family use is more valuable than land zoned for single-family use. But this differential is mitigated if a single-family house is built on land zoned for multi-family use, because to realize the added value of the higher zoning, the house must be demolished. The cost of demolishing the single-family house to make room for a new multi-family structure will reduce the observed differential in selling prices of single-family houses in studies like Maser, Riker and Rosett (1977) and Peterson (1974). To avoid the bias present in sales of single-family houses, a test for binding zoning must be conducted across sales of undeveloped (no structures) land.

Grieson and White (1981) present a multi-market zoning model from which White (1988) later derives an unbiased test for binding zoning. Unfortunately, no further applications of the White test for binding zoning are reported in the literature. Nonetheless, the question of binding zoning has serious implications for zoning decision makers. If zoning officials' desire zoning laws that do not interfere with the efficiency of the local real estate market, they should be aware of which of their laws are binding. Similarly, if zoning officials desire to restrain the local real estate market, perhaps as a means of population control, they should be aware of which of their laws are binding. So, regardless of the desires of zoning officials, knowledge of whether or not their zoning laws are binding is important information. Thus, the test for binding zoning deserves further attention.

Theory

The theory in this study builds on the multi-market model of zoning developed in Grieson and White (1981) and White's (1988) later extension of this model. The presence of many autonomist communities, each with a different minimum lot size ordinance, makes the White test possible. In this study, variation in minimum lot sizes is achieved within a single jurisdiction by the presence of lots smaller than the current minimum that were created under an older, less restrictive zoning ordinance (*e.g.*, parcels nonconforming to the existing minimum lot size ordinance). In order to find sales of these types of lots within a single jurisdiction, the time frame of the analysis is extended with a two-fold adjustment process to correct for market changes over the extended time frame.

The housing production function is defined as $H = H(T, K, L)$, where H is housing measured in units of standardized service, T is land, K is capital and L is labor. In short-run equilibrium, the price (per unit area)[1] of land, r, will equal the value of its marginal product in a competitive market, or $r = P_h * MPT$, where P_h is the price of H and MPT is the marginal product of land. The location of any parcel of land is defined as S.

Next, assume that non-land subdivision costs (per unit land area) are constant, regardless of the size of the tract of land being subdivided ($\partial H/\partial K = 0$ and

$\partial H/\partial L = 0$), and that premiums are not paid for one location over another ($\partial P_h/\partial S = 0$). Of course, these are unrealistic assumptions, but they help in understanding the White test. Later, these assumptions will be relaxed. Now, further assume that zoning is not binding. Under these assumptions, as White (1988) shows, the price of land will not vary with lot size. That is, the price of land is the same across all lot sizes and in all locations ($\partial P_h/\partial T = 0$ and $\partial P_h/\partial S = 0$).

Next, one change is made in the above situation, namely that the zoning ordinance is binding. A binding zoning ordinance forces the builder to use more land than would be used without the ordinance. Therefore, the marginal productivity of land is lower than it would be without the ordinance, or $MPT_b < MPT_n$, where the subscript b denotes a binding ordinance and the subscript n denotes a non-binding ordinance.

White (1988) adds to the above situation the presence of many contiguous communities, each with a different minimum lot size ordinance, generating lots of many different sizes across these communities. The many atomistic communities generate a continuum of minimum lot sizes across the urban area. However, unlike White, in this study the presence of lots of various sizes is introduced in a different manner. In practice, zoning ordinances evolve over time. In any given community, there often are parcels of various sizes smaller than that required by the current ordinance. There might be many reasons why these smaller lots remain empty. But whatever the reason, these types of parcels exist in many communities.

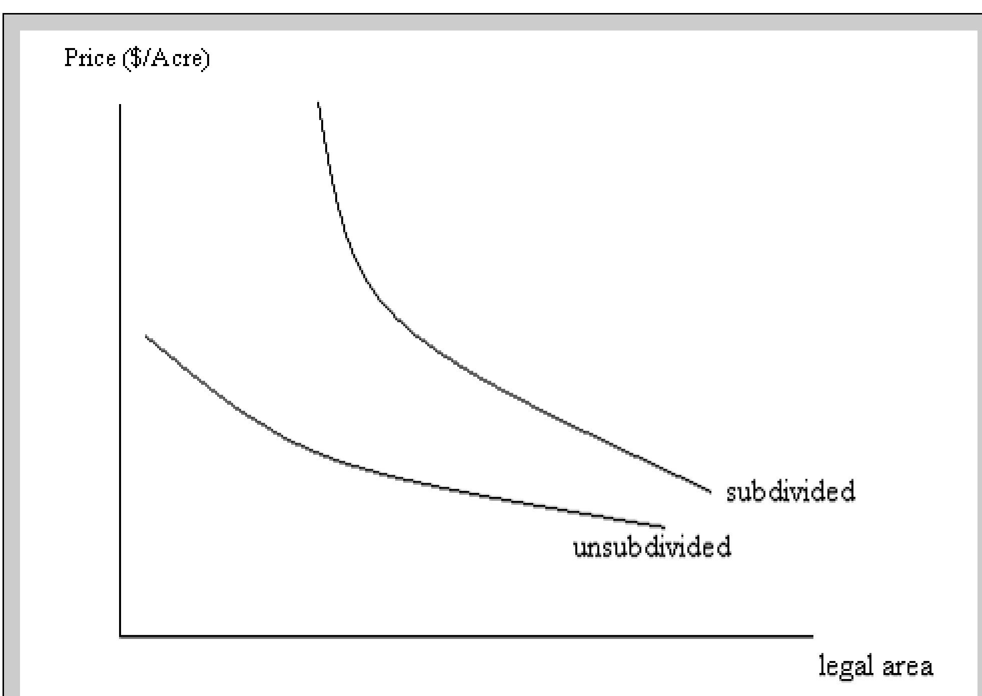
With a binding zoning ordinance, a negative relationship between lot size and price can be observed. Because the ordinance is binding, there will be a shortage of smaller lots. Therefore, the price of the smaller lots will be driven upward, but never so high that the value of the lot exceeds the value of a new, larger lot. In White (1988), this phenomenon is driven by the presence of many communities with different minimum lot size zoning ordinances. However, in this study, this relationship is driven by the presence of smaller lots created under older zoning ordinances. The approach in this study avoids the need to control for differences in the various jurisdictions included in the White approach. Instead, this study pools land sales across an extended period of time, controlling for market changes over time with a two-step technique. However, in either approach, a binding-zoning ordinance will create an inverse relationship between the price and lot size of undeveloped (no structure) land.

But an inverse relationship between the price and lot size of undeveloped land can also emerge if subdivision costs are not constant, as assumed earlier. In fact, one would expect subdivision costs per unit area to increase as lot sizes become smaller and smaller. For example, it is more costly per unit area to subdivide a ten-acre tract of land into twenty lots than to subdivide it into ten lots. The costs of utility lines, sewerage lines, water lines and possibly streets become greater as the number of lots to be carved out of a given tract of land is increased. Thus, although an inverse relationship between price and lot size is consistent with the presence of binding zoning, it is also consistent with increasing subdivision costs per unit area.

To separate these two effects requires the examination of land prices across parcels of land that can be further subdivided (unsubdivided) and parcels that cannot be further subdivided (subdivided). But to achieve this separation, a new variable is needed to account for the fact that some parcels might be divisible into many more parcels than others. To deal with this problem, White (1988) uses a variable called ''legal area.'' The legal area of a parcel is the lot size that would result after a parcel of land has been subdivided into the maximum number of *equal* sized lots allowed by the zoning ordinance. In other words, legal area is the area of the parcel divided by the whole number (integer) part of the ratio between the parcel's size and the minimum lot size. For example, a five-acre parcel zoned with a two acre minimum lot size would have a legal area of 2.5 acres.[2]

When zoning is binding, the price—legal area relationship for subdivided land will lie above and have a steeper slope than the price—legal area relationship for unsubdivided land, as shown in Exhibit 1. In this study, a parcel can have a legal

Exhibit 1 | Binding Zoning



area less than the minimum lot size only if it was created under an earlier zoning ordinance that allowed smaller lot sizes. In this context, there will be no difference between the two lines in Exhibit 1 if zoning is not binding. If subdivision costs per unit area of land were constant across all parcel sizes and zoning was not binding, then the price—legal area line (not drawn) in Exhibit 1—would be horizontal. Thus, the comparison of subdivided with unsubdivided lots enables a separation of the effects of a binding zoning ordinance from the effects of subdivision costs.

The only ingredient not yet addressed is the importance of location. Earlier it was assumed that location does not matter. However, in practice, location does matter. Fortunately, Grieson and White (1981) demonstrate that including a location variable in the model does not affect the price–legal area relationships. Of course, location must still be controlled for within any empirical model, but it does not affect the price–legal area relationships in Exhibit 1.

Testing for the presence of a binding zoning ordinance can be achieved by examining the price–legal area relationship. The theoretical model upon which this test is based is a partial equilibrium model. That is, it tests for the presence of a binding zoning ordinance by examining how the price of a parcel of land changes if the legal area of the parcel changes, *ceteris paribus*. One cannot use this model to infer either the magnitude or direction of land price changes, in general, if the legal area of many parcels were to change at once. Grieson and White (1981) show that the effects of this sort of change are best understood within the context of a general equilibrium model. Thus, testing for the presence of binding zoning can be achieved using the above model, but the results of such tests cannot be used to estimate what land prices would be with no zoning in the market.

The Empirical Model

The empirical model is developed for similarly (single-family) zoned land. The variables are defined as:

$P_{s,t}$ = The log of the price of a parcel of land sold at location s and at time t;
s = The location of the parcel given by the state plane coordinates of the centroid of the parcel;
t = The time of the sale;
L = The log of the legal area of the parcel as defined above;
U = 1 if the parcel is unsubdivided (number of maximum lots is at least 2);
k = An arbitrary constant term; and
$e_{s,t}$ = A disturbance term defined below.

Now, the theoretical relationship between price per acre and legal area can be defined as:

$$p_{s,t} = k + \beta_1 U + \beta_2 L + \beta_3 U * L + \varepsilon_{s,t}. \quad (1)$$

For now, assume that the disturbance term has an expected value of zero with a constant variance.

As White (1988) shows, the appropriate test for the null hypothesis that zoning is not binding is:

$$\beta_2 + \beta_3 > 0. \quad (2)$$

A negative sum of these two coefficients is consistent with the presence of binding zoning. Also, as White (1988) points out, the sign of β_3 is positive if subdivision costs are increasing. Thus, the effect of the zoning can be separated from the effect of increasing subdivision costs by examining the sign of $(\beta_2 + \beta_3)$. Additionally, a by-product of this test is a test ($\beta_3 > 0$) for the presence of increase subdivision costs.

There are still two variables in the model that require attention. Specifically, the time or the location of the sale should not bias the above test. The time of a sale can be influenced at both the macro and micro levels. Specifically, changes in the purchasing power of a dollar as well as local market trends can affect land prices. Changes in the GDP Deflator are used to adjust for the former. Changes in local market trends are more challenging to manage. In an experimental analysis of the data, the use of dummy variables to divide the sales into numerous cohorts proved to be statistically insignificant. Therefore, a continuous time variable is added to the mean structure of the model to control for local market trends.

The location of a parcel can also affect its value in a macro and micro manner. Location at the macro level is usually captured by accessibility variables. That is, accessibility to a point of economic influence, such as the central business district (CBD). The simplest measure of accessibility is distance. Although distance to a nearby CBD is often used in many theoretical and empirical models, it is not always the best construct to capture the macro level influences in small communities. Knowledge of the area under study can prove invaluable toward constructing variables that capture the macro level influences.

Next, S, a vector containing the appropriate measure(s) of accessibility, and t, the time of sale, are added to the model. Also, p_s is redefined as the price of the parcel in constant 1980 dollars (adjusted using quarterly GDP deflators). Thus, the empirical model can be restated as:

$$p_s = k + \beta_1 U + \beta_2 L + \beta_3 U * L + \beta_4 t + \beta_5 S + \varepsilon_s. \quad (3)$$

Notice that the price and error terms still have a location (s) subscript, indicating that additional, micro level location related influences might still be present in the data.

This micro level influence is created by proximity to smaller but much closer points of economic influence, such as a park, a golf course, a library, etc. These micro level features are all but impossible to capture within the mean structure of a model because they would involve adding many additional variables, most of which would not be statistically significant over an entire data set. A well-established method for handling these micro level effects is to model them in the disturbance term.[3] However, sometimes the variables of this sort of mixed model structure are difficult to estimate. The approach taken in this study for dealing with these micro level effects is described in the next section.

Spatial Correlation

The presence of micro level location influences, even after including a macro location variable in the model, can bias the coefficient estimates of the model. Specifically, if the disturbance term of a model such as in Equation (3) contains a spatially correlated error term, the possibility of biased coefficient estimates exists. So, the first step in dealing with this source of bias is to examine the residuals of the empirical model for the presence of spatial correlation. If the residuals are not spatially correlated, then no further steps are necessary. But if they are spatially correlated, then it is necessary to check whether or not the estimated coefficients of the model, especially β_2 and β_3, are biased.

In order to explore the possibilities of spatially correlated residuals, the model must be restated with a disturbance term capable of capturing spatial correlation. Thus, consider the following geostatistical model:

$$p_s = k + \beta_1 U + \beta_2 L + \beta_2 UL + \beta_4 t + \beta_5 S + w(s), \quad (4)$$

where $w(s_i) \sim N(0,\sigma^2 \rho(\varphi, d_{ij}))$, a spatial correlation term for the location s_i. Also, $\rho(\varphi, d_{ij})$ is defined as a valid (positive definite) correlation function, d_{ij} as the Euclidean distance between parcels i and j, φ as a set of parameters controlling the strength of spatial correlation, and $w(s_i)$ as independent of ε_i. The techniques described in Isakson and Ecker (2001) are used to estimate the variogram parameters (nugget, sill and range) representing $w(s)$. Once these parameters are estimated, the coefficients of the mean structure of the model in Equation (4) are re-estimated using the maximum likelihood technique. Comparing the OLS parameter estimates of β_2 and β_3 to those obtained from Equation (4) provides a test of whether or not the presence of the spatially correlated OLS residuals biases the results of the test.

The Data

The data in this study consists of 359 arms-length sales of vacant land, zoned either agricultural or R-1 residential, that occurred in Black Hawk County, Iowa between 1980 and 2000. The data was provided by the Black Hawk County Board of Supervisors.[4] Each transaction was screened by the County Information Systems Department to insure them to be genuine arms-length transactions.

Certain political features relevant to zoning and land values in Black Hawk County make it a desirable laboratory for testing whether or not local zoning ordinances are binding. First, the zoning in the unincorporated (rural) areas of the county is designed to protect farmland from urban sprawl. Since the 1960s, the minimum lot size in the unincorporated parts of the county is thirty-five acres. The county has no master plan, and the Board of Supervisors rarely approves requests to rezone land into classifications that allow smaller lots. Some land in the unincorporated areas does get rezoned for one and a half acre residential lots, but the Board approves this type of zoning only for land with a very low crop growing suitability rating. Some of the most expensive housing in the county is built on one and a half acre rural lots. Given the policies of the county, one would expect to find the zoning in the rural areas to be binding, if the zoning ordinance is indeed effective in protecting farmland from urban sprawl. On the other hand, if the county's large lot zoning is superfluous, it should be found to be non-binding.

Second, the two largest cities in the county, Cedar Falls and Waterloo, share a common border, and their zoning ordinances are very similar; both have required a 9,000 square foot minimum lot sizes for R-1 (single-family) land since the late 1960s. The land sales in the cities are limited to land zoned R-1. Additionally, significant acreage of vacant farmland is found in each city, all of it zoned according to each city's master plan. Subsequently, each master plan contains an abundance of land zoned R-1 residential. With so much vacant land available for subdivision, the zoning ordinances of these cities may very well be found to be non-binding. Also, the land area of both cities and the rural areas did not change during the study period due to land annexations.

Some of the geographic and transportation features of the county also make the county an interesting laboratory. The terrain of the county is very flat, with a major river passing through it from its northwest to its southeast corner. A divided highway parallels the river thru the two cities. Most of the older, industrial development of the cities and most of the poorest farmland is located near the river. Also, a major highway (Highway 20) passes through the southern half of the county on an east–west line. The CBDs of each city are small and suffer from incipient decline. Although downtown businesspeople try from time to time to revitalize the downtown areas, the downtown areas are not major destinations points. One of the cities, Cedar Falls, is a small college town in which the travel time from one side of the city to the other is about ten to fifteen minutes. The other city, Waterloo, is over twice as large, with no particularly important destination points.

Exhibit 2 contains the descriptive statistics of the key variables in the model. The largest variation in selling prices is found in the rural areas, probably because the rural area sales have a very large variation in size. The largest variation in legal area is also found in the rural areas, yet the variation in legal area in Cedar Falls and Waterloo is relatively large. The sales are spread fairly evenly throughout the three study areas, and the split between unsubdivided and subdivided parcels is also fairly even within each study area.

Exhibit 2 | Summary Statistics

Variable	Min.	Mean	Max.	Std. Dev.
Panel A: Rural Areas				
Total price ($)	10,450	88,674	910,000	116,544
Price / Acre ($)	1,017	17,993	87,122	22,062
Size (acres)	0.188	33.203	374.240	56.196
Legal area (acres)	0.188	15.564	57.690	18.438
Time of sale*	1.241	17.100	20.562	3.167
Panel B: Cedar Falls				
Total price	10,500	35,933	90,000	14,254
Price / Acre	6,920	86,338	256,699	46,968
Size (acres)	0.164	0.685	10.837	1.140
Legal area (acres)	0.164	0.257	0.400	0.048
Time of sale*	0.441	17.351	20.559	4.757
Panel C: Waterloo				
Total price	10,500	29,165	117,000	19,652
Price / Acre	1,123	54,867	231,400	42,946
Size (acres)	0.160	1.541	24.040	3.124
Legal area (acres)	0.160	0.253	0.409	0.056
Time of sale*	0.359	15.038	20.573	5.751

Notes: Rural Areas: N = 153; Cedar Falls: N = 112; and Waterloo: N = 94.
* Time is measured in years with January 1, 1980 = 0.

Exhibit 3 contains a summary of the zoning of the land sales, and the number of sales of subdivided and unsubdivided land within each jurisdiction, and the number of nonconforming parcels. None of the sales in the two cities are zoned agricultural, while about half of the sales in the rural area are zoned residential. In Iowa, property taxes are equalized across all property, but agricultural land is always assessed based on its income-producing ability. Because the agricultural land in the rural areas enjoys a slight tax advantage over the residential land, the estimated zoning effects on value will represent conservative estimates.[5]

Due to the way the variable *U* is defined, there is a chance that it will be highly correlated with the variable *L* (legal area). Fortunately, the actual correlation between *U* and *L* is very low (0.227). Thus, although *U* and *L* are slightly correlated, this correlation is not expected to affect the estimates of the coefficients of the model.

Exhibit 4 shows the geographical distribution of the sales data, the boundaries of the cities, the Cedar River and Highway 20. The rural sales surround the two cities, but tend to be clustered near the northwest and southeast quadrants of the county. Exploratory analysis of the data reveals that the traditional macro level measure of location, proximity to a CBD, is not statistically significant. However, distance to the river and the east–west highway variables are statistically significant. Therefore, proximity to the river and the highway will be used as the macro level location variables in the model.

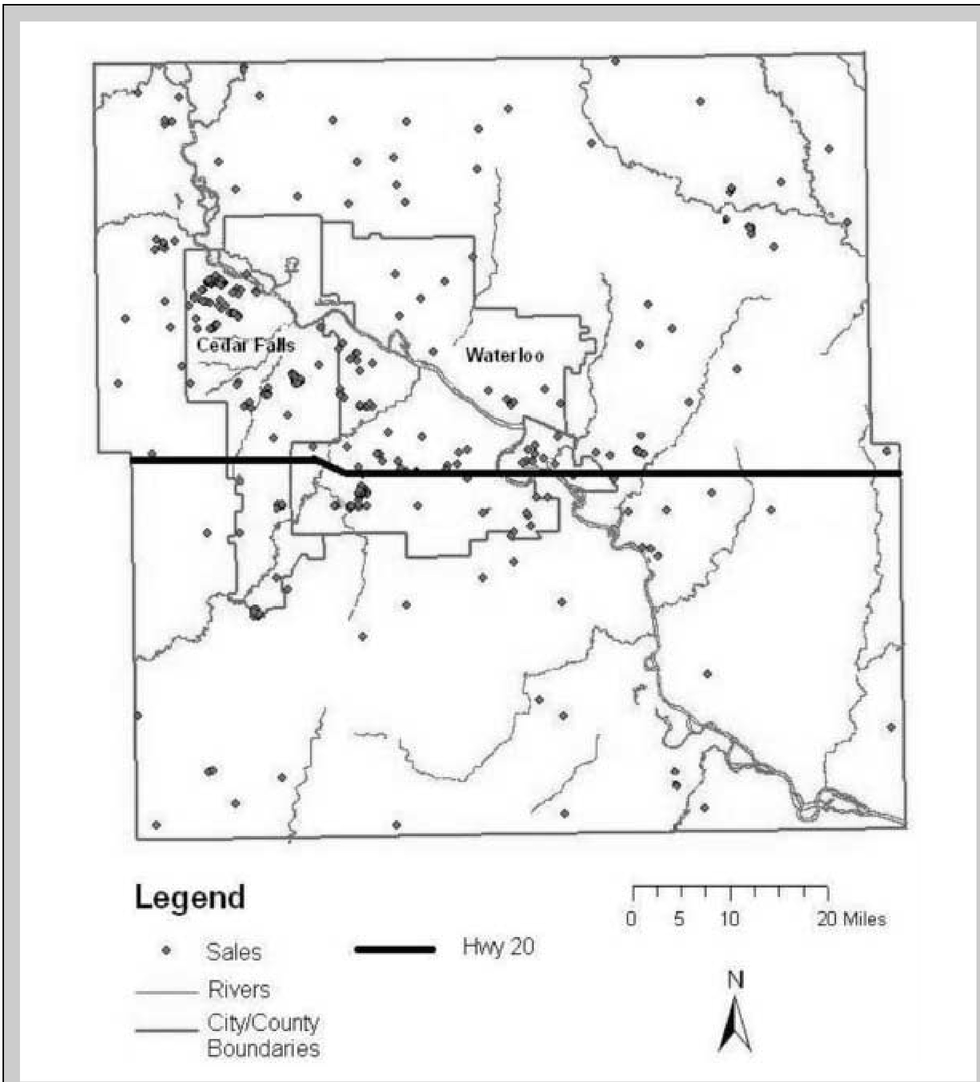
The OLS Results

Although it is possible to pool the data across jurisdiction as White (1988) did, doing so forces the mean structure of the model and the error term to have the same structure in all three jurisdictions (rural, Cedar Falls and Waterloo).

Exhibit 3 | Zoning and Type of Land

Zoning	Rural Areas	Cedar Falls	Waterloo
Panel A: Zoning			
Agricultural	79	0	0
Residential	74	112	94
Panel B: Type of Land			
Subdivided	76	61	36
Unsubdivided	77	51	58
Nonconforming	17	15	11

Exhibit 4 | Geographical Distribution of Sales Data and Salient Points of Influence



Furthermore, pooling the data across multiple jurisdictions defeats one of the purposes of this study, namely to avoid the problems associated with pooling land sales data across multiple jurisdictions. Therefore, the coefficients of Equation (3) will be estimated separately for each of the three jurisdictions. Exhibit 5 contains the coefficient estimates for each of the jurisdictions. First and foremost, the OLS estimates indicate that zoning in the rural areas is indeed binding as suspected, while the zoning in both cities appears not to be binding. It appears that the presence of considerable amounts of vacant, undeveloped land within each city is sufficient to prevent the 9,000 square foot minimum lot size from being binding.

Exhibit 5 | OLS Results

	Rural Areas		Cedar Falls		Waterloo	
Variable / Stat.	β	*t*-value	β	*t*-value	β	*t*-value
Intercept	92.212	5.54	125.538	1.14	249.296	2.34
Distance to River	−0.082	−4.96	−0.112	−1.05	−0.230	−2.24
Distance to Hwy 20	0.076	3.010	0.038	0.48	−0.146	−0.97
Time of Sale	−0.025	−1.34	0.023	2.56	−0.061	−3.58
Un (0, 1)	−1.230	−9.12	2.461	2.76	5.636	2.89
Log(Legal area)	−0.665	−16.81	−0.310	−1.05	−0.486	−0.83
UnLog(Legal Area)	0.266	4.74	2.368	3.75	4.630	3.44
$\beta_2 + \beta_3$	−0.399*		2.058*		4.144*	
R^2	0.7535		0.5664		0.4679	

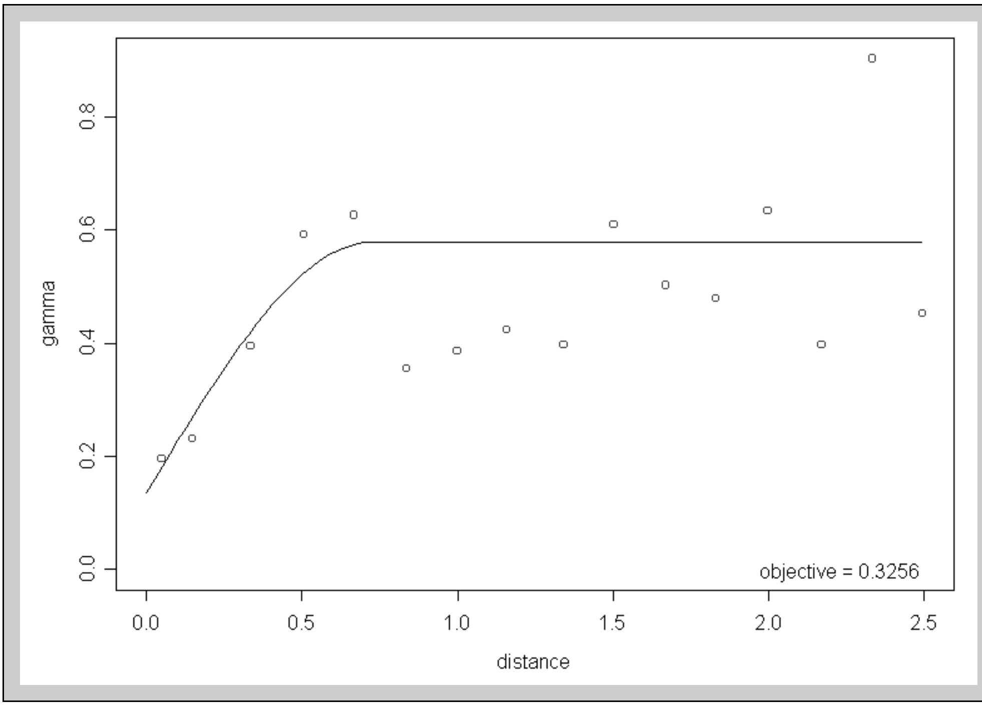
Notes:
*Indicates that ($\beta_2 + \beta_3$) is statistically significant at an $\alpha = 0.05$ level.
Un = 1 if the lot is unsubdivided, 0 otherwise. A lot is considered unsubdivided if it can be legally split into at least two smaller lots.

The rest of the coefficient estimates are also interesting. The two macro location variables have mixed coefficients. In Cedar Falls, neither of the macro location variables is significant, while in Waterloo only distance to the river is significant and has a negative coefficient. In Waterloo, proximity to the river increases land values, every thing else held constant. In Cedar Falls, proximity to the river or Highway 20 has no effect. However, in the rural areas, proximity to the river and Highway 20 are significant. In the rural areas, proximity to the river increases land values, while proximity to Highway 20 decreases land values. The pattern of the signs and significance of these estimates is not contrary to theory. Land near the river is very poor at growing crops; it is the only type of land that the county approves for subdivision into residential lots smaller than thirty-five acres. Highway 20 is obviously more influential in the urban areas than in the cities, and the sign of the coefficient needs explanation. In the rural areas, proximity to Highway 20 lowers land values, everything else held constant. Two features of the market explain this phenomenon. First, rural land further south of the highway has an increasing crop growing suitability rating. Second, rural land located north of the highway is very near the two cities. Thus, proximity to the highway is associated with higher land prices.

The time coefficient estimate is also revealing. Recall that all of the sales prices have been adjusted for inflation using the GDP Deflator. Thus, the time variable is picking up any trend in real prices over the twenty-year time span in the data. The coefficient estimates show that *real* land values, everything else held constant,

Exhibit 6 | Variogram

Panel A: Cedar Falls



Panel B: Waterloo

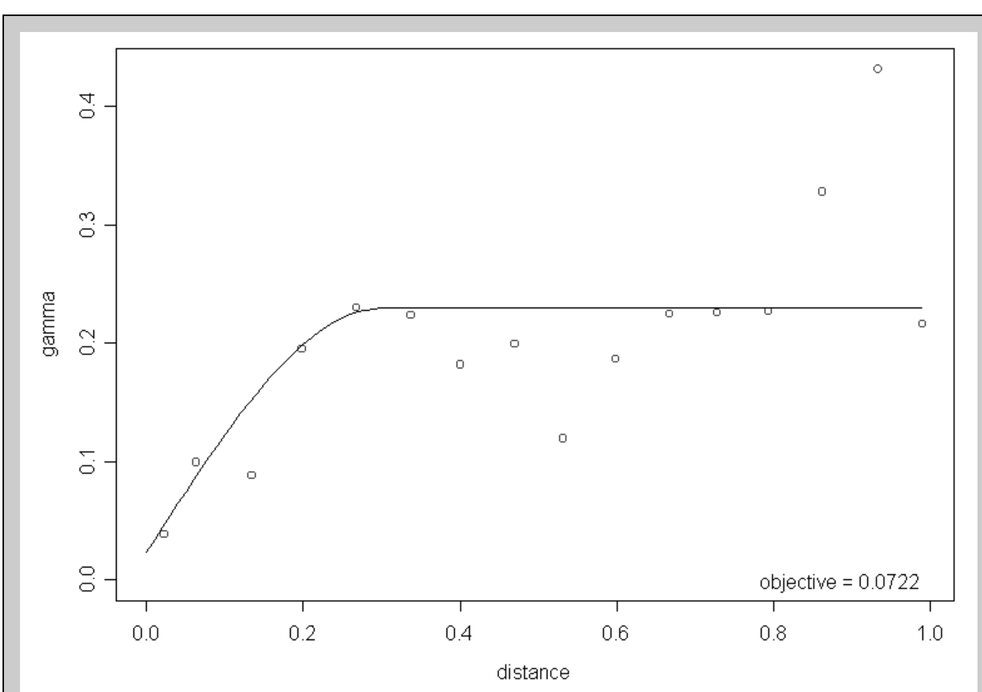
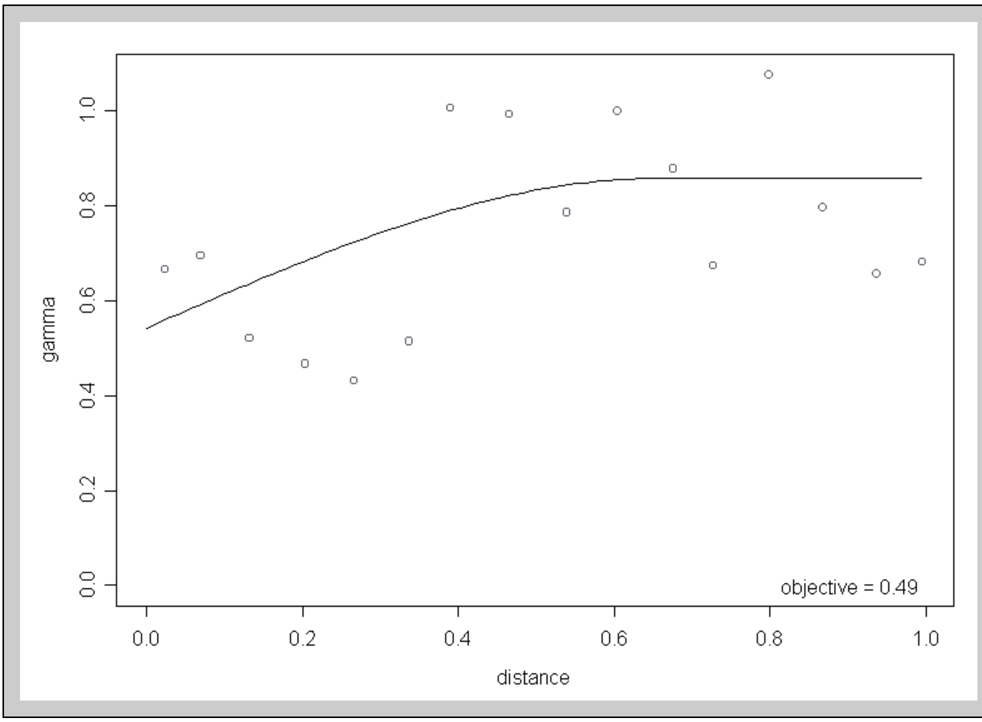


Exhibit 6 | (continued)

Variogram

Panel C: Rural



are increasing in Cedar Falls, constant in the rural areas and declining in Waterloo over the twenty-year time frame of the study. This pattern is not unexpected. Cedar Falls is considered a white-collar community, while Waterloo is considered more of a blue-collar community. Incomes in Cedar Falls were increasing, while incomes in Waterloo were declining over the time frame of the study. Moreover, as found in the experimental analysis mentioned earlier, these trends are indeed continuous. That is, the trends do not display a change point over the time frame of the study.

The Maximum Likelihood Results

In the second phase of the analysis, the residuals are examined for signs of spatial correlation. This examination is performed using variograms. Isakson and Ecker (2001) demonstrate how to make use of a variogram to examine residuals for spatial correlation. The variograms for the three study areas are portrayed in Exhibit 6. Although all three variograms are somewhat different, they all indicate the presence of spatially correlated residuals. Subsequently, each variogram is fitted using the spherical functional form to obtain estimates of the nugget, sill and range.[6] The nugget is the intercept of the variogram with the vertical axis; the sill is the value of gamma (plotted on the vertical axis) at the plateau reached for large distances; and the range is the distance at which the variogram reaches the sill.[7]

Maximum likelihood regressions are performed to estimate the coefficients of the mixed effects model. The mean structure of the mixed effects model is identical to the mean structure of the OLS model. However, the structure of the disturbance term is altered to match that of a spherical variogram with the three parameters estimated above. The results of this analysis are reported in Exhibit 7. The most important aspect of these results is that the estimates for β_2 and β_3 have not significantly changed. Therefore, the implications of the OLS analysis regarding binding zoning have not changed. That is, the maximum likelihood results confirm that the presence of binding zoning the rural areas cannot be rejected, while in the cities it can be rejected. The finding of increasing subdivision costs in all three study areas is also not affected by the spatially correlated residuals.

However, the presence of spatial correlation in the OLS residuals did appreciably change the significance of some of the other variables. For example, the time variable is now insignificant in Cedar Falls, but its significance is unchanged in Waterloo and the rural areas. There is also a slight change in the pattern of significance for the two macro level location variables. Distance to the river in

Exhibit 7 | Maximum Likelihood Results

	Rural Areas		Cedar Falls		Waterloo	
Variable / Stat.	β	*t*-value	β	*t*-value	β	*t*-value
Intercept	89.239	5.10	77.973	0.58	224.630	2.07
Distance to River	−0.070	−4.54	−0.065	−0.50	−0.207	−1.96
Distance to Hwy 20	0.067	2.58	0.022	0.24	−0.138	−0.88
Time of Sale	−0.013	−0.73	0.007	1.06	−0.053	−3.26
Un (0, 1)	−1.180	−8.96	2.437	3.09	5.432	2.84
Log(Legal area)	−0.646	−16.47	−0.137	−0.40	−0.407	−0.69
UnLog(Legal Area)	0.245	4.45	2.368	3.75	4.547	3.45
$\beta_2 + \beta_3$	−0.401*		2.231*		4.139*	
R^2	346.4		143.4		242.0	

Notes:
*Indicates that ($\beta_2 + \beta_3$) is statistically significant at an $\alpha = 0.05$ level.
Un = 1 if the lot is unsubdivided, 0 otherwise. A lot is considered unsubdivided if it can be legally split into at least two smaller lots.

Waterloo became barely ($t = -1.96$) insignificant, while the significance of the two macro level location variables in the rural areas and Cedar Falls has not changed.

In is important to note that the maximum likelihood estimates in Exhibit 6 should not be considered final estimates. In order to obtain more precise coefficient estimates, the maximum likelihood estimates should be used to estimate a new set of residuals, which should be examined for spatial correlation. If spatial correlation is still present, a new set of variogram parameters should be estimated and plugged into another maximum likelihood regression. Ideally, this process would continue until all of the spatial correlation is removed from the residuals. But this iterative process is not warranted in this study, because the first step in the process revealed no significant change in the key coefficients, β_2 and β_3. If the focus of the study was the time coefficient in Cedar Falls or the macro level location variables in Waterloo, additional iterations would have been warranted. But if there is no significant change in a coefficient of interest, there is no need to perform additional iterations.

Conclusion

This study extends the White test for the presence of binding zoning, which was originally developed to be applied across multiple jurisdictions, so that it can be applied within a single jurisdiction. The test is based on the relationship between the selling price of a parcel of land and the parcel's legal area. The legal area is the average lot size that would result if the parcel were subdivided into as many lots as legally permissible. The price–legal area relationship will differ between parcels that can and cannot be subdivided into smaller parcels. When zoning is binding, the price–legal area relationship for parcels already fully subdivided should lie above and have a steeper slope than the price–legal area relationship for land that can be further subdivided into smaller parcels.

Because this test needs many sales of parcels that are both fully subdivided, but of various sizes, and parcels that are less than fully subdivided, many years of land sales data are typically needed. This study applies the extended White test to twenty years of land sales data drawn from a small Midwest county containing two adjacent cities surrounded by rural land. The minimum lot size within the rural area is large (35 acres) compared to the cities (9,000 square feet), suggesting that the rural area zoning may be binding. Examination of the OLS estimates of the key coefficients of the model reveal the presence of binding zoning in the rural area but not the cities.

However, to test for the presence of binding zoning requires unbiased estimates of the key coefficients of the price–legal area model. Simple OLS estimates of these coefficients can be biased by the presence of spatially correlated errors. Upon examination of the error terms using the variogram technique, spatial correlation is highly evident. Therefore, the OLS estimates might be biased. To determine the extent of this bias, the coefficients are re-estimated using a mixed effects model in which the error term is structured to incorporate the spatial correlation reflected by the variograms. The coefficients of the mixed effects model are estimated using the maximum likelihood technique. Although some of the OLS coefficients were found to be biased, the key coefficients used to test for the presence of binding zoning were found to be unbiased. The results support the conclusion that the large lot zoning in the rural areas of the county is binding, while the minimum lot size in the cities is not binding.

Endnotes

1 Throughout this study the term ''price'' is used to denote the price per unit area, while the term ''value'' is used to denote the total price of the parcel; value = price * area.

2 In this example, the maximum number of lots (the whole number part of five divided by two) is two. The whole number (two) must be used because it is not possible to have any parcel less than the minimum lot size. Therefore, the legal area of the five-acre parcel is 5/2 acres or 2.5 acres.

3 See Gelfand, Ecker, Knight and Sirmans (2004) for additional discuss of this process.

4 The author thanks the Black Hawk County Board of Supervisors for their support of this study. But the any opinions expressed in this study are strictly those of the author.

5 See Anderson (1999) and Turnbull (1988) for details.

6 The S+ statistical package with a spatial module is used to estimate the parameters of the variogram.

7 See Wachernagel (1995) for further discussion of the nugget, sill and range parameters of a variogram.

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