Growth Controls and Fragmented Suburban Development: The Effect on Land Values

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Abstract
Spatially fragmented patterns of development have led to an interest in growth control measures aimed at altering the fragmented pattern and creating incentives to cluster development in the landscape. Due to the spatially dependent nature of land values, a geographic information system is used with statistical software to visualize and analyze the spatial pattern of land values in a fast growing suburban county of Washington DC. Spatial statistical measures of correlation and the semivariogram are used to measure the degree of spatial correlation and the distance over which the residuals of the hedonic land value model are correlated. These results are used in a spatial econometric framework to more efficiently draw inference on the effects of growth controls on the spatial pattern of land value. Hedonic analysis reveals that open space and rural preservation are implicitly positively capitalized into newly developed land values through zoning regulations.

I. INTRODUCTION

Policy makers use a variety of tools to curb growth, including limits on building permits, up zoning to reduce development densities, increasing development costs, and adequate public facility ordinances [11]. In the economics literature growth controls that restrict the amount of developable land have been shown to increase developed land values through either the supply effect of restricted development or the amenity effect of restricted development. [1] The supply effect increases land values because as supply becomes insufficient relative to the increasing demand caused by population growth prices are bid up. The amenity effect is the result of reduced population growth due to growth controls. Amenity effects could include reduced congestion, a reduction in the rate of loss of open space, or a reduced need for more schools.

A commonly used economic approach to modeling land values is based on the utility and preferences of the individuals supplying and demanding land. Preferences are based on the large variety of parcel attributes to which individuals attribute value, the supply and amenity effects of growth control. For example, individuals place different levels of value on proximity to road networks, open space, or school overcrowding depending upon their lifestyle and work habits. The preference based approach attempts to model the scope of individuals' preferences with hedonic techniques attributed to Rosen [30].

There has been a long history of spatial statistical methods with applications in many fields such as mining, geology, geography, and oceanography, but the recognition of spatial relationships is only in its infancy in economics. The typical hedonic study of land values has assumed the complete independence of land values and no spatial relationships. Only recently have economists begun to recognize the spatial relationships among individual values [8,9,10,12,13,16]. The commonality of these studies is that spatial relationships are imposed on the data with no empirical investigation of the relationships before a spatial structure is imposed.

This paper proposes an economic model of land values that uses the spatial statistical technique of semivariogram analysis to investigate the spatial relationships among land values and use this information to develop spatial structures and improve the estimation of hedonic models of land values. Semivariogram analysis is a well-established technique for analyzing spatial relationships in spatial statistical applications, but has not been used by economists to better understand the spatial relationships of economic phenomenon. The application of these techniques is to investigate the capitalization of growth controls on land values.

II. SPECIFICATION AND ESTIMATION

The Hedonic Land Value Function

Within the theoretical framework of Rosen [30], the hedonic price function represents the market clearing solution to the interaction of suppliers of land and the buyers of land. Sellers offer parcels of land as bundles of land characteristics and buyers bid for

[1] Studies of growth controls as supply restrictions include Katz and Rosen [24], Pollakowski and Wachter [29], Beaton [6], and Beaton and Pollock [7]. Studies of growth controls as amenity effects include Fischel [18], Navarro and Carson [28], and Engle, Navarro, and Carson [17].

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bundles of characteristics with the solution to the allocation problem represented by the hedonic price function. The hedonic price function describes the relationship between the value of a parcel of land and the characteristics of the parcel. These characteristics can be broadly classified as parcel specific characteristics, neighborhood specific characteristics, and location specific characteristics. This implies a general functional specification of land values as a composite bundle of characteristics,

$$V_i = f(S_i, N_i, L_i) \quad (1)$$

where V_i is the market value of the parcel, S_i is the set of parcel specific characteristics (such as lot size or zoning), N_i is the set of neighborhood characteristics (such as school quality, surrounding open space, or vacancy levels in the area), and L_i is the set of location specific characteristics (such as distances to urban centers and proximity to shopping).

Hedonic theory gives little guidance on the choice of the functional form for the hedonic specification. A variety of functional forms have been used, including semilog, log-log, and flexible Box-Cox transformation [14,19],which Goodman [19] used to allow flexibility in the hedonic specification across urban submarkets. Because the extent of this analysis is unlikely to transcend market boundaries and the focus is on an ex-urban region experiencing development pressure, this paper uses the semilogarithmic form,

$$V_i = e^{x_i\beta}, \quad (2)$$

where V_i is the land value, x_i is the vector of land characteristics (S_i,N_i,L_i), and b is the hedonic parameter vector.[2] This functional form allows the implicit prices of various characteristics to vary with other characteristics and reduces heteroskedasticity in estimation.

Incorporating the Spatial Relationship

Spatial hedonic models used to analyze growth control effects on developed land attempt to incorporate the spatial nature of land values through the use of spatial weight matrices that relate observations to each other over space. Usually the spatial relationships are assumed to be a function of neighborhood and location attributes of the parcel that are not included in the hedonic specification, a spatial lag of the dependent variable that is a function of neighborhood land values, or both.

Economists refer to the omission of attributes in the hedonic as omitted variable misspecification. It is unlikely that data is collected on all possible location characteristics affecting the housing decisions of the consumer because this type of data is hard to collect and there is no theoretical underpinning for the exact location characteristics that are relevant [14]. In addition, hedonic characteristics are often multicollinear so that adding characteristics to the hedonic function reduces the ability to draw inference from the model. The economist is required to determine as parsimonious a specification as possible while including the most relevant variables. Therefore, many characteristics are omitted either because they are unmeasured or they are left out of the specification to reduce multicollinearity.

The omitted characteristics are likely to be spatially correlated for two reasons. Neighborhoods are usually developed at the same time because of the development process. A developer must apply to the local government for development of a subdivision, which, upon acceptance, is divided into housing lots and built upon. The resulting development will have similar neighborhood characteristics such as similar quality of construction materials, architectural details, interior finishes etc. [5]. Secondly, the parcels share similar location amenities such as school districts, crime rates, income profiles, parks, and surrounding land uses. The fewer of these characteristics that are included in the hedonic specification the greater the spatial correlation amongst the omitted variables is likely to be [5,16].

The empirical link between omitted characteristics and spatial autocorrelation is well documented. Basu and Thibodeau [5] find evidence of spatial autocorrelation in residential submarkets of Dallas. They include parcel specific characteristics in the hedonic specification so that the spatial correlation is assumed to be location and neighborhood related. Can [12,13] develops hedonic housing specifications that include neighborhood and location characteristics. Can tests for spatial autocorrelation and finds significant evidence for its existence. Bell and Bockstael [8] use GIS technologies to develop a variety of neighborhood and location characteristics based on parcel location, including distance along roads networks to urban centers, direct measures of distance to landscape characteristics such as major roads, and percentage measures of various land uses within each parcel's local neighborhood.

The Spatial Hedonic Land Value Function

To add space to the hedonic land value function spatial data is thought of as a partial realization of a spatial stochastic process, $\{Z(s) : s \in D\}$, where D is a positive dimensional region and s is a continuous spatial index [15]. In other words, the process is

[2] Bocstael [9], Bockstael and Bell [10], and Bell and Bockstael [8] use the same functional form for similar applications to the one presented here.

observed at specific locations (the data points), but exists continuously throughout space. Spatial and temporal data can be included in this spatial stochastic process by considering *Z(s,t)*. Aggregating data over time returns the stochastic process to one of space only. Using the spatial interpretation of the data, the spatial lag is a weighted average of neighboring observations of the spatial stochastic process, and the spatially correlated omitted variables are unobserved variables at observed locations of the spatial stochastic process.

The hedonic can be respecified with spatial relationships as,

$$V_i = e^{\rho V_{lag} + x_i \beta + \varepsilon_i} \quad (3)$$

where ε_i represents the spatially correlated omitted variables, V_{lag} is the spatial lag, ρ is the associated parameter, and the other terms are as before. A parameterized spatial functional form is assumed for the spatially correlated omitted variables,

$$\varepsilon_i = \lambda \sum_j w_{ij} \varepsilon_j + e_i, e_i \sim N(0, \sigma_e^2), \quad (4)$$

where w_{ij} is a weight associating ε_i to all other ε_j, e_i is an assumed normally distributed random error, and λ is a spatial parameter. The weight elements, w_{ij}, relate every observation to all other observations in the neighborhood to represent a posited spatial structure of omitted characteristics in space. The speed with which the relationship declines is dependent on the construction of the weights,

$$w_{ij} = 1 / d_{ij}^{\,b} \quad (5)$$

where d_{ij} is the distance between observations i and j, and b is a parameter greater than one that effects the rate of decline in the spatial relationship, with an increasing rate of decline for higher b. Observations are not allowed to affect themselves so $w_{ii}=0$.

The spatial lag is the spatial representation of a time series lag implying that the land value of one parcel is in part determined by the value of neighboring parcels of land. V_{lag} is constructed as $V_{lag} = \sum_j w_{vij} V_j$. The weights, w_{vij}, are constructed in a similar manner to the omitted variables case with possibly different parameters, but represent the set of neighboring land values that affect the value of V_i.

The spatial relationship, whether for the omitted variables or the spatial lag, is assumed to be zero past some finite distance. In order to determine what the appropriate distance should be many authors try a number of different distances [8,12,13]. Others have suggested specifying a variety of finite distance bands and calculating spatial correlation statistics for each one [4,20]. The resulting spatial correlogram can be used to select the weights that will be used in the spatial analysis.This approach suffers from sometimes conflicting results such as non monotonic changes in the test statistic over the distance band and non-independence of the repeated statistical test.

Alternatively the semivariogram, a spatial statistical tool that requires no prior formulation of a spatial weights structure can be used. The semivariogram is based on the spatial stochastic process theory described above. It quantifies spatial variation over distance for a set of values, z_i, with spatial location, (x_i,y_i) and can be used to determine the appropriate distance past which spatial dependence is not present (see e.g. Cressie [15]). This approach has the advantage of not requiring prior information on the spatial relationships and it uses the data to assess the extent of the spatial relationship.

The variogram is,

$$2\gamma(s_i - s_j) = Var[\varepsilon(s_i) - \varepsilon(s_j)], \quad (6)$$

where s_i and s_j are paired location coordinates,(x_i,y_i) and (x_j,y_j) respectively. The semivariogram is $\gamma(\cdot)$. The experimental semivariogram corresponding to the theoretical variogram is the average squared difference in value between sample pairs of points seperated by h, the separation distance (or lag length),

$$\gamma(h) = \frac{1}{2n} \sum \{\varepsilon(s_i) - \varepsilon(s_i + h)\}^2, \quad (7)$$

where n is the number of sample points separated by h. Fitting a spherical variogram model to the above experimental semi-variances yields a function that represents the spatial correlation over distance. The spherical variogram model is chosen because it has a non-linear form with a finite range or sill. These properties are also likely to be found in spatial relationships of the data.The spherical semivariogram model is,

$$\gamma(d,\theta) = \begin{cases} 0 & d = 0 \\ \theta_0 + \theta_1 \left(\frac{3}{2}\left(\frac{d}{\theta_2}\right) - \frac{1}{2}\left(\frac{d}{\theta_2}\right)^3 \right) & 0 < d \le \theta_2 \\ \theta_0 + \theta_1 & d \ge \theta_2 \end{cases} \quad (8)$$

where θ_0 is referred to as the nugget, θ_2 is the range, and $\theta_0+\theta_1$ is the sill. The nugget allows the spherical semivariance model to be discontinuous near the origin. The sill, $\theta_0+\theta_1$, implies that correlation goes to zero at some distance, θ_2.[3] Using the estimated range of the theoretical semivariogram as a guide for the appropriate distance cutoff, the spatial weights can be constructed with more accurate information about the underlying spatial structure.

The spatial hedonic can be transformed as,

[3] For detailed discussions of the semivariogram see Cressie[15], Haining[20].

$$\ln(V_i) = \rho V_{lag} + x_i\beta + \varepsilon_i$$
$$\varepsilon_i = \lambda \sum_j w_{ij}\varepsilon_j + e_i, e_i \sim N(0,\sigma_e^2) \quad (9)$$

where the w_{ij} for the omitted variables and the w_{vij} for the spatial lag are implicitly functions of semivariograms, $w_{ij}(\gamma)$ and $w_{vij}(\gamma)$ Equation (9) describes the theoretical model of land values that corresponds to the following vectorized equation,

$$y = \rho \mathbf{W}_1 y + x\beta + \varepsilon \,, \varepsilon = \lambda \mathbf{W}_2\varepsilon + e, \quad (10)$$

where y is the vector of logged land values, $\rho W_1 y$ is vector notation for V_{lag}, $x\beta$ is vector notation for $x_i\beta$, $\lambda V_2\varepsilon$ is vector notation for $\lambda\sum_j w_{ij}\varepsilon_j$, and e is the vector of normally distributed errors, e_i. The complete parameter vector is $\theta = [\rho, \beta', \lambda, \sigma^2]'$.

From this general model one can derive the Ordinary Least Squares (OLS) model by restricting the spatial parameters to zero, $\rho=\lambda=0$, the Generalized Autoregressive (GAR) model, $\lambda=0$, and the Spatial Autoregressive (SAR) model, $\rho=0$. Therefore the OLS model has no spatial lag or omitted variables, the GAR form incorporates the spatial lag, and the SAR form incorporates the omitted spatial variables.

The empirical model can be estimated using Maximum Likelihood (ML) [3] implemented in the Matlab Spatial Econometrics Toolbox by James LeSage (www.econ.utoledo.edu). The general form of the likelihood function is,

$$L = -\left(\frac{N}{2}\right)\cdot\ln(\pi) - \left(\frac{N}{2}\right)\cdot\ln(\sigma)^2 + \ln|B| + \ln|A|$$
$$-\left(\frac{1}{2\sigma^2}\right)(Ay - x\beta)'B'B(Ay - x\beta) \quad (11)$$

where $\mathbf{A=I}-\rho\mathbf{W}_1$ and $\mathbf{A=I}-\lambda\mathbf{W}_2$. Applying the necessary parameter restrictions leads to the forms of the likelihood function for the OLS, GAR, and SAR model specifications.

III. APPLICATION AND RESULTS

In 1997 the Maryland State General Assembly adopted a set of programs that are collectively known as Smart Growth Initiatives. The key program in the set of initiatives is the Priority Funding Areas legislation, which limits state funding of infrastructure and economic development to "Smart Growth Areas" that local governments designate for growth. Additional programs in the legislation support the reuse of brownfields (previous industrial sites), provide tax credits for privately created jobs in Priority Funding Areas, and preserve undeveloped land through the Rural Legacy Program that provides resources for the protection of farm and forest lands from development. Smart growth is not "No growth", but planning that attempts to reduce the sprawling nature of development and preserve open space and quality of life, while providing development opportunities. Smart growth attempts to encourage development in locations that are environmentally and economically sensible with available or planned infrastructure capacity to accommodate the development.

Howard County was an early standard bearer for smart growth initiatives as described in its 1990 General Plan [22]. The General Plan includes growth control measures intended to preserve the rural nature of western Howard County, establish a definitive suburban/rural boundary, and provide opportunities for growth and development while ensuring sufficient public facilities availability. These ideas are paralleled in the Priority Funding Areas legislation and the Rural Legacy Program in the 1997 Smart Growth Initiatives.

Data has been gathered on sales transactions of newly developed residential parcels in Howard County between 1991 and 1997. Preliminary regressions found no significant time trend in land values over the eight-year sample period, therefore the data is treated as a partial realization of a continuous spatial process with no time dimension as described above. An observed sale in one year is treated as part of the same spatial stochastic process as an observed sale in a different year because sales are viewed as observable events that provide information on the spatial stochastic process regardless of their "location" in time. This is only possible when the data is stationary over the sample time span.

As one can see from the zoning map in Figure 1 with overlaid sales transaction locations, the 1990 General Plan is reflected in two large zoned areas for rural conservation and rural development that define the rural side of the suburban/rural boundary. Rural conservation zoning is intended to conserve farmland, encourage agricultural activities, and preserve natural resources and the rural landscape. Rural conservation zoning allows low density residential development that has minimal impact on the pre-residential state of the landscape with a density exchange option. Rural residential zoning allows low density residential development with a density exchange option, while maintaining a rural environment. It applies to an area of the county that is already committed to low density residential subdivision development [23].

The density exchange option for both zoning ordinances allows development at a higher density in one area in exchange for no development in another area. The land from which development is being removed must have important agricultural or

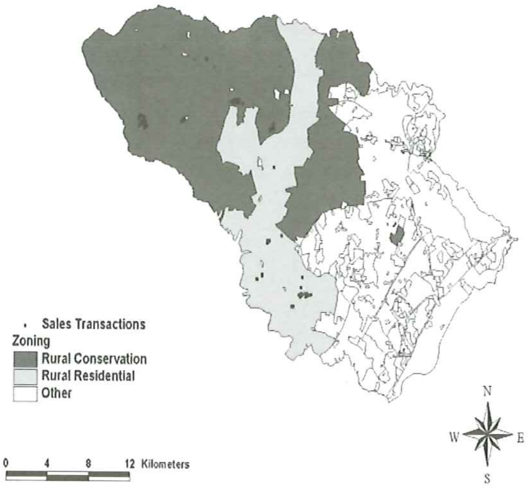

Figure 1. Howard County Zoning

environmental value, precluding the preservation of land with little or no value in alternative uses. The land must be a part of a larger area of protected land. This is intended to prevent scattered development of parcels, in effect clustering the undeveloped land as well as the developed land. The developer can add one housing unit to the receiving area for every three acres of land preserved, but is allowed to send the increased density to multiple receiving sites. In addition, the development rights for the undeveloped land must be permanently removed through enrollment in agricultural preservation, environmental easement programs, or donation to a land trust. The effects of clustering can be seen in the location of sales transactions in the rural conservation and rural residential zoning regions.

The value of land is the difference in the sales price and the assessed value of the structure on the parcel (Lnfmlv). The parcel size is expressed in acres (Lnacres). Of particular interest in the analysis is the effect of rural conservation and rural residential zoning. The sample of sales transactions is taken from these two zoning regions, providing the opportunity to investigate the value associated with the growth control mechanisms embedded in zoning ordinances (reduced development density, open space and rural preservation). Rural conservation zoning is distinguished by a dummy variable (Rural_Cons) equal to one for sales transactions located in rural conservation zoning areas. Rural conservation zoning is expected to have a significant effect on value relative to rural residential zoning, but it is unclear what the sign of the effect should be. If the effect on land values is positive then rural conservation zoning and the implied open space and rural preservation are positively valued in individual preferences. If the effect is negative then the rural residential zoning, with less open and rural space preservation in exchange for more shopping and transportation conveniences, is more prized in individual preferences.

Important location amenities include the nearby urban centers, Washington DC and Baltimore, MD. The distance over the road network is calculated from each sales transaction to Washington DC (Lndistdc) and Baltimore, MD (Lndistba). The affect of urban centers on the value of land is a likely proxy for any

Table 1. Variable Definitions[1-a]

Variable	Definition
Lnfmlv[1-b]	Dependent variable -Natural logarithm of land value
Lnacres	Natural logarithm of parcel size (acres)
Rural_ Cons	Dummy variable- 1 if sales transaction is in Rural Conservation Zoning
Lndistdc	Natural logarithm of traveling distance to Washington DC (meters)
Lndistba	Natural logarithm of traveling distance to Baltimore MD (meters)
Open[1-c,1-d]	% of land surrounding parcel in non developed use
Co800[1-c]	% of commercial land surrounding parcel within 800 meters
Pvacant	% of unoccupied housing units in the census tract
Yrsold	Year in which the property was sold

[1-a] Sample includes 86 observations of newly developed parcels of land in rural western Howard County Maryland between 1991 and 1997.
[1-b] Land value is the total sales price minus the assessed value of the structure at the time of sale.
[1-c] Surrounding land use is defined using GIS to include all parcels whose centroids are within a radial distance of a parcel.
[1-d] Open space includes agricultural land and undeveloped forest land.

Table 2. Regression Results

Variable	OLS	GAR (Variogram Ranges)	SAR (Variogram Range)	GAR (1600m Range)	SAR (1600 m Range)	GAR (Contiguity)	SAR (Contiguity)
Constant	43.032 (4.331)	42.050 (4.453)	42.733 (4.496)	42.153 (4.488)	42.410 (4.428)	48.035 (4.496)	42.171 (4.568)
Lnacres	0.269 (2.858)	0.277 (3.081)	0.270 (3.021)	0.277 (3.068)	0.271 (3.024)	0.238 (2.736)	0.251 (2.847)
Rural_Cons	0.511 (2.687)	0.495 (2.748)	0.504 (2.770)	0.498 (2.768)	0.499 (2.723)	0.510 (3.111)	0.491 (2.857)
Lndistdc	-2.085 (-3.176)	-1.995 (-3.148)	-2.070 (-3.306)	-2.021 (-3.235)	-2.057 (-3.271)	-2.084 (-3.535)	-1.996 (-3.308)
Lndistba	-1.294 (-3.803)	-1.302 (-4.029)	-1.288 (-3.961)	-1.294 (-3.996)	-1.282 (-3.915)	-1.377 (-4.346)	-1.263 (-4.092)
Open	-0.249 (-0.557)	-0.283 (-0.656)	-0.242 (-0.568)	-0.267 (-0.621)	-0.236 (-0.551)	-0.268 (-0.731)	-0.230 (-0.579)
Co800	15.006 (1.851)	14.524 (1.882)	15.006 (1.941)	14.693 (1.912)	14.953 (1.926)	17.506 (2.477)	14.036 (1.947)
Pvacant	8.522 (1.753)	8.367 (1.811)	8.578 (1.847)	8.520 (1.848)	8.645 (1.852)	10.058 (2.368)	8.196 (1.890)
Yrsold	0.041 (1.302)	0.043 (1.424)	0.042 (1.396)	0.043 (1.451)	0.043 (1.425)	0.037 (1.274)	0.037 (1.259)
ρ	-	7.099 (10.933)	-	93.291 (18.913)	-	0.126 (0.661)	-
λ	-	0.374 (0.086)	5.935 (0.197)	2.404 (0.093)	93.729 (0.412)	-0.321 (-71.655)	-0.157 (-0.832)

commuting costs or cultural amenity effects that individuals may attach to having access to these urban centers. The percentage of land within 1600 meters that is open space (Open), defined as agricultural or forest land, measures the capitalization effect of open space in land values. This is also an indirect measure of the benefits of open space and agricultural preservation programs. A measure of the percentage of commercial land within 800 meters (Co800) is included to determine whether land values are effected by the proximity of shopping and other commercial ventures. The effect of vacancy rates on housing values is represented by the 1990 Census percentage of vacant stock in the census tract (Pvacant). The year of the sales transaction is included to capture any possible price inflation over the seven year time period of sales transactions (Yrsold). All of the variables are described in Table 1.

The ordinary least squares results (Table 2) depict a positive effect of increasing parcel size on the value of land. The results also indicate a positive and significant effect of rural conservation zoning on land values. By restricting lot size and emphasizing clustering options to prevent excessive loss of open space the rural conservation zoning is capable of significantly increasing the value of land relative to rural residential zoning. If the increase in land value is significant enough to make the cost of development too high, zoning may be an effective growth control measure through a supply restriction. Alternatively, the increased value due to zoning may be the result of the implied open space and rural preservation, the amenity effects of rural conservation zoning.

The road network distances to Washington DC and Baltimore MD are both significant and negative indicating that land values decrease with distance from an urban center. This result implicitly supports the conjecture of monocentric and polycentric city models that describe land values as a decreasing function of distance gradients emanating from urban centers [1,25,27], but the proliferation of employment centers throughout the suburbs and the resulting complexity of commuting patterns makes the monocentric and polycentric models less suitable. In the hedonic preference based approach used in this paper the road network distance to the urban centers may explain the preferences of individuals to be close to the shopping, restaurant, nightlife, and cultural amenities that are usually found in urban centers.

One may expect open space to be a significantly valued amenity, but the results in the OLS regression indicate that this is not the case. Both zoning designations for the sample of sales transactions require larger lot sizes and are intended to preserve agricultural and rural open space. Therefore in a region with large amounts of open space the marginal value of more open space is not significant.
Commercial space in close proximity to a property is marginally significant. Figure 1 shows that some

commercial zoning (part of the Other classification) is present within the rural conservation zoning with a number of sales transactions clustered in close proximity to the commercial region. It is likely that this result indicates the preferences of individuals to have easy access to shopping conveniences.

The percentage of vacant properties is marginally significant and positive. This is counterintuitive to the notion that increased vacancy decreases value. The variable is derived from the 1990 census and the sales transactions occurred in the period between 1991 and 1997. Therefore, the vacancy variable is a measure of vacant non-residential land available prior to development. Increasing vacancy implies reduced agricultural activity, the primary non-residential land use in Howard County. The positive effect may then be explained by the negative externalities that residential land-owners associate with agricultural activities.

The attempt to control for possible inflationary effects over the seven year period of sales transactions is very marginally significant but positive. This implies that there has been very little systematic appreciation of land values during the 1990's in the rural portion of Howard County and justification for considering a spatial process underlying the data that has no time dimension.

An important diagnostics should be noted about the OLS regression. With an R-squared measure of .36, there remains a substantial amount of unexplained variation in land values. Two key variables remain omitted from the specification- crime rates and a measure of school quality. Home-owners and potential home buyers often place great importance in these two components of value. The author hopes to be able to include these variables in future work using this data, but presently they are unavailable land value attributes.

Spatial Models of Land Values

The actual and theoretical spherical semivariograms are estimated with a lag length of 200 meters. In Figure 2 the semivariogram for land values themselves indicates spatial correlation with an estimated range of 11,672.7 meters. After controlling for spatial effects with distanced based variables in the OLS regression, the residuals remain correlated to a range of 11,904.2 meters (Figure 3). Both semivariograms indicate spatial correlation over significant distances.

Spatial weights matrices are constructed using the semivariogram ranges, a predefined range of 1600 meters, and first order contiguity. Table 3 gives the mean, variance, and number of non-zero elements, neighbors, for each of the weighting schemes. These results highlight the differences that result from the different implicit spatial structures. Most obviously the number of neighbors is greatly affected by the choice of range. The variance of the weights increases with the range, the lowest being first order contiguity weighting scheme and the highest being the weights based on the semivariogram ranges. Intuitively, as the range increases more neighbors are included, but neighbors at greater distances are less likely to have similar subdivision and local neighborhood characteristics.

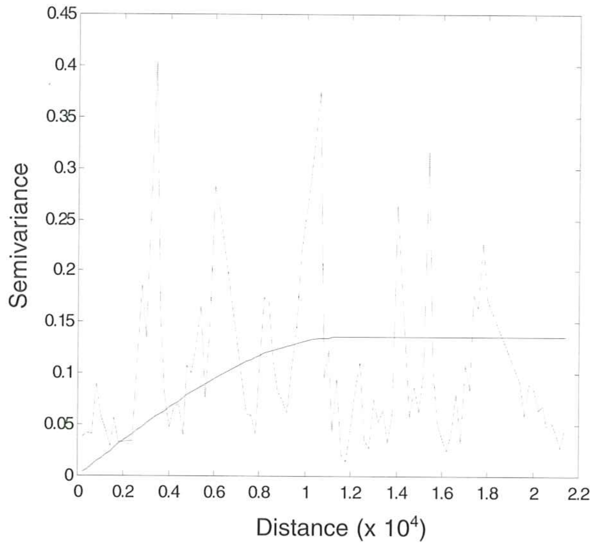

Figure 2. Land Value Semivariogram

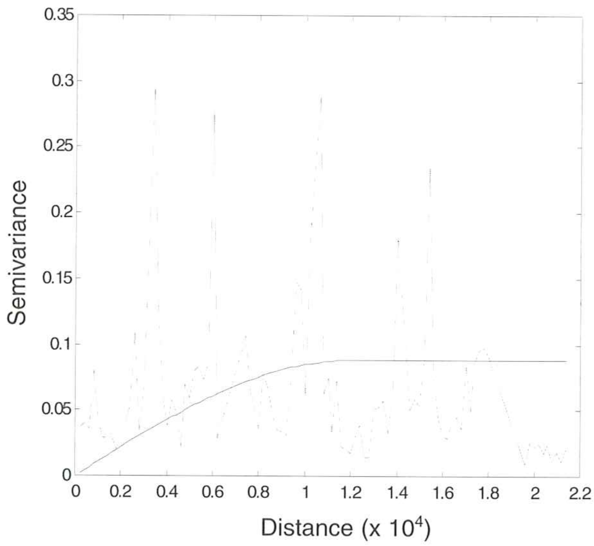

Figure 3. Residuals Semivariogram

Table 3. Spatial Weights

Weights	Mean[3-a]	Var[3-b]	Nghbrs[3-c]	Moran's I (prob)[3-c]	Description[3-e]
Residual Semivariogram	0.023	0.004	3774	0.911 (0.263)	Inverse Distance Squared Range=11,904.2 m
Land Value Semivariogram	0.023	0.004	3762	0.911 (0.263)	Inverse Distance Squared Range=11,672.7 m
A Priori Range	3.076 e-005	5.901 e-005	1292	0.6282 (0.3275)	Inverse Distance Squared Range=1600 m
Contiguity	0.174	8.673 e-004	486	0.310 (0.3802)	First Order Contiguity

[3-a] Mean is the mean of all non-zero elements of the weights matrix.
[3-b] Var is the variance of all non-zero elements of the weights matrix.
[3-c] Nghbrs is the number of neighbors (non-zero elements) in the weight matrix.
[3-d] Moran's I is a normally distributed test statistic with a null hypothesis of no spatial error correlation. These values are based on the residuals from the OLS regression and each weight matrix. Probabilites are given in parentheses.
[3-e] Description describes the weight type and the range used to construct non-zero elements.

Row standardization distorts the spatial relationships for each observation independent of the other observations by fixing each observation's neighbors influence to one. In reality there may be neighborhoods with very strong influences and neighborhoods with very weak influences. If one observation is located in a "dense" residential neighborhood and another observation is located in a "sparse" residential neighborhood we may not want to restrict the overall effect for each observation to be equal. Instead, the desire may be to allow some observations to have a larger overall spatial influence from its neighbors than others. For this reason the spatial weights are not row standardized.

Moran's I tests are also reported in Table 3. Moran's I is based on a quadratic formed by OLS residuals and the weights. The normal test statistic rejects the null hypothesis of no spatial correlation with a value of 1.96 only for the weighting scheme used in the quadratic form. Therefore, each test is a test of the specific weighting scheme. While the semivariograms indicate spatial correlation, the test statistics do not support this fact. This may mean that the weighting schemes are not based on the correct functional form of the spatial correlation or there are an insufficient number of observations in the data set.

Although the tests for spatial correlation are not significant, based on the semivariogram results two spatial models are estimated for each weight scheme. The generalized autoregressive form (GAR) and the spatial autoregressive error form (SAR).

In light of the test statistics, significance of the spatial parameters, ρ andλ, is not expected and the estimates should not change significantly from the OLS results. The GAR results for the weights based on the estimated semivariogram ranges are qualitatively identical to the OLS results. The t-statistics are generally higher in absolute value for all spatial GAR models relative to the OLS model indicating efficiency gains from the use of the GAR models. The GAR models using semivariogram based weights and 1600 meter range weights have significant spatial lag parameters, ρ, but insignificant spatial error autocorrelation parameters, λ, indicating that land values are a function of surrounding land values but not a function of omitted spatial variables. The SAR model spatial parameters, λ, are also insignificant, further evidence of no omitted variable effects. A point of interest that highlights the difference between the semivariogram based weights and the 1600 meter range weights is the difference in size of the spatial lag parameter (7.099 versus 93.291). The semivariogram weights draw on a much larger set of neighbors than the 1600 meter range weights so that the overall effect on land values of diverse neighbors is much less than more local neighbors. This result stresses the dependence of model results on spatial weight ranges.

In contrast to the distance based weighting schemes, the first order contiguity model reverses the significance of the spatial parameters. In the GAR model, the spatial lag,ρ, is insignificant and the spatial error autocorrelation parameter, λ, is significant. The standard errors change enough to make the vacancy and commercial space variables become significant. Otherwise, the parameter estimates for the other variables in the contiguity based models are remarkably consistent with those of all the other spatial models as well as the OLS model. These results highlight the different conclusions that can be drawn from the use of contiguity based weights relative to distance based weights.

IV. CONCLUSION

This analysis of land values in a spatial context has made use of the semivariogram, spatial statistics of correlation, and spatial econometric models to investigate the spatial pattern of land values. Results show that growth control through zoning that focuses on open space and rural land use preservation is positively capitalized into land values. The marginal effect of open space in the immediate neighborhood is not important, but proximity to commercial land uses is important. Semivariograms indicated the presence of spatial correlation, but Moran I tests did not find significant spatial correlation for the spatial weighting schemes chosen. Spatial econometric models improved the efficiency of OLS results and provide evidence that neighboring land values are correlated, but spatial omitted variables have no significant impact on land values.

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