GIS-Based Estimation of Housing Amenities:

The Case of High Grounds and Stagnant Streams

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Abstract: We use GIS and econometric methods to estimate the marginal implicit values of environmental amenities associated with residential land parcels in the mountain town of Logan, Utah. Amenities include proximity to open spaces (such as parks, golf courses and lakes), commercial zones, major roads, streams, and general visibility of surrounding topography in the valley as determined by the elevation of the land parcel. The amenity value estimates are corrected for spatial autocorrelation. We find spatially dependent relationships between (1) a parcel's value and its elevation, and (2) a parcel's value and its adjacency to a stagnant stream. To our knowledge, this is the first hedonic study to assess the effect of stream stagnancy on land value.

Keywords: hedonic valuation; stagnant streams; high elevation

JEL Classification: Q51, Q59

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1. Introduction

With the recent downturn in the US home market, prospective homebuyers have become more attentive to implicit values associated with the amenities of a given house (Little, 2010 and Boyce, 2010). In concert with the economic downturn and homebuyers' heightened attentiveness, local governments now have greater incentive to understand the determinants of land values, for both property-tax and community-planning purposes. An amenity value that is not commonly estimated in hedonic valuation studies and thus not well understood by local policy makers is adjacency to stagnant streams.[1]

This paper fills this gap in the literature by using Geographic Information System (GIS) data for the mountain town of Logan, Utah, and by employing recently developed econometric methods to control for spatial autocorrelation in the estimation of marginal implicit amenity values. We find a spatially dependent relationship between value and adjacency to a stagnant stream, in particular that the marginal implicit price of adjacency increases (from negative to positive values) as a land parcel's proximity to a commercial unit increases (i.e., as the land parcel is located nearer to a commercial unit, all else equal). To our knowledge, this is the first hedonic study to assess the effect of stream stagnancy on land value.[2] To the extent that stagnant streams are prevalent in other towns such as Logan, the need to estimate their effect on land values is warranted. Residential land parcels located close to these streams are commonly affected by bugs and excessive

[1] By "adjacency" we mean that the stream either intersects or borders a parcel. We describe how adjacency is actually measured in Section 4.

[2] Doss and Taff (1996) report ambiguous results for urban wetlands in Ramsey County, Minnesota, depending upon the wetland's characteristics. The authors find positive relationships between land values and proximity to what they call "open-space," "emergent vegetation," and "scrub-shrub" wetlands, but a negative relationship between land values and proximity to "forested" wetlands.

foliage, in addition to any potential positive attributes associated with stream access. Therefore, in towns with a prevalence of streams, adjacency is a potentially important, spatially dependent determinant of land value that local planners need to better understand.

Rosen (1974) initially interpreted housing as a differentiated product embodying varied characteristics. According to Rosen, these characteristics are not explicitly traded in markets, however their implicit marginal values can nevertheless be “revealed” through hedonic analysis. Rosen’s (1974) method of estimating the hedonic equation through demand and supply interaction was later criticized by several authors, such as Bartik (1987) and Palmquist (1984), which in turn spawned interest in measuring the effects of different spatial arrangements. More recently, hedonic studies have incorporated GIS data to account for the “viewshed” characteristics of housing units (Benson et al., 1998 and Paterson et al., 2002).

Using GIS applications to analyze spatial information, such as land records, natural resource features, and public infrastructure location, has become popular in the hedonic literature (Geoghegan, et al., 1997). For example, Cavailhes et al. (2009) evaluate hedonic landscape prices in the urban fringe of Dijon, France. The authors’ analysis quantifies the fringe’s visibility zone, enabling an estimation of how landscape features affect housing prices. They find that an obstruction of 10% of the viewshed (primarily of fields and trees) entails a loss in housing value of as much as € 2000 or more (approximately 2% of the average house price).

Irwin (2002) estimates the marginal values of different open space attributes using residential sales data from central Maryland in the US. The author reports marginal benefits of preserving open space ranging from $994 to $3,307 per acre of farmland, depending upon whether the land parcel is publicly or privately owned. However, Irwin's (2002) results do not control for spatial autocorrelation in the data. In contrast, Sengupta et al.'s (2003) estimation of ranchette prices in Arizona uses an inverse squared distance weights matrix to correct for spatial autocorrelation. The authors find that spatial autocorrelation exists in the data. Correcting for autocorrelation, the authors find that per-acre value of ranchettes increases by approximately $1,400 for a one-percent improvement in a satellite greenness index. They also report that increased distance from a major road decreases per-acre ranchette value by more than one dollar per mile.

In conjunction with this literature, this paper uses assessed values of land parcels and a host of GIS-derived explanatory variables to estimate the marginal implicit values of a variety of housing amenities. Explanatory variables include distance of the residential land parcel to nearest major road, distance to nearest commercial units (which include shopping malls, groceries, and other businesses), distance to nearest recreational area (which includes parks, lakes, and golf courses), year in which a house was built on the land parcel (which proxies for age of the parcel's development), neighborhood median household income, neighborhood population density, elevation of the land parcel, and, as discussed above, the parcel's proximity to the nearest stagnant stream.

In our dataset, streams are distinguished by slope, and slopes vary considerably in our study area. The main river flowing through Logan is a tributary of the Little Bear River. This river supplies irrigation water through a system of canals, which are more or less stagnant. Since Logan is a mountain town, a land parcel's elevation also potentially determines value based upon social prestige and perceived safety during floods.

The remainder of the paper is organized as follows. Section 2 briefly describes the geography and demography of Logan, focusing on the housing sector. Section 3 presents the underlying hedonic theory adopted in this study. Section 4 describes the data and Section 5 develops the empirical model used to estimate the data. Section 6 presents our empirical findings, and Section 7 concludes.

2. Description of study area

Logan is the main city in Cache County, located in northern Utah at an elevation of 4534 feet above mean sea level (USGS, 2008) and covering approximately 17 square miles in area (see Figure 1). Mormon Pioneers settled in Logan in 1859 and incorporated the settlement in 1866 (Simmonds, 1976). From 1990 to 2000 the city's population increased by 30.2%. It is expected that Logan's population will triple in size within the next 50 years, from its current size of 53,000 to 150,000 people (USCB, 2009).

[INSERT FIGURE 1 HERE]

During the period 2000-2003 Cache County, Utah was ranked 12th among US counties in births per 1000 people and ranked 49th lowest in number of deaths per 1000 (Utah Governor's Office, 2009). According to the Utah Health Department (2008), the state's average age of marriage for women is 22 years, and that for men is 24 years, both of which are among the lowest in the US. More than 40% of the city's population is between the ages of 20 – 34 years. Due to early marriages, the average age of couples buying homes is therefore relatively low.

3. Hedonic Valuation Model

We adopt Paterson and Boyle's (2002) theoretical framework and specify both the demand and supply sides of an underlying hedonic-pricing function.[3] Letting x represent the numeraire good (e.g., a composite commodity representing all goods other than housing), **E** represent a vector of environmental characteristics from which households derive amenity value, **L** represent lot characteristics (e.g., year built, acreage, and elevation), and **N** represent a vector of neighborhood characteristics (e.g., population density), a household's utility can be specified as,

$$U = U(x, \mathbf{\Omega}) \tag{1}$$

where $\mathbf{\Omega}$ represents the set containing vectors **E**, **L,** and **N**.

The household's problem is to maximize (1) subject to its budget constraint,

$$I = x + V(\mathbf{\Omega}) \tag{2}$$

where I represents household income and V represents the land parcel's value, which is directly dependent upon the elements of $\mathbf{\Omega}$. In addition, a potential seller's profit from offering a land parcel for sale can be thought of as:

$$V(\mathbf{\Omega}) - \mathrm{C}(\mathbf{\Omega}) \tag{3}$$

where C represents a standard cost function defined over $\mathbf{\Omega}$. In a market equilibrium, for any given attribute included in $\mathbf{\Omega}$, denoted q, a household chooses a parcel such that its marginal valuation of that q (i.e., the household's implicit value for q) equals a seller's marginal valuation of the same q (i.e., the seller's implicit value for q).[4] In other words,

$$\frac{\partial V}{\partial q} = \frac{\partial U / \partial q}{\partial U / \partial x} = \frac{\partial C}{\partial q} \tag{4}$$

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[3] See Rosen (1974) and Palmquist (1991) for more detailed theoretical frameworks.

[4] Since we are using tax assessor data, rather than actual market data, our hedonic model essentially approximates the equilibrium that our data would reflect if it were in fact market data.

Our objective in this study is to estimate a vector of regression coefficients (***β***s), which are akin to the marginal implicit values represented by $\frac{\partial V}{\partial q}\left(= \frac{\partial C}{\partial q} \right)$ in (4) for each q.

4. Data

The data used in this analysis is a cross-section from the year 2006. The sample of Logan residential land parcels was drawn from a GIS database provided by the Cache County Development Services Office in Logan, Utah. The database contains assessed values for a population of over 46,000 parcels located in the county, including separate tax values for land and buildings. It also includes acreage, year home was built, and tax ID number.

Utah is one of twelve non-disclosure states (meaning that when real estate transactions occur, the sales price is not required to become public information). Utah tax assessors use three methods to value a property: sales comparison, replacement cost, and rental income. Utah law requires properties to be adjusted to market value every year and physically inspected every five years (Utah County Government, 2011).[5]

Taylor (2003) notes that using assessed land value rather than sales price data can introduce measurement error in the dependent variable. However, this does not result in biased estimates of the implicit values if the error is uncorrelated with the set of independent variables. Rather, it reduces efficiency. As Taylor (2003) points out, the empirical question is whether tax assessor or sales prices are uncorrelated with the characteristics of the land parcels. She reports the results of an earlier study of assessed

[5] To validate these assessed values, the Utah State Tax Commission (USTC) performs an annual Assessment/Sales Ratio Study to measure the overall assessment performance and effectiveness of local assessments. According to its report for the period January 1 to Dec 31, 2006 (our study period) no corrective action order was issued for Cache County (USTC, 2011).

versus homeowner estimates of actual sales data by Ihlandfeldt and Martinez-Vazquez (1986) that found correlations with both types of data. However, tax-assessed values exhibited less correlation than homeowner estimates, suggesting that type of sales data may be a more important issue than whether the data is assessed value or actual sales price. Doss and Taff (1996) report similar evidence in their hedonic study of urban wetlands; in particular sales price and assessed values are found to be equally good proxies for land value in their sample from Ramsey County, Minnesota.

Prior to estimation, invalid and inappropriate records were omitted (these included lots with zero acreage, negative land assessed values, etc.). A zoning map (which categorizes the parcels into agricultural, commercial, industrial, manufactured homes, public, recreational, residential, and residential overlay) was used to filter out Logan's residential land parcels. After accounting for these restrictions and deletions, the final dataset contained observations on 8,322 parcels.

A GIS shapefile of major roads, streams, and recreational zones was obtained from the website of Utah GIS Portal (http://gis.utah.gov/sgid) on January 05, 2010. Data on population density and median household income was obtained from the U.S. Census Bureau (2010). Topographical data were taken from the digital elevation model (DEM), constructed by the U.S. Geological Survey from 7.5 minute (1:24,000 scale) quadrangles with ten-foot contour intervals. This data was converted to the projection North American Datum 1983, Universal Transverse Mercator – zone 12 north. The polygon shapefiles of parcels were converted into point shapefiles to calculate proximity measures such as distance to nearest major road, stream, commercial unit, and recreational zone.

The remaining explanatory variables – parcel elevation and stream slope – were generated using ArcGIS software. Proximity of a stagnant stream was ultimately defined as a dummy variable, where adjacent parcels receive a value equal to 1, and 0 otherwise.[6] A stream with slope one degree or less (i.e., a fall of at most 0.0174 meters per meter) is considered stagnant according to Paustian (1992) and Maser (2010). Lastly, the latitudinal-longitudinal information for each parcel was added to the original dataset using a DEM of Cache County, which was also available on the Utah GIS portal. Table 1 describes each variable used in our ensuing regression analysis, along with its sample mean (for logged and level values) and standard deviation.

[INSERT TABLE 1 HERE]

Of particular interest is the mean value for the dummy variable *dsl1*. The mean value of 0.28 indicates that roughly 30 percent of the parcels in our dataset are located adjacent to a stagnant stream.

5. Empirical Model

Overall, a double-log specification fit our data best.[7] Thus, our general estimation equation is specified as,

$$\ln V = \alpha_0 + (\ln \mathbf{\Omega})'\boldsymbol{\beta} + e \tag{5}$$

where, α_0 is a constant term, $\boldsymbol{\beta}$ is a corresponding vector of coefficients for attributes included $\mathbf{\Omega}$ (which are taken from Table 1 for this study), and e represents an error term

[6] We have measured adjacency to a stagnant stream as a dummy variable based on the assumption that only the values of those properties located strictly adjacent to a stream are affected by the stream's presence. By comparison, the values of non-adjacent parcels are relatively unaffected. This assumption was verified by regression analyses that revealed adjacency measured as a cardinal distance does not enhance its marginal significance in explaining a parcel's value.

[7] Box-Cox transformation analysis (using the 'boxcox' command in Stata SE v. 11.1) indicated that a double-log specification is statistically justified. Dummy variables are not logged in our double-log models.

(independent and identically distributed with mean zero and constant variance σ^2 after correcting for spatial autocorrelation). As is well known, in the double-log specification the **β** coefficients provide mean estimates of elasticity.

The most common problem with spatial data is spatial dependency, or spatial autocorrelation. This problem is similar to that of serial autocorrelation in time series data. Spatial autocorrelation implies a covariation of land parcels within geographic space: characteristics at proximal locations are correlated with one another, either positively or negatively. There are three possible explanations for this.

One explanation is a simple spatial relationship: latent determinants of an observation in one location also determine similar observations in nearby locations. A second possibility is spatial causality: something at a given location directly influences the characteristics of nearby locations. A third possibility is spatial interaction: the movement of people, goods or information creates apparent relationships between locations (Bhatta, 2010). The standard assumption of independence of observations is violated due to the existence of spatial autocorrelation. This problem can lead to unreliable coefficient estimates.

In our case, various spatiality tests using the GeoDa software indicated the presence of spatial autocorrelation in the data (in particular, statistically significant (and positive) lag coefficient, ρ, and Moran's I statistic reported in Table 2 below).[8] GeoDa offers two different modeling approaches to control for spatial autocorrelation – lag and error models. The spatial lag model introduces an additional regressor to the basic model (5) in the form of a spatially dependent variable, i.e., an inverse distance matrix. This model is

[8] We used GeoDa alpha release 0.9.8.16 to test and correct for spatial autocorrelation in our data. For a nice introduction to GeoDa's characterization of the spatial autocorrelation problem and its solution techniques see Anselin et al. (2004).

appropriate when the focus is on the assessment of existence and strength of spatial interaction. On the other hand, the spatial error model addresses spatial dependence in the regression disturbance term directly. It is a special case of a regression with a non-spherical error term, in which the off-diagonal elements of the covariance matrix express the structure of spatial dependence (Anselin, 1999). We estimated both models and report results for the spatial lag model.[9]

Following Anselin (1988), a general model of housing valuation including spatial effects can be expressed as, [Shish, you will need to investigate the specific model that GeoDa estimates and make any necessary changes to the following discussion about the empirical model we describe in equations (6) and (7).]

$$\begin{aligned} V &= \rho W_1 V + \mathbf{\Omega}'\boldsymbol{\beta} + \varepsilon \\ \varepsilon &= \lambda W_2 \varepsilon + \mu \\ \mu &\sim N(0, \sigma^2 I) \end{aligned} \tag{6}$$

where W_1 and W_2 are NxN spatial weights matrices. We have used inverse distance between parcels as spatial weights for our study. Vector ε is an Nx1 spatial autoregressive error term, μ is an Nx1 normally distributed random error term with mean zero and constant variance σ^2, and ρ and λ are coefficients on spatially lagged variables V and ε.

According to Taylor (2003), estimation of models with spatial dependence, but not spatial heterogeneity (i.e., λ=0 in equation (6)), are less computationally intensive. Gawande et al. (2001) also point out that estimation of λ via maximum likelihood becomes problematic with large samples sizes. Therefore, we assume λ=0 and the hedonic valuation model with spatial effects in our case becomes,

[9] Results for both models were qualitatively similar. The spatial-error model results are available from the authors upon request.

$$\ln V = \rho W_1 \ln V + \mathbf{\Omega}'\boldsymbol{\beta} + \varepsilon$$
$$\varepsilon \sim N(0, \sigma^2 I). \tag{7}$$

Equation (7) is the equation we ultimately estimate in Section 6.

6. Empirical Results

As mentioned in Section 5, the double-log specification of our model fit the data sufficiently well. We therefore began by estimating an OLS version of the double-log model to establish a basis for comparison. For both the OLS and Spatial Autocorrelation Models presented in Table 2, we follow Fik et al.'s (2003) variable interaction approach to provide additional spatial control in our estimation by accounting for intraurban variation in land valuation. In our case, we have created a dummy variable, *dc*, which takes the value one if the land parcel is located within the sample mean distance to the nearest commercial unit, and zero otherwise (see Table 1). This dummy variable is then included in the regression equation, both alone and as an interaction term with each of the remaining explanatory variables.

[INSERT TABLE 2 HERE]

In columns two and three of Table 2, we report the coefficient estimates and associated standard errors, respectively, from the OLS model (corrected for heteroscedasticity using White's (1980) method). We find that several of our coefficients are statistically significant in explaining variation in assessed land value.[10] These results

[10] We ran several specifications of (7) using different combinations of the explanatory variables listed in Table 1. In the end, the income variable, *incln*, was excluded from the analysis due to its relatively high correlations with several of the remaining variables [Shish, you need to confirm this statement]. Being a neighborhood characteristic that is likely measured with error (particularly relative to the other location and and property characteristics included as explanatory variables in Table 1), Graves et al. (1988) and Boyle and Taylor (2001) suggest that removing *incln* may reduce bias in the remaining coefficient estimates. Results for our analysis with *incln* included are available upon request from the authors.

are interpreted below as part of our discussion of results from the Spatial Autocorrelation Model since the results across the two models are qualitatively similar.

Since the estimated Moran's I index (Moran, 1948) and Lagrange Multiplier (lag) for the OLS regression reported in Table 2 (70.75 and 530.57, respectively) are both statistically significant at the 1% level, uncontrolled spatial autocorrelation in the data is affecting the OLS results. Results for the Spatial Autocorrelation Model are presented in columns four and five of Table 2. To begin, *dsl1* is negatively related to land value. In particular, the value of a parcel located adjacent to a stagnant stream (and *beyond* the mean distance to the nearest commercial unit of 900 meters) averages four percent less than an identical non-adjacent parcel, all else equal.[11] In dollar terms, this reduction in land value associated with adjacency to a stagnant stream equals approximately $9,300 on average (based on the mean value of assessed land value of $232,470 from Table 1). Any advantages associated with living adjacent to a stream of at most one percent slope (again, beyond the mean distance to the nearest commercial unit) are therefore offset by their disadvantages.

To the contrary, the value of a parcel located adjacent to a stagnant stream and *within* the mean distance to the nearest commercial unit, denoted by the sum of the coefficient estimates for *dsl1* and *dc_dsl1* in Table 2, averages roughly nine percent more than an identical non-adjacent parcel, all else equal, which translates into an associated increase in per-acre land value of roughly $20,922.[12] The marginal implicit values of stream adjacency and proximity to a commercial unit therefore appear to be complementary,

[11] Following Halvorsen and Palmquist (1980), we convert the coefficient on dummy variable *dsl1*(-0.040) to its corresponding percentage marginal effect using the equation $100*(e^{\beta} - 1)$, where $\beta = -0.040$. We thank an anonymous reviewer for pointing out this necessary transformation.
[12] In this case, $\beta = 0.124 - 0.040 = 0.084$.

since the mean coefficient value associated with the sum of dummy variable *dc* and its interaction terms, where each term is evaluated at its mean value (from Table 1), is roughly 40 percent.[13] We are presently unsure what could be driving such a strong positive effect of stream adjacency on land value for parcels located closer to commercial units. Since there are no apparent direct monetary benefits associated with stream access regardless of parcel location, it seems that latent preferences for the esthetics of stream adjacency are driving this spatial dependency.

Results for elevation also exhibit a spatially dependent pattern. In this case, land value is positively(negatively) related to elevation for parcels located beyond(within) the mean distance to the nearest commercial unit. In specific, beyond the mean distance to the nearest commercial unit a one-percent increase in elevation results in a roughly four-percent increase in mean land value (\$9,300), all else equal, suggesting that Logan households prefer living at higher elevations, where there is generally less congestion and better views of the valley. Within the mean distance to the nearest commercial unit a one-percent increase in elevation results in a roughly five-percent decrease in mean land value (\$11,600). Thus, the values associated with being nearer a commercial unit and higher elevations are inversely related. This result likely reflects the fact that the preponderance of commercial units in the valley are located at relatively lower elevations.[14]

The coefficient estimates for *roadln* and *dc_roadln* demonstrate the opposite pattern of spatial dependency as those for *dsl1 and dc_dsl1*, i.e., land value is negatively related

[13] The sum of the interaction terms (evaluated at their respective mean logged values) equals -62.66, which, when added to the coefficient value for *dc*, equals 0.34. Applying the Halvorsen and Palmquist (1980) conversion for $\beta = 0.34$ results in a roughly 40 percent marginal effect.
[14] Garrod et al. (1992) and Paterson et al. (2002) find that elevation can have a negative effect on land value when the parcels are associated with specific disamenities.

to distance from the nearest major road for parcels located beyond the mean distance to the nearest commercial unit, but positively related for parcels located within the mean distance of the nearest commercial unit. This result suggests that people living further from a commercial unit nevertheless positively value living closer to a major road, but those already living relatively close to a commercial unit do not obtain additional benefit from a major road's proximity.

Finally, the coefficient estimates for *denln* and *dc_denln* indicate that neighborhood population density negatively affects land value (solely within the mean distance to the nearest commercial unit); *recln* and *dc_recln* indicate that a parcel's value increases with distance from the nearest recreational zone (reflecting the fact that the majority of recreational areas in the city are located in lower-elevation areas, which in turn are associated with lower land values on average); and *builtln* and *dc_builtln* indicate that, on average, more recent land developments are associated with higher parcel values. The Spatial Autocorrelation Model reports an R^2 of 34 percent.

7. Conclusions

We have used GIS data and econometric methods that control for spatial autocorrelation in the estimation of marginal implicit values of environmental amenities associated with residential land parcels in the mountain town of Logan, Utah. Amenities include proximity to open spaces (such as parks, golf courses and lakes), commercial zones, major roads, streams, and general visibility of surrounding topography in the valley as determined by the elevation of the land parcel. Most pertinent for this study, we have found spatially dependent relationships between (1) a parcel's value and its elevation, and

(2) a parcel’s value and its adjacency to a stagnant stream. Although hedonic analysis of environmental attributes has become increasingly prevalent in the economic literature, mountain towns such as Logan, Utah have not been studied as often. To our knowledge, classification of streams based on slope is a novel approach to controlling for stream adjacency.

For states such as Utah, which have implemented non-disclosure policies, assessed land values are a convenient source of real estate data, but may not provide as accurate a measure of value as market sales prices themselves. Future work should therefore work to incorporate market transaction values obtained from local real estate agents. Nevertheless, an approximate implicit value of housing amenities can be identified using assessed valuation, as has been done in this study. Our results can help real estate developers and local planners price undeveloped areas with similar amenities. The study’s results can also reduce the cost of obtaining estimated assessed values. Our empirical approach can be used to help cities estimate the effect on their tax bases of various land improvements.

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Figure 1. Map of Logan's Location in Utah.

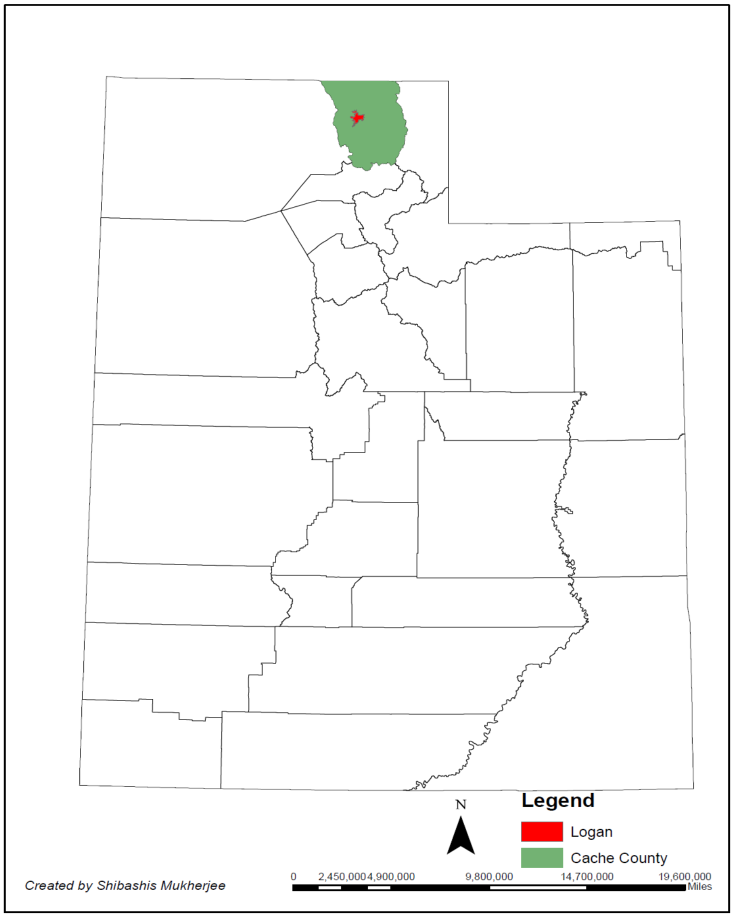

Table 1. Dependent and Explanatory Variables: Definitions and Descriptive Statistics.

Variable	Description	Mean Logged Value	Standard Deviation[a]	Mean Level Value
lvalacln	Natural log of assessed per acre land value (dollars).	12.36	0.74	232,470.95
roadln	Natural log of distance of parcel to nearest major road (meters).	5.97	0.95	391.40
dsl1	Adjacency to stream with slope one degree or less, = 1 if adjacent, 0 otherwise.	---	0.45	0.28
dc	Distance to nearest commercial unit, = 1 if less than 898.47 meters (mean of distance of parcel to nearest commercial unit), 0 otherwise.	---	0.50	0.52
builtln	Natural log of year in which residential land parcel was first developed (1862 =1, 1863 = 2, etc.).	4.61	0.36	100.91
eleln	Natural log of elevation of parcel (meters above mean sea level).	7.24	0.03	1397.14
recln	Natural log of distance of parcel to nearest recreational zone (meters).	6.30	0.62	545.11
denln	Natural log of neighborhood population density (persons per square mile).	4.73	0.83	113.62
incln	Natural log of neighborhood median household income (dollars).	10.53	0.33	37271.65

[a]Standard deviations are reported for the logged values, except in the case of the two dummy variables *dsl1* and *dc*.

Table 2. Estimation Results (*lvalacln* dependent variable).

Explanatory Variables	OLS Model		Spatial Autocorrelation Model	
	Coefficient	Standard Error	Coefficient	Standard Error
constant	-16.730***	2.678	-19.995***	2.592
dc	63.495***	3.928	63.000***	3.797
roadln	-0.080***	0.011	-0.078***	0.010
dc_roadln	0.187***	0.015	0.170***	0.015
dsl1	-0.045**	0.022	-0.040*	0.021
dc_dsl1	0.125***	0.030	0.124***	0.029
eleln	3.590***	0.378	3.899***	0.366
dc_eleln	-9.098***	0.549	-8.985***	0.531
denln	0.008	0.012	0.008	0.012
dc_denln	-0.071***	0.019	-0.056***	0.019
recln	0.059***	0.018	0.058***	0.018
dc_recln	0.073***	0.024	0.074***	0.024
builtln	0.648***	0.032	0.652***	0.031
dc_builtln	0.316***	0.043	0.242***	0.041
ρ	-	-	0.084***	0.004
Summary Statistics				
N	8,322		8,322	
R^2	0.29		0.34	
F	260.09***		.	
Moran's I	70.75***		.	
Lagrange Multiplier (lag)	530.56***		.	
Log Likelihood	-7,643.88		-7,380.23	

***significant at 1% level, ** significant at 5% level, *significant at 10% level