

# Hedonic Valuation of Land Protection Methods in the Rural-Urban Fringe: Implications for Cluster Development

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## Abstract

This study applies a spatial-autocorrelation hedonic model in the context of the rural-urban fringe in a high-growth, high-amenity region, to estimate the degree to which residential property values are affected by the proximity of various types of protected lands, and by inclusion in a county-approved cluster development. The sample includes 4,008 single-family residential transactions in the non-urban portions of Larimer County in northern Colorado from the period 2001-2004. The model allows for differentials among topographically different areas, in a region that is geographically diverse and includes numerous types of publicly and privately preserved lands. Key findings include: (1) property values exhibit robust relationships to core hedonic attributes, namely parcel attributes and neighborhood characteristics; (2) strong neighborhood price externalities exist within census block groups; (3) significant price differentials apply to topographically distinct subsections of the county property market; (4) under a variety of model specifications, only proximity to national and state parklands has a significant positive impact on property values, while city/county land, national forest, and privately conserved land exhibit marginally significant or no significant effects; (5) inclusion of a property in a county-mandated “cluster development” decreases its value. The results suggest important considerations for policy makers designing development rules and alternative land protection measures aimed at managing rural sprawl.

**JEL Classification:** *Q51, R14*

**Key Words:** *Hedonic valuation, open space, cluster development*

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## 1. Introduction

While urban sprawl is of major concern on the fringes of nearly every important metropolitan area, in some regions rural sprawl can be an equally serious threat to ecological integrity, natural and cultural landscapes, and socially efficient land use. Rural sprawl is the phenomenon of increasing population density in exurban and rural areas, beyond the immediate urban fringe (e.g., see Theobald, 2001). It often is more gradual, less dramatically visible, and more challenging to address in planning processes.

One planning concept of fairly recent application is “cluster development” in which an approved number of new houses is built in denser clusters, leaving larger areas of the developable land open and preserved for ecological, recreational, aesthetic, or agricultural purposes. Depending on the jurisdiction, such an approach may be required (if the planners have the authority) or may need to be induced (if landowners are vested with development rights that limit planners’ prerogatives). If cluster development provided sufficient “internalized” benefits to developers and the eventual homeowners, the market value of these developments would provide private motivation to undertake the approach. The fact that the approach normally must be mandated or induced by incentives suggests that such a private motivation does not exist, and that the social justification for adopting it must be based on “external” benefits to society. As with most other regulations, then, adoption will impose costs on the private parties involved, which may or may not require compensation depending on the structure of rights accruing to landowners.

In the present study we consider the case of a Western U.S. county in a high-growth, high-amenity region, where rural sprawl is a significant issue and rural landowners are legally vested with certain development rights that affect planners’ prerogatives. The area of study is Larimer County in north-central Colorado, which generally lies from 50 to 100 miles north of Denver, bordered on the north by Wyoming and on the west by the Continental Divide. The county includes urban and rural areas, and mountains and plains; it is home to some 300,000 residents and also hosts a large number of seasonal second homes. For the purposes of this study, we consider all of the non-urban regions of the county to be proximate enough and developable enough (protected lands aside) to be classified as the urban-rural fringe. Longstanding state legislation has provided landowners with a virtually unregulated right to divide and develop land so long as parcels are of at least 35 acres. As a result, a prevailing rural development pattern has been the division of large ranches and farms

into 35- or 40-acre “ranchettes,” with the accompanying fragmentation of the landscape.

We use a spatial-autocorrelation hedonic model to estimate the impact on home values of (1) proximate protected lands in various categories and (2) being in a county-approved cluster development, either a Conservation Development (CD) or a Rural Land Use Plan (RLUP) development. County planning has included the cluster concept since the late 1990s. We estimate hedonic price functions from a random sample of 4,008 non-urban single-family home transactions from 2001 to 2004, using spatial-lag, spatial-error, and generalized spatial-autocorrelation models. We use the results of these models to assess some implications of cluster development compared to other approaches to protecting open lands.

## 2. Review of Literature

The effect of proximate open space on property values is theoretically uncertain because positive environmental externalities (e.g., recreational opportunities or scenic views) can be outweighed by associated costs. Certain types of open space, such as golf courses or public parks, can also be associated with traffic congestion, noise, and other disamenities, making the net effect theoretically ambiguous. However, a large body of longstanding and recent literature indicates that proximity, location or total quantity of open spaces can significantly increase property values.<sup>1</sup>

Some studies stress the importance of distinguishing between publicly protected open spaces and privately owned spaces, which are potentially developable. A common finding is that the former type increases home property values, while the impact of the latter is often significant and can even be negative. According to Geoghegan (2002), for instance, a permanently preserved open space increases the value of residential lands almost three times as much as a developable open space. Other studies similarly demonstrate that, overall, preserved open space tends to increase the value of adjacent properties, while unprotected open space either decreases property values, or impacts them insignificantly (e.g., Irwin and Bockstael, 2001, Irwin 2002, Geoghegan et al. 2003). Furthermore, various land use planning policies might also affect housing values by limiting development and putting constraints on the types of structure that are allowed to be built. Essentially, planning policies create a constraint on land supply for individual uses (including housing), and increase the

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<sup>1</sup>See, among others, Kitchen and Hendon (1967), Weicher and Zerbst (1973), Correll et al. (1978), Nelson (1988), Lee and Linneman (1998), Bolitzer and Netusil (2000), Lutzenhiser and Netusil (2001), Acharya and Bennett (2001), Smith et al. (2002) and many more references therein.

costs of the structures put on the land. Thus, houses using larger, more expensive land parcels are likely to be affected most by the planning system. In fact, Cheshire and Sheppard (1989) find a significant effect of planning policies on house prices, and conclude that the impact is felt less on properties such as flats and terraced houses, as opposed to larger detached houses.

Other studies focus specifically on the amenity effects of surrounding land use patterns on property values. For example, an intact landscape is likely capable of supporting a well-functioning ecosystem with healthy habitat and less environmental degradation. On the other hand, increased fragmentation also can be associated with various amenities, such as easier access to shopping areas and schools. Thus, Geoghegan et al. (1997) find that people value the patterns of surrounding landscapes, and the impact of increased landscape fragmentation on a home's selling price may be negative or positive, depending on whether the parcel is in an urban or rural area. For example, only in immediate proximity to urbanized areas is greater fragmentation likely to be desirable. Anderson and West (2006) find a positive impact of open space on property values, but the results are substantially more pronounced for urban settlements with high population densities. They find that in neighborhoods that are twice as dense as average the value of the proximity to nearby parks is roughly three times higher than average, while the value of special parks is two-thirds higher than average.

A practical public ramification of how protected space affects private land values arises in connection with property tax revenues. Suppressing development by protecting land (by public ownership, acquisition of agricultural easements, etc.) will have a negative impact on the tax base, while the associated amenity benefits would be capitalized into affected land and home prices and increase the tax base. The net effect may be negative and represent a public cost of providing a public good, or it may be positive and enable the financing of even more open space acquisition, or other public goods.<sup>2</sup> Thus, Geoghegan et al. (2003) estimate that a 1 percent increase in preserved agricultural land generates sufficient tax revenue to purchase over 100 new acres of agricultural easement in one year.

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<sup>2</sup>Nickerson and Lynch (2001) reveal some statistical evidence that agricultural easements get capitalized into the price of an agricultural parcel. Blakely (1991) suggests that preservation restrictions are not fully capitalized into the farmland prices. Irwin and Bockstael (2001) and Geoghegan (2002) reach the opposite conclusions regarding preserved agricultural open spaces and the residential parcel values.

### 3. Theoretical Model

Following Rosen (1974) on hedonic theory, let the price of a house be a function of the various attributes when the housing market is in equilibrium. Formally,  $\mathbf{P}$  is an  $\{n \times 1\}$  vector of housing prices, with  $n$  standing for the number of observations;  $\mathbf{S}$  is an  $\{n \times k\}$  matrix of structural characteristics;  $\mathbf{N}$  is an  $\{n \times l\}$  matrix of neighborhood characteristics;  $\mathbf{L}$  is an  $\{n \times m\}$  matrix of locational/spatial characteristics. The objective is to estimate a hedonic price function:

$$\mathbf{P} = f(\mathbf{S}, \mathbf{N}, \mathbf{L}; \boldsymbol{\alpha}, \boldsymbol{\beta}, \boldsymbol{\gamma}), \quad (1)$$

where  $\boldsymbol{\alpha}$ ,  $\boldsymbol{\beta}$ ,  $\boldsymbol{\gamma}$  are the respective vectors of parameters.

Several problems may arise in estimation of equation (1). First, economic theory provides little guidance about the specific functional form of the hedonic price function. Some common functional forms are linear, semi-log, double-log, quadratic, linear or quadratic Box-Cox (see Taylor 2003).

Second, the econometric method matters in delivering more precise estimation of the parameters vectors. For instance, consider the case when a particular open space variable in (1) may be endogenous to a home value. That might happen when the open space is potentially developable at any time in the future so, in fact, nearby house prices *per se* influence how much open space remains. As a result, the traditional ordinary least squares (OLS) estimator will produce biased coefficient estimates (Irwin and Bockstael 2001, Irwin 2002).

Third, there might be spatial effects, not captured by the standard estimators. These are *spatial dependence* (when observations at one location depend on other observations in different locations), and *spatial heterogeneity* (when some spatially-varying omitted variables exist in the hedonic price equation).<sup>3</sup> Consider the first case, e.g., when a home's price is impacted by the values of neighboring homes. This can be represented by the *spatial-lag* (or the *spatial autoregressive*) model (SAR):

$$\mathbf{P} = \rho \mathbf{W}_1 \mathbf{P} + \boldsymbol{\alpha} \mathbf{S} + \boldsymbol{\beta} \mathbf{N} + \boldsymbol{\gamma} \mathbf{L} + \boldsymbol{\epsilon}, \quad (2)$$

where  $\rho$  is the spatial autocorrelation coefficient,  $\mathbf{W}_1$  is  $\{n \times n\}$  row-standardized spatial weight matrix,<sup>4</sup> capturing a definition of the neighborhood (by distance, contiguity, shared jurisdiction,

<sup>3</sup>See Anselin (1988), Lesage (1999), and Taylor (2003).

<sup>4</sup>The rows of the matrix are standardized to sum one.

etc.), and  $\epsilon$  is the  $\{n \times 1\}$  vector of independent and identically distributed (i.i.d.) error terms.<sup>5</sup> Due to the endogeneity in the  $\mathbf{W}_1\mathbf{P}$  (spatial-lag) term, the OLS estimators for (2) are biased and inconsistent, and maximum-likelihood or instrumental variables estimations are appropriate.

Now, consider the spatial heterogeneity case, where the error terms are spatially dependent due to the price at any location being a function of both the local explanatory variables and the omitted variables at neighboring locations. This can be represented by the *spatial-error model* (SEM):

$$\begin{aligned}\mathbf{P} &= \alpha\mathbf{S} + \beta\mathbf{N} + \gamma\mathbf{L} + \epsilon, \\ \epsilon &= \sigma\mathbf{W}_1\epsilon + \mathbf{v},\end{aligned}\tag{3}$$

where  $\sigma$  is the spatial autoregressive coefficient, and  $\mathbf{v}$  is an  $\{n \times 1\}$  vector of i.i.d. errors. The OLS estimator for (3) is unbiased, but inefficient. Either maximum-likelihood estimation or the method of generalized moments is required.

Lagrange multiplier tests and Moran's I statistics (Anselin 1988) are commonly used to detect either spatial heterogeneity or spatial dependence, or both. In the case when both spatial effects are present, the estimated model can be represented by the *general spatial model* (SAC), including both the spatial lag term and a spatially correlated error structure:<sup>6</sup>

$$\begin{aligned}\mathbf{P} &= \rho\mathbf{W}_1\mathbf{P} + \alpha\mathbf{S} + \beta\mathbf{N} + \gamma\mathbf{L} + \epsilon, \\ \epsilon &= \sigma\mathbf{W}_2\epsilon + \mathbf{v},\end{aligned}\tag{4}$$

where  $\mathbf{W}_2$  is the arbitrarily chosen  $\{n \times n\}$  row-standardized spatial weight matrix, different from  $\mathbf{W}_1$ .<sup>7</sup> The maximum-likelihood approach can be used for (4).

#### 4. Data

Our study area of analysis is Larimer County, Colorado which lies in a north-central area of the state within a range of approximately 50–100 miles north of Denver. Larimer County is topographically diverse from the perspective that the western portions of the county are very mountainous and are primarily comprised of Roosevelt National Forest and Rocky Mountain National Park.

<sup>5</sup>Spatial econometrics discussions in this section will closely follow Kim et al. (2003) and Taylor (2003).

<sup>6</sup>Specifically, the SAC should be used if there is an evidence that spatial dependence exists in the error structure from SAR model (Lesage 1999).

<sup>7</sup>Consult Lesage (1999) and Taylor (2003) on the specification of the spatial weight matrices.

Indeed, the Continental Divide constitutes much of the western boundary of the county. However, ranch and farmland comprise much of the eastern portions of the county at much lower elevations. Over 50 percent of Larimer County is publicly owned which provides a wide spectrum of recreational opportunities for residents and tourists. The cities of Fort Collins and Loveland are the largest in the county and these cities lie at the edge of the mountain/plain interface. Several of the smaller surrounding cities are located high in the mountains, such as Estes Park and Red Feather which lie to the west of Fort Collins and Loveland, yet several other smaller surrounding cities, such as Wellington and Timnath, are located on the plains in the more eastern portions of the county. Major employers in the county include Hewlett-Packard, Celestica, LSI Logic, Anheuser Busch, and Colorado State University. Larimer County has experienced rapid commercial and housing development into unprotected open space (such as private agricultural and ranch land), but the county also contains significant amounts of state-, county-, and city-protected open space in addition to the previously mentioned federal lands. In addition to core housing characteristics and traditional open-space valuation with hedonic methods, we are also particularly interested in assessing the value of the county's relatively recent manifestations of the cluster development concept, known as a *Conservation Development* (CD) or a *Rural Land Use Plan* (RLUP).

The observations in our econometric analysis are drawn from three distinct sources which we have merged into one data set. The unique observation identifier across all three data-sources is a parcel number with our focus being on single-family residential properties only. Housing characteristics as well as the most recent nominal sales price for each respective property were obtained from Larimer County Assessor's data. Demographic data on each single-family residential property within our data set were obtained from Census 2000 of the U.S. Census Bureau. Lastly, the spatial attributes of interest were drawn from a GIS-based open space analysis, the Colorado Ownership, Management, and Protection (COMaP) project of the Natural Resource Ecology Laboratory (NREL) at Colorado State University. In addition to obtaining spatial attributes via GIS from COMaP, we also categorized our data set into smaller distinct samples/subsamples such as urban, rural, and GMA for estimation purposes. A single-family residential property is defined as urban if it is located within an incorporated city limit, as GMA if the property is located within the county's *Growth Management Area*, and as rural if the property is located outside both incorporated cities

and GMA.<sup>8</sup>

For computational purposes, we narrowed our sample down from approximately 36,000 to exactly 4,008 observations to include only those that have a rural or a GMA designation. We thereby focus our statistical analysis on those parts of the county which can, overall, be considered the urban-rural fringes. Further, we narrowed our focus to only those parcels with a sales transaction within the years 2001–2004 to control for possible macroeconomic effects in housing markets that might be expected over larger periods of time. Furthermore, we used the local Denver-Boulder-Greeley, CO Consumer Price Index of the U.S. Bureau of Labor Statistics to convert all nominal sales prices into July–December 2004 housing prices.<sup>9</sup> In the case of repeated transactions for a particular parcel during the sample period, we included only the most recent transaction. Our final list of housing characteristics of interest include parcel square feet, building square feet, finished basement square feet, garage square feet, number of bedrooms, number of bathrooms, age of the home, and a dummy variable for central air conditioning.<sup>10</sup> We also include, as neighborhood characteristic variables, the following demographic data from Census 2000 at the block-group level for each observation: median household income, population density, percent of the census block-group that is white, median age of the population, housing density, percent of the block-group that is vacant, and percent of the block-group that is renter-occupied.

At the present, COMaP v6 is the most comprehensive, detailed and up-to-date spatial database about various types of open-space protection by federal, state, county, and city governments as well as non-governmental and privately-protected lands in Colorado. Using GIS software with our unique observation identifier, we computed euclidean distances (measured in meters) from each single-family residential property to the closest location of each respective type of open space documented within COMaP v6. A partial, nonexhaustive list of the specific types of publicly-protected open-space includes city parks, city dog parks, city open-space, city natural areas, city/county golf courses, county open-space, county natural areas, state parks, state wildlife areas, state fish-

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<sup>8</sup>The Growth Management Area (GMA) is the creation of an intergovernmental planning cooperation effort and is essentially an agreed band of county land that closely surrounds the cities and is likely headed for development and/or annexation.

<sup>9</sup>The local Denver-Boulder-Greeley, CO CPI is reported in semi-annual increments by the U.S. Bureau of Labor Statistics.

<sup>10</sup>At this juncture we should mention that we narrowed our list of final explanatory variables using a correlation coefficient, wherein we eliminated some variables with a correlation coefficient greater than 0.6 in order to reduce the risk of collinearity in our estimation.

eries, state habitat areas, U.S. Forest Service land, and U.S. National Park land.<sup>11</sup> In addition to publicly-protected lands, we also computed distance measures from each single-family residential property in our refined data set to privately-protected land held by non-governmental organizations and private land trusts, and (of particular interest) open space land associated with Conservation Developments and Rural Land Use Plans.<sup>12</sup> As an alternative to euclidean distance, we include dummy variables that indicate the proximity of a single-family residential property to different types of protected open space. For example, we have a proximity dummy variable that measures whether city/county open space falls within a 1/2 km radius extending in any direction from each parcel.<sup>13</sup> Related to open space and land plannign, we also include a dummy variable indicating whether a particular single-family residential property is part of a Conservation Development or a Rural Land Use Plan.

In order to control for possible intra-county differences in the local real estate market (differences purely due to location ), we classify observations in our samples with two additional dummy variables: an “EstesDummy” and a “SouthDummy”. The EstesDummy includes those observations that are in the mountain area near Rocky Mountain National Park and the twon of Estes Park; the SouthDummy includes those observations that are located in the southern areas of the county near Loveland and Berthoud, with shorter commute time to Denver; and the default location is the northern plains along with some northern mountain areas of the county, including Fort Collins. Lastly, to control for varying market conditions over the 4-year period of the sample, we include yearly dummy variables.

## 5. Estimations and Discussion

To allow for comparison and examination of robustness of the results, we modeled the hedonic price function several ways.

First, we used two different specifications regarding the measure of proximity to each type of protected open space. One set of models includes as explanatory variables the simple euclidean distance from each property to the nearest instance of each type of protected land. The other set

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<sup>11</sup>Euclidian distance measures are but one type of distance measure wherein we attempt to capture the effect of open space protection on housing prices. An alternative measure might be that of driving distance that could potentially capture open-space access benefits.

<sup>12</sup>We attempt to capture the internalized effect on housing price of participating in a Conservation Development or Rural Land Use Plan by including this dummy variable. The euclidean distance measure is intended to capture external effects on housing prices of residing in proximity to such private open-space protection plans.

<sup>13</sup>We believe that such a distance measure can capture open-space access benefits.

of models uses dummy variables to indicate whether each particular type of protected land occurs within a given distance or not. Thus we are able to compare the implications of one quantitative and one qualitative proximity variable.

Second, for each case we applied a spatial lag model (SAR), a spatial error model (SEM), and a generalized spatial autocorrelation model (SAC) allowing for both spatial lag and spatial error.

Third, these spatial models require use of a spatial weight matrix, and in the generalized model, two possibly different matrices. Given that the weight matrix is intended to represent the impact on each property's price of the prices of other properties in the neighborhood, specification of a weight matrix requires a definition of "neighborhood." A variety of options are available and, as suggested by Taylor (2003), it falls to the researcher to apply a definition that is relevant for the context. In our case of a county that is partly mountainous, "neighborhoods" would often be defined as long, narrow stretches of a canyon or county road. It can be more reasonable to count as a neighbor a property that is two miles up a shared canyon, than to count a property that lies over a high ridge but is only a quarter mile away and might even be contiguous. Two easily utilized location identifiers that correspond well with "neighborhoods" in this context are census block groups and zip codes. Therefore our analysis includes models that apply each one in each of the relevant instances.

The results of the estimations are shown in Tables 1 and 2. Table 1 summarizes the models in which  $\mathbf{W}_1$  is based on census block groups and  $\mathbf{W}_2$  is based on zip codes; Table 2 summarizes the models in which the roles are reversed. We can make the following observations from the estimation results summarized in Tables 1 and 2:

- All the models have a pseudo- $R^2$  of about 0.52, indicating a respectable degree of explanatory power, for cross-sectional analysis.
- The significance of the spatial effect parameters  $\rho$  and  $\sigma$ , at the 1 percent level of significance in each of the relevant models, indicates the presence of spatial effects of both the spatial-lag and spatial-error types. Consequently, though 12 models are presented for the purpose of comparison, there is justification for focusing on the generalized spatial autocorrelation (SAC) models as representing the fullest incorporation of spatial effects.
- The estimated hedonic price impacts of "core" property attributes are very robust across all

12 versions of the model. Lot size, building square-footage, and number of bedrooms all have significant positive effects on property value. Finished basement and garage size also generate statistically significant coefficients, though the practical impacts on price are virtually zero. Home age, air conditioning, neighborhood racial composition, and percentage renter-occupied appear not to have a significant effect. Neighborhood median income and median age have positive impacts on property values.

- Although transaction prices across the sample period have been adjusted for inflation in the basic data, the year of transaction still shows a significant effect on those real prices. Even adjusted for inflation, real prices of transactions in 2004 tended to be higher than in 2003, 2002, and 2001, in varying degrees, reflecting the varying strength of the housing market over these years.
- Other factors constant, prices in the Estes Park region of the county tended to be higher than in the Loveland area (“South”) or the Fort Collins area (the default).
- Focusing more on the primary research objectives of the study, we see that the estimated models indicate very robustly that inclusion of a property in a county-designated "Cluster" development—either a Conservation Development or a Rural Land Use Plan development—tends to markedly decrease parcel properties, other factors held constant. The magnitude of this effect, and its policy implications, are discussed in more detail below.
- Both the Euclidean distance models and the proximity-dummy models indicate that proximity to city and county open lands, as well as the National Park and state protected lands, tends to increase home values. On the contrary, there is much weaker evidence for such an impact for National Forest land, and no statistically evident effect of a proximity value for privately protected lands such as those that would be associated with cluster housing.

The actual magnitudes of the hedonic model coefficients cannot be interpreted as the marginal impacts on housing prices, in the SAR and SAC models, due to the neighborhood "externality" effects in those models, which are captured by the  $\rho$  coefficient. We now elaborate on this issue the value implications.

Table 1: Estimation results: with census block groups for  $W_1$  and zip codes for  $W_2$  <sup>a</sup>

Variable	SAC 1	SEM 1	SAR 1	SAC 2	SEM 2	SAR 2
Constant	2.927 <sup>***</sup> (8.236)	3.494 <sup>***</sup> (4.929)	2.802 <sup>***</sup> (5.607)	2.097 <sup>***</sup> (4.483)	2.469 <sup>***</sup> (4.085)	2.016 <sup>***</sup> (4.877)
2003	-0.068 <sup>***</sup> (-4.482)	-0.065 <sup>***</sup> (-4.260)	-0.067 <sup>***</sup> (-4.388)	-0.066 <sup>***</sup> (-4.356)	-0.063 <sup>***</sup> (-4.145)	-0.065 <sup>***</sup> (-4.243)
2002	-0.121 <sup>***</sup> (-7.676)	-0.115 <sup>***</sup> (-7.332)	-0.120 <sup>***</sup> (-7.625)	-0.121 <sup>***</sup> (-7.666)	-0.114 <sup>***</sup> (-7.289)	-0.120 <sup>***</sup> (-7.602)
2001	-0.131 <sup>***</sup> (-8.042)	-0.129 <sup>***</sup> (-7.869)	-0.129 <sup>***</sup> (-7.943)	-0.135 <sup>***</sup> (-8.295)	-0.133 <sup>***</sup> (-8.118)	-0.132 <sup>***</sup> (-8.093)
SouthDummy	-0.004 <sup>***</sup> (-0.192)	-0.011 <sup>***</sup> (-0.480)	0.001 <sup>***</sup> (0.049)	-0.003 <sup>***</sup> (-0.152)	-0.012 <sup>***</sup> (-0.502)	0.002 <sup>***</sup> (0.144)
EstesDummy	0.075 <sup>***</sup> (2.324)	0.106 <sup>***</sup> (2.692)	0.098 <sup>***</sup> (3.554)	0.068 <sup>***</sup> (1.963)	0.099 <sup>***</sup> (2.381)	0.102 <sup>***</sup> (3.730)
LN(ParcelFT <sup>2</sup> )	0.081 <sup>***</sup> (15.764)	0.089 <sup>***</sup> (16.377)	0.079 <sup>***</sup> (16.012)	0.079 <sup>***</sup> (15.060)	0.089 <sup>***</sup> (16.161)	0.078 <sup>***</sup> (15.421)
LN(BldgFT <sup>2</sup> )	0.491 <sup>***</sup> (24.210)	0.497 <sup>***</sup> (23.829)	0.499 <sup>***</sup> (23.340)	0.495 <sup>***</sup> (22.833)	0.502 <sup>***</sup> (24.164)	0.502 <sup>***</sup> (24.587)
BsmntFIN <sup>2</sup>	0.000 <sup>***</sup> (12.496)	0.000 <sup>***</sup> (12.548)	0.000 <sup>***</sup> (13.320)	0.000 <sup>***</sup> (12.484)	0.000 <sup>***</sup> (12.657)	0.000 <sup>***</sup> (13.411)
GarageFT <sup>2</sup>	0.000 <sup>***</sup> (4.713)	0.000 <sup>***</sup> (4.703)	0.000 <sup>***</sup> (4.690)	0.000 <sup>***</sup> (4.710)	0.000 <sup>***</sup> (4.653)	0.000 <sup>***</sup> (4.704)
DAC	0.016 <sup>***</sup> (1.019)	0.013 <sup>***</sup> (0.794)	0.018 <sup>**</sup> (1.172)	0.015 <sup>***</sup> (0.930)	0.011 <sup>***</sup> (0.664)	0.018 <sup>***</sup> (1.140)
LN(Bedrooms)	0.010 <sup>***</sup> (0.453)	0.012 <sup>***</sup> (0.526)	0.007 <sup>***</sup> (0.297)	0.014 <sup>***</sup> (0.623)	0.017 <sup>***</sup> (0.739)	0.011 <sup>***</sup> (0.476)
Age	0.000 <sup>***</sup> (0.337)	0.000 <sup>***</sup> (0.616)	0.000 <sup>***</sup> (0.616)	0.000 <sup>***</sup> (0.579)	0.000 <sup>***</sup> (0.965)	0.000 <sup>***</sup> (0.830)
LN(MedHHInc)	0.113 <sup>***</sup> (3.814)	0.357 <sup>***</sup> (6.601)	0.106 <sup>***</sup> (3.947)	0.135 <sup>***</sup> (3.892)	0.407 <sup>***</sup> (15.717)	0.116 <sup>***</sup> (3.889)
% White	-0.167 <sup>***</sup> (-0.894)	-0.398 <sup>*</sup> (-1.406)	-0.192 <sup>***</sup> (-1.056)	-0.127 <sup>***</sup> (-0.682)	-0.361 <sup>***</sup> (-1.217)	-0.125 <sup>***</sup> (-0.708)
LN(MedAge)	0.233 <sup>***</sup> (3.543)	0.322 <sup>***</sup> (3.030)	0.221 <sup>***</sup> (3.661)	0.199 <sup>***</sup> (2.942)	0.285 <sup>***</sup> (2.343)	0.169 <sup>***</sup> (2.820)
LN(HousDens, units/km <sup>2</sup> )	0.025 <sup>***</sup> (4.387)	0.029 <sup>***</sup> (3.385)	0.025 <sup>***</sup> (4.462)	0.028 <sup>***</sup> (4.875)	0.035 <sup>***</sup> (3.919)	0.030 <sup>***</sup> (5.570)
% RentOcc	-0.025 <sup>***</sup> (-0.294)	-0.002 <sup>***</sup> (-0.015)	-0.051 <sup>***</sup> (-0.590)	0.044 <sup>***</sup> (0.462)	0.076 <sup>***</sup> (0.477)	0.007 <sup>***</sup> (0.081)
DCD/RLUP	-0.260 <sup>***</sup> (-5.689)	-0.244 <sup>***</sup> (-5.320)	-0.262 <sup>***</sup> (-5.812)	-0.274 <sup>***</sup> (-5.966)	-0.259 <sup>***</sup> (-5.591)	-0.278 <sup>***</sup> (-6.141)
LN(City/CountyED)	-0.029 <sup>***</sup> (-3.784)	-0.022 <sup>***</sup> (-2.331)	-0.032 <sup>***</sup> (-4.232)	-	-	-
LN(NGO/Trust/PrProtED)	-0.000 <sup>***</sup> (-0.027)	-0.008 <sup>***</sup> (-0.935)	0.000 <sup>***</sup> (0.054)	-	-	-
LN(NForED)	-0.006 <sup>***</sup> (-0.899)	-0.003 <sup>*</sup> (-0.365)	-0.009 <sup>*</sup> (-1.437)	-	-	-
LN(NPark/SPark/SWldED)	-0.019 <sup>***</sup> (-2.852)	-0.025 <sup>***</sup> (-3.302)	-0.014 <sup>**</sup> (-2.288)	-	-	-
DCity/County 0.5km	-	-	-	-0.005 <sup>***</sup> (-0.123)	-0.028 <sup>***</sup> (-0.713)	0.012 <sup>***</sup> (0.329)
DCity/County 2km-0.5km	-	-	-	0.037 <sup>**</sup> (2.212)	0.019 <sup>***</sup> (0.929)	0.047 <sup>***</sup> (2.876)
DNGO/Trust/PrProt 0.5km	-	-	-	0.017 <sup>***</sup> (0.567)	0.025 <sup>***</sup> (0.787)	0.019 <sup>***</sup> (0.635)
DNFor 0.5km	-	-	-	0.047 <sup>*</sup> (1.425)	0.039 <sup>***</sup> (1.081)	0.056 <sup>**</sup> (1.947)
DNFor 2km-0.5km	-	-	-	0.015 <sup>***</sup> (0.507)	0.012 <sup>***</sup> (0.357)	0.014 <sup>***</sup> (0.558)
DNPark/SPark/SWld 2km	-	-	-	0.062 <sup>***</sup> (3.032)	0.082 <sup>***</sup> (3.314)	0.044 <sup>**</sup> (2.290)
DNPark/SPark/SWld 5km-2km	-	-	-	0.028 <sup>*</sup> (1.539)	0.043 <sup>**</sup> (2.022)	0.016 <sup>***</sup> (0.904)
$\rho$	0.280 <sup>***</sup>	-	0.299 <sup>***</sup>	0.293 <sup>***</sup>	-	0.323 <sup>***</sup>
$\sigma$	0.358 <sup>***</sup>	0.474 <sup>***</sup>	-	0.408 <sup>***</sup>	0.505 <sup>***</sup>	-
pseudo-R <sup>2</sup>	0.53	0.53	0.52	0.53	0.53	0.52
Lik	2107.4	-188.0	-191.4	2104.6	-189.5	-194.9

<sup>a</sup> n = 4,008; Numbers in parentheses indicate asymptotic t-stats.  
 \*\*\* Significant at 1% level; \*\* Significant at 5% level; \* Significant at 10% level.

Table 2: Estimation results: with zip codes for  $W_1$  and census block groups for  $W_2$  <sup>b</sup>

Variable	SAC 3	SEM 3	SAR 3	SAC 4	SEM 4	SAR 4
Constant	2.044* (1.601)	4.108*** (12.840)	1.419*** (3.390)	0.929** (1.670)	3.392*** (8.028)	0.654*** (2.619)
2003	-0.066*** (-4.333)	-0.067*** (-4.387)	-0.067*** (-4.367)	-0.064*** (-4.231)	-0.066*** (-4.292)	-0.065*** (-4.242)
2002	-0.116*** (-7.412)	-0.121*** (-7.643)	-0.121*** (-7.641)	-0.116*** (-7.378)	-0.121*** (-7.640)	-0.121*** (-7.604)
2001	-0.130*** (-7.941)	-0.133*** (-8.078)	-0.131*** (-7.990)	-0.133*** (-8.177)	-0.139*** (-8.493)	-0.135*** (-8.254)
SouthDummy	-0.011 (-0.514)	-0.005 (-0.205)	-0.002 (-0.145)	-0.012 (-0.523)	-0.017 (-0.623)	-0.008 (-0.514)
EstesDummy	0.086** (2.080)	0.077** (2.061)	0.099*** (3.617)	0.076** (1.891)	0.048 (1.163)	0.102*** (3.698)
LN(ParcelFT <sup>2</sup> )	0.086*** (15.507)	0.084*** (16.036)	0.080*** (15.892)	0.086*** (15.631)	0.082*** (15.804)	0.077*** (14.809)
LN(BldgFT <sup>2</sup> )	0.494*** (23.909)	0.504*** (24.218)	0.511*** (25.400)	0.498*** (24.045)	0.508*** (25.050)	0.515*** (24.965)
BsmntFIN <sup>2</sup>	0.000*** (12.409)	0.000*** (12.203)	0.000*** (12.967)	0.000*** (12.506)	0.000*** (12.323)	0.000*** (13.041)
GarageFT <sup>2</sup>	0.000*** (4.676)	0.000*** (4.947)	0.000*** (4.899)	0.000*** (4.638)	0.000*** (4.901)	0.000*** (4.929)
DAC	0.013 (0.820)	0.021* (1.346)	0.023* (1.503)	0.011 (0.694)	0.020 (1.233)	0.023* (1.505)
LN(Bedrooms)	0.011 (0.489)	0.014 (0.592)	0.009 (0.392)	0.015 (0.675)	0.018 (0.806)	0.012 (0.537)
Age	0.000 (0.586)	0.000 (0.669)	0.000 (0.160)	0.000 (0.898)	0.000 (0.911)	0.001* (1.303)
LN(MedHHInc)	0.314*** (10.013)	0.284*** (7.239)	0.267*** (8.912)	0.349*** (15.313)	0.309*** (8.041)	0.289*** (8.307)
% White	-0.287* (-1.148)	-0.256* (-1.394)	-0.210 (-1.239)	-0.244 (-0.870)	-0.213 (-1.215)	-0.157 (-0.866)
LN(MedAge)	0.338*** (3.158)	0.327*** (4.947)	0.345*** (5.430)	0.306*** (2.764)	0.307*** (4.963)	0.301*** (4.786)
LN(HousDens, units/km <sup>2</sup> )	0.026*** (2.985)	0.019*** (3.471)	0.020*** (3.728)	0.031*** (3.565)	0.022*** (3.980)	0.025*** (4.656)
% RentOcc	0.039 (0.259)	0.012 (0.133)	0.045 (0.514)	0.109 (0.779)	0.094 (0.947)	0.107 (1.271)
DCD/RLUP	-0.246*** (-5.365)	-0.261*** (-5.665)	-0.258*** (-5.677)	-0.260*** (-5.637)	-0.274*** (-5.901)	-0.272*** (-5.962)
LN(City/CountyED)	-0.021** (-2.167)	-0.026*** (-3.191)	-0.028*** (-3.791)	-	-	-
LN(NGO/Trust/PrProtED)	-0.005 (-0.548)	-0.008 (-1.105)	-0.001 (-0.140)	-	-	-
LN(NForED)	-0.004 (-0.469)	0.003 (0.430)	-0.005 (-0.817)	-	-	-
LN(NPark/SPark/SWldED)	-0.024*** (-3.163)	-0.022*** (-3.298)	-0.014** (-2.250)	-	-	-
DCity/County 0.5km	-	-	-	-0.027 (-0.710)	-0.041 (-1.089)	-0.009 (0.236)
DCity/County 2km-0.5km	-	-	-	0.020 (1.022)	0.010 (0.605)	0.027** (1.654)
DNGO/Trust/PrProt 0.5km	-	-	-	0.022 (0.714)	0.019 (0.627)	0.022 (0.716)
DNFor 0.5km	-	-	-	0.043 (1.212)	0.009 (1.272)	0.032 (1.150)
DNFor 2km-0.5km	-	-	-	0.016 (0.482)	-0.012 (-0.392)	-0.002 (-0.069)
DNPark/SPark/SWld 2km	-	-	-	0.080*** (3.310)	0.068*** (3.229)	0.035** (1.847)
DNPark/SPark/SWld 5km-2km	-	-	-	0.039** (1.867)	0.026* (1.427)	0.002 (0.137)
$\rho$	0.143**	-	0.219***	0.165***	-	0.236***
$\sigma$	0.428***	0.542***	-	0.456***	0.626***	-
pseudo-R <sup>2</sup>	0.53	0.52	0.52	0.53	0.52	0.52
Lik	2110.3	-209.7	-209.6	2109.9	-214.1	-214.0
Moran's I statistic: 9.1			LM statistic: 45.7			

<sup>b</sup> n = 4,008; Numbers in parentheses indicate asymptotic t-stats.

\*\*\* Significant at 1% level; \*\* Significant at 5% level; \* Significant at 10% level.

## 6. Marginal Price Impact Estimates

A complication arises in interpreting the marginal impact of an open space variable in the SAR and SAC models, since the price vector is not given explicitly in terms of the independent variables in (2) and (4). Therefore, it is first necessary to present the models in explicit forms. After a series of algebraic manipulations, the marginal benefit (implicit price) of an arbitrary spatial variable can be presented as follows (Kim et al. 2003):

$$\frac{\partial \mathbf{P}}{\partial \mathbf{l}'_l} = \left\| \begin{array}{cccc} \partial P_1 / \partial l_{1m} & \partial P_1 / \partial l_{2m} & \dots & \partial P_1 / \partial l_{nm} \\ \partial P_2 / \partial l_{1m} & \partial P_2 / \partial l_{2m} & \dots & \partial P_2 / \partial l_{nm} \\ \dots & \dots & \dots & \dots \\ \partial P_n / \partial l_{1m} & \partial P_n / \partial l_{2m} & \dots & \partial P_n / \partial l_{nm} \end{array} \right\| = \gamma_l [\mathbf{I} - \rho \mathbf{W}_r]^{-1}, \quad (5)$$

where  $\mathbf{l}'$  is  $\{1 \times n\}$  row-vector of one spatial characteristic,  $\mathbf{I}$  is  $\{n \times n\}$  identity matrix and  $r = \overline{1, 2}$  in our specification. The Jacobian matrix in (5) implies that the home value at one point in space is affected both by a marginal change of one particular locational characteristic at that point and by marginal changes of locational characteristics at all other points in space. To obtain the total impact, we sum across the space to find that  $\frac{\partial \mathbf{P}}{\partial \mathbf{l}'_l} \mathbf{i} = \gamma_l [\mathbf{I} - \rho \mathbf{W}_r]^{-1} \mathbf{i}$  reduces to  $\gamma_l \left( \frac{1}{1-\rho} \right) \mathbf{i}$ , where  $\mathbf{i}$  is a given column of the  $\mathbf{I}$  matrix (see Kim et al. 2003), and  $\frac{1}{1-\rho}$  is called a *spatial multiplier*. Finally, it is clear that in the case of the spatial-error models (SEM) the estimated coefficient parameters can be interpreted as they are, in determining the marginal value effects.

Our estimation results suggest that development in a CD or RLUP decreases a typical home price by roughly 18 and 26 percent for the spatial-lag and spatial-error specifications, respectively. In general spatial model, the impact estimate is 17 percent.

## 7. Implications and Conclusions

The hedonic models presented here appear, on the basis of summary statistics and the robustness of core results across the 12 variations, to meaningfully represent many of the major influences on single-family home values in a rural-urban fringe housing market such as the non-urban portions of Larimer County, Colorado. The modeling indicates that it is important to account for spatial effects of both the spatial-lag and spatial-error types. Of central interest to the objectives of this study are the implications that:

- Proximate protected open space in the form of public lands such as state and national parks, and city and county parks and natural areas, has a significant effect on home values. It is plausible that this effect is due in part to the fact that these open lands tend to be visible, accessible for recreation, and perhaps particularly secure in their status as protected land, or at least perceived as such. The values arising from these attributes, or from other special qualities generated by these lands, have a positive effect that presumably dominates possible negative impacts of associated congestion factors.

- Open space in the form of national forest has a weaker impact, possibly due to its relative plentifulness in a region such as our study area, or to a shorter list of associated recreational amenities, or to greater uncertainty about possible negative externality uses of forest land.

- Lands that are privately protected via conservation easements or outright ownership by land trusts and other non-governmental entities appear to have no appreciable impact on nearby home values. One can speculate that this lack of impact is due to the lack of publicly visible identification of these areas, to the lack of access by the general public, to the limited associated recreational options, or to greater perceived uncertainty about the permanence of the protection.

- Separate from simple proximity to privately protected open space, inclusion of a property in a cluster development appears to have a significant negative impact on value. This effect occurs independent of lot size or home size which may be other effects of a cluster housing approach. It indicates a reasonable decrement to market values when developers are not free to respond to pure market demands.

- The negative impact of clustering appears to be on the order of 15 to 25 percent. By coincidence or not, this is roughly the magnitude of the “bonus,” in terms of the number of approved additional home sites, that local planners tend to permit in cluster developments. Such a proportional offset would serve both to compensate developers for the per-house discounts they bear from clustering, and also to make such a planning approach tax-revenue-neutral in terms of its effect on the property tax base.

Further investigation of these issues could include analysis of more detailed data regarding the public amenities provided by different sorts of protected lands, and could follow the evolution of cluster-associated hedonic values as that approach begins to dominate the urban-rural fringe landscape. While alternative specifications of the spatial weight matrices, proximity measures,

housing attributes, etc., might be of some interest, the robustness of our results across several specifications suggests that the central conclusions may be unaffected,

Overall our results reinforce the idea that as a planning approach, cluster housing must be implemented using incentives from planners, and cannot be expected to arise from market incentives alone. The rationale for building such incentives into the planning and permitting process is based on the assumption that maintaining swaths of protected lands provides beneficial social externalities. These positive externalities may apply not so much to immediately proximate landowners, but to citizens more generally, who may hold values in support of the protection of ecological systems, pastoral landscapes, and efficient public infrastructure.

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