DISSERTATION

USING THE HEDONIC PROPERTY METHOD TO VALUE FEDERAL LANDS PROXIMATE TO URBAN AREAS: A CASE STUDY OF COLORADO SPRINGS, COLORADO

Submitted by

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ABSTRACT

USING THE HEDONIC PROPERTY METHOD TO VALUE FEDERAL LANDS PROXIMATE TO URBAN AREAS:

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Federal lands provide public benefits in many forms from consumptive to passive use. This dissertation explores the relationship between housing prices and federal land proximity to determine if there are property price effects for homes in close proximity to federal lands by using multiple spatial econometric techniques and model specifications for estimating hedonic pricing functions. First, relative economic values are estimated for public open spaces in El Paso County, Colorado. Then, the sensitivity of the estimated marginal values of proximity to federal lands is examined by varying the scale of the analysis from global (ordinary least squares) to local (geographically weighted). Finally, marginal values for the characteristics of the land uses on a federal land are calculated to determine if homeowner's value alternate land uses differently. The results show that multiple scales of analysis and model specifications should be explored when evaluating natural resource trade-offs because marginal values for environmental amenities vary across the landscape.

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TABLE OF CONTENTS

CHAPTER ONE

Introduction

There are three broad purposes for this research. First, the output provides resource managers and policy makers with information about how homeowners value federal land proximity for use when estimating the welfare implications of alternative resource allocation decisions in public lands management. Second, the research contributes to the field of natural resource management through a comparison of alternative model estimation techniques that incorporate spatial patterns when applying the hedonic property method. Third, the geo-database created will be available for future research on the interplay between land uses and societal values in the Colorado Springs area.

Research Questions

(1) Do homes adjacent or in close proximity to federal lands convey a price premium (discount) and how does the property price effect compare to other public lands in the study area?

(2) How do local and global model estimation techniques compare when applying the hedonic pricing method?

(3) Does differentiating the federal land based on the lands characteristics rather than ownership provide additional information important for setting natural resource policy?

Background

Approximately 30% of the United States land area, equivalent to 650 million acres, is owned and managed by the federal government and an additional 10%, approximately 200 million acres, by the states. These lands are managed to provide the public with maximized net social benefits through the allocation of natural and built capital to meet multiple objectives. Benefits accrue as public and private goods from the use of the lands (such as recreating or sustainable natural resource production) and because people value the existence of natural resources for use now and in the future. The ability to measure the total value of environmental resources to society is difficult because, unlike private goods where property rights allow for price signals, beneficiaries of public goods are not required to pay directly. Price signals from private goods are used by both buyers and sellers to determine if and when to enter transactions and therefore revealing values through the interactions between market participants.

Public goods and private goods differ because public goods are non-rivalrous and non-excludable (Samuelson 1954). Non-rivalry indicates one person's consumption does not reduce the availability of the good for another person, e.g. one person's consumption of air does not reduce the amount of air available for others. Non-excludability occurs when there is no way to prevent people who have not paid for the good from consuming, e.g. a lighthouse or national security, resulting in free-riding. Public goods exhibit jointness in supply where the rate of change (slope) of the supply curve is zero (vertical line) because there are no costs of supplying an additional unit of the public good. Markets fail in the case of public goods because of how aggregate demand and supply interact.

Demand curves represent the marginal benefits consumers have for additional units of a good. Aggregate demand is the sum of the individual demand curves and is equivalent to the market demand curve. For private goods, the demand curves for individuals are summed horizontally to get total marginal benefits equivalent to the market demand curve. For public goods, the demand curves for individuals (d_A and d_B) are summed vertically ($p_a + p_b$) and the total marginal benefit curve is steeper than would be the case for private goods with more price responsive demand curves (figure 1). If Q^* of the public good is provided, total marginal benefits from the last unit is P^* and, because consumers do not actually pay, the consumer's willingness to pay is used to estimate demand for public goods.

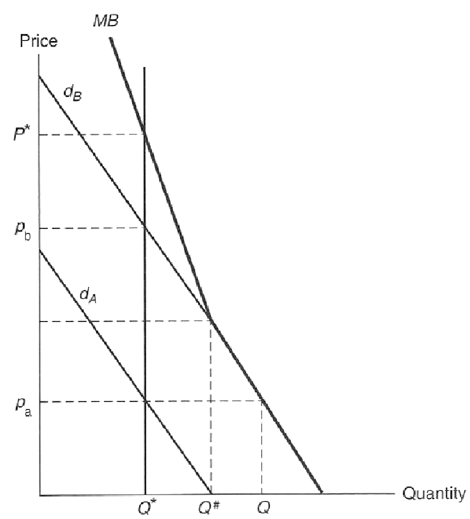

FIGURE 1. TOTAL MARGINAL BENEFITS CURVE FOR PUBLIC GOODS[1]

[1] Graphic from Boardman, A.E., D.H. Greenberg, A.R. Vining, and D.L Weimer. 2006. Cost-Benefit Analysis: Concepts and Practice. Upper Saddle River, NJ: Prentice Hall, page 89.

Valuing Public Goods Using Nonmarket Valuation Approaches

There are two primary methodological approaches to estimating willingness to pay for public goods. The first is the revealed preference approach based on people's behavior when there exists a (1) surrogate markets to value the public good in association with a market good that is used jointly in the consumption or an (2) existing markets for comparable private goods. A second approach is attitudinal and based on stated preferences to survey questions about hypothetical markets for public goods. General descriptions about how each approach is applied to valuing public goods are presented next.

The revealed preference approach is used when a market for a comparable or compatible good exists. Two methods are the hedonic pricing method and the travel cost method. The hedonic pricing method is the one chosen for this research and will be described in terms of the theoretical background and empirical specification in detail below. Generally, the hedonic pricing method is used to estimate economic values of local environmental attributes as is reflected in price differentials in labor and housing markets. In labor markets wage differentials are estimated based on job characteristics and is often used to estimate values for mortality risk (Viscusi 1979). In the housing market, the market price is considered to be the sum of the values for the individual characteristics of the house such as structural, neighborhood, location and environmental components. To apply the method, data on the components are needed in accordance with a well specified market area and time frame. Using regression analysis the housing price is modeled as a function of the individual components/characteristics that uniquely define each house. The results tell how much the value of the property will change for marginal changes in each characteristic, *ceteris paribus*. Then, conclusions regarding relative values for the various housing characteristics can be made. However, these estimates represent only the benefits to homeowners, but not renters or recreators. The model can be estimated for renters (Yoo and Kyriakidis 2009) but recreators require an alternate valuation method based on travel costs (Parsons 2003).

A second revealed preference approach can be applied to recreation because there are private markets to which comparisons can be made. The travel cost method is used to determine the value people place on recreation by determining the demand for the recreational site relative to the total cost of taking the trip. The total cost of taking the trip includes the opportunity cost of the recreators' time, costs associated with travel such as gas, the prices of substitute goods (other recreational sites). Factors that affect demand include income and other demographics that may influence tastes and preferences. Then, the willingness to pay to visit the site is estimated based the demand curve represented by the number of trips made based on the variations in travel costs. The most challenging elements are determining the opportunity cost of travel time, how to represent multi-purpose trips, and whether travel time is a cost versus part of the benefit of the trip.

Stated preference approaches are scenario-based and respondents are asked to report their values (willing to pay) for an environmental improvement or alternative. For example, the scenario could be for the protection of public open space and the payment mechanism could be a property tax. The benefit of the stated preference approach over the revealed preference approach is that the stated preference approach allows the experimenter to measure non-use values including existence, bequest and option values, as well as values for new goods or services beyond the current situation (Boyle 2003). Much effort goes into the survey design, pre-testing and implementation. Questions may be open where respondents state an amount or closed-ended providing discrete choices.

The contingent choice method, also called conjoint analysis, is a version of contingent valuation where respondents are provided hypothetical scenarios that differ with respect to attributes and then asked to choose their preferred scenario indirectly stating their willingness to pay for each attribute. Scenarios are analyzed based on relative marginal values for scenario attributes (Holmes and Adamowicz 2003). Contingent choice methods are particularly useful in valuation of alternative policies since the focus is on trade-offs among scenarios with different attributes and therefore relative rather than absolute values. An example application is provided in the next sections about estimating second-stage hedonic pricing functions, along with marginal and non-marginal welfare changes from environmental amenities.

Alternative methods to stated and revealed preference approaches for quantifying non-market values include benefits transfer, avoided cost, replacement cost, opportunity costs, production function and net factor income. The benefits transfer method estimates values using existing information from completed studies similar enough to warrant transferable results (Rosenberger and Loomis 2003). While original studies report mostly point estimates, the trend has been to provide more information through the transfer of the entire demand function (Loomis 1992) or use meta-regression analyses for more robust results (Walsh, Johnson, and McKean 1992). The steps to conducting a benefits transfer study include: identification and review of relevant studies to ensure estimates a transferable based on site and demographic characteristics and validity of results then to make an adjustments needed to better reflect the values for the site to which the benefits are being quantified. The other methods of avoided costs, replacement costs and net factor income are just as the name implies. Opportunity cost is the value of the next best alternative that could have been pursued. The production function method provides an estimate of what it costs to produce the good or service.

Hedonic Pricing Method

The hedonic pricing method is used to estimate economic benefits and costs associated with environmental amenities by examining market interactions for housing and wages. The theoretical specification for the hedonic price function applied to housing defines the house price vector (**P**) as a function of the individual characteristics of the house according to four categories in matrix form: structural components of the house (**S**), neighborhood demographic variables (**N**), location-specific attributes (**L**) and timing variables (**T**).

$$\mathbf{P}=f(\mathbf{S},\mathbf{N},\mathbf{L},\mathbf{T};\ \alpha,\beta,\gamma,\delta), \qquad [1]$$

where the estimated parameters ($\alpha,\beta,\gamma,\delta$) describe the relationships between house prices and the measures included within the four categories. The incremental change in the price of the house represents the additional amount house buyers are willing to pay for a marginal change in the attribute holding all the other attributes constant.

There are two stages to the hedonic pricing method. The first is to estimate the hedonic housing price function and calculate marginal implicit prices for the attributes of the house. The first stage provides information about the values for marginal changes attributes, such as a decrease in house square footage or an increase in the distance to open space. The first stage to modeling preferences is sufficient for answering questions at the margin such as what magnitude, direction and significance does an additional mile closer to a land use add or detract from house price. Then, the second stage is to estimate the demand function for the attribute under investigation with the observed quantity demanded as a function of the marginal implicit prices (estimated in stage one), along with other demand shifters such as income. Variation in predicted marginal implicit prices is used to trace out the bid and offer functions for each attribute/characteristic. This allows for estimation of the welfare effects from non-marginal changes by providing estimates using existing levels and hypothetical ones.

To date, most hedonic studies only estimate the first stage. Palmquist (1992) shows that the first stage equation sufficiently measures total benefits in the case of localized externalities that affect a small geographic area and a small number of people as may be the case for some environmental amenities or disamenities. The first-stage is insufficient, however, when trying to measure the benefits of an amenity that affects a large geographic area and a larger number of homeowners. In such cases, the second stage hedonic analysis, which estimates the marginal willingness to pay for attributes, is necessary (Freeman 1993; Palmquist 1991). In the latter case, the market supply and/or demand can shift due to the non-localized benefit. Figure 2 demonstrates that compensating surplus[2] for an amenity, q_1, is the change in total consumer surplus for a

[2] Compensating welfare measures tell the amount of income one is willing to give up after a policy has been implemented to return to the original utility level. Equivalent welfare measures tell the amount of additional income needed to obtain the same utility without a policy change (stay at q^0). They differ based on the unit of comparison (original utility or subsequent) and imply different property rights. They are computed by integrating under the compensated inverse demand curve or the marginal bid function.

weakly separable market good, the house . Here the increase in the amenity level from q_0 to q_1 increases consumer surplus by the area in between the demand curves above the price line.

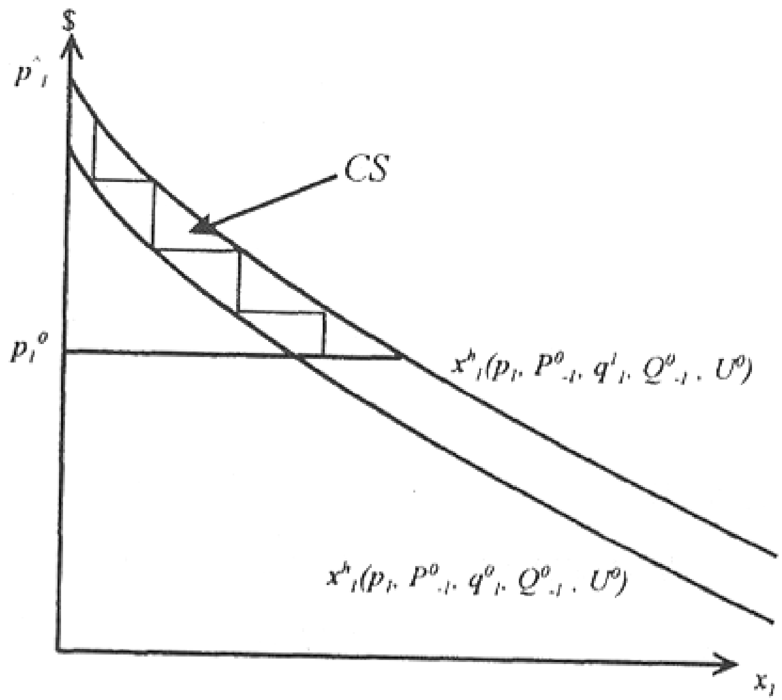

FIGURE 2. WEAK COMPLEMENTARITY OF MARKET GOOD (x^h) AND COMPENSATING SURPLUS FOR A CHANGE IN AMENITY LEVEL (q) [3]

The net benefit from a change in an amenity level,

$$NB = \sum_{k=1}^{N} x_1^h(p_1, P_1^0, q_{1,}^1, Q_1^0, U^0) - x_1^h(p_1, P_1^0, q_{1,}^0, Q_1^0, U^0) \qquad [2]$$

[3] Graphic from page Flores, N.E. 2003. "The Hedonic Method." In: Champ P, Boyle KJ, Brown T (eds.) A Primer on Nonmarket Valuation. Kluwer Academic Publishers, Dordrecht, page 41.

Where $x_1^h(p_1, P_1^0, q_{1,}^1, Q_1^0, U^0)$ is the ex-ante hedonic price function evaluated for the attribute, the amenity level.

Many econometric issues arise when estimating the first stage hedonic price models that can either bias the coefficient estimates or result in less efficient estimators invalidating hypothesis tests. A few examples are a high degree of collinearity among independent variables, spatial dependence and omitted variables within the housing market, and endogeneity of housing prices and land availability (Irwin and Bockstael 2001, Irwin 2002). By examining the correlations among the independent variables, along with variance inflation factors, a subset of variables can be chosen to reduce multicollinearity (Belsley, Kuh, and Welsch 2005). Spatial dependence and omitted variables are addressed in the section on model specification.

There are also challenges to estimating the second stage (inverse demand functions) for attributes because of endogeniety from simultaneity of marginal attribute prices and levels. Two-stage least squares can be used to produce more efficient results so long as instrumental variables can be found that are correlated with the attribute level but not the error term in the attributes demand function. A second issue is that sometimes information on tastes and preferences for attributes to estimate the inverse demand function may need to come from stated preference methods.

Two studies for Portland, Oregon have estimated the second stage (Mahan, Polasky, and Adams 2000; Netusil, Chattopadhyay, and Kovacs 2010). The authors of the 2010 study estimated benefits of large patches of tree canopy per-property and per-acre from percentage changes in canopy cover by integrating multiple Marshallian demand[4] functions for tree canopy levels, from 0 to various levels. Then, the difference between benefits at various levels (a change in tree canopy cover 2.5% to 7%) averaged over the sample gives an estimate of total benefits. Mahan, Polasky, & Adams (2000) perform the second-stage analysis to identify the marginal willingness to pay for proximity to wetland amenities but were unable to get reliable estimates for the size of the nearest wetland possibly due to sporadic pockets of housing with high degree of local multicollinearity.

Theoretical Background

In his seminal article, Sherwin Rosen (1974) defines a differentiated product, Z, by its various characteristics $z_1, z_2, ..., z_n$.

$$Z = (z_1, z_2, ..., z_n) \quad [3]$$

The hedonic price function, $p(Z)$, relates changes in the price of the differentiated product to changes in the quantities of various attributes.

$$p = p(Z) \quad [4]$$

Buyers and sellers in a competitive market take the price schedule as given when making their consumption and production decisions because individually they cannot set market prices. In the housing market, the marginal implicit prices of home characteristics may

[4] Marshallian demand is the quantity demanded as a function of price holding income constant. Hicksian compensated demand adjusts for income effects. For normal goods, Marshallian demand is flatter because income and substitution effects.

be retrieved by regressing home values on a vector of home characteristics, a vector of location attributes, and one that includes neighborhood effects. Housing is a unique good because location is fixed, therefore no other house can be identical in the housing characteristics bundle such that the degree of substitutability between housing within a neighborhood can affect utility levels. The equilibrium marginal implicit price of an attribute of the house is given by the partial derivative of the hedonic price function with respect to that attribute.

$$\frac{\partial p(Z)}{\partial(z_i)} = p(z_i) \qquad [5]$$

Consumers gain satisfaction from the characteristics of the differentiated good, *Z*, and a composite good, *x*, and factors that influence preferences, α, and maximize utility

$$U(x, z_1, z_2, ..., z_n; \alpha) \qquad [6]$$

subject to the budget constraint

$$y = x + p(z_1, z_2, ..., z_n) \qquad [7]$$

where *y* is the buyer's income and the price of *x* is set to 1. The first-order conditions for the consumer problem are satisfied by setting the marginal rate of substitution between one of the characteristics and the composite good equal to the marginal price of the characteristic.

$$\frac{\frac{\partial U}{\partial z_i}}{\frac{\partial U}{\partial x}} = \frac{\partial p(Z)}{\partial(z_i)} = p(z_i) \qquad [8]$$

A buyer's actions in the housing market can be represented by a bid function

$$\theta(Z, u, y; \alpha) \qquad [9]$$

where θ is an individual's willingness to pay for a particular house with characteristics, Z, given a certain level of income, y, and constant utility. Modifying the consumer utility function slightly, the bid functions are defined implicitly by

$$U(y - \theta, z_1, z_2, ..., z_n; \alpha) = u \qquad [10]$$

and trace out a set of indifference surfaces relating changes in the z_i to corresponding changes in the total bid that hold consumers at the same utility level. In this context, utility is maximized when the marginal bid with respect to a given attribute is equal to the implicit price, consumer's marginal willingness to pay (WTP), in the housing market for that attribute.

$$\frac{\partial \theta(Z; u, y)}{\partial z_i} = \frac{\partial p(Z)}{\partial z_i} \qquad [11]$$

Graphically, this optimization occurs where the two surfaces $p(Z)$ and $\theta(Z;u,y)$ are tangent (figure 3).

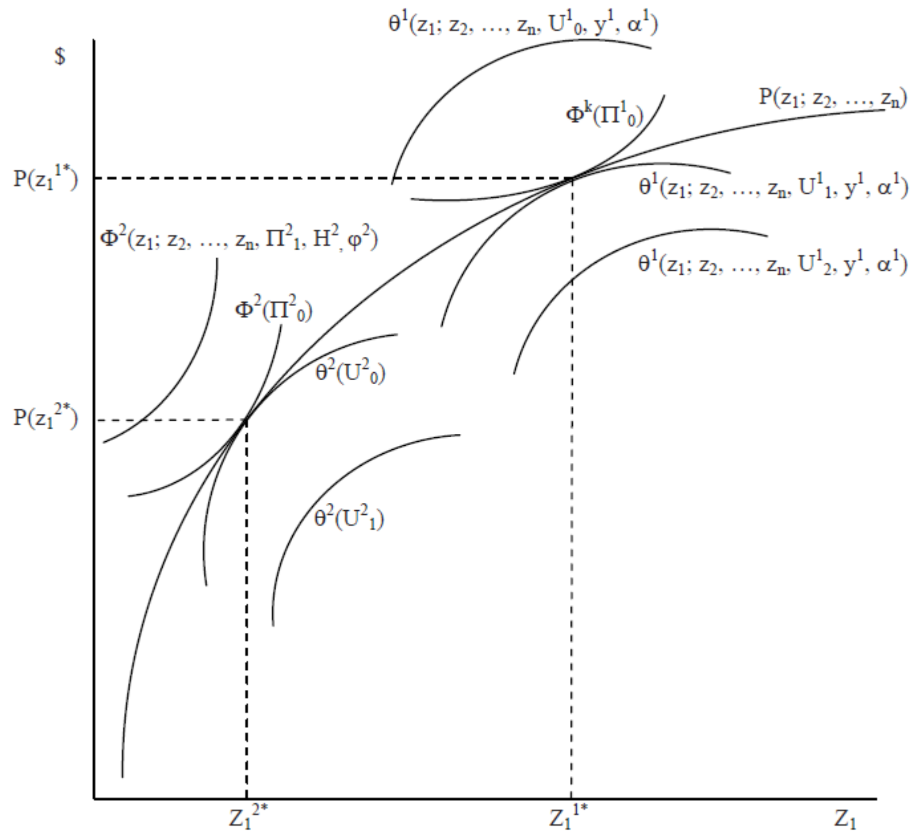

FIGURE 3. THE INTERSECTION OF BUYER AND SELLER INDIFFERENCE CURVES IS THE HEDONIC PRICE FUNCTION[5]

On the seller's side of the market, sellers must choose if and when to sell based on market relationships. Costs vary differently for different sellers conditional on the prices for factors, β, needed to make the sale and so the cost function can be represented by

$$c(M, Z; \beta) \qquad [12]$$

where *M* is the decision to sell or not given a house with attributes, *Z*. Revenues depend on the hedonic price schedule and profits are simply revenues minus costs.

[5] Graphic from page Taylor, L.O. 2003. "The Hedonic Method." In: Champ P, Boyle KJ, Brown T (eds.) A Primer on Nonmarket Valuation. Kluwer Academic Publishers, Dordrecht, page 337.

$$\pi = M \cdot p(Z) - c(M, Z; \beta) \quad [13]$$

The behavior of sellers can be represented by a set of offer functions

$$\phi(Z, \pi; \beta) \quad [14]$$

where ϕ represents the minimum price a seller can accept for a product with characteristics, *Z,* and still make profits π. Like the buyers side, these offer functions trace out a set of indifference surfaces. In this context, profits are maximized by setting the marginal offer with respect to a particular characteristic equal to the marginal price for that characteristic. Graphically, this relationship occurs when the surfaces *p(Z)* and ϕ *(Z; π)* are tangent (figure 3).

The interaction of buyers and sellers represented by their respective bid and offer functions determine the hedonic price schedule in a competitive market (figure 3). Each buyer's bid surface represents varying bids and quantities of a characteristic given a particular level of utility; each seller's offer surface represents varying offers and quantities of a characteristic given a particular profit level. The matching of consumers and producers results in a set of individual equilibria, the hedonic price function, *p(Z).* Buyers attempt to maximize utility by seeking out the lowest bid possible; sellers attempt to maximize profits by seeking the highest possible offer. Market interactions match buyers with sellers in such a way that buyers cannot achieve a higher utility by choosing a product with different characteristics, nor can sellers increase profits by altering the quantity or version of the house. Bid functions do change with income and are represented for two individuals, $\theta_{zi}^{1}$and θ_{zi}^{2}, in the figure 4 below. The optimal level of consumption for individual 1 is where the hedonic price function and the bid function are tangent and represented as point A where the line passing through A and B (marginal bid function) crosses the associated implicit price function is P_{zi}^{A}.

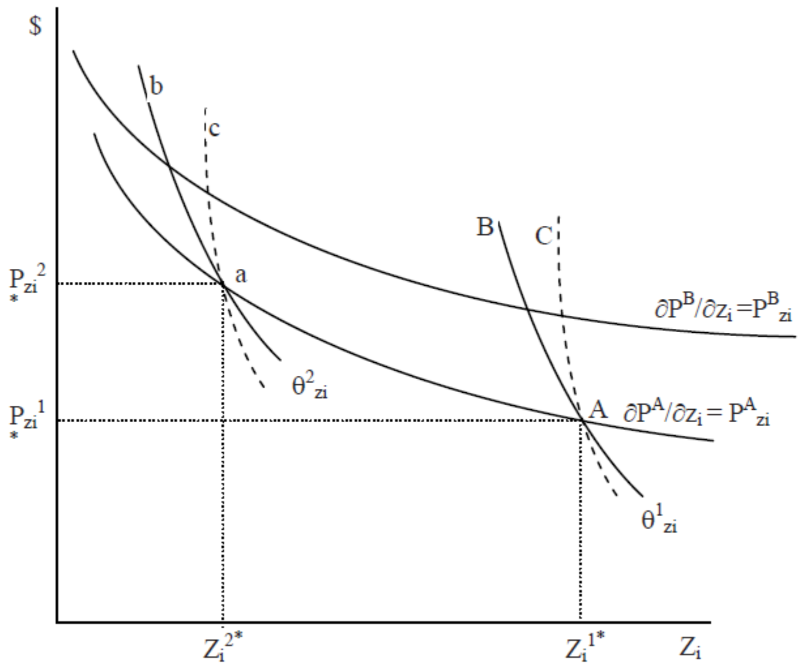

FIGURE 4. MARGINAL BID IDENTIFICATION FOR THE SECOND STAGE HEDONIC FUNCTION[6]

Empirical Specification

The empirical specification of the hedonic property model relates the sales price of the house to lot and housing structural characteristics and neighborhood patterns, along with market, location and environmental variables (Freeman 1993). The empirical specification is as follows:

[6] Graphic from page Taylor, L.O. 2003. "The Hedonic Method." In: Champ P, Boyle KJ, Brown T (eds.) A Primer on Nonmarket Valuation. Kluwer Academic Publishers, Dordrecht, page 365.

$ln\mathbf{P} = \alpha\mathbf{S} + \beta\mathbf{N} + \gamma\mathbf{L} + \delta\mathbf{T} + \varepsilon$ [15]

$\varepsilon \sim N(0,\sigma^2 I_n)$ [16]

where $ln\mathbf{P}$ the natural log of adjusted house price, **S** represents the structural variables, **N** neighborhood variables, **L** is the location variables, **T** is the timing variables and ε is independently and identically distributed error term. The estimated coefficients are α, β, γ, and δ. Estimating the coefficients using Ordinary Least Squares for *k* observations gives the mean marginal value:

$$\beta_{OLS} = \begin{bmatrix} \beta_0 & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & \beta_k \end{bmatrix}, \quad [17]$$

The log transformation of the dependent variable is chosen to minimize heteroskedasticity (Wooldridge 2003) and because the sales data have a long right side tail. Cropper, Deck, and McConnell (1988) provide a comparison of possible choices for functional forms and suggest the semi-log model is a robust functional form when there is a possibility of omitted variable bias as is the case often in hedonic models. If the individual characteristic of the house is measured as continuous, the estimate describes the direction, magnitude and significance of the change in the house price for one more unit. If the characteristic is represented using a dummy variables, the estimate describes the change in the house price based on including the characteristic such as if the house was new when sold. Finally, because marginal effects of some of the determinants of house price may vary with the price level of the house, the double log functional form is chosen for distances, areas and income levels except for the garage and basement areas and mean time to work because these variables may not exhibit similar diminishing returns (Iwata, Murao, and Wang 2000; Bin and Polasky 2004).

Spatial Considerations

Spatial dependence occurs when observations across space are systematically related. The interconnection is more formally called spatial autocorrelation and a direct result of Tobler's (1979) First Law of Geography that states "everything is related to everything else, but near things are more related than distant things." One form of spatial dependence in hedonic price models occurs when house prices are based on comparable homes in the immediate vicinity such as within a half mile. The justification for using neighboring values in the calculation is that homes share the value of being located in a particular place such as near common environmental amenities or public services. A second form of spatial dependence called spatial error dependence may occur when an omitted variable is also correlated with the error of its neighbor and it is similar to serial correlation in time series data. Spatial error can also be due to measurement errors that may occur with overlapping data layers from multiple data sources or generally when the variable is hard to measure. We examine each spatial component separately and jointly using the spatial statistics software, R.

Spatial Lag Models

In the real estate industry it is common practice to assess a property's value based on the prices of nearby homes (Can 1990). This process justifies the need to include a measure that specifies the interconnection between houses in close proximity through the form of a spatially lagged dependent variable. The spatially lagged dependent variable is composed of a spatial lag parameter, ρ, and a spatial weighting matrix, $\mathbf{W}$. To determine if significant spatial autocorrelation exists due to the influence of neighbors, we look at the OLS residuals of the standard hedonic price model. Erroneously omitting the spatial lag term leads to biased and inconsistent estimation of coefficients (Anselin 1988). If a spatial pattern is in the residuals of the OLS model, then we want to include the information as an additional explanatory variable. In matrix form:

$$ln\mathbf{P} = \rho\mathbf{WP} + \alpha\mathbf{S} + \beta\mathbf{N} + \gamma\mathbf{L} + \delta\mathbf{T} + \varepsilon \qquad [18]$$

If spatial autocorrelation is significant, the lagged dependent variable, $\rho\mathbf{WP}$, provides spatial structural information to the model thus reducing omitted variable bias and improving efficiency of estimators. If ρ is statistically different from zero, then the spatial multiplier, $(1/1\text{-}\rho)$, is needed to adjust coefficient estimates to reflect the marginal values that are related to location, in addition to the marginal value of the characteristic (Kim, Phipps, and Anselin 2003). Alternatively, if the spatial weight matrix adequately accounts for the spatial lag effect then ρ may be insignificant while the inclusion of the lagged variable significantly improves the model fit (Anselin 2005).

To estimate the spatial models, the researcher must specify a spatial weight matrix that captures the spatial dependence expected in the data. For example, spatial dependence between objects of analysis may occur based on Euclidean distance (actual or perceived), distance by road, travel time, number of nearest neighbors or a river network. The spatial weight matrix (**W**) in equation 19 represents the expected relationship between house i and house j.

$$\mathbf{W} = \left[w_{ij}\right]_{i,j=1}^{n} \qquad [19]$$

The data for hedonic price models are expected to exhibit a spatial lag and the process for selecting the spatial weight involves including the prices of houses within various distance ranges to see if inclusion of neighborhood price structure reduces the spatial autocorrelation. The form of the spatial weights used for this study is shown in equation 20. The spatial weights are created using inverse distance weighting, also called distance-decay, which allows for homes closer to each other to have a greater influence in the estimation process up to some distance (*b*).

$$w_{ij} = \begin{cases} \frac{1}{d_{ij}}, if\ d_{ij} \leq b \\ 0, otherwise \end{cases} \qquad [20]$$

To determine the distance (*b*), one examines the semi-variogram of the residuals from the Ordinary Least Squares (OLS) regression estimation of the hedonic price function to learn more about the patterns in the residuals that are related to distance (Cressie 1993). With more information about patterns in the residuals, the spatial weight matrix that accounts for the spatial autocorrelation can be constructed. The weight matrix is row-standardize so that the parameter coefficients for the spatial components are bound by -1 and 1 (equation 21).

$$\widetilde{w}_{ij} = \frac{w_{ij}}{\sum_{j=1}^{n} w_{ij}} \qquad [21]$$

Spatial Error Models

A second spatial relationship that needs to be considered in the model is caused by misspecification. The misspecification may be due to improper functional form, measurement error in the variables included or omitted variables due to challenges in measuring the concept. The original error term from OLS is modeled as an autoregressive error term where ε denotes the residual matrix, **W** is a spatial weighting matrix and λ is the coefficient. In matrix form:

$$ln\mathbf{P} = \alpha\mathbf{S} + \beta\mathbf{N} + \gamma\mathbf{L} + \delta\mathbf{T} + \varepsilon, \quad [22]$$

$$\varepsilon = \lambda\mathbf{W}\,\varepsilon + \upsilon \quad [23]$$

The transformed residuals υ are independently distributed about a mean of zero.

Joint Spatial Lag and Spatial Error Models

Finally, the joint model that includes both the spatial lag and the spatial error components is specified by:

$$ln\mathbf{P} = \rho\mathbf{WP} + \alpha\mathbf{S} + \beta\mathbf{N} + \gamma\mathbf{L} + \delta\mathbf{T} + \varepsilon, \quad [24]$$

$$\varepsilon = \lambda\mathbf{W}\,\varepsilon + \upsilon \quad [25]$$

For the joint spatial model, the values of ρ and λ are simultaneously estimated by the maximum likelihood method. If ρ is significant, coefficient estimates in the joint model will also need to be adjusted using the spatial multiplier.

The test statistics used to determine whether spatial autocorrelation exists are (1) Moran's I and (2) the Lagrange Multiplier (Anselin and Rey 1991). Moran's I test statistic (equation 26) is used to determine whether spatial autocorrelation exists where N is the number of houses indexed by i and j; X is the variable of interest, $\bar{X}$ is the mean of X, and w_{ij} is the spatial relationship between house i and house j.

Moran's I: $I = \frac{N}{\sum_i \sum_j w_{ij}} \frac{\sum_i \sum_j w_{ij}(X_i - \overline{X})(X_j - \overline{X})}{\sum_i (X_i - \overline{X})^2}$ [26]

The Lagrange Multiplier test statistic (equation 27) relays information about local (smaller-scale) variability and the need for a lagged dependent variable where spatial correlation is rejected if:

$$\left[\frac{n\hat{\varepsilon}^1 W \hat{\varepsilon}}{\hat{\varepsilon}' \hat{\varepsilon}\, tr(W^2 + W'W)^{\frac{1}{2}}}\right]^2 > \chi^2_{1,0.95} = 3.84 \qquad [27]$$

Then, the model with the smallest Akaike Information Criteria (AIC) is deemed the most appropriate model for hypothesis testing (Jones, Leishman, and Watkins 2003).

Study Area

El Paso County, Colorado, is located along the eastern edge of the southern Rocky Mountains 70 miles south of Denver (figure 5) where the Southern Rockies and Southwestern Tablelands Ecosystems meet.[7] The western portion of the county is extremely mountainous, composed of igneous Pikes Peak Granite and home to Pikes Peak (14,110 feet) and the Pike National Forest. From west to east there is a 9,000 foot change in elevation leveling out to prairie land with dairy cows and beef cattle. The

[7] The Southern Rockies portion contains the Crystalline Mid-elevation Forests and Foothill Shrublands Ecoregions. The Southwestern Tablelands Ecoregions are Pine-Oak Woodlands, Foothill Grasslands, Piedmont Plains and Tablelands, Pinon Juniper Woodlands and Savannas. Sources of greenness are herbaceous grasslands, evergreen forest, shrubland, pasture hay, deciduous forest, small grains, and row crops. Graphs that illustrate the variations in source of greenness over study time period (2005-2007) using Normalized Difference Vegetation Index (NDVI) data are found in Appendix along with the land cover map from the National Land Cover Database for the area.

climate ranges from alpine to desert resulting in much diversity in flora and fauna along with varying precipitation levels and temperatures.

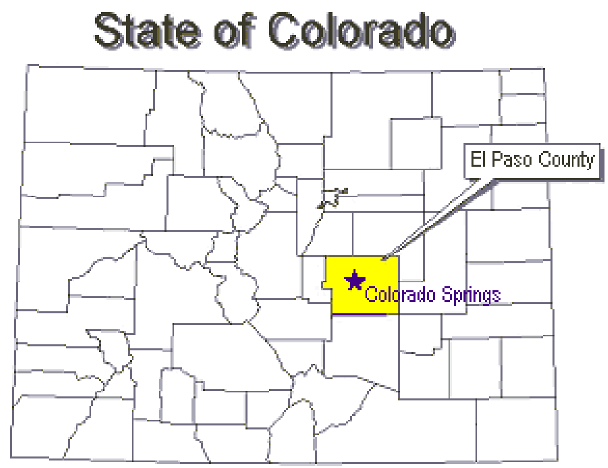

FIGURE 5. THE LOCATION OF THE STUDY AREA IN COLORADO

El Paso County is approximately 2,158 square miles and the western portion is the study area. According to 2006 Census data, the county population totaled 576,884 people and population density was estimated 271 persons per square mile (compared to the state average of 46). The county contains the cities of Colorado Springs, Fountain, Manitou Springs; towns of Monument, Palmer Lake, Calhan, Green Mountain Falls, and Ramah. A significant proportion of the county is federal land including the Pike National Forest, United States Air Force Academy, Fort Carson, Peterson Air Force Base, Schriever Air Force Base, and Cheyenne Mountain Air Force Station (NORAD). These military installations encompass about 8% of the total land area in the county and play a strategic and critical role in the national defense of our country and the sustained economic vitality of the county and State of Colorado.

Fort Carson, established in 1942, was the state's largest employer in 2005 and estimated to be currently responsible for 10% of all economic activity in El Paso County and a little over 1% of all economic activity in Colorado. It serves approximately 100,000 people counting personnel, contractors, families and area military retirees that use Fort Carson facilities (Colorado Department of Local Affairs). Federal commodity demand in the county totaled $10.9 billion in 2007. It is estimated that every $1 million in federal defense military spending results in an estimated 15.7 local jobs (IMPLAN 2007 Implan Version 3 software).[8] As of 2007, most building was occurring in South El Paso County and into Pueblo County to meet the demand of the expected 15,000 troop growth and four separate conservation easements were purchased in the area (1-2005, 1-2006, 2-2007).[9]

There are seventeen neighborhoods that comprise the area real estate market (figure 6). Interstate 25 runs north-south and neighborhoods to the west have high natural amenity value because of the views of Pikes Peak and the Front Range Mountains along with Cheyenne Canyon. The neighborhoods of Manitou Springs and Southwest have the high performing school districts of Cheyenne Mountain and Manitou Springs.[10]

To the east of the interstate neighborhoods vary considerably from north to south. In the north natural amenities, large areas of government designated parkland, and dense vegetation abound with views of the Rocky Mountains, the U.S. Air Force Academy

[8] At the national level, jobs created are considered to be transfers with no implication on aggregate welfare.

[9] Personal communication with Steve Kettler, U. S. Fish and Wildlife Service, Denver (9/24/2007).

[10] http://www.edu.cde.state.co.us/growthmodel/public

campus, and Black Forest Regional Park. The school districts of Academy and Lewis Palmer are in the area and rank highly in achievement and growth. These neighborhoods are approximately 15 minutes north of downtown Colorado Springs and 45 minutes south of Denver.

Closer to the center of the city the Powers neighborhood, with homes built in the 1980's and 1990's, and surrounding neighborhoods are attractive to military homeowners because of the close proximity to Peterson Air Force Base, Fort Carson, and Shriever Air Force Base. Southest, Central, West, Old Colorado City, Powers and East neighborhoods have the highest overall crime rates. Further south, about 15 minutes south of downtown Colorado Springs, the Fountain Valley neighborhood is growing rapidly with newer housing options for predominately military families.

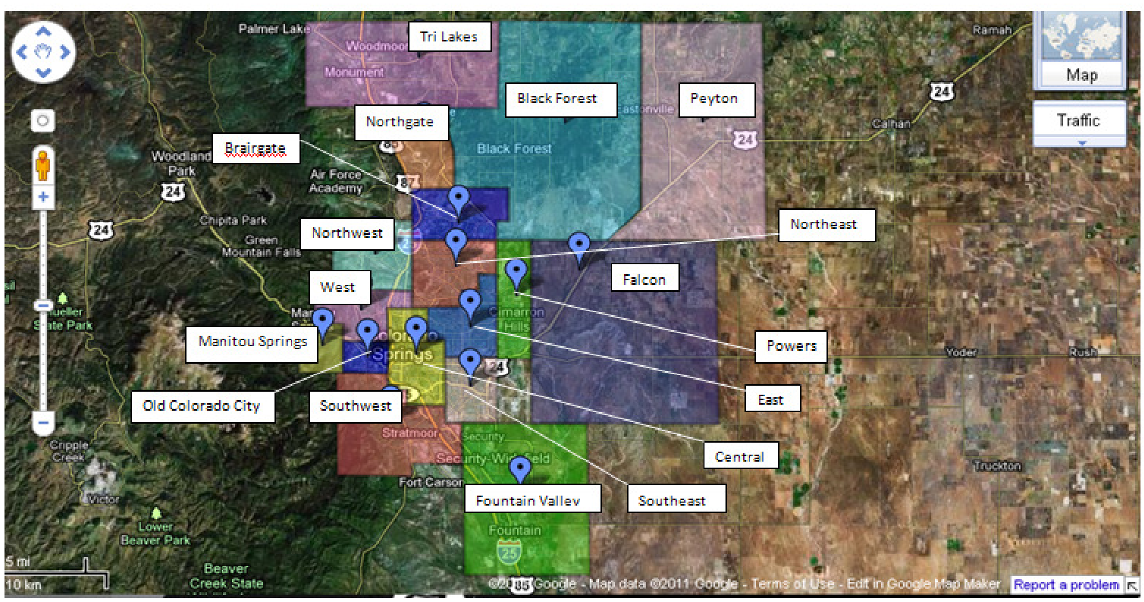

FIGURE 6. EL PASO COUNTY REAL ESTATE NEIGHBORHOODS

Data

Residential property sales transaction information was obtained from the El Paso County Tax Assessor. The data included parcel level information on sale prices, sale dates, and structural characteristics of the property with spatial coordinates. Housing structural characteristics include the year the house was built, the square footage of the house, lot, basement and garage, along with the number of bedrooms and bathrooms.[11] The total number of house sales over the 2005 to 2007 time frame was 31,414.

As the decision to purchase a home occurs when the buyer enters the contract approximately two months prior to the sales date, we subtract 60 days from the sales date to represent the decision date, e.g. the sales in March 2005 were entered January 2005 (Loomis and Feldman 2003). Using the date of the decision, we calculated the age of the house and the age squared to capture any premiums or discounts for older homes and created dummy variables to differentiate newer homes. Additional discrete measures capture market timing by the year of the sale with 2005 as the reference to which we compare 2006 and 2007. Because homes on more than an acre are potentially developable, we only include homes on one acre or less (Heimlich and Anderson 2001; Lewis, Bohlen and Wilson 2008). Next, we trimmed the bottom and top 1% of sales to remove outliers and transactions that are not considered arms-length, such as transactions among family members at less than fair market price. Then, we adjusted the house sales prices using the consumer price index to make comparisons in 2005 dollars.[12]

[11] Frequency distributions for housing variables are in the appendix.

[12] Quarterly Consumer Price Indexes with January 2005 as base 1, 2nd quarter is 1.0055, 1.0127, 1.0232, 1.0227, 1.0221, 1.0265, 1.0343, 1.0558, 1.0564, 1.0448, 1.0376, 1.0464, 1.047, 1.052, 1.063, 1.0697,

Neighborhood demographic information was obtained through the United States Census website. Median income levels, mean time to work, percentage rental properties, percentage without high school education, percentage over 60 years old, population, and mean house price at the census tract level are the neighborhood variables expected to influence the purchaser's decision that are considered. The Census tract shapefile available from the website provides the spatial reference for El Paso County and the variables are appended as attributes to the census tracts layer using ArcGIS software. Among census tracts for the county, the median housing value was $154,700.[13] The difference between these estimates and our data may be due to aggregation effects over tracts decreasing the actual variances or because the deletions mentioned earlier relating to lot size and arm's length transactions.

Measures that represent location were obtained from multiple sources. First, the El Paso County Assessor website has many shapefiles available free from their website.[14] Boundaries for the county, cities, school districts, military lands, national forest land and roads were accessed.[15] The second data source was the Colorado Ownership and Management Project (COMaP) spatial database that provides comprehensive information about Colorado open spaces including land ownership and levels of protection. Open space types in El Paso County include agriculture, community separators, greenway/stream, local parks, state parks, and urban open space. The percentages of

1.0708, 1.0724, 1.0746, 1.0674, 1.0569, 1.0542, 1.0576, 1.0629, 1.0751, 1.0838, 1.0933, 1.094, 1.0913, 1.0879, 1.0929, and 1.0955.

[13] The appendix contains frequency distributions for census variables.

[14] http://adm.elpasoco.com/InformationTechnologies/GeographicInformationSystem

[15] Relationships between housing prices and distances are graphed by federal land in the appendix.

homes within distance intervals for each open space type are provided in table 1. Agricultural land was defined using the National Land Cover dataset which has explicit values for agricultural land, however the nearest agricultural land was at least 5 miles from the nearest house in the study area.

Greenway/stream corridor areas were defined as long strips of open space within a municipal area or areas within ¼ mile of a stream. Stream data used was a commonly available 1:100k hydrology dataset. Community separator areas were defined as extending three miles beyond municipal boundaries where one municipality is next to another and both have greater than 1,000 people, or greater than 10,000 people if a municipality is not next to another municipality having greater than 1,000 people. State parks were areas acquired to be state parks. Urban open space areas were defined as land within a municipal boundary regardless of size. Natural area/wildlife habitat areas were those that fit none of the other categories.

TABLE 1. PERCENTAGE OF HOUSE SALES WITHIN DISTANCE INTERVALES

	0-0.5	0.5-1	1-2	2-3
Pike National Forest	0.8	2.7	7	10.1
Air Force Academy	1.7	1.2	3.3	10
Fort Carson	2.7	3.9	10.4	8
Perterson Air Force Base	0	0.4	4.8	8.8
NORAD	0.9	0.7	1.9	3.6
Community Separator	1.5	1.9	3.2	5.9
Greenway/Stream	17.2	19.4	17.7	10.4
Local Park	61.9	14.9	10.9	3.8
NaturalArea/Wildlife	2.2	4	12.9	18.3
State Park	0.2	0.3	0.5	2.2
Urban	44.8	22.6	17.4	5.9
Non-federal lands were only included in models if the home is within a half mile.				

Merging the sales information with Census neighborhood demographics and land use layers from COMaP and El Paso County Assessor, we created a geo-database of spatially referenced attributes for the analysis. Figure 7 demonstrates spatial arrangement of homes within a neighborhood. Figure 8a highlights the distribution of open space types throughout the study area with a closer look at the open space types in the center in figure 8b.

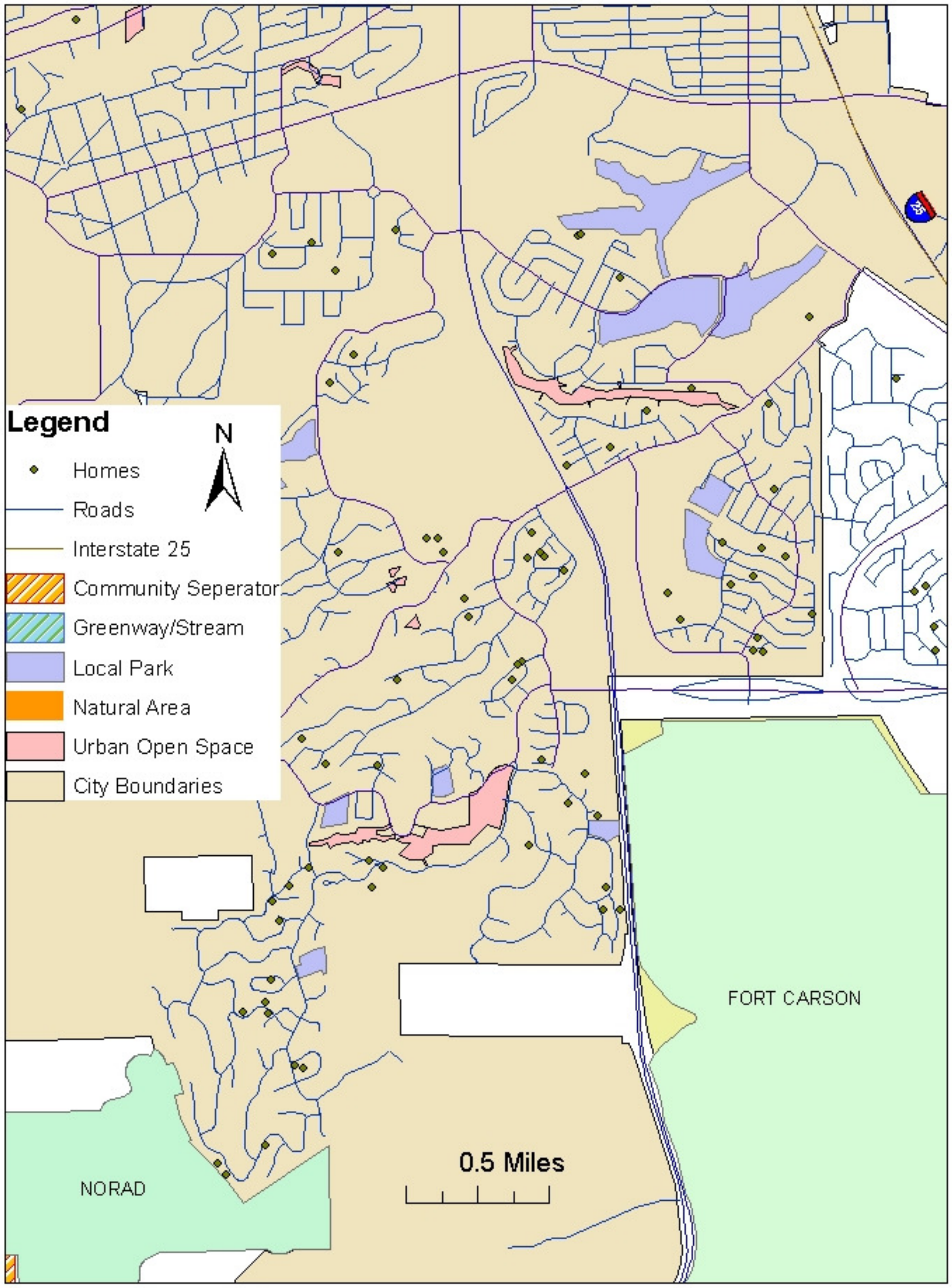

FIGURE 7. SPATIAL ARRANGEMENT OF HOMES WITHIN A NEIGHBORHOOD

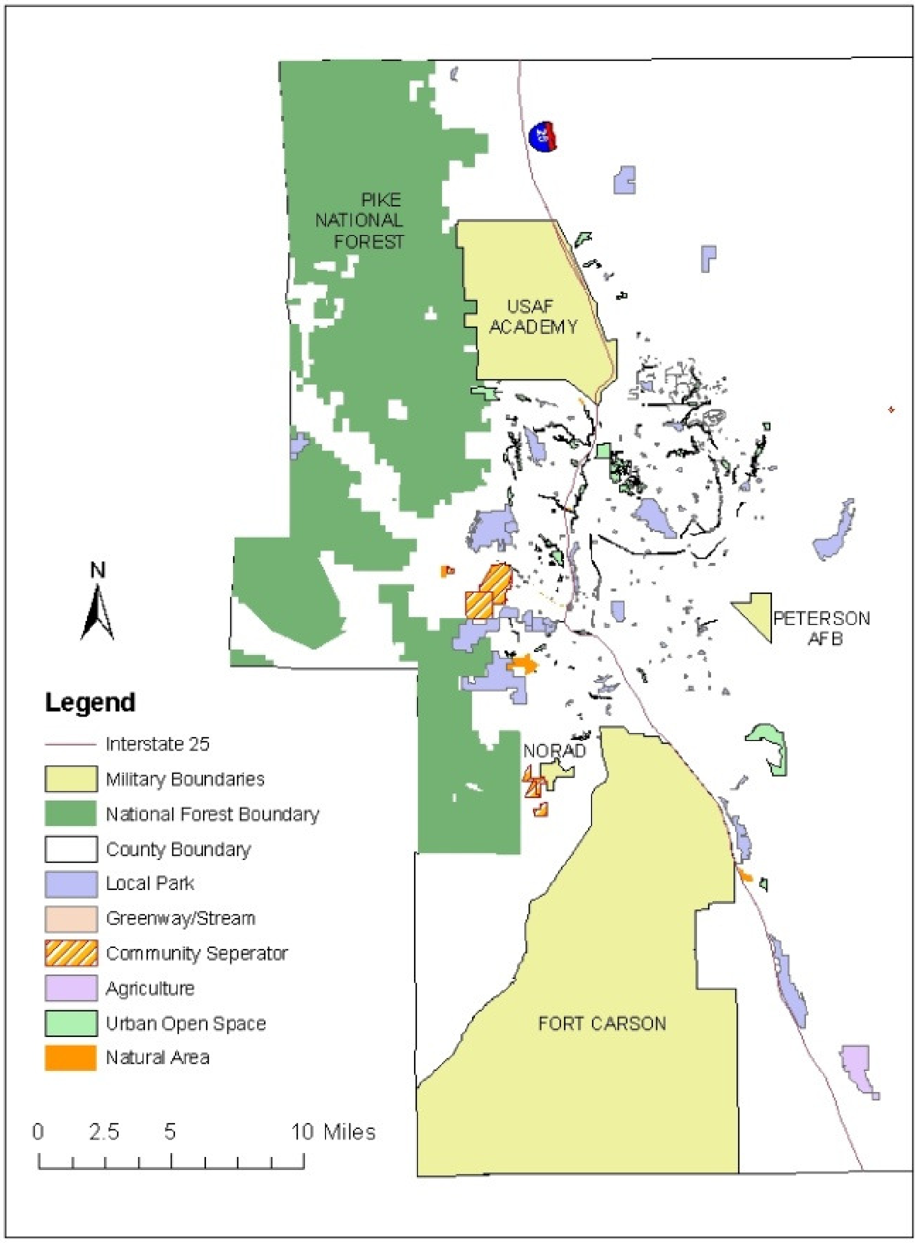

FIGURE 8a. EL PASO COUNTY COLORADO OPEN SPACE

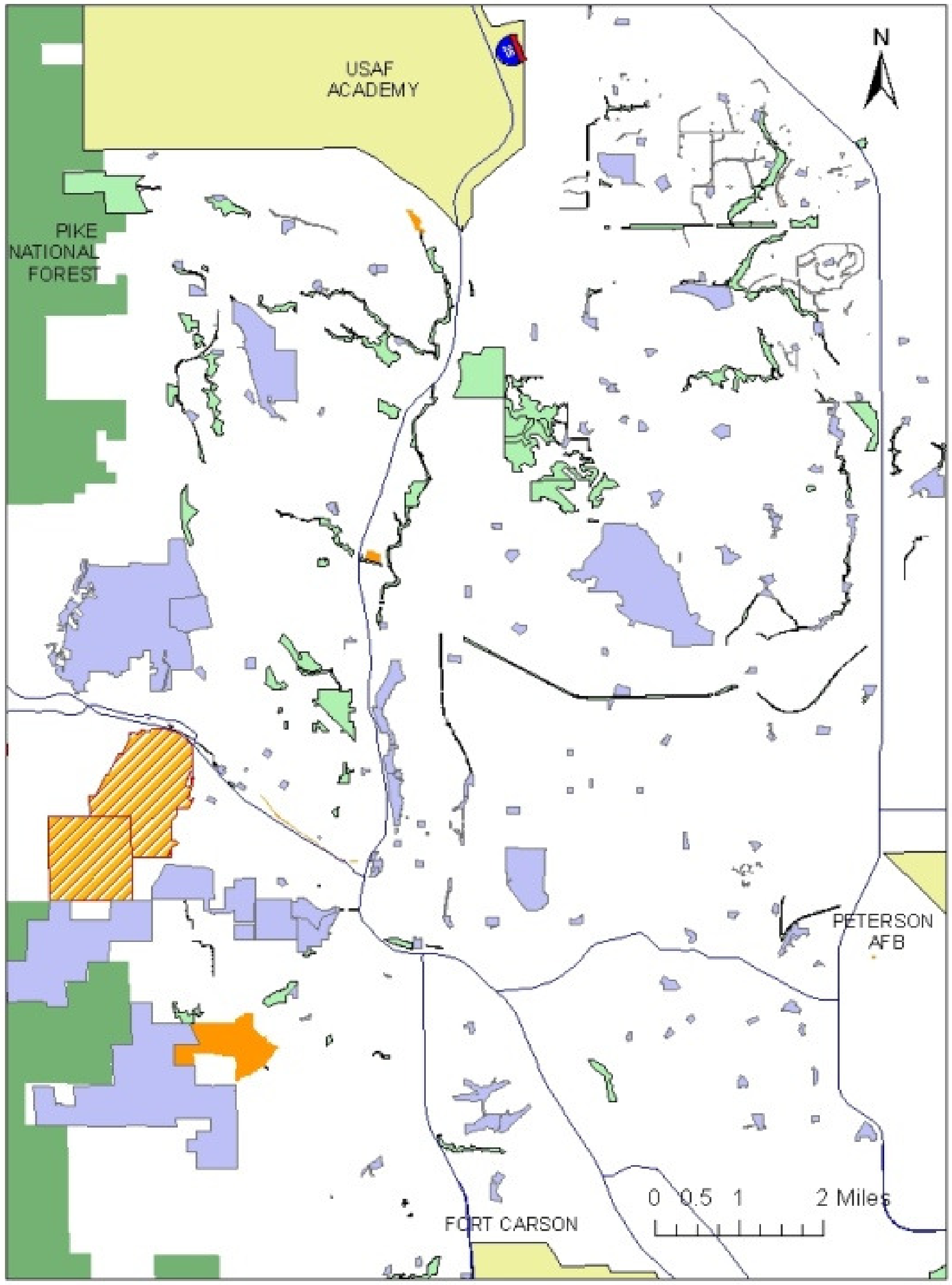

FIGURE 8b. EL PASO COUNTY COLORADO OPEN SPACE

Next Steps

Past studies have explored the relationship between public lands and housing prices to estimate price differentials for characteristics of the house, a market good, as a method to partially quantify the environmental benefits (costs) for neighboring residents (Cho et al. 2009; Hand et al. 2008; Irwin 2002; Kim and Johnson 2002; Neumann et al., 2009; Shultz and King 2001). Property values adjacent to public lands may yield price premiums (discounts) impacting local budgets through the increase (decrease) property tax revenues impacting local budgets. In chapter two, marginal values for proximity to a variety of open space types are estimated to determine the relative relationships focusing primarily on alternative measures for distance to federal lands. The third chapter applies local and global model estimation techniques to compare how hedonic property price effects differ based on location and scale of analysis. The fourth chapter examines how heterogeneity of public lands effect property prices using the Pike National Forest specified generally, and then by characteristics of land uses on the forest. The final chapter of the dissertation synthesizes the results, conclusions, and policy implications. Then, extensions to this effort and the field are proposed. Finally, limitations to the current effort are noted.

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CHAPTER TWO

Relative Economic Values of Open Space Provided by National Forest and Military Lands to Surrounding Communities in Colorado

Abstract

The relative economic values of open space provided by national forest and military lands are estimated and compared to agricultural lands, community separators, natural areas/wildlife habitat, greenway/streams, local parks and urban open space. Three spatial models are developed for El Paso County Colorado over the 2005 to 2007 time frame using the hedonic pricing method. Results of this study indicate proximity to the Pike National Forest and the Cheyenne Mountain Air Force Station positively affects house prices over two miles and the effects are similar for homes within a half mile of community separators and natural area/wildlife habitats which are located in the same region. Proximity to Fort Carson contributes negatively within the first two miles while only homes between two and three miles from Peterson Air Force Base are discounted. The marginal price effect of proximity to the United States Air Force Academy is statistically insignificant.

KEYWORDS Hedonic model - Housing prices - Public lands

JEL Classification R21 - Q31

Introduction

An assessment of the relative contributions provided locally by national forest and military lands is needed when evaluating land management options and growth plans with cities and counties. These federal lands are primarily dedicated to meeting national level needs including the sustainable production of renewable resources (National Forest Management Act of 1976) and national security (National Security Act of 1947). In doing so, there are direct, indirect and induced effects on income and employment that accrue regionally (Deger 1983); as well as the local open space. While the former contributions are measurable directly from market interactions (Maki and Lichty 2000), the latter require the application of indirect valuation methods (Freeman 2003) because open space is not explicitly traded between beneficiaries and producers. Therefore, many studies utilize the hedonic property method to estimate peoples' willingness to pay for different types of open space by examining housing market transactions to determine if property price effects exist for homes closer to various open space types. If there is a property price premium for these land use allocations, then local governments benefit from the additional tax revenue. Uncovering the enhancement effects would be worthwhile for the managing agencies to know from a positive community relations standpoint.

Because the primary function of the military is to supply the forces needed for national security, military lands are managed to ensure necessary operations can occur to deliver the national level service of protection. To do so, the military lands are allocated to housing and training for soldiers as well as weapons and equipment testing. Unfortunately, by-products locally can include noise, pollution and other hazards. As urban growth approaches installation boundaries, points of conflict arise because competing land uses may be incompatible for both residential living (Deal et al. 2002) and military training operations (Lozar and Schneider 2005). These military lands can become a physical barrier to local growth and the activities that occur within the installation boundaries may be viewed as inconsistent with community values possibly resulting in operation restrictions (Westervelt and MacAllister 2006). To mitigate community-installation conflict, buffer zones are being established that, in addition to reducing noise or hazard impacts outside installation boundaries (Eerkens 1999), yield wildlife viewing opportunities and provide other ecosystem benefits that may not be provided if the land were privately developed (Armsworth et al. 2006). Proactive management for threatened and endangered species and species at risk is required to minimize the threat of restrictions to the military's mission (Department of the Army 2006; Efroymson et al. 2009) while also an opportunity to provide unique biodiversity benefits from maintaining heterogeneous habitats with respect to age structure and species composition (Warren et al. 2007).

There are also trade-offs when managing national forests and grasslands for multiple uses as is required of the Forest Service. The Forest Service was established by Congress in 1905 to provide quality water and timber. However, over time with development open space has become relatively scarcer and the public good benefits are diminishing (Millennium Ecosystem Assessment 2005). There has been recognition that the demand for recreational uses of national forest land has grown rapidly in recent years as less recreation area is available and, with an increase in private in-holdings, the population has increased in surrounding areas (White et al. 2010). Similarly, forest plans prioritize locating recreation adjacent to neighborhoods as urban growth approaches national forest boundaries (Stein et al. 2009, personal communication with Pike National Forest District Ranger Brett Botts 2009). Because preferences have changed, the list of multiple uses has expanded to include sustainable production of wood, water, range, wildlife, and recreation across 193 million acres nationally.

Relatively few open space studies have focused on the value of open space amenities provided by federal lands. In 2002, when Irwin examined the effects of open space on residential property values in central Maryland, she found the only effects from neighboring military lands occurred for the largest of the installations, Fort Meade, while the other military land proximity measures were insignificant. A recent paper by Neumann et al. (2009) estimated relative amenity values for the National Wildlife Refuge in Massachusetts and found homes within 100 meters of the wildlife refuge sold for a premium similar to golf courses and sport/recreation parks ($984) and more than agricultural land, cemeteries, and conservation land. A third study in Oregon of federal land amenity effects estimated that property values are higher closer to McDonald-Dunn Research Forest but visible clear-cut decreased the average property price by 13.3% ($16,381) (Kim and Johnson, 2002). A last example is that Shultz and King (2001) study in Arizona found homes 1/10th mile closer to the protected natural resource areas of Coronado National Forest, Tucson Mountain Park, and Saguaro National Monument, as well as Class II wildlife habitat sell for more (0.07%); a 1% increase in vacant land increased house prices (0.08%); while homes near smaller and undeveloped natural resource based parks and pristine wildlife habitats sold for less (-0.36%) possibly due to the risk of flooding.

In this study, the marginal implicit prices attributable to proximity to federal lands on neighboring residential properties are estimated using Hedonic Property Models. The study location is the Colorado Springs, Colorado area that includes the Pike National Forest (PIKE) and serves as a military hub with Fort Carson Military Installation (FTC), the United States Air Force Academy (AFA), Cheyenne Mountain Air Force Station (NORAD), and Peterson Air Force Base (PAFB). By combining assessor information on property structural characteristics with neighborhood attributes, we create distance measures to various open space types using the geographic information. Then, the economic value of proximity to national forest and military lands can be compared relative to the other open space types that exist as substitutes or as additional marginal benefits whose sum is the total amenity value of a location. Improved estimation of amenity values is vital for policies aimed at open space preservation and land use conflict resolution.

Methods

The hedonic price method is a revealed preference nonmarket valuation approach that uses information from actual market transactions to infer the values consumers place on attributes of a good (Rosen 1974). Applications of the hedonic price method to housing are common and often applied to estimate values of open space for inclusion in policy-analysis (McConnell and Wells 2005). In the housing market, the equilibrium hedonic price function is determined by the interaction of utility-maximizing house buyers and profit-maximizing house sellers. The house, the optimal consumption bundle, is an envelope function where marginal bids and marginal offers equal the marginal prices for house characteristics. A review of the hedonic method for nonmarket valuation can be found in Freeman (2003), Taylor (2003), Palmquist (2005), and Bockstael and McConnell (2007).

The theoretical specification for the hedonic housing price function defines the house price vector (**P**) as a function of the individual characteristics of the house according to four categories in matrix form: structural components of the house (**S**), neighborhood demographic variables (**N**), timing variables (**T**) and location-specific attributes (**L**).

$$\mathbf{P}=f(\mathbf{S},\mathbf{N},\mathbf{L},\mathbf{T};\ \alpha,\beta,\gamma,\delta), \qquad [28]$$

$$\mathbf{P} = \alpha\mathbf{S} + \beta\mathbf{N} + \gamma\mathbf{L} + \delta\mathbf{T} + \varepsilon \qquad [29]$$

$$\varepsilon \sim N(0,\sigma^2 I_n) \qquad [30]$$

where the estimated parameters (α,β,γ,δ) describe the relationships between house prices and the measures included within the four categories. The incremental change in the price of the house represents the additional amount house buyers are willing to pay for a marginal change in the attribute holding all the other attributes constant. The error term is assumed to be independent and identically distributed. However, in real estate markets houses are expected to be dependent on the prices of neighboring homes because they share location specific amenities and disamenities. Therefore, spatial error and spatial dependence are examined independently and jointly using the first three model specifications described in chapter 1.

Using the coefficient estimates, marginal implicit prices associated with each attribute are calculated to get an average dollar value associated with each characteristic included in the price function based on average house values (Taylor 2003). The exact implicit price calculation depends on the functional form of the dependent and independent variables, along with any adjustments for neighborhood effects that will be addressed in the section on spatial considerations. For independent variables specified as linear, the implicit price is the estimated coefficient times the mean house price. For independent variables specified as logarithmic, the implicit price is the estimated coefficient times the average house price divided by the average value for the independent variable in question. Finally, for variables that represent discrete characteristics using dummy variables, the implicit price is the exponential value of the coefficient minus one then multiplied by the average house price. With the estimated implicit prices, the relative contribution of each variable included in the model can be stated as a percentage of the total average house price to indicate the relative importance of that variable to the total value of the house.

Study Area and Data

To perform the spatial analyses 1,000 observations were sampled with federal land proportions similar to that of the population.[16] Descriptive statistics are provided in table 2. For the sample, house sales prices adjusted (2005 dollars) ranged from $90,352

[16] Spatial sampling is needed because of computational limits when calculating the log-determinant of the matrix ($I_n - \rho\mathbf{W}$) when estimating the spatial lag model because:

$$E\tilde{Y} = (I - \rho W)^{-1} X\tilde{\beta}$$

$$Cov(\tilde{Y}) = \sigma^2 (I - \rho W)^{-1} (I - \rho W)^{n-1}$$

to $717,826 with the average of $265,296 and the median of $230,279 (figure 9). The average house was 20 years old and had house, lot, basement, and garage square footage of 1640, 9226, 860, and 459, respectively. The sales were distributed over time with 39.9% sold in 2005, 39.3% in 2006, and 20.8% in 2007; of the total sales 60% occurred during peak sales period from April through September and 20.5% of the homes that sold were new. Mortgage rates ranged from 5.86% to 6.41% with an average of 6.18%.

TABLE 2. DESCRIPTIVE STATISTICS

Variable	Description	Mean	Std Dev	Min	Max
Dependent variable					
Price	Sales price of house	$265,296	$115,964	$90,353	$717,827
Structural characteristics					
Age	Age of house (in years)	19.486	21.3048	0	114
Bedrooms	Number of bedrooms	3.474	0.9572	1	7
Bathrooms	Number of bathrooms	2.96	0.9479	1	5
Houseft	Square footage of house	1640	589	378	4047
Lotft	Square footage of lot	9226	5464	1500	42688
Baseft	Square footage of basement	860	594	0	2749
Garagesf	Square footage of garage	459	188	0	1369
Market timing					
y2005	Year entered contract (2005)	0.399	0.4899	0	1
y2006	Year entered contract (2006)	0.393	0.4887	0	1
y2007	Year entered contract (2007)	0.208	0.4061	0	1
Location/neighborhood					
Work	Mean time to work by census tract (in minutes)	23.5551	3.8564	13.8	38.3
Income	Median income by census tract	$62,335	$17,780	$24,097	$104,631
Open space measures					
PIKE	Distance to Pike National Forest	6.8229	3.5767	0.0658	16.1121
AFA	Distance to U.S. Air Force Academy	7.4451	4.7924	0.0716	20.2212
FTC	Distance to Fort Carson	8.7460	5.8044	0.0497	25.1152
PetersonAFB	Distance to Peterson Air Force Base	7.0258	3.9353	0.5745	22.2030
NORAD	Distance to Cheyenne Mountain Air Force Station	11.0203	5.3689	0.0113	26.1493
Ag	Distance to agricultural land	20.9080	6.5940	5.6418	39.0720
Comsep	Distance to community seperator	6.4268	3.2688	0.0269	18.6154
Green	Distance to greenway/stream	3.1263	3.1598	0.0053	12.1543
Localpark	Distance to local park	0.8243	1.2205	0.0069	6.6606
NaturalArea	Distance to natural area/wildlife habitat	3.9923	2.5679	0.0367	12.7190
UrbanOS	Distance to urban open space	1.0829	1.3600	0.0080	7.5597
PIKE_half	Within half mile of Pike National Forest	0.008	0.0891	0	1
PIKE_0to1	Within first mile of Pike National Forest	0.035	0.1839	0	1
PIKE_1to2	Between first and second mile of Pike National Forest	0.07	0.2553	0	1
PIKE_2to3	Between second and third mile of Pike National Forest	0.101	0.3015	0	1
AFA_half	Within half mile of U.S. Air Force Academy	0.017	0.1293	0	1
AFA_0to1	Within first mile of U.S. Air Force Academy	0.029	0.1679	0	1
AFA_1to2	Between first and second mile of U.S. Air Force Academy	0.093	0.2906	0	1
AFA_2to3	Between second and third mile of U.S. Air Force Academy	0.1	0.3002	0	1
FTC_half	Within half mile of Fort Carson	0.027	0.1622	0	1
FTC_0to1	Within first mile of Fort Carson	0.066	0.2484	0	1
FTC_1to2	Between first and second mile of Fort Carson	0.104	0.3054	0	1
FTC_2to3	Between second and third mile of Fort Carson	0.08	0.2714	0	1
PAFB_0to1	Within first mile of Peterson Air Force Base	0.004	0.0632	0	1
PAFB_1to2	Between first and second mile of Peterson Air Force Base	0.048	0.2139	0	1
PAFB_2to3	Between second and third mile of Peterson Air Force Base	0.088	0.2834	0	1
NORAD_half	Within half mile of Cheyenne Mountain Air Force Station	0.009	0.0945	0	1
NORAD_0to1	Within first mile of Cheyenne Mountain Air Force Station	0.016	0.1255	0	1
NORAD_1to2	Between first and second mile of Cheyenne Mountain Air Force Station	0.019	0.1366	0	1
NORAD_2to3	Between second and third mile of Cheyenne Mountain Air Force Station	0.036	0.1864	0	1
Ag_half	Within half mile of agricultural land	0	0.0000	0	0
Comsep_half	Within half mile of community seperators	0.016	0.1255	0	1
Green_half	Within half mile of greenway/stream	0.164	0.3705	0	1
Localpark_half	Within half mile of local park	0.638	0.4808	0	1
NaturalArea_half	Within half mile of natural area/wildlife habitat	0.027	0.1622	0	1
UrbanOS_half	Within half mile of urban open space	0.454	0.4981	0	1

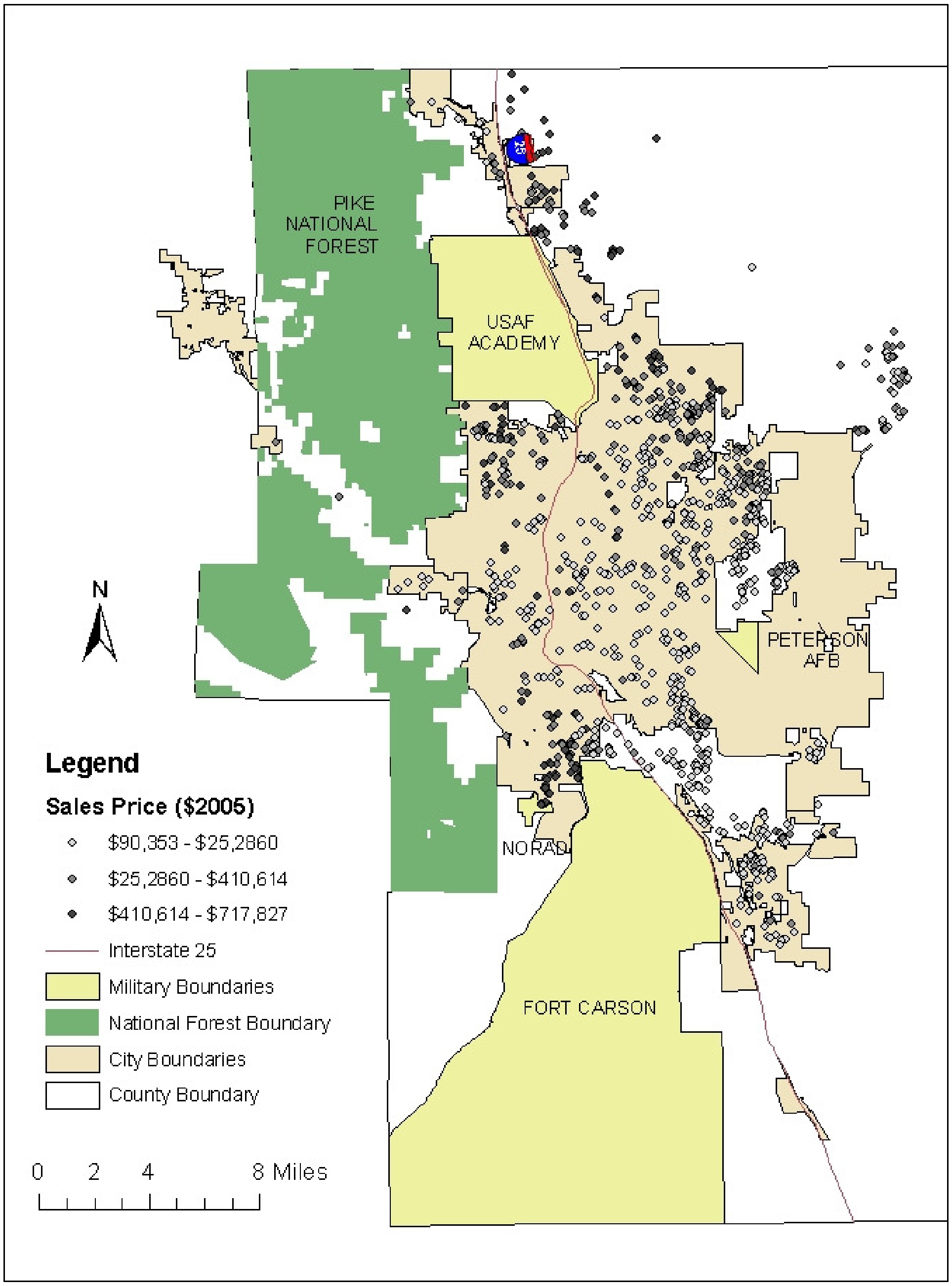

FIGURE 9. MAP OF STUDY AREA HOUSE SALES VALUES 2005-2007 ($2005)

Median income by census block group and average travel time to work by census track were the neighborhood variables selected for the final models because many of the other demographic measures, such as the percentage of students with no high school degree, the percentage non-white, and crime rates are highly correlated with income. Mean time to work was found to be correlated with distance to city center, therefore, we selected the mean time to work variable to control for employment opportunities not at city center. The average travel time to work 23.6 minutes and the average median income was $62,335. With respect to location, the average house was located 6.8 miles from Pike National Forest, 7.4 miles for U.S. Air Force Academy, 8.7 miles from Fort Carson, 7 miles from Peterson Air Force Base, and 11 miles from NORAD. The average distance to open space types in miles were local parks (0.82), urban open space (1.08), greenway (3.1), natural area/wildlife habitat (4), community separator (6.4), state park (10.9), and agricultural lands (11). Figure 10 represent the spatial arrangement of homes and open space for a portion of the study area.

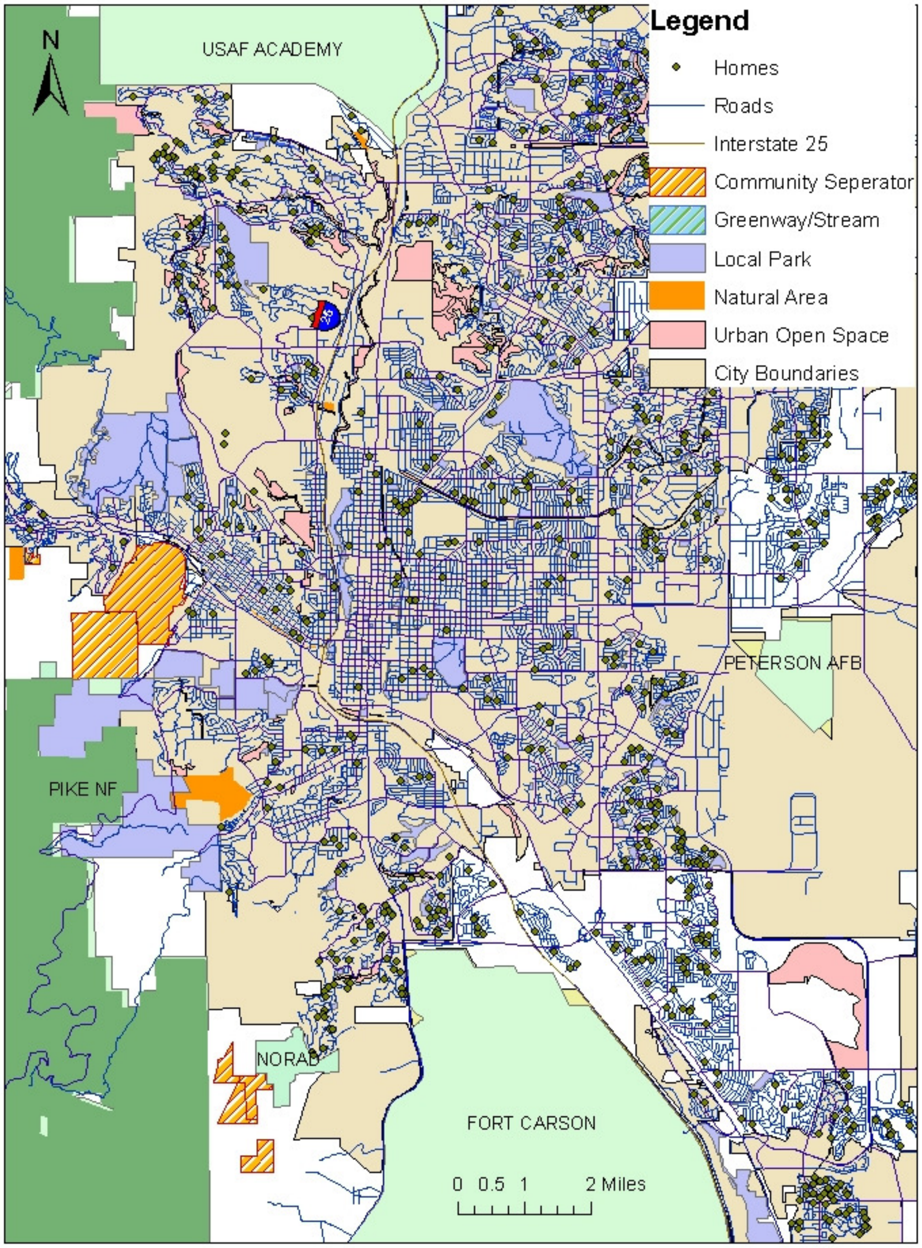

FIGURE 10. SPATIAL ARRANGEMENT OF HOMES AND OPEN SPACE

Models

Three models are estimated. For the first model, the natural log of the distance from each open space type to each house is the measure used to determine the effect of proximity on price. The sign of the coefficient will be negative if house prices decrease as distance increases and the coefficient is interpreted as the percentage change in price for a one percent change in mean distance. Then, because the relationship with distance may not be linear, two alternative models are estimated using discrete measures.

To estimate the marginal effect of adjacency in the second model, houses within a half mile of each open space type are designated using dummy variables. In the third model, dummy variables for distances within the first mile, between the first and second mile, and from the second to third miles are used to provide information about the per mile marginal effects of the national forest and each military land. Non-federal open space types are included to designate homes within a half mile. For the dummy variables, the coefficient estimate is the percentage change in price from the inclusion of the variable. These values signal the magnitude, direction and significance for marginal changes, such as an additional half mile. For significant variables, one can conclude the two variables have different marginal effects if there is no overlap in the confidence intervals.

Results

The results are presented in three sections. The first is on spatial considerations; the second reports the housing structural, neighborhood and market variable estimates; and the third addresses the open space measures.

Spatial Considerations

The joint spatial lag and spatial error models achieved the lowest AIC relative to the other models that either do not include spatial effects (OLS) or represent either the spatial lag or the spatial error components independently. The semi-variogram of the residuals from the ordinary least squares models indicates nearer neighbors have more influence than those further away and the effect levels out around 100 meters. Specifically, the joint spatial lag and error specification using an inverse distance weight matrix to 100 meters accounts for dependence among neighbors, results in an insignificant ρ and therefore there is no need to adjust coefficient estimates with the spatial multiplier. Across all spatial weight matrices considered (100, 200, 400, and 800 meters), Moran's I and the Lagrange Multiplier test statistics are found to be highly significant when the spatial lag and error components are included separately (p-value<0.0001). However, when both spatial components are included both test statistics are insignificant and the AIC is much smaller. A comparison across spatial models for the first model that represents proximity using continuous distance is in the Appendix, and others are available upon request.

A comparison of the regression results across models is provided in table 3. The first model is the best fit with the lowest AIC value (-2,121), model three is second (-2,085), and model two is third (-2,078). The relationship between the actual and predicted values for model one is 88.54%, model three is 88.35% and model two is 87.99%. Next, the results for the housing, neighborhood, and market timing variables are discussed with comparisons across models. Then, the results for the open space variables are presented.

TABLE 3. COMPARISON OF RESULTS ACROSS MODELS

Variables	Model 1			Model 2			Model 3		
	Coef Est	Std Err		Coef Est	Std Err		Coef Est	Std Err	
Constant	5.8034	0.3232	a	4.5974	0.2603	a	5.4428	0.3269	a
Age	-0.0075	0.0007	a	-0.007	0.0007	a	-0.0069	0.0007	a
Age_2	0.0001	6.9E-06	a	0.0001	6.83E-06	a	0.0001	6.89E-06	a
Bathrooms	0.0358	0.0073	a	0.0353	0.0074	a	0.0372	0.0073	a
Baseft	0.0002	9.7E-06	a	0.0002	9.86E-06	a	0.0002	9.78E-06	a
Garagesf	0.0003	3.2E-05	a	0.0003	0.0000326	a	0.0003	3.226E-05	a
ln (Houseft)	0.3097	0.0207	a	0.3248	0.0211	a	0.3164	0.0211	a
ln (Lotft)	0.0844	0.0134	a	0.0867	0.0133	a	0.0833	0.0133	a
Work	-0.0062	0.0022	a	-0.0142	0.0017	a	-0.0127	0.0018	a
ln (Income)	0.2839	0.0285	a	0.3615	0.0228	a	0.2815	0.029	a
2006	0.0905	0.0096	a	0.0916	0.0099	a	0.0914	0.0097	a
2007	0.1357	0.0115	a	0.1356	0.0117	a	0.1348	0.0116	a
rho	-0.0005	0.0007		-0.0005	0.0007		-0.0006	0.0007	
lambda	0.2403	0.0365	a	0.2403	0.0365	a	0.2473	0.0363	a
Variance	0.0178	0.0008		0.0186	0.0008		0.0181	0.0008	
Model statistics									
Residual Standard Error	0.1349			0.1379			0.1366		
R-Square	0.8854			0.8799			0.8835		
AIC	-2120.68			-2077.98			-2085.13		
	statistic	p-value		statistic	p-value		statistic	p-value	
Likelihood Ratio	36.6598	<0.0001		35.9315	<0.0001		38.8338	<0.0001	
Moran's I	0.0335	0.5741		0.0369	0.5369		0.0334	0.5751	
Lagrange Multiplier	0.2983	0.5849		0.3627	0.547		0.2971	0.5857	

[a] indicates significance at the 0.01 levels
[b] indicates significance at the 0.05 levels
[c] indicates significance at the 0.1 levels

TABLE 3 COMPARISON OF RESULTS ACROSS MODELS CONTINUED

Variables	Model 1			Model 2			Model 3		
	Coef Est	Std Err		Coef Est	Std Err		Coef Est	Std Err	
ln (PIKE)	-0.029	0.0103	a						
ln (AFA)	0.0002	0.0123							
ln (FTC)	0.0142	0.0127							
ln (PAFB)	0.0204	0.0137							
ln (NORAD)	-0.044	0.0152	a						
ln (Agriculture)	0.0523	0.0357							
ln (CommunitySeperator)	-0.0138	0.0093							
ln (Greenway/Stream)	-0.0064	0.0054							
ln (LocalPark)	-0.0026	0.0054							
ln (NaturalArea/Wildlife)	-0.0342	0.01	a						
ln (Urban)	0.0075	0.005							
PIKE_half				0.1614	0.0515	a			
AFA_half				-0.0244	0.0384				
FTC_half				0.0152	0.0299				
NORAD_half				0.0821	0.0593				
Comsep_half				0.1307	0.0399	a			
Green_half				0.0085	0.0144				
Localpark_half				-0.0012	0.0127				
Naturalarea_half				0.1257	0.0299	a			
UrbanOS_half				-0.0209	0.0121				
PIKE0to1							0.0878	0.0268	a
PIKE1to2							0.0454	0.0222	b
PIKE2to3							0.0268	0.0184	
AFA0to1							0.0481	0.0309	
AFA1to2							-0.0004	0.0197	
AFA2to3							0.0098	0.0176	
FTC0to1							-0.0636	0.0275	b
FTC1to2							-0.0492	0.0199	b
FTC2to3							-0.0288	0.0199	
NORAD0to1							0.1384	0.0527	a
NORAD1to2							0.1557	0.0479	a
NORAD2to3							0.042	0.0346	
PAFB0to1							0.0003	0.0684	
PAFB1to2							-0.0324	0.0241	
PAFB2to3							-0.0446	0.0189	b
Comsep_half							0.0902	0.0407	b
Green_half							0.0122	0.0149	
Localpark_half							-0.007	0.0135	
NaturalArea_half							0.1018	0.0302	a
UrbanOS_half							-0.0321	0.0125	a

[a] indicates significance at the 0.01 levels

[b] indicates significance at the 0.05 levels

[c] indicates significance at the 0.1 levels

Housing Structural, Neighborhood, and Market Relationships

The coefficients on the housing, neighborhood, and market timing variables had the expected signs and are consistent across models. All coefficient estimates were statistically significant at the 1% level. House prices increase with an increase in the number of bathrooms, median income levels, along with lot, house, garage, and basement area. House prices decrease with age and depreciation has a greater effect on newer homes than older homes similar to the result in Lewis, Bohlen and Wilson (2008). For market variables, houses sold in 2006 and 2007 sell for a premium relative to those sold in 2005 (9% and 14% respectively).

Open Space Measures

The first model that measures open space proximity based on the natural log of distance indicates there is a price premium for a 1% change in the mean distance closer increases house prices for Pike National Forest (2.9% premium), NORAD (4.4%), and natural area/wildlife habitat (3.4%). A similar positive and significant contribution of national forest land was found in the Cho et al. (2009) and Hand et al. (2008) studies. Doss and Taff (1996) found similar 1.9-2.8% premiums for proximity to wetlands and Lutzenhiser and Netusil (2001) found a 2.6% premium for living 200 meters closer to a natural area/park. Exact comparisons are difficult because of the possible non-linear effects of distance. U.S. Air Force Academy, Fort Carson, and Peterson Air Force Base proximity was not found to have a statistically significant effect on house prices. Evaluated at the mean house price ($265,296) with 95% confidence intervals the marginal implicit price for proximity to the Pike National Forest is -$1,128 [-$1,913, -

$343], to NORAD is -$1,059 [-$1,776, -$342], and to natural areas/wildlife habitat is -$2,273 [-$3,575, -$970]. Confidence intervals overlap for all three indicating their effects are not different.

The second model that measures open space using half mile dummy variables indicates there are price premiums for homes within a half mile of the Pike National Forest (17.5%), community separators (13.9%) and natural area/wildlife habitat (13.4%). The marginal implicit price for homes within a half mile of the Pike National Forest is $46,468 [$16,535, $65,899]. The marginal implicit price for homes within a half mile of a community separator is $37,042 [$14,299, $53,338]. The marginal implicit price for homes within a half mile of natural area/wildlife habitat is $35,534 [$18,411, $56,411]. All other open space categories were found to be statistically insignificant.

The third model that measures proximity to national forest and military lands with three one mile intervals provides more information about how the marginal price effect varies with distance. For the Pike National Forest, the first mile is valued at 9.2% and the second is valued approximately half as much, 4.6%, while the third mile was found to be insignificant. For NORAD, the first two miles yield similar price premiums with 14.8% for the first mile, 16.8% for the second mile, and no statistically significant effect for the third mile. For Fort Carson, the first mile and second miles are valued negatively (-6.2% and -4.8% respectively) and the third had no statistically significant effect. Houses between two and three miles of Peterson Air Force Base exhibited a -4.4% discount while proximity to the Air Force Academy did not have a statistically significant effect over any interval within the three miles. As for the other open space types, within a half mile of the community separators and natural areas/wildlife habitat increased house prices

9.4% and 10.7% respectively. Urban open space is statistically significant and negative (-3. 2%) indicating it is a disamenity. All other open space types were insignificant. The marginal implicit price for homes within the first mile of the Pike National Forest is $24,346 [$9,525, $39,967] and the second mile is $12,322 [$501, $24,668]. The marginal implicit price for homes within the first mile of NORAD is $39,379 [$9,479, $72,532] and the second mile is $44,696 [$16,917, $75,209]. The marginal implicit price for homes within the first mile of Fort Carson is -$16,348 [-$29,411, -$2,561] and the second mile is -$12,737 [-$22,398, -$2,691]. For Peterson Air Force Base the discount for homes between two and three miles is -$11,572 [-$20,799, -$1,997]. Within a half mile of community separators is $37,042 [$14,299, $53,338]. The marginal implicit price for homes within a half mile of community separators is $25,042 [$2,781, $49,152], for natural area/wildlife habitat is $28,430 [$11,548, $46,341], and urban open space is -$8,381 [-$14,599, -$2,009].

Table 4 provides a summary of the direction of the effects of proximity to open space across models. Based on the proximity measures, the Pike National Forest, NORAD, community separators, and natural areas/wildlife habitat are amenities. Fort Carson, Peterson Air Force Base, and urban open space are disamenities.

TABLE 4. SUMMARY OF DIRECTION OF EFFECTS FOR PROXIMITY ACROSS MODELS

	Model 1	Model 2		Model 3	
	Continuous*	0-half	0-1	1-2	2-3
PIKE	-	+	+	+	ns
USAFA	ns	ns	ns	ns	ns
Fort Carson	ns	ns	-	-	ns
Peterson AFB	ns	ns	ns	ns	-
NORAD	-	ns	+	+	
	Continuous	0-half	0-half		
Community Seperator	ns	+	+		
Natural Area/Wildlife Habitat	-	+	+		
Urban Open Space	ns	ns	-		

* Negative represents that house prices decrease when moving from open space in model 1 as opposed to models 2 and 3 that represent amenity (+) and disamenity (-).

ns=not statistically significant at 95% confidence level

Total Implicit Expenditures and Tax Revenue

The total implicit expenditure (TIE) is the product of the marginal implicit price and the quantity of the amenity (Carruthers and Clark 2010). To calculate the total implicit expenditure and tax revenue by open space type the following information is required. The house sales values and the dummy variables for open space measures are needed for all observations. Then, the coefficients estimated for each statistically significant open space measures are used as factors in the equation to calculate the marginal implicit prices. Additionally, the El Paso County property tax rate was 7.7% per $1,000 in 2007 and the number of single family housing units in El Paso County was 179,080 according to the U.S. Census American Community Survey 2005-2009. Therefore, to extrapolate the results from the sample (n=1,000) to the population (n=179,080) the TIE from the sample is multiplied by the factor 179.08. The formula to calculate the total implicit expenditure for each open space type represented discretely is:

$$\text{House Price}_i*[\text{Exp}(\beta_{dummy})-1] = \sum_{i=1}^{n} \text{TIE}_{sample} = \text{annual TIE}_{sample} \quad [31]$$

$$\text{TIE}_{sample} * 179.08 = \text{TIE}_{population} \quad [32]$$

$$\text{TIE}_{population}/1000 * 0.077 = \text{tax revenue} \quad [33]$$

TABLE 5. TOTAL IMPLICIT EXPENDITURES AND TOTAL TAX REVENUE

Model	Open Space	Measure	Coefficient	Annual TIE sample	Annual tax revenue sample	Annual TIE population	Annual tax revenue population
Model 2	Pike National Forest	half	0.1752	$464,473	$36	$333,993,333	$25,717
Model 2	Community separator	half	0.1396	$491,881	$38	$353,701,486	$27,235
Model 2	Natural/wildlife	half	0.1339	$975,364	$75	$701,364,698	$54,005
Totals						$1,389,059,517	$106,958
Model 3	Pike National Forest	0-1	0.0918	$992,328	$76	$713,563,442	$54,944
Model 3	Pike National Forest	1-2	0.0464	$1,301,512	$100	$935,891,474	$72,064
Model 3	NORAD	0-1	0.1484	$1,244,312	$96	$894,760,143	$68,897
Model 3	NORAD	1-2	0.1685	$1,415,447	$109	$1,017,819,917	$78,372
Model 3	Fort Carson	0-1	-0.0616	-$1,081,831	-$83	-$777,923,026	-$59,900
Model 3	Fort Carson	1-2	-0.048	-$2,195,799	-$169	-$1,578,954,893	-$121,580
Model 3	Peterson AFB	2-3	-0.0436	-$768,825	-$59	-$552,846,676	-$42,569
Model 3	Community separator	half	0.0944	$332,618	$26	$239,179,229	$18,417
Model 3	Natural/wildlife	half	0.10716	$780,583	$60	$561,301,277	$43,220
Model 3	Urban open space	half	-0.0316	-$3,970,633	-$306	-$2,855,202,735	-$219,851
Totals						-$1,402,411,849	-$107,986

Table 5 provides the breakdown of total implicit expenditures and tax revenue by open space type. Models 2 and 3 were selected because they measure the effects over discrete ranges. In model 2 that estimates the value for homes with a half mile of the open space types, the annual total implicit expenditure for the population was $1,389,059,517 from which $106,958 tax revenue is generated. Half of the total value is from homes within a half mile of natural areas that are relatively more dispersed throughout the study area. Proximity to the Pike National Forest and community separators raise similar revenues.

In the third model that estimates the value for homes within three miles of the federal lands and within half mile of the other open space types provides a very different result partially because many more homes are included in the analysis. The total implicit expenditure for the population was -$1,402,411,849 from which -$107,986 tax revenue was lost. The gain in tax revenue from proximity to Pike National Forest, NORAD, community separators and natural areas/wildlife habitat was $335,914. The loss in tax revenue associated with proximity to Fort Carson, Peterson Air Force Base and urban open space totaled -$443,900.

Summary and Conclusions

The objective of this study was to determine (1) if proximity to national forest and military lands effects house prices in El Paso County Colorado and (2) if the effect is similar or different from other open space types in the area. Results for the federal lands indicate proximity to Pike National Forest and NORAD increases house prices while proximity to Fort Carson and Peterson Air Force Base decreases house prices. Then relative to the other open space types, premiums are generated from proximity to community separators and natural areas/wildlife habitat similar to that of the Pike National Forest and NORAD. These open space types are located in close proximity to one another in an area with high natural amenity value. Conversely, there are discounts associated with proximity to urban open space that are similar to those for Fort Carson and Peterson Air Force Base. The homes that are experiencing the discount are located in an older part of town that is more attractive to military families. Proximity to the U.S. Air Force Academy did not result in statistically significant effects.

These results may be used by land use planners and policy makers when determining the distribution of open space across the county. For example, the addition of community separators and natural areas/wildlife habitat closer to Fort Carson and Peterson Air Force Academy can reduce the disamenity value associated with proximity to these federal lands.

However, a limitation of this study is that the land uses on each federal land vary within and between them especially for Pike National Forest and Fort Carson that occupy large areas. This study does not differentiate the positive values of recreation access from negative values from noise-intensive activities like off-road vehicles or timber harvesting. In the next chapter, individual hedonic housing functions are estimated for each house and marginal values are averaged globally across the study area using ordinary least squares and with half mile intervals using geographically weighted regression. Then, in the chapter that follows, focus is placed on Pike National Forest proximity values based on homogeneous and heterogeneous land use classifications for homes within the first two miles, the distance at which this chapter found a significant non-linear price premium.

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Appendix

REGRESSION RESULTS MODEL 1 (Continuous)

Variable	Estimated Coefficient	Standard Error	*p* -value	Marginal Price
Housing characteristics				
Constant	5.8034	0.3232	<0.0001	
Age	-0.0075	0.0007	<0.0001	-$1,990
Age_2	0.0001	0.00000686	<0.0001	$27
Bathrooms	0.0358	0.0073	<0.0001	$9,498
Baseft	0.0002	0.00000973	<0.0001	$53
Garagesf	0.0003	0.00003198	<0.0001	$80
ln (Houseft)	0.3097	0.0207	<0.0001	$50
ln (Lotft)	0.0844	0.0134	<0.0001	$2
Neighborhood characteristcs				
Work	-0.0062	0.0022	0.0057	-$1,645
ln (Income)	0.2839	0.0285	<0.0001	$1,208
Timing				
y2006	0.0905	0.0096	<0.0001	$25,129
y2007	0.1357	0.0115	<0.0001	$38,558
Open space				
ln (PIKE)	-0.029	0.0103	0.005	-$1,128
ln (AFA)	0.0002	0.0123	0.9892	$7
ln (FTC)	0.0142	0.0127	0.2665	$431
ln (PAFB)	0.0204	0.0137	0.1385	$770
ln (NORAD)	-0.044	0.0152	0.0039	-$1,059
ln (Agriculture)	0.0523	0.0357	0.1437	$664
ln (CommunitySeperator)	-0.0138	0.0093	0.1374	-$570
ln (Greenway/Stream)	-0.0064	0.0054	0.2398	-$543
ln (LocalPark)	-0.0026	0.0054	0.6295	-$837
ln (NaturalArea/Wildlife)	-0.0342	0.01	0.0006	-$2,273
ln (Urban)	0.0075	0.005	0.136	$1,837
Spatial measures				
rho	-0.0005	0.0007	0.4557	
lambda	0.2403	0.0365	<0.0001	
Variance	0.0178	0.0008		
Model statistics				
N=1,000; Mean House Price=$265,296; Residual Standard Error = 0.1349; FIT = 0.8854; AIC = -2120.68				
Likelihood Ratio = 36.6598 (<0.0001); Moran's I=0.0335 (0.5741); Lagrange multiplier=0.2983 (0.5849)				

REGRESSION RESULTS MODEL 2 (Half mile)				
Variable	Estimated Coefficient	Standard Error	*p* -value	Marginal Price
Housing characteristics				
Constant	4.5974	0.2603	<0.0001	
Age	-0.007	0.0007	<0.0001	-$1,857
Age_2	0.0001	0.00000683	<0.0001	$27
Bathrooms	0.0353	0.0074	<0.0001	$9,365
Baseft	0.0002	0.00000986	<0.0001	$53
Garagesf	0.0003	0.0000326	<0.0001	$80
ln (Houseft)	0.3248	0.0211	<0.0001	$53
ln (Lotft)	0.0867	0.0133	<0.0001	$2
Neighborhood characteristcs				
Work	-0.0142	0.0017	<0.0001	-$3,767
ln (Income)	0.3615	0.0228	<0.0001	$1,539
Timing				
y2006	0.0916	0.0099	<0.0001	$25,449
y2007	0.1356	0.0117	<0.0001	$38,527
Open Space				
PIKE_half	0.1614	0.0515	0.0018	$46,468
AFA_half	-0.0244	0.0384	0.5249	-$6,395
FTC_half	0.0152	0.0299	0.6107	$4,063
NORAD_half	0.0821	0.0593	0.1663	$22,700
Comsep_half	0.1307	0.0399	0.0011	$37,042
Green_half	0.0085	0.0144	0.5555	$2,265
Localpark_half	-0.0012	0.0127	0.924	-$318
Naturalarea_half	0.1257	0.0299	<0.0001	$35,534
UrbanOS_half	-0.0209	0.0121	0.0825	-$5,487
rho	-0.0005	0.0007	0.4656	
lambda	0.2403	0.0365	<0.0001	
Variance	0.0186	0.0008		
Model statistics				
N=1,000; Mean House Price=$265,296; Residual Standard Error = 0.1379; FIT = 0.8799; AIC = -2077.98				
Likelihood Ratio = 35.9315 (<0.0001); Moran's I=0.0369 (0.5369); Lagrange multiplier=0.3627 (0.547)				

REGRESSION RESULTS MODEL 3 (0-1,1-2,2-3)				
Variable	Estimated Coefficient	Standard Error	*p* -value	Marginal Price
Housing characteristics				
Constant	5.4428	0.3269	<0.0001	
Age	-0.0069	0.0007	<0.0001	-$1,831
Age_2	0.0001	0.00000689	<0.0001	$27
Bathrooms	0.0372	0.0073	<0.0001	$9,869
Baseft	0.0002	0.00000978	<0.0001	$53
Garagesf	0.0003	0.00003226	<0.0001	$80
ln (Houseft)	0.3164	0.0211	<0.0001	$51
ln (Lotft)	0.0833	0.0133	<0.0001	$2
Neighborhood characteristcs				
Work	-0.0127	0.0018	<0.0001	-$3,369
ln (Income)	0.2815	0.029	<0.0001	$1,198
Timing				
y2006	0.0914	0.0097	<0.0001	$25,391
y2007	0.1348	0.0116	<0.0001	$38,284
Open Space				
PIKE0to1	0.0878	0.0268	0.0011	$24,346
PIKE1to2	0.0454	0.0222	0.0406	$12,322
PIKE2to3	0.0268	0.0184	0.1466	$7,206
AFA0to1	0.0481	0.0309	0.12	$13,073
AFA1to2	-0.0004	0.0197	0.9841	-$106
AFA2to3	0.0098	0.0176	0.5779	$2,613
FTC0to1	-0.0636	0.0275	0.0212	-$16,347
FTC1to2	-0.0492	0.0199	0.0135	-$12,737
FTC2to3	-0.0288	0.0199	0.1481	-$7,532
NORAD0to1	0.1384	0.0527	0.0087	$39,379
NORAD1to2	0.1557	0.0479	0.0012	$44,696
NORAD2to3	0.042	0.0346	0.2253	$11,380
PAFB0to1	0.0003	0.0684	0.9967	$80
PAFB1to2	-0.0324	0.0241	0.1784	-$8,458
PAFB2to3	-0.0446	0.0189	0.0184	-$11,572
Comsep_half	0.0902	0.0407	0.0269	$25,042
Green_half	0.0122	0.0149	0.4138	$3,256
Localpark_half	-0.007	0.0135	0.6051	-$1,851
NaturalArea_half	0.1018	0.0302	0.0008	$28,430
UrbanOS_half	-0.0321	0.0125	0.01	-$8,381
rho	-0.0006	0.0007	0.4083	
lambda	0.2473	0.0363	<0.0001	
Variance	0.0181	0.0008		
Model statistics				
N=1,000; Mean House Price=$265,296; Residual Standard Error = 0.1366; FIT = 0.8835; AIC = -2085.13				
Likelihood Ratio = 38.8338 (<0.0001); Moran's I=0.0334 (0.5751); Lagrange multiplier=0.2971 (0.5857)				

COMPARISON ACROSS OLS AND SPATIAL MODELS FOR MODEL 1

Variables	OLS			Spatial Lag			Spatial AR			Joint Spatial		
	Coef Est	Std Err		Coef Est	Std Err		Coef Est	Std Err		Coef Est	Std Err	
Constant	5.7133	0.3157	a	5.702	0.3118	a	5.8356	0.3258	a	5.8034	0.3232	a
Age	-0.008	0.0007	a	-0.0078	0.0007	a	-0.0076	0.0007	a	-0.0075	0.0007	a
Age_2	0.0001	0.00000693	a	0.0001	0.00000687	a	0.0001	0.00000688	a	0.0001	0.00000686	a
Bathrooms	0.0332	0.0076	a	0.0339	0.0075	a	0.0356	0.0072	a	0.0358	0.0073	a
Baseft	0.0002	0.00000995	a	0.0002	0.00000982	a	0.0002	0.00000972	a	0.0002	0.00000973	a
Garagesf	0.0003	0.00003317	a	0.0003	0.00003276	a	0.0003	0.0000319	a	0.0003	0.00003198	a
ln (Houseft)	0.3222	0.021	a	0.3218	0.0208	a	0.3078	0.0207	a	0.3097	0.0207	a
ln (Lotft)	0.0785	0.0137	a	0.0808	0.0137	a	0.0828	0.0134	a	0.0844	0.0134	a
Work	-0.0068	0.0022	a	-0.0066	0.0022	a	-0.0063	0.0022	a	-0.0062	0.0022	a
ln (Income)	0.2893	0.0279	a	0.2862	0.0276	a	0.2866	0.0287	a	0.2839	0.0285	a
2006	0.0899	0.01	a	0.0902	0.0099	a	0.0904	0.0096	a	0.0905	0.0096	a
2007	0.1324	0.012	a	0.1327	0.0119	a	0.1358	0.0114	a	0.1357	0.0115	a
ln (PIKE)	-0.0253	0.01	b	-0.0261	0.0099	a	-0.0285	0.0104	a	-0.029	0.0103	a
ln (AFA)	-0.0007	0.0118		0.0008	0.0117		-0.0018	0.0125		0.0002	0.0123	
ln (FTC)	0.0092	0.0115		0.009	0.0113		0.0159	0.013		0.0142	0.0127	
ln (PAFB)	0.0183	0.013		0.0182	0.0129		0.0211	0.0139		0.0204	0.0137	
ln (NORAD)	-0.0368	0.0132	a	-0.0351	0.0131	a	-0.0486	0.0157	a	-0.044	0.0152	a
ln (Agriculture)	0.0567	0.0337	c	0.0591	0.0333	c	0.0479	0.0362		0.0523	0.0357	
ln (CommunitySeperator)	-0.0141	0.0086		-0.0137	0.0085		-0.0144	0.0094		-0.0138	0.0093	
ln (Greenway/Stream)	-0.0047	0.0051		-0.005	0.005		-0.0062	0.0055		-0.0064	0.0054	
ln (LocalPark)	-0.005	0.0052		-0.0054	0.0051		-0.0017	0.0055		-0.0026	0.0054	
ln (NaturalArea/Wildlife)	-0.036	0.0098	a	-0.0365	0.0097	a	-0.0332	0.0101	a	-0.0342	0.01	a
ln (Urban)	0.0085	0.0048	c	0.0084	0.0047	c	0.0075	0.0051		0.0075	0.005	
rho				0.0011	0.0008					-0.0005	0.0007	
lambda							0.2812	0.0354	a	0.2403	0.0365	a
Variance				0.0187	0.0008		0.0177	0.0008		0.0178	0.0008	
Model statistics												
Residual Standard Error	0.1386			0.1384			0.1346			0.1349		
R-Square	0.8789			0.8788								
AIC	-1092.021			-1092.093			-1123.371			-2120.68		
	statistic	p-value		statistic	p-value		statistic	p-value		statistic	p-value	
Likelihood Ratio				2.0728	0.1499		317.3111	<0.0001		36.6598	<0.0001	
Moran's I	0.3322	0.3554		0.33139	<0.0001		-0.012586	0.850266		0.0335	0.5741	
Lagrange Multiplier	29.2329	<0.0001		29.0992	<0.0001		3.1657	0.0752		0.2983	0.5849	

[a] indicates significance at the 0.01 levels
[b] indicates significance at the 0.05 levels
[c] indicates significance at the 0.1 levels

CHAPTER THREE

Marginal Implicit Prices for Federal Land Proximity: A Comparison of Local and Global Estimation Techniques

Abstract

This study addresses spatial heterogeneity when estimating marginal values of proximity to federal lands in El Paso County, Colorado. Hedonic property price functions are estimated using local and global regression techniques. Results indicate that federal land proximity positively relates to house prices in the western and southern portions of the study area for 43% of the housing transactions, negatively relates in the east for 11% of the transactions, and no effect is found for the other 46%. Differences between the local and global models indicate there is significant variation in marginal implicit prices across the landscape and the degree of variation is dependent on the bandwidth included in the estimation.

KEYWORDS Hedonic model - Locally Weighted Regression - Public Lands

JEL Classification R21 - Q31

Introduction

Natural-human systems are functions of interdependent ecological, social and physical components that vary over space and time. As a result, much can be learned from exploring natural-human systems with respect to spatial heterogeneity because constituent processes are coupled and exhibit legacy effects were past couplings impact present conditions and future possibilities (Liu et al. 2007). In 2008, half of the world's population lived in urban areas and sixty percent is projected by 2030 (Population Reference Bureau 2007). Alterations by humans managing natural and built features within urban areas impact ecosystem structure and function (McDonnell and Pickett 1990, Cadenasso et al. 2007) also known as the ecology of cities (Grimm et al. 2008). Spatial configurations influence interactions within and beyond urban ecosystems based on the spatial variability matrix of state factors and interactive controls (Holling 1992). Patterns and processes emerge from interactions at local micro-levels and global macro-levels resulting in variability across the landscape, i.e. spatial heterogeneity.

Humans tend to cluster as do other organisms and organizations. In 2003, Rhode and Strumpf assessed whether people stratify within or between neighborhoods based on the supply of local public services (municipality/county level) and mobility costs based on long-run trends. When they added mobility costs to the more traditional Tiebout model that represents residential choice as a function of local public services only, they find increasing heterogeneity between neighborhoods within the same municipality while municipalities become more alike.

Patchiness in spatial configurations is common across scales (Levins 1992). Spatial heterogeneity in coupled natural-human ecosystem fluctuates over time as humans shift from dependence on primary production (agriculture, fishing, forestry, mining) to secondary production (manufacturing and construction) to tertiary sectors (services) (Fisher 1939). Economies transition and humans relocate from rural areas to urban settings significantly impacting ecological trends through land use and land cover changes (Ojima et al. 1994; Vitousek 1994). Human induced impacts on air quality and water quantity and quality resulted in the creation of the Clean Air and Clean Water Acts in the United States in the late 1960's and early 1970's. The Air Quality Act of 1967 was the first to address pollution as the preface to the Clean Air Act in 1970. The Clean Air Act created National Ambient Air Quality Standards (NAAQS) to address human health hazards and reduce atmospheric alterations from carbon monoxide, nitrogen dioxide, ozone, sulfur dioxide, lead and particulate matter with aerodynamic size less than or equal to 10 micrometers (PM-10). The Clean Water Act was established to reduce the effects of agricultural and industrial production through limiting point and non-point source pollution. These government policies were developed to effect local processes with global implications (Berkes 2006). Therefore, estimation methods that allow for variation in marginal values across the landscape are needed to evaluate welfare effects of targeted environmental policies.

The challenge of defining the appropriate scale for analysis is common among applied researchers (Levin 1992). Scales depend on species relationships within environments (de Knegt et al. 2010). Therefore, techniques that identify natural scales of underlying deterministic dynamics most evident within systems, also called characteristic length scales (CLSs), are valuable across disciplines (Habeeb et al. 2005). Habeeb et al. (2005) model spatial multispecies systems with varying complexity and find CLSs signal the degree of connectivity between species. The connectivity is determined by the spatial organization and topology of the interaction networks within the system such that the more similar the CLSs, the more closely connected are the species. Complex spatial selforganization exhibited multiple CLSs. Veldkamp and Fresco examined how the spatial distributions of human land use/cover and biophysical elements are related using nested scale analysis in the Costa Rican context (1997). They found scale-dependencies are present for each land use/cover type during the years of the study, 1973 and 1984.

Performing analyses at incorrect or inappropriate scales has significant implications statistically (de Knegt et al. 2010). The de Knegt et al. paper examined the joint effects of spatial scaling and residual spatial autocorrelation when modeling species-environment relationships. They found the scale of analysis and the scale of a species response to the environment need to be the same in order for statistical models to estimate unbiased coefficient estimates. They used residual spatial autocorrelation to examine error-predictor dependencies when the scales are incorrectly specified and there are important implications to misspecification of scale in interpreting species-environment interactions.

Therefore, to provide decision makers with information about how marginal values for environmental amenities vary across the landscape for homeowners, variations on scale are performed using locally and globally weighted regressions for estimating hedonic housing price functions. The first model represents house prices as a function of the housing structural variables, school district, and time. Then, the distance to federal lands is added to examine if there are property price effects for proximity and how the marginal values vary. Results provide insight into how levels of aggregation influence the valuation of natural resources in Colorado Springs, Colorado from 2005 to 2007.

Study Area and Data

The study area is the western portion of El Paso County, Colorado. The dataset for this analysis has many similarities to that from the last chapter for residential single family housing on one acre or less that sold from 2005 to 2007 excluding transactions not considered arms-length. The sample used to estimate the models is the same as in the last chapter and additionally the data for the entire population are used to estimate the global models. The local and global models are specified differently because factors that influence where someone chooses to live within a region are different than those used to narrow down a particular house within a neighborhood (Jones 2002). Therefore, the global (ordinary least squares) more regional models include school districts as important determinants, while the local (geographically weighted) models perform best without the discrete breaks imposed by the use of dummy variables. For the same reason, time is captured as a continuous variable (TIME) rather than by year or season. Housing structural variables that exhibit significant variation are the house age (AGE), and area of the house (HOUSE SQ FT), lot (LOT SQ FT), basement (BASE SQ FT), and garage (GARAGE SQ FT).

When homebuyers select a neighborhood the location decision may be based on many different factors. School districts, commute routes and natural amenities may influence the location decision in varying degrees depending on the household's priorities. For the global models we assume the market is defined by school districts (figure 11). The districts are Academy (S_ACADEMY), Cheyenne Mountain (S_CHEYMTN), Falcon

(S_FALCON), Fort Carson (S_FTCARSON), Harrison (S_HARRISON), Lewis Palmer (S_LEWISPAL), Manitou Springs (S_MANITOU), Widefield (S_WIDEFIEL) and Colorado Springs is the omitted district to which the others are compared. According to the Colorado Department of Education the school districts with the highest achievement and highest growth are Academy, Cheyenne Mountain, and Lewis Palmer.[17] These areas coincide with the locations of the Pike National Forest, the U.S. Air Force Academy, and NORAD therefore including both the school districts and the individual federal lands results in significant multicollinearity. Therefore we included the school districts independently and created a composite variable for measuring proximity to federal lands (FEDLANDS). This FEDLANDS variable is calculated as the distance to the nearest federal land and the coefficient captures the average contribution of proximity to federal lands in the OLS model. Then, in the local models the coefficients on the FEDLANDS variable vary indicating the locations where proximity is positive, no effect or negative rather than one average value.

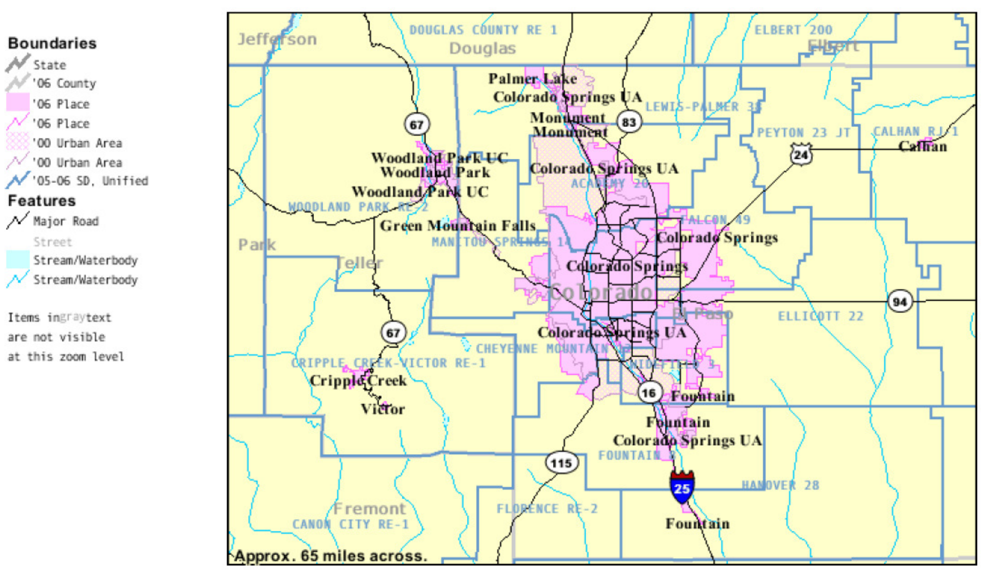

FIGURE 11. CENSUS MAP OF AREA SCHOOL DISTRICTS IN 2006

[17] http://www.edu.cde.state.co.us/growthmodel/public

Models

By observing home buying behavior across sites with varying degrees of environmental benefits, one can estimate the economic value that additional environmental benefits provide to homebuyers. The economic value is estimated in dollar terms because dollars are the common metric from which most resource allocation decisions are based. Researchers have employed various techniques to identify demand parameters from hedonic price equations in the market for homes (Blomquist & Worley 1981; Palmquist 1984), automobiles (Agarwal & Ratchford 1980; Arguea, Hsiao and Taylor 1993), and other goods. Two regression techniques are applied herein.

Ordinary Least Squares Regression

$$\ln(y_i) = \beta_0 + \sum_k \beta_k x_{ik} + \varepsilon_i, \qquad [34]$$

where $\ln(y_i)$ is the natural log of the house sale price for house i; x_{ik} are house i structural, neighborhood, and location characteristics k. The error term ε_i is assumed to be independent and identically distributed with a mean of 0 when estimating the model using ordinary least squares.

$$\beta_{OLS} = \begin{bmatrix} \beta_0 & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & \beta_k \end{bmatrix}, \qquad [35]$$

However, the condition is not expected to hold in housing markets because of known and unknown spatial autocorrelation. Thus, the alternative estimation method is the locally (geographically) weighted regression.

Locally Weighted Regression

$$\ln(y_i) = \beta_0(u_i, v_i) + \sum_k [\beta_k(u_i, v_i)] x_{ik} + \varepsilon_i, \qquad [36]$$

where (u_i,v_i) represents the coordinates of the ith house in space, and $\beta_k(u_i,v_i)$ is the ith house contribution to the continuous function $\beta_k(u,v)$.

$$\hat{\beta}(u_i, v_i) = (\mathbf{X}^T\mathbf{W}(u_i, v_i)\mathbf{X})^{-1}\mathbf{X}^T\mathbf{W}(u_i, v_i)\mathbf{Y}, \qquad [37]$$

where $\hat{\beta}$ is an estimate of β; **X** is a vector of house characteristics x_{ih}; **Y** is a vector of $\ln(y_i)$; $\mathbf{W}(u_i,v_i)$ is an n x n diagonal matrix with diagonal elements; w_{ii} is the geographical weighting of the observed value of house i.

The classical regression equation is:

$$\mathbf{Y} = (\boldsymbol{\beta} \otimes \mathbf{X})\mathbf{1} + \varepsilon, \qquad [38]$$

where ⊗ is a multiplication operator in which each element of is **β** multiplied by the corresponding element of **X**, and **1** is a conformable vector of 1's. If there are n homes and k explanatory variables including the constant, both **β** and **X** are of dimensions n x k. The matrix for the locally weighted regression consists of n sets of local parameters represented as,

$$\beta_{GWR} = \begin{bmatrix} \beta_0(u_1, v_1) & \cdots & \beta_k(u_1, v_1) \\ \vdots & \ddots & \vdots \\ \beta_0(u_n, v_n) & \cdots & \beta_k(u_n, v_n) \end{bmatrix}, \qquad [39]$$

$\mathbf{W}(i)$ is an n x n spatial weight matrix of the form

$$\mathbf{W}(i) = \begin{bmatrix} w_{i1} & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & w_{in} \end{bmatrix}, \qquad [40]$$

where w_{ij} is the weight given to house *j* in the calibration of the model for house *i*. The diagonal elements of the weight matrix, w_{ij}, are equal to:

$$w_{ij} = \begin{cases} \left[1 - (\frac{d_{ij}}{b})^2\right]^2 & if\ d_{ij} < b, \\ 0\ otherwise, \end{cases} \qquad [41]$$

Where d_{ij} is the Euclidean distance between house *i* and j, and *b* is the bandwidth. The bandwidth is the distance range for which the GWR is estimated. There is an important trade-off between bandwidth length and spatial heterogeneity representation: the longer the bandwidth, the less chance for variation in coefficients across the landscape. At the largest bandwidth that covers the entire study area, coefficients become the mean in OLS. In this paper, the models are estimated in ESRI's ArcGIS Spatial Statistics tool and the optimal bandwidth is selected iteratively by comparing Akaike Information Criteria (AIC) across models with varied bandwidth. The number of neighbors selected by AIC are compared to those when selecting by cross-validation.

$$CV = \sum_{i=1}^{n}[y_i - \hat{y}_{\neq i}(b)]^2 \qquad [42]$$

The cross-validation (CV) approach is almost identical to least squares criteria estimated without house *i* (Cleveland 1979). Then, an imposed distance of a half mile is examined to provide insight about how the estimates vary with variations in bandwidth.

Results

To begin, the coefficient estimates for the housing structural variables were of the expected sign such that homes with more square footage of all types sell for more and older homes sell for less. Additional garage square footage was valued highest, house square footage was next, then basement and last and, sometimes insignificantly, lot. The restriction of the sample to homes on one acre or less may be influencing the lot size marginal value while some other studies have examined the relationship between lot size and adjacent open space types to find they can be considered substitutes in some cases (Cho et al. 2009).

Ordinary Least Squares

Table 6 provides a comparison of the global models using the different datasets.[18] The magnitude, direction and general relationships hold across models. However, the federal land proximity measure is statistically insignificant in the model with the least observations, only -0.21% change in house price per mile increase in distance indicating average homes closer to federal lands do not exhibit price premiums. In the model of the population, the marginal effect of federal land proximity is minute (0.000001% change per mile in house price) and is likely a false positive (type I error) because the significant spatial autocorrelation detected in the residuals. Homes in the Falcon, Fort Carson, Harrison and Widefield school districts sell for less while homes in Academy, Manitou Springs, Cheyenne Mountain, and Lewis Palmer districts sell for more than Colorado Springs. Also, house sale prices increased over time.

[18] White's heteroskedasticity consistent covariance and standard errors are reported for OLS.

TABLE 6. COMPARISON ACROSS OLS MODELS FOR SAMPLE & POPULATION

Variables	OLS Model 1 (n=1,000)			OLS Model 2 (n=1,000)			OLS Model 1 (n=31,414)			OLS Model 2 (n=31,414)		
	Coef Est	Std Err		Coef Est	Std Err		Coef Est	Std Err		Coef Est	Std Err	
CONSTANT	11.603436	0.033775	a	11.6086	0.0357	a	11.593254	0.006705	a	11.591047	0.006705	a
AGE	-0.002207	0.000497	a	-0.0022	0.0005	a	-0.001617	0.000001	a	-0.001621	0.000089	a
BASESQFT	0.000217	0.000012	a	0.0002	0.00001	a	0.000194	0.000001	a	0.000194	0.000003	a
HOUSESQFT	0.000255	0.000018	a	0.0003	0.00001	a	0.000267	0.000001	a	0.000267	0.000003	a
GARAGESQFT	0.000309	0.000052	a	0.0003	0.0001	a	0.000278	0.000001	a	0.000277	0.000011	a
LOTSQFT	0.000002	0.000001		0.000002	0.000001		0.000002	0.000001	a	0.000002	0.000001	a
S_ACADEMY	0.10409	0.018331	a	0.1016	0.0185	a	0.110679	0.003401	a	0.112146	0.003401	a
S_CHEYMTN	0.249146	0.024233	a	0.2446	0.0250	a	0.251717	0.009598	a	0.253968	0.009598	a
S_FALCON	-0.052122	0.016553	a	-0.0471	0.0168	a	-0.03671	0.002844	a	-0.038905	0.002844	a
S_FTCARSON	-0.106504	0.0213	a	-0.1094	0.0220	a	-0.080274	0.004011	a	-0.078813	0.004011	a
S_HARRISON	-0.107673	0.019364	a	-0.1100	0.0197	a	-0.127921	0.003476	a	-0.126875	0.003476	a
S_LEWISPAL	0.058869	0.033685	a	0.0555	0.0346		0.108956	0.006733	a	0.110767	0.006733	a
S_MANITOU	0.375368	0.074584	a	0.3707	0.0747	a	0.27265	0.013739	a	0.275035	0.013739	a
S_WIDEFIELD	-0.11314	0.015997	a	-0.1155	0.0166	a	-0.112071	0.00313	a	-0.110804	0.00313	a
TIME	0.000161	0.000019	a	0.0002	0.00001	a	0.000005	0.00001	a	0.000005	0.00001	a
FEDLAND				-0.0021	0.0029					0.000001	0.00001	c
Model statistics												
Adj R-Square	0.8418			0.8419			0.8142			0.8142		
AIC	-855.90242			-854.33345			-25368			-25369		

[a] indicates significance at the 0.01 levels
[b] indicates significance at the 0.05 levels
[c] indicates significance at the 0.1 levels

Geographically Weighted

The geographically weighted regressions were estimated using the spatial analyst tool in ESRI's ArcGIS software (2009). For the geographically weighted regression the optimal bandwidth selected for the first model included 94 neighbors using the lowest AIC rule and the same results were found when evaluating based on CV. The sensitivity of the geographically weighted regression to bandwidth length was examined by imposing a longer bandwidth that included neighbors within a half mile and approximately a third of the local estimates exhibited significant local multicollinearity with condition numbers well above 30 indicating the shorter bandwidth with fewer neighbors captures the spatial heterogeneity.

The percentage of the variation explained by the local models ranged from 52.7% to 92.6% in model 1 that only includes housing and time variables (figure 12) to 62.7% to 90.6% in model 2 with the addition of federal land distances (figure 13). The predicted house values for the first model range $135,741 to $663,975 (figure 14) and the second model range $135,741 to $681,192 (figure 15).

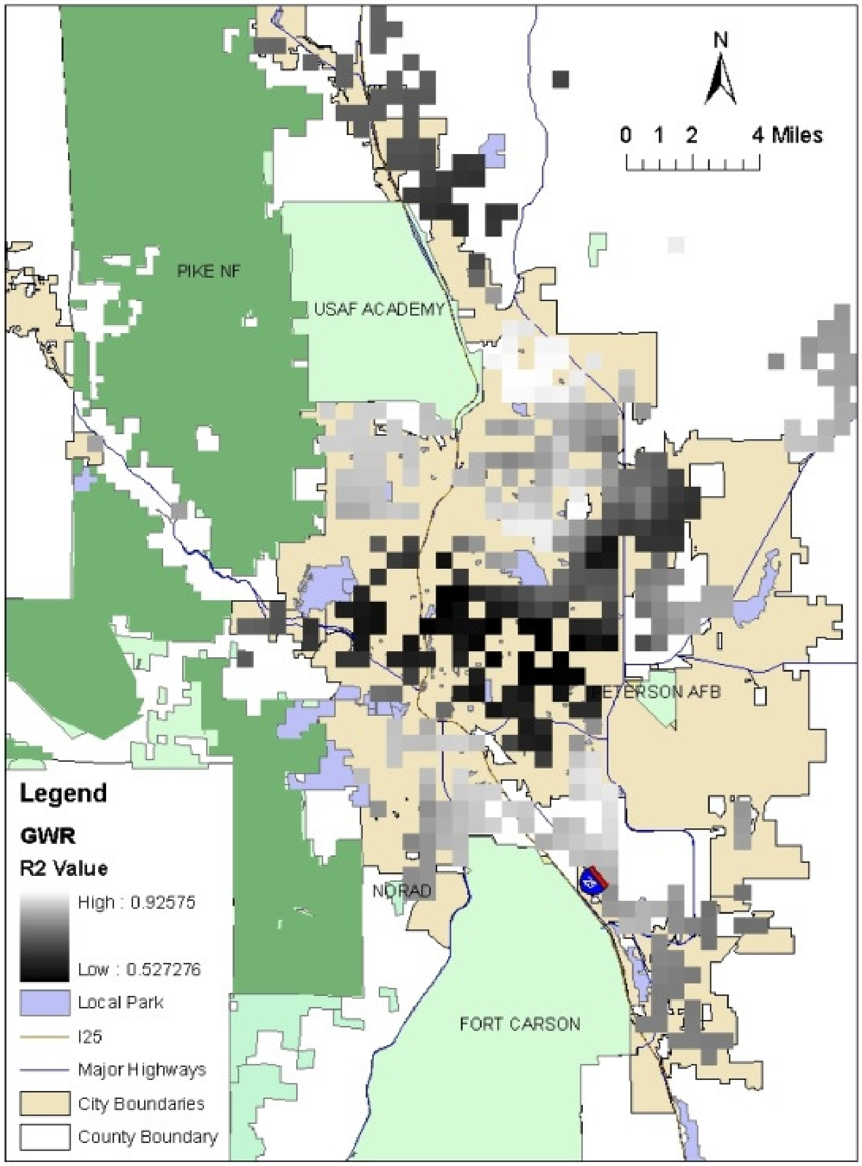

FIGURE 12. PERCENTAGE OF THE VARIATION EXPLAINED USING GWR FOR MODEL 1

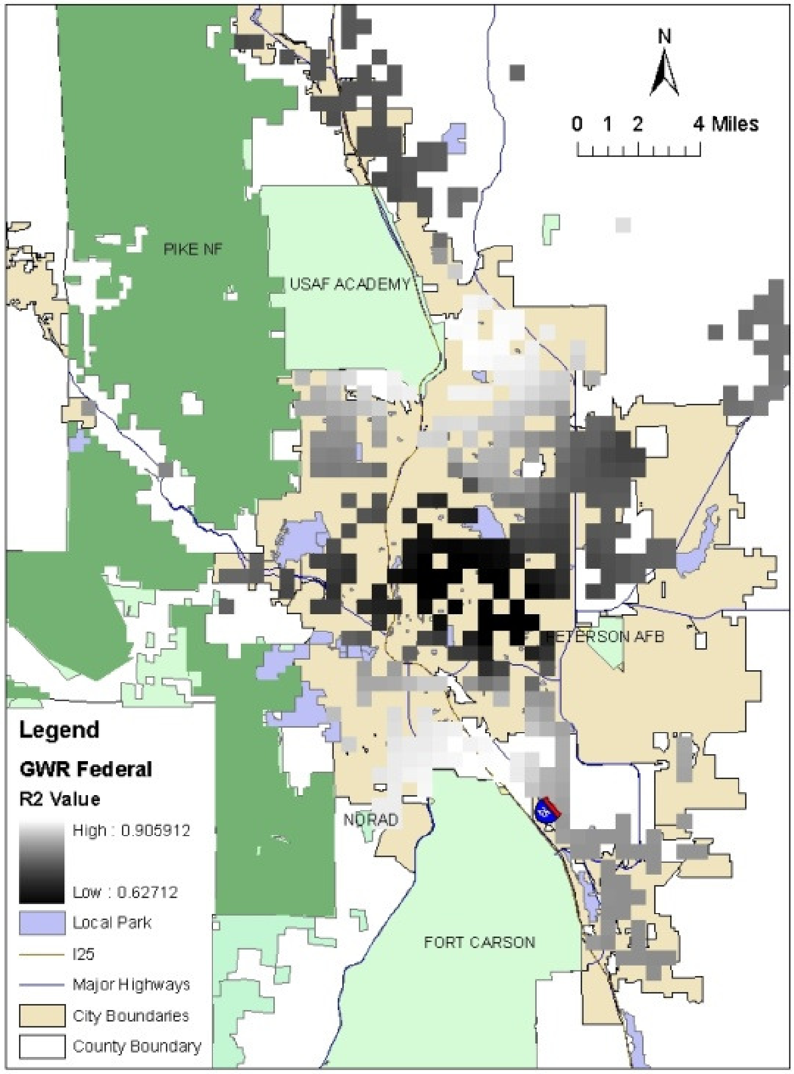

FIGURE 13. PERCENTAGE OF THE VARIATION EXPLAINED USING GWR FOR MODEL 2

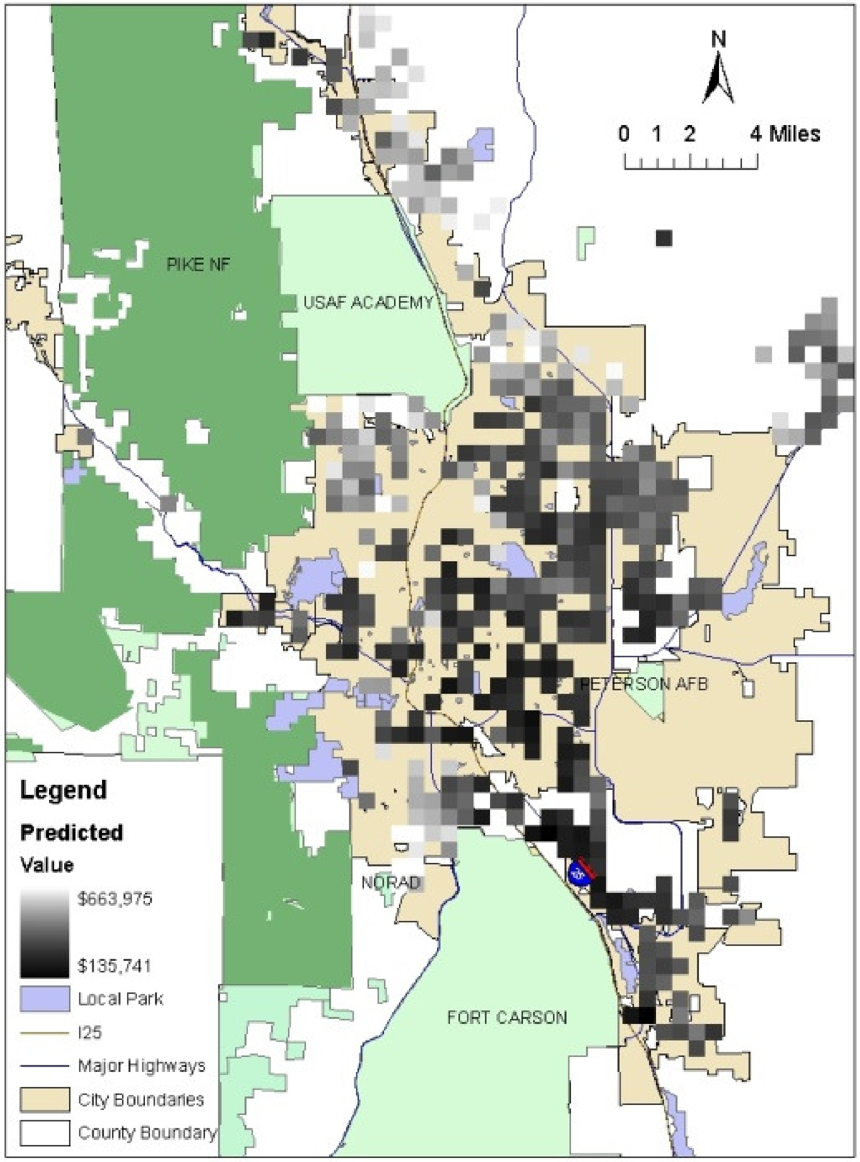

FIGURE 14. PREDICTED HOUSE PRICES FOR GWR MODEL 1

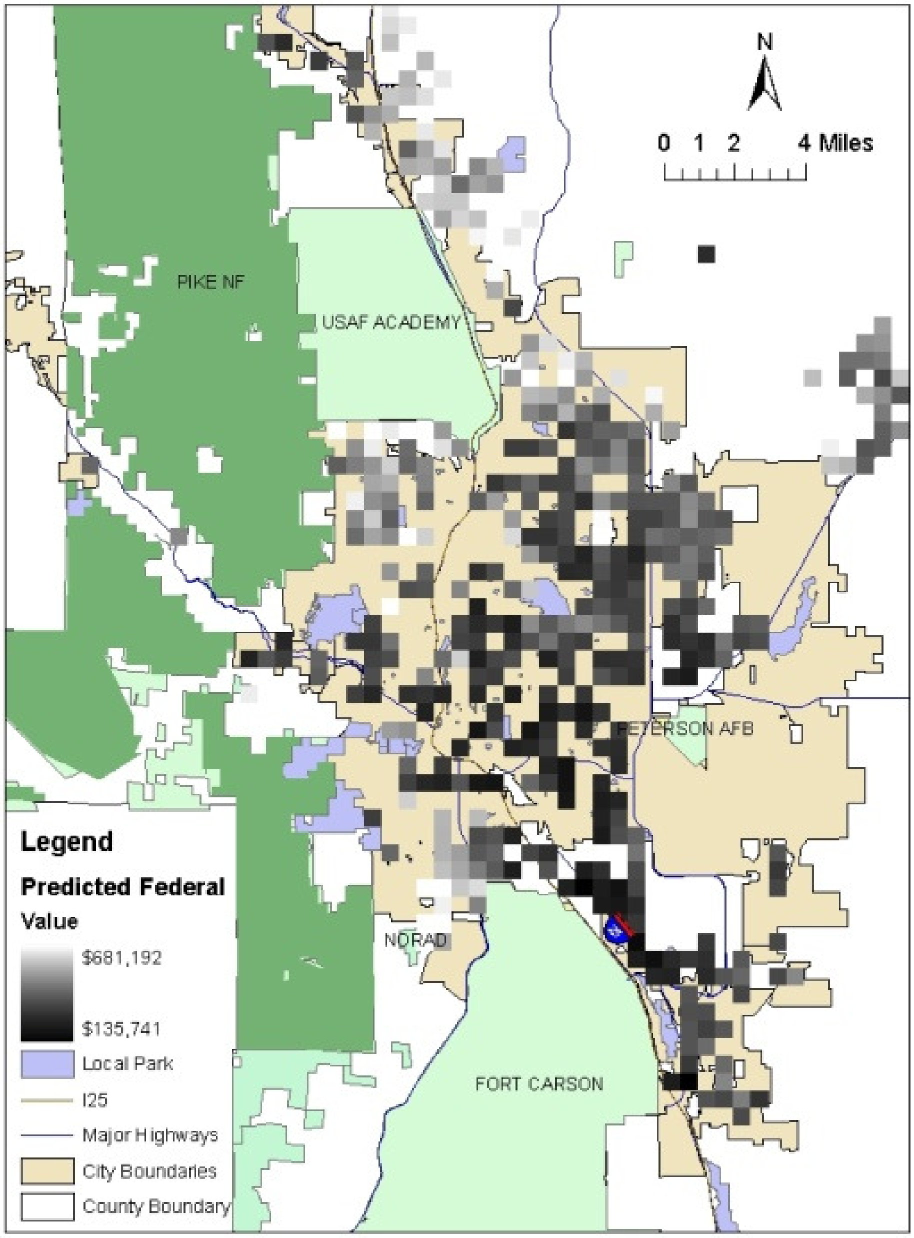

FIGURE 15. PREDICTED HOUSE PRICES FOR GWR MODEL 2

The local geographically weighted regression models demonstrate how the marginal values for proximity to federal lands wax and wane such that 43.2% of the homes sell for a premium to the Southwest and West, 10.9% a discount to the East (red), and no statistically significant effect (yellow) for the 45.9%.[19] Table 7 provides the range in marginal implicit prices for federal land proximity representing amenity (-) and disamenity (+) effects. Figure 16 illustrates the variations in marginal values across the study area. The premiums (green) range 1.08% to 8.88% per mile ($2,865 to $23,556 evaluated at the mean house price) and they occur primarily along the foothills of the Front Range and east of the U.S. Air Force Academy where there are many environmental amenities for recreation and excellent views of Pikes Peak. The discounts (red) range 1.67% to 4.99% (-$13,397 to -$44,304) with the greatest discounts found east of city center in an area of older development, 1950's-1960's, where many military families are located for easier access to work. To the North properties may be exhibiting the discount associated with being farther from the city center.

TABLE 7. GWR ESTIMATES OF MARGINAL IMPLICIT PRICES FOR FEDERAL LAND PROXIMITY (CONTINUOUS)

		Amenity			Disamenity	
	Minimum	Lwr Quartile	Mean*	Median	Upr Quartile	Maximum
PERCENTAGE OF HOUSE PRICE	-8.88%	-2.92%	-0.21%	-1.53%	0.63%	5.05%
MEAN	-$23,557	-$7,742	-$557	-$4,049	$1,666	$13,387
MEDIAN	-$20,447	-$6,720	-$484	-$3,514	$1,446	$11,620
House Prices: mean=$265,296 median=$230,279						
* Mean value in GWR is only estimate provided from OLS.						

[19] The GWR models were estimated with distance to city center but it was insignificant and the model did not perform as well as the ones selected (AIC=-971.8).

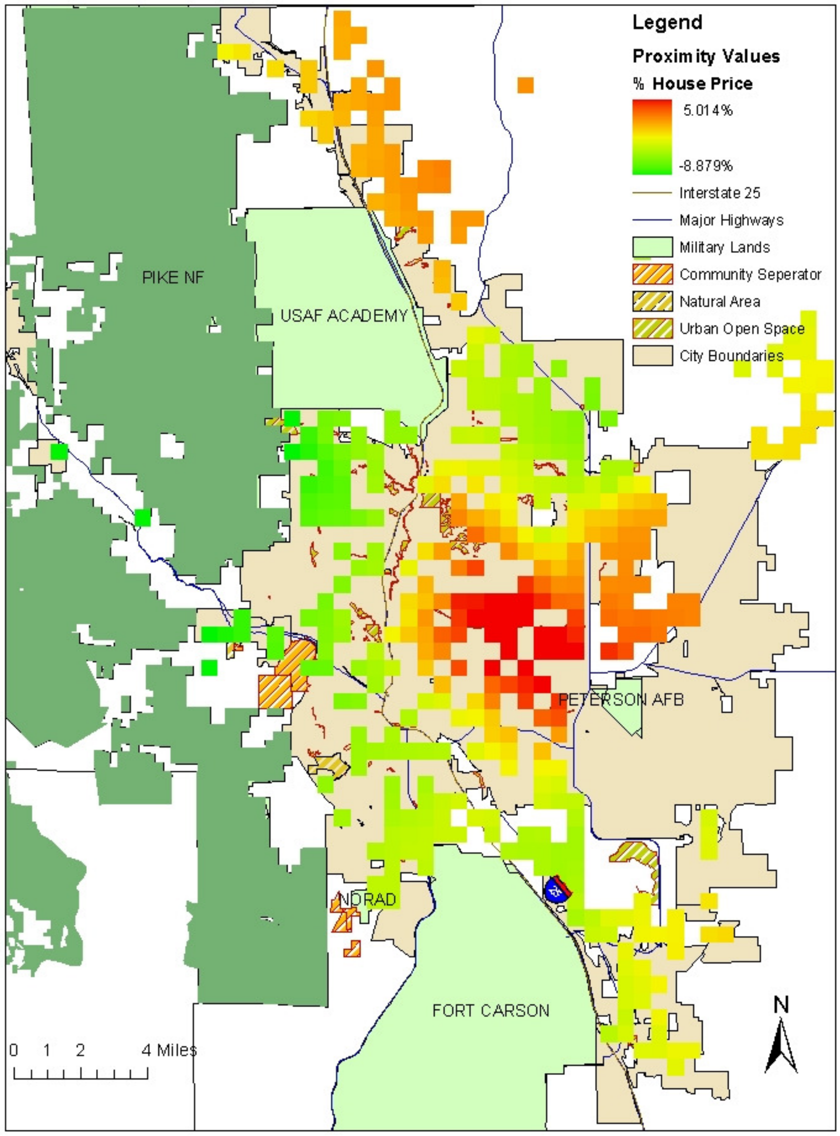

FIGURE 16. AMENITY AND DISAMENITY VALUES FOR FEDERAL LAND PROXIMITY ACROSS THE STUDY AREA (CONTINUOUS MEASURE)

The positive and significant contribution of national forest land was also found in the Cho et al. (2009) and Hand et al. (2008) studies; and Lutzenhiser and Netusil (2001) found a 2.6% premium for living 200 meters closer to a natural area/park. Irwin (2002) found the effects of open space on residential property values in central Maryland only occurred for the largest of military installation, Fort Meade, while the other military land proximity measures were insignificant.

Table 8 presents the estimated marginal implicit prices for all variables across local and global models for comparison. When comparing marginal implicit prices across OLS and GWR models there are similar estimates for the house, basement and garage square footage indicating the values are similar at the neighborhood and market levels. However, the age of the house and the square footage of the lot are different indicating these characteristics are more important when selecting across neighborhoods.

TABLE 8. MARGINAL IMPLICIT PRICE ESTIMATES ACROSS MODELS

Variable	OLS Sample		OLS Population		GWR Sample	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
AGE	-$586	-$584	-$429	-$430	-$1,553	-$1,173
BASESQFT	$58	$58	$51	$51	$52	$55
HOUSESQFT	$68	$68	$71	$71	$65	$72
GARAGESQFT	$82	$82	$74	$73	$81	$85
LOTSQFT	$1	$1	$1	$1	$25	$25
S_ACADEMY	$29,103	$28,361	$31,049	$31,484	.	.
S_CHEYMTN	$75,060	$73,500	$75,936	$76,705	.	.
S_FALCON	-$13,474	-$12,206	-$9,562	-$10,123	.	.
S_FTCARSON	-$26,802	-$27,487	-$20,464	-$20,106	.	.
S_HARRISON	-$27,081	-$27,632	-$31,856	-$31,612	.	.
S_LEWISPAL	$16,087	$15,126	$30,539	$31,075	.	.
S_MANITOU	$120,849	$119,034	$83,155	$83,987	.	.
S_WIDEFIEL	-$28,380	-$28,946	-$28,126	-$27,826	.	.
TIME	$43	$43	$1	$1	$48	$44
FEDLAND		-$558		$0.27		-$3,128

. The GWR does not include the school districts because they are discrete boundaries.

Summary and Conclusions

The primary objective of this analysis was to examine the differences in estimates of marginal values for housing attributes across scales using local and global regression techniques, particularly with respect to federal land proximity. Results from the ordinary least squares estimation indicate that on average federal lands do not affect house prices. Then, the geographically weighted regression tells how the marginal values vary across federal lands from -8.88% to 5.05% (-$23,557, $13,387). Geographically weighted regressions are especially useful when analyzing the effects of proximity to large land areas because they show that marginal values differ along the borders rather than just representing the value as an average.

Homes in the west and southwest nearer to the Pike National Forest, NORAD and Fort Carson experience price premiums while homes closer Peterson Air Force Base sell for less. The distribution is 43% of the homes exhibit the premium, 11% the discount and 46% experience no statistically significant price effects. While the preceding analysis provides valuable information for location-specific amenities, it is the land uses that occur on these federal lands that are addressed in the next chapter.

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Appendix

MODEL 1: OLS RESULTS

Variable	Parameter Estimate	Standard Error	*p* -value	Marginal Price
CONSTANT	11.43708	0.030214	<0.0001	
AGE	-0.000924	0.000447	0.0389	-$245
BASESQFT	0.00024	0.000014	<0.0001	$64
HOUSESQFT	0.000312	0.000019	<0.0001	$83
GARAGESQFT	0.00034	0.000061	<0.0001	$90
LOTSQFT	0.000004	0.000002	0.0308	$1
TIME	0.00016	0.000022	<0.0001	$42
N=1,000, MEAN HOUSE PRICE=$265,296, AICC = -584.64, Adj R2 = 0.791				

MODEL 2: OLS RESULTS

Variable	Parameter Estimate	Standard Error	*p* -value	Marginal Price
CONSTANT	11.472746	0.033146	<0.0001	
AGE	-0.001034	0.000457	0.0239	-$274
BASESQFT	0.000239	0.000014	<0.0001	$63
HOUSESQFT	0.000309	0.000018	<0.0001	$82
GARAGESQFT	0.00035	0.00006	<0.0001	$93
LOTSQFT	0.000004	0.000002	0.0311	$1
FEDMILES	-0.010996	0.002768	0.0001	-$2,917
TIME	0.000161	0.000021	<0.0001	$43
N=1,000, MEAN HOUSE PRICE=$265,296, AICC = -598.45, Adj R2 = 0.794				

CHAPTER FOUR

Accounting for Heterogeneity of Public Lands in Hedonic Property Models

Abstract

Open space lands, national forests in particular, are usually treated as homogeneous entities in hedonic price studies. Failure to account for the heterogeneous nature of public open spaces may result in inappropriate inferences about the benefits of proximate location to such lands. In this study the hedonic price method is used to estimate the marginal values for proximity to the Pike National Forest. The results indicate that specifying the forest as homogeneous overstates the benefits for homes within two miles relative to specifying the forest based on land use characteristics because the significant negative effect from noise-intensive activities is omitted.

Introduction

Living proximate to public lands provides amenities such as convenient access to recreation and wildlife viewing as well as disamenities such as crowds, litter and noise (Garber-Yonts 2004, Bolitzer and Netusil 2000, Moore et al. 1992). National forests are particularly heterogeneous with respect to provision of amenities and disamenities as these forests are often thousands or even millions of acres in size and allow multiple uses.

In general, hedonic studies have found a positive effect on sales prices of homes located near national forest lands (Cho et al. 2009, Hand et al. 2008, Kim and Johnson 2002, Shultz and King 2001). However, a few recent studies have found negligible or negative price effects of living near a national forest (Kling et al. 2007, Mueller and Loomis 2008). For example, in a study that considered different kinds of open space at the rural-urban fringe in Larimer County, Colorado, no price effect was found for homes proximate to the Arapaho-Roosevelt National Forest for the majority of model specifications. The authors posit that this result could be due to the relative abundance of substitutes and uncertainty about potential negative externalities from national forest land uses (Kling et al. 2007). Mueller and Loomis (2008) found negative price effects of being proximate to the Angeles National Forest in California after two wildfire events in that forest.

In these past studies, a national forest was considered a homogeneous entity and distance was measured from a housing area to a forest boundary. However, this homogeneous land use representation in the model does not reflect the multiple use management approach required of the U.S. Forest Service under the mandate of the 1976 National Forest Management Act. The Forest Service "working lands" are managed for specific resource uses including wildlife, timber, water quality, range and recreation. Thus, living near active timber management or motorized recreation areas might be undesirable relative to living by wildlife habitat or hiking trails. Many past studies of national forests have not included this spatial heterogeneity and treated the forest as one homogeneous unit of public land.

We hypothesize that some of the divergent findings with respect to the influence of proximity to national forests on property values arise from a failure to differentiate a property's distance to different land uses. To test our hypothesis, we compare the approach of representing a national forest as homogenous with one that differentiates proximity to quiet recreational areas and noisier areas of the national forest. This approach allows us to evaluate whether spatial heterogeneity matters in calculating implicit values. Specifically, we use the hedonic approach to estimate the marginal values associated with living proximate to the Pike National Forest under the standard assumption of the forest as a homogenous land entity. Then, we examine the marginal values when proximity to recreation opportunities (e.g., roaded natural and rural recreation areas) are differentiated from proximity to noisy activities (e.g., areas that allow off road vehicles, logging activities, etc.). This approach allows us to tell a more nuanced story about the relationship between the Pike National Forest and proximate home values. Whether it is good or bad to live near the Pike National Forest may depend on whether one lives near land uses that are quiet and scenic like hiking trails or something noisy like an off road vehicle trail.

Methods

The hedonic method is a revealed preference nonmarket valuation approach that uses information from actual market transactions to infer the values consumers place on attributes of a good (Rosen 1974). Applications of the hedonic method to housing are common and often applied to estimate values of environmental amenities such as open space for inclusion in policy-analysis (McConnell and Wells 2005). A review of the hedonic method for nonmarket valuation can be found in Freeman (2003), Taylor (2003), Palmquist (2005), and Bockstael and McConnell (2007). In the housing market, the equilibrium hedonic price function is determined by the interaction of utility-maximizing house buyers and profit-maximizing house sellers. The house, the optimal consumption bundle, is an envelope function where marginal bids and marginal offers equal the marginal prices for house characteristics. The theoretical specification for the hedonic price function defines the vector of house sales prices **(P)** as a function of the individual characteristics of the houses according to three categories in matrix form: structural components of the houses **(S)**, neighborhood demographic variables **(N)**, location-specific attributes **(L)**, and time **(T)**:

$$\mathbf{P}=f(\mathbf{S},\mathbf{N},\mathbf{L},\mathbf{T};\ \alpha,\beta,\gamma,\delta), \qquad [43]$$

$$ln\mathbf{P} = \alpha\mathbf{S} + \beta\mathbf{N} + \gamma\mathbf{L} + \delta\mathbf{T} + \varepsilon \qquad [44]$$

$$\varepsilon \sim N(0,\sigma^2 I_n) \qquad [45]$$

where the estimated parameters (α,β,γ,δ) describe the relationships between house prices and the measures included within the three categories. The incremental change in the price of the house represents the additional amount house buyers are willing to pay for a marginal change in the attribute holding all the other attributes constant. The error term is assumed to be independent and identically distributed.

Cropper, Deck, and McConnell (1988) provide a comparison of possible choices for functional forms and suggest the semi-log model is a robust functional form to the omitted variables problem common in hedonic property models. In this study, the log transformation of the dependent variable is chosen to minimize heteroskedasticity (Wooldridge 2003) and because the sales data have a long right side tail. If the individual characteristic of the house is measured as continuous, the estimate describes the direction, magnitude and significance of the change in the house price for one more unit. If the characteristic is represented using a dummy variable, the estimate describes the change in the house price based on including the characteristic such as if the house was new when sold. Thus, because marginal effects of the determinants of house prices may vary with the price level of the house, the double log functional form is chosen for distances, areas and income levels except for garage and basement areas that may not exhibit similar diminishing returns (Iwata, Murao, and Wang 2000; Mahan, Polasky, and Adams 2000; Bin and Polasky 2004).

Implicit prices for each house attribute included in the hedonic price function can be calculated using the coefficient estimates (Taylor 2003). The exact implicit price calculation depends on the functional form of the dependent and independent variables, along with any adjustments for neighborhood effects that will be addressed in the section on spatial considerations. Assuming a log dependent variable and an independent variable specified as linear, the implicit price is the estimated coefficient times the mean house price. For independent variables specified using the logarithmic transformation, the implicit price is the estimated coefficient times the average house price divided by the average value for the independent variable in question. Finally, for variables that represent discrete characteristics using dummy variables, the implicit price is the exponential value of the coefficient minus one then multiplied by the average house price. With the estimated implicit prices, the relative contribution of each variable included in the model can be stated as a percentage of the total average house price to indicate the relative importance of that variable to the total value of the house.

This first stage to modeling demand preferences is sufficient for answering questions at the margin such as what magnitude, direction and significance does an additional unit of some attribute add or detract from the sales price of a home. In this study, we are interested in the marginal values of homes located closer to the Pike National Forest so the first stage analysis is sufficient. Second-stage hedonic analysis utilizes implicit prices from the first-stage analysis, along with observed quantities purchased and demographic information, to recover inverse demand functions for the house characteristics to calculate the welfare effects of non-marginal changes.

However, many econometric issues arise when estimating the first stage hedonic price models that can either bias the coefficient estimates or simply result in less efficient estimators. A few examples are a high degree of collinearity among independent variables, spatial dependence and omitted variables within the housing market, and endogeneity of housing prices and land availability (Irwin and Bockstael 2001, Irwin 2002). By examining the correlations among the independent variables, particularly the Pike National Forest distance measures, along with variance inflation factors, the subset of variables is chosen to reduce multicollinearity (Belsley, Kuh, and Welsch 2005). Spatial considerations are addressed in the next section while endogeneity of housing prices and land availability are modestly addressed using market timing variables to represent the variation in sales annually.

Spatial Considerations

Spatial dependence occurs when observations across space are systematically related. The interconnection is more formally called spatial autocorrelation and a direct result of Tobler's (1979) First Law of Geography that states "everything is related to everything else, but near things are more related than distant things." One form of spatial dependence in hedonic price models occurs when house prices are based on comparable homes in the immediate vicinity such as within a half mile. The justification for using neighboring values in the calculation is that homes share the value of being located in a particular place such as near common environmental amenities or public services. A second form of spatial dependence called spatial error dependence may occur when an omitted variable is also correlated with the error of its neighbor and it is similar to serial correlation in time series data. Spatial error can also be due to measurement errors that may occur with overlapping data layers from multiple data sources or generally when the variable is hard to measure. We examine each spatial component separately and jointly using the spatial statistics software, R.

Spatial Lag Models

In the real estate industry it is common practice to assess a property's value based on the prices of nearby homes (Can 1990). This process justifies the need to include a measure that specifies the interconnection between houses in close proximity through the form of a spatially lagged dependent variable. The spatially lagged dependent variable is composed of a spatial lag parameter, ρ, and a spatial weighting matrix, $\mathbf{W}$. To determine if significant spatial autocorrelation exists due to the influence of neighbors, we look at the OLS residuals of the standard hedonic price model. Erroneously omitting the spatial lag term leads to biased and inconsistent estimation of coefficients (Anselin 1988). If a spatial pattern is in the residuals of the OLS model, then we want to include the information as an additional explanatory variable. In matrix form:

$$ln\mathbf{P} = \rho\mathbf{WP} + \alpha\mathbf{S} + \beta\mathbf{N} + \gamma\mathbf{L} + \delta\mathbf{T} + \varepsilon \qquad [46]$$

If spatial autocorrelation is significant, the lagged dependent variable, $\rho\mathbf{WP}$, provides spatial structural information to the model thus reducing omitted variable bias and improving efficiency of estimators. If ρ is statistically different from zero, then the spatial multiplier, $(1/1\text{-}\rho)$, is needed to adjust coefficient estimates to reflect the marginal values that are related to location, in addition to the marginal value of the characteristic (Kim, Phipps, and Anselin 2003). Alternatively, if the spatial weight matrix adequately accounts for the spatial lag effect then ρ may be insignificant while the inclusion of the lagged variable significantly improves the model fit (Anselin 2005).

To estimate the spatial models, the researcher must specify a spatial weight matrix that captures the spatial dependence expected in the data. For example, spatial dependence between objects of analysis may occur based on Euclidean distance (actual or perceived), distance by road, travel time, number of nearest neighbors or a river network. The spatial weight matrix ($\mathbf{W}$) in equation 47 represents the expected relationship between house i and house j.

$$\mathbf{W} = \left[w_{ij}\right]_{i,j=1}^{n} \qquad [47]$$

The data for hedonic price models are expected to exhibit a spatial lag and the process for selecting the spatial weight involves including the prices of houses within various distance ranges to see if inclusion of neighborhood price structure reduces the spatial autocorrelation. The form of the spatial weights used for this study is shown in equation 48. The spatial weights are created using inverse distance weighting, also called distance-decay, which allows for homes closer to each other to have a greater influence in the estimation process up to some distance (*b*).

$$w_{ij} = \begin{cases} \frac{1}{d_{ij}}, if\ d_{ij} \leq b \\ 0, otherwise \end{cases} \quad [48]$$

To determine the distance (*b*), one examines the semi-variogram of the residuals from the Ordinary Least Squares (OLS) regression estimation of the hedonic price function to learn more about the patterns in the residuals that are related to distance (Cressie 1993). With more information about patterns in the residuals, the spatial weight matrix that accounts for the spatial autocorrelation can be constructed. The weight matrix is row-standardize so that the parameter coefficients for the spatial components are bound by -1 and 1 (equation 49).

$$\widetilde{w}_{ij} = \frac{w_{ij}}{\sum_{j=1}^{n} w_{ij}} \quad [49]$$

Spatial Error Models

A second spatial relationship that needs to be considered in the model is caused by misspecification. The misspecification may be due to improper functional form, measurement error in the variables included or omitted variables due to challenges in measuring the concept. The original error term from OLS is modeled as an autoregressive error term where ε denotes the residual matrix, **W** is a spatial weighting matrix and λ is the coefficient. In matrix form:

$$ln\mathbf{P} = \alpha\mathbf{S} + \beta\mathbf{N} + \gamma\mathbf{L} + \delta\mathbf{T} + \varepsilon, \quad [50]$$

$$\varepsilon = \lambda\mathbf{W}\,\varepsilon + \upsilon \quad [51]$$

The transformed residuals υ are independently distributed about a mean of zero.

Joint Spatial Lag and Spatial Error Models

Finally, the joint model that includes both the spatial lag and the spatial error components is specified by:

$$ln\mathbf{P} = \rho\mathbf{WP} + \alpha\mathbf{S} + \beta\mathbf{N} + \gamma\mathbf{L} + \delta\mathbf{T} + \varepsilon, \quad [52]$$

$$\varepsilon = \lambda\mathbf{W}\,\varepsilon + \upsilon \quad [53]$$

For the joint spatial model, the values of ρ and λ are simultaneously estimated by the maximum likelihood method. If ρ is significant, coefficient estimates in the joint model will also need to be adjusted using the spatial multiplier.

The test statistics used to determine whether spatial autocorrelation exists are (1) Moran's I and (2) the Lagrange Multiplier (Anselin and Rey 1991). Moran's I test statistic (equation 54) is used to determine whether spatial autocorrelation exists where N is the number of houses indexed by i and j; X is the variable of interest, $\bar{X}$ is the mean of X, and w_{ij} is the spatial relationship between house i and house j.

$$\text{Moran's I: } I = \frac{N}{\sum_i \sum_j w_{ij}} \frac{\sum_i \sum_j w_{ij}(X_i - \overline{X})(X_j - \overline{X})}{\sum_i (X_i - \overline{X})^2} \quad [54]$$

The Lagrange Multiplier test statistic (equation 55) relays information about local (smaller-scale) variability and the need for a lagged dependent variable where spatial correlation is rejected if:

$$\left[\frac{n\hat{\varepsilon}^1 W\hat{\varepsilon}}{\hat{\varepsilon}'\hat{\varepsilon}\, tr(W^2 + W'W)^{\frac{1}{2}}}\right]^2 > \chi^2_{1,0.95} = 3.84 \quad [55]$$

Then, the model with the smallest Akaike Information Criteria (AIC) is deemed the most appropriate model for hypothesis testing (Jones, Leishman, and Watkins 2003).

Study Area and Data

El Paso County, Colorado, is located along the eastern edge of the southern Rocky Mountains, 70 miles south of Denver. The western portion of the county is extremely mountainous and home to Pikes Peak and the Pike National Forest. El Paso County is approximately 2,158 square miles. The study location is shown in Figure 17 and descriptive statistics are in Table 9 below. The sample of houses that sold over the time frame of the study is represented such that homes within two miles of noise and recreation on the Pike National Forest have different symbols than the rest of the sample as defined in the legend.

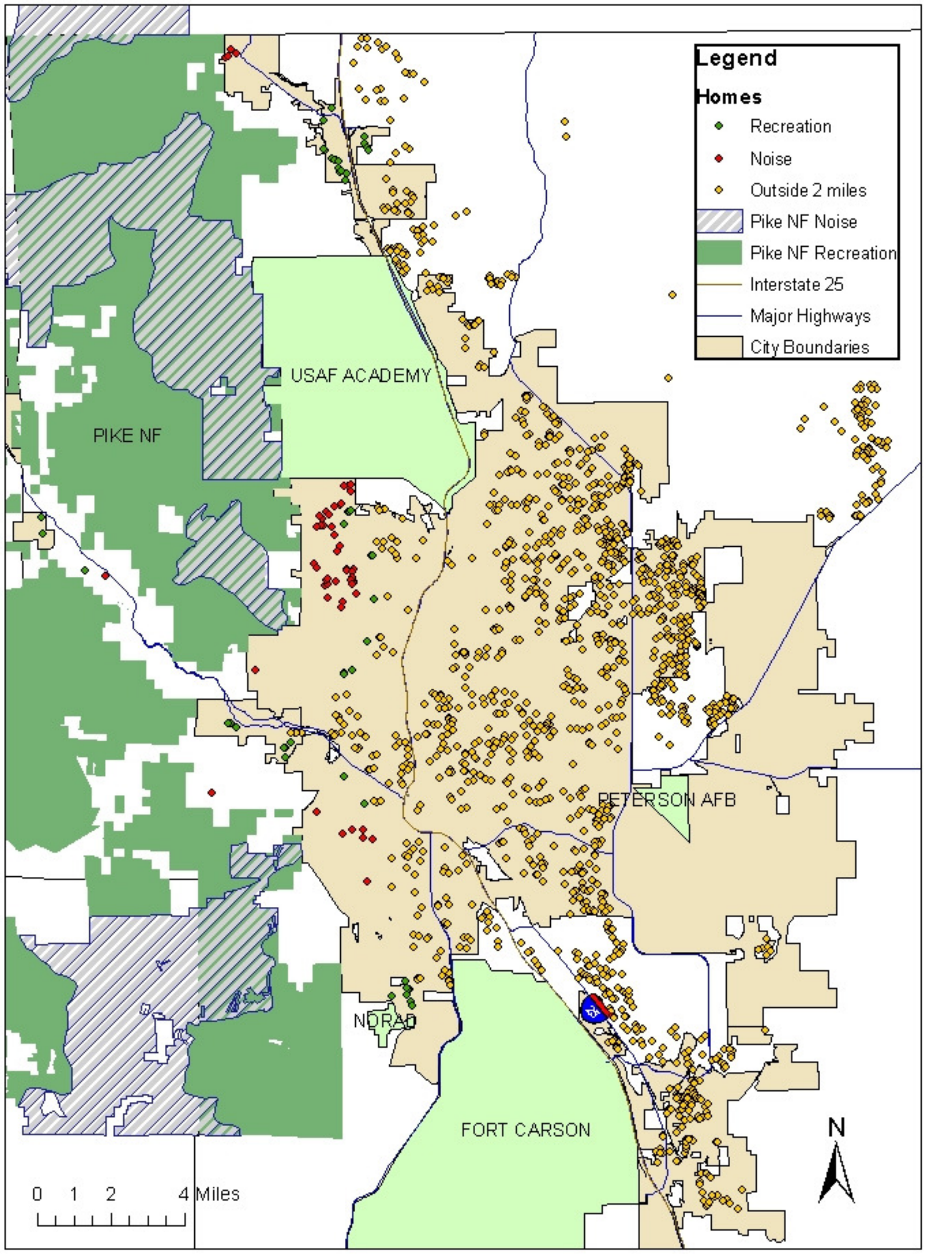

FIGURE 17
HOUSES IN THE STUDY AREA AND LAND USES ON
THE PIKE NATIONAL FOREST.

TABLE 9.VARIABLE NAMES, DEFINITIONS AND MEAN VALUES OR FREQUENCIES

Variable Name	Variable Definition	Mean/Frequency
SALES PRICE	Sale price adjusted to 2005 dollars using Consumer Price Index	$257,755
HOUSE AGE	House age when sold (Year sold less year built)	20
AGE_2	House age squared	390
BATHROOMS	Number of bathrooms	2.7
LOT AREA	Total square footage of lot	9250
HOUSE AREA	Total above ground square footage of house	1626
BASEMENT AREA	Total square footage of finished basement	844
GARAGE AREA	Total square footage of garage	457
2006	Dummy variable for sale year (1 if 2006, 0 otherwise)	39.0%
2007	Dummy variable for sale year (1 if 2007, 0 otherwise)	20.2%
MEDIAN INCOME	Median income by census tract	$61,065
TIME TO WORK	Mean time to work by census tract in minutes	24
PIKE within 2 miles	Dummy variable for within 2 miles of the Pike National Forest boundary	6.5%
PIKE RECREATION within 2 miles	Dummy variable for within 2 miles of recreational activities on the Pike National Forest	6.5%
PIKE NOISE within 2 miles	Dummy variable for within 2 miles noise intensive activities on the Pike National Forest	3.4%
PIKE distance	Distance from house coordinates to nearest boundary for the Pike National Forest in miles	7

The residential property sales transaction information was obtained from the El Paso County Tax Assessor. The data included parcel level information on sale prices, sale dates, and structural characteristics of the property with spatial coordinates. Market timing variables indicate the year of the sale. Housing structural characteristics include the square footage of the house, lot, basement and garage, along with the number of bedrooms and bathrooms and the age of the house. However, the number of bedrooms was found to be highly correlated with the house square footage variable, therefore we did not include the number of bedrooms in the final model.

As the decision to purchase a home occurs when the buyer enters the contract approximately two months prior to the ownership change, we subtract 60 days from the sales date and keep transactions from the beginning of March 2005 to end of February 2008 to represent activity within the years of 2005 to 2007. Because homes on more than an acre are potentially developable, we only include homes on one acre or less (Heimlich and Anderson 2001, Lewis, Bohlen and Wilson 2008). Next, we trimmed the bottom and top 1% of sales to remove outliers and transactions that are not considered arms-length, such as transactions among family members at less than fair market price. Then, we adjusted the house sales prices using the consumer price index to make comparisons in 2005 dollars.

Neighborhood demographic information was obtained through the United States Census website. Geographic Information System (GIS) shapefiles available from the website provide the spatial reference for El Paso County census tracts. Census tract statistics are appended as attributes of the census tracts layer using ArcGIS software. Median income and mean time to work were the two neighborhood variables included in the models from the Census 2000 because many of the other demographic measures, such as the percentage of students with no high school degree and the percentage non-white are highly correlated with income. Mean time to work was found to be highly correlated with distance to city center, therefore, we selected the mean time to work variable to control for employment opportunities not at city center.

Merging the sales information with Census neighborhood demographics and land use layers from the Colorado Ownership and Management Project (COMaP) (Theobald et al. 2008) and El Paso County, we created a geo-database of spatially referenced attributes for the analysis. COMaP provided the details regarding the specific land uses on the Pike National Forest while the county's website[20] was the source for the roads layer and other land use boundaries.

[20] El Paso County Colorado Accessor GIS maps online, Accessed 9/23/2010, http://www.elpasoco.com/gis/

Amenity Measures for the Pike National Forest

We define national forest proximity through two types of measures: one is continuous Euclidean distance to capture the relative value of location across the landscape and the other is discrete, within two miles, for adjacency. Similar to Loomis (2004) we created dummy variables for within two miles of the national forest boundary. The two mile measure captures the visual amenity backdrop of forests and open space. Noise intensive activities are relatively further from the houses such that only half of the houses within two miles of the Pike National Forest are also within two miles of noise intensive activities.

For specifying the heterogeneous land use models, we categorized two types of land uses, noise intensive activities and recreational activities. We created distance measures to each of the land use types using Euclidean distance in ArcGIS. Noise intensive activities include motorized vehicle use for recreation and active timber management areas. We expect proximity to noise intensive activities to decrease house sale prices (Day and Batemen 2007). Recreational activities are defined in COMaP as roaded natural and rural recreation areas and we expect homes with closer access to these to sell for more.

The total number of house sales over the 2005 to 2007 time frame was 31,414 after removing the outliers and homes on more than one acre. To estimate the true values for the parameters with a 95% confidence level the sample size is 1,536. Stratified random sampling was used to create the sample using two strata: (1) homes within 2 miles of Pike National Forest and (2) homes 2 miles or more from Pike National Forest. A sample of the data was also needed to ensure the dataset is computationally feasible for estimation.[21]

Empirical Models

Base Hedonic Property Model

The hedonic property model relates the sales price of the house to lot and housing structural characteristics and neighborhood patterns, along with market, location and environmental variables (Freeman 1993). The empirical specification for Model 1 which treats the national forest lands as homogeneous is:

$$lnP_i = \alpha_i + \sum_{a=1}^{A} \beta_a S_{ia} + \sum_{c=1}^{C} \beta_c N_{ic} + \sum_{d=1}^{D} \beta_d T_{id} + \sum_{f=1}^{F} \rho_f W_{if} P_{if} + \sum_{g=1}^{G} \lambda_g \varepsilon_{ig}$$

$$+ \sum \beta_{PIKE\ distance} PIKE\ distance_i + \sum \beta_{PIKE\ 2\ miles} PIKE\ 2\ miles_i + v_i, \qquad [56]$$

where lnP_i the natural log of adjusted house price for observation i, S_{ia} is the ath structural variable for observation i, N_{ic} is the cth neighborhood variable for observation i, T_{id} is the dth timing variable for observation i, P_{if} is the price of the fth lagged dependent variable, W_{if} is the fth spatial weight matrix for observation i, ε_{ig} is the gth spatial error for observation i, α_i is the intercept term for observation i, and v_i is the i.i.d. error term for

[21] Spatial sub-sampling is needed because of computational limits when calculating the log-determinant of the matrix ($I_n - \rho\mathbf{W}$) to estimate the spatial lag component because:
$E(\widetilde{Y}) = (I - \rho\mathbf{W})^{-1} X\tilde{\beta}$
$Cov(\tilde{Y}) = \sigma^2 (I - \rho\mathbf{W})^{-1} (I - \rho\mathbf{W})^{n-1}$

observation i. The variables that represent the location of observation i with respect to the Pike National Forest are continuous distance, $PIKE\ distance_i$, anda dummy variable for homes within 2 miles, $PIKE\ 2\ miles_i$. The β's are the estimated coefficients that describe the direction, magnitude and significance for each independent variable.

Variables were selected to represent the economic system while reducing the risk of inflated standard errors of the coefficient estimates from the inclusion of highly correlated variables (Johnston 1984). House structural characteristics included in the model are the living area of the home (HOUSE AREA), basement (BASEMENT AREA), garage (GARAGE AREA) and lot size in square feet (LOT AREA). The age of the house (AGE) and the age squared (AGE_2) are included to determine if non-linearities exist and the number of bathrooms are represented as continuous (BATHROOMS). Neighborhood characteristics by census tract include median income (MEDIAN INCOME) and mean travel time to work (TIME TO WORK). Market variables that represent the time of the sale include the annual dummy variables 2006 and 2007 with 2005 as the base case.

Proximity to the Pike National Forest is captured in the variable called PIKE distance. A negative coefficient indicates houses further from the national forest sell for less. This continuous distance measure is included in both the homogeneous and heterogeneous model specifications to represent the marginal value for a 1% change in mean distance relative to the houses in the rest of the county.

H_o: $\beta_{PIKE\ distance} = 0$ if no marginal price effect of proximity to the Pike National Forest

H_a: $\beta_{PIKE\ distance} < 0$ if house prices are lower further from the Pike National Forest

Homogeneous Land Use Specification

To see if there are additional marginal price effects due to adjacency, Model 1 includes a dummy variable to indicate whether the parcel is within two miles of the Pike National Forest (PIKE 2 miles). The hypothesis test for Model 1 is:

H_o: $\beta_{PIKE\ 2\ miles} = 0$ if there is no marginal price effect from being within two miles of the Pike National Forest

H_a: $\beta_{PIKE\ 2\ miles} > 0$ if there is a positive marginal price effect from being within two miles of the Pike National Forest

Heterogeneous Land Uses Specification

Model 2 allows for a heterogeneous land use classification by differentiating within two miles of noise intensive activities (PIKE NOISE 2 miles) from those only within two miles of quiet recreational activities (e.g. hiking trail) on the Pike National Forest (PIKE RECREATION 2 miles).

$$lnP_i = \alpha_i + \sum_{a=1}^{A} \beta_a S_{ia} + \sum_{c=1}^{C} \beta_c N_{ic} + \sum_{d=1}^{D} \beta_d T_{id} + \sum_{f=1}^{F} \rho_f W_{if} P_{if} + \sum_{g=1}^{G} \lambda_g \varepsilon_{ig}$$

$$+ \sum \beta_{PIKE\ distance} PIKE\ distance_i + \sum \beta_{PIKE\ NOISE\ 2\ miles} PIKE\ NOISE\ 2\ miles_i$$

$$+ \sum \beta_{PIKE\ RECREATION\ 2\ miles} PIKE\ RECREATION\ 2\ miles_i + v_i \qquad [57]$$

We test the following hypotheses to assess whether adjacency to noise intensive activities has an additional negative marginal effect on home sales prices.

H_o: $\beta_{PIKE\ NOISE\ 2\ miles} = 0$ if no marginal price effect from being within two miles of noise intensive activities on Pike National Forest

H_a: $\beta_{PIKE\ NOISE\ 2\ miles} < 0$ if negative marginal price effect from being within two miles of noise intensive activities on Pike National Forest

Likewise, we test whether adjacency to recreational activities has an additional positive marginal effect on home sales prices.

H_o: $\beta_{PIKE\ RECREATION\ 2\ miles} = 0$ if no marginal price effect from being within two miles of recreational activities on Pike National Forest

H_a: $\beta_{PIKE\ RECREATION\ 2\ miles} > 0$ if positive marginal price effect from being within two miles of recreational activities on Pike National Forest

If there are misspecification effects from only identifying the Pike National Forest as a homogeneous land use, the expected relationship among the relative adjacency measures used to calculate implicit prices would be:

$$\beta_{PIKE\ NOISE\ 2\ miles} < \beta_{PIKE\ 2\ miles} < \beta_{PIKE\ RECREATION\ 2\ miles}$$

Thus, the marginal value of adjacency to noise intensive activities is expected to be less than the marginal value of proximity to the Pike National Forest in general. The marginal value of adjacency to recreation is expected to be greater than both the marginal value of adjacency to noise intensive activities and adjacency to the Pike National Forest in general.

Results

Spatial Dependence

We found evidence of spatial dependence. The joint spatial lag and spatial error models achieved the smallest AIC relative to the other models that represent only the spatial lag or the spatial error components. Across all spatial weight matrices considered (100 and 200 meters),[22] Moran's I and the Lagrange Multiplier test statistics are found to be highly significant when the spatial lag and error components are included separately indicating there remains spatial dependence unexplained and thus the need for the joint specification. The semi-variogram of the residuals from the ordinary least squares models indicates nearer neighbors have more influence than those further away and the effect levels off around 200 meters (*Appendix*). Therefore, the joint spatial lag and error specification using an inverse distance weight matrix to 200 meters accounts for spatial dependence among neighbors.

Housing, Neighborhood and Market Variables

The coefficients on the housing and neighborhood variables have the expected signs and are consistent across the two models (tables 10 and 11). The direction, magnitude and significance of the housing structural variables are as expected such that house prices increase with an increase in lot, house, garage, and basement area. The lot and housing marginal implicit prices are similar to those found in the study by Donovan, Champ, and Butry (2007) which also used an El Paso County sample. House prices decrease as they

[22] Results from models estimated using alternative spatial weight matrices are available in the appendix.

age and the rate is higher for newer homes than older ones. House prices increase with the number of bathrooms. For neighborhood characteristics by census tract, median household income is positively related to house prices and house prices decrease as the mean travel time to work increases. For market variables, houses sold in 2006 and 2007 sell for a premium relative to those sold in 2005.

TABLE 10. RESULTS FROM JOINT SPATIAL ESTIMATION FOR MODEL 1

Variable	Parameter Estimate	Standard Error	*p* -value	Marginal Price	95% Confidence Interval*
CONSTANT	5.7426	0.2567	<0.0001		
HOUSE AGE	-0.0085	0.0006	<0.0001	-$2,191	[-$2,494,-$1,888]
AGE_2	0.0001	0.00000604	<0.0001	$26	[$23,$29]
BATHROOMS	0.0153	0.0067	0.0225	$3,944	[$559,$7,328]
ln (LOT AREA)	0.1049	0.0118	<0.0001	$3	[$2.28,$3.57]
ln (HOUSE AREA)	0.318	0.0187	<0.0001	$50	[$45,$56]
BASEMENT AREA	0.0002	0.00000914	<0.0001	$52	[$47,$56]
GARAGE AREA	0.0002	0.00003073	<0.0001	$52	[$36,$67]
2006	0.0884	0.0088	<0.0001	$23,823	[$19,008,$28,722]
2007	0.1255	0.0106	<0.0001	$34,466	[$28,457,$40,600]
ln (MEDIAN INCOME)	0.3053	0.022	<0.0001	$1	[$1.11,$1.47]
TIME TO WORK	-0.0126	0.0015	<0.0001	-$3,248	[-$4,006,-$2,490]
ln (PIKE distance)	-0.0635	0.0115	<0.0001	-$2,243	[-$3,039,-$1,447]
PIKE within 2 miles	-0.0073	0.0269	0.7862		
RHO	-0.0002	0.0005	0.6596		
LAMBDA	0.2059	0.0259	<0.0001		
VARIANCE	0.0231	0.0008			
N=1,536, MEAN HOUSE PRICE=$257,755, FIT=0.8405, AIC = -2903.758, Likelihood Ratio= 53.9534 (<0.0001)					
IDW= 200 meters, Lagrange Multiplier=0.2409 (0.6236), Moran's I=0.017965 (0.6119), Residual Std Error=0.1526					
*Confidence intervals for coefficient estimates are calculated at the 95% confidence level using the mean +/- 1.96 times the standard error.					

TABLE 11. RESULTS FROM JOINT SPATIAL ESTIMATION FOR MODEL 2

	Parameter Estimate	Standard Error	*p* -value	Marginal Price	95% Confidence Interval*
CONSTANT	5.7666	0.2563	<0.0001		
HOUSE AGE	-0.0085	0.0006	<0.0001	-$2,191	[-$2,494,-$1,888]
AGE_2	0.0001	0.00000602	<0.0001	$26	[$23,$29]
BATHROOMS	0.0152	0.0067	0.0229	$3,918	[$533,$7,303]
ln (LOT AREA)	0.1049	0.0118	<0.0001	$3	[$2.3,$3.6]
ln (HOUSE AREA)	0.3177	0.0187	<0.0001	$50	[$45,$56]
BASEMENT AREA	0.0002	0.00000913	<0.0001	$52	[$47,$56]
GARAGE AREA	0.0002	0.00003071	<0.0001	$52	[$36,$67]
2006	0.0887	0.0088	<0.0001	$23,907	[$19,091,$28,808]
2007	0.1263	0.0106	<0.0001	$34,700	[$28,686,$40,839]
ln (MEDIAN INCOME)	0.3076	0.022	<0.0001	$1	[$1.12,$1.48]
TIME TO WORK	-0.0129	0.0015	<0.0001	-$3,325	[-$4,083,$2,567]
ln (PIKE distance)	-0.0654	0.0115	<0.0001	-$2,310	[-$3,106,$1,514]
PIKE NOISE within 2 miles	-0.0711	0.0342	0.038	-$17,690	[-$33,255,-$1,046]
PIKE RECREATION within 2 miles	0.0255	0.0312	0.4126		
RHO	-0.0002	0.0005	0.6316		
LAMBDA	0.2019	0.0259	<0.0001		
VARIANCE	0.023	0.0008			
N=1,536, MEAN HOUSE PRICE=$257,755, AIC =-2906.044, FIT=0.8408, Likelihood Ratio= 51.6457 (<0.0001)					
IDW=200 meters, Lagrange Multiplier=0.2444 (0.6211), Moran's I=0.0181 (0.6094), Residual Std Error=0.1525					

*Confidence intervals for coefficient estimates are calculated at the 95% confidence level using the mean +/- 1.96 times the standard error.

Pike National Forest Proximity Measures

A one percent decrease in mean distance to the Pike National Forest increases house prices by 6.4% (95% confidence interval is 4.1% to 8.6%, table 10) in the homogeneous model and by 6.5% (4.3% to 8.8%, table 11) in the heterogeneous model, indicating people value living closer to the Pike National Forest. The positive and significant contribution of national forest land was also found in the Cho et al. (2009) and Hand et al. (2008) studies. In addition to the value across the landscape, the adjacency measure in the homogeneous model that represents homes within two miles of the Pike National Forest is not statistically significant (*p*-value=0.7862) indicating there is no additional price premium other than that represented in the continuous distance measure. However, the adjacency measures in the heterogeneous model indicate being within two miles of noise-intensive activities decreases house sales prices by 6.9% (0.4% to 13.8%) or evaluated at the mean -$17,690 (-$1,046 to -$33,255) ($p$-value=0.038).[423] Adjacency to recreation does not exhibit an additional premium over that captured in the continuous distance measure. In terms of our hypothesis tests only $\beta_{PIKE\ distance} < 0$ and $\beta_{PIKE\ NOISE\ 2\ miles} < 0$ indicating there is a price premium for living closer to the Pike National Forest but homes closer to noise intensive activities sell for less.

Thus, to test the usual hypothesis that house prices near a national forest would be higher requires more than just examining houses within a given distance of the nearest national forest boundary. It is important to know what and where different land management activities are occurring relative to houses. Some of these activities may be undesirable (timber harvesting) and some may be desirable (hiking trails). Treating the entire national forest as one undifferentiated land use can lead to an erroneous estimate of the implicit price of the national forest when there are disparate activities.

Conclusion

This paper investigates the importance of accounting for heterogeneity of land uses on a national forest using data on single-family housing sales transactions around the Pike National Forest in Colorado from 2005 to 2007. In particular, we examined the direction and magnitude of the price effects for being closer to the Pike National Forest depending on the land uses in the areas nearest homes. To learn more about the value of adjacency to the Pike National Forest, we examined two separate models: one that

[23] Results from models estimated using multiple distance cutoffs are available in the appendix.

designates houses within two miles of the Pike National Forest in general, and the other according to the characteristics of specific land uses occurring near the federal land boundary including recreation or noise intensive activities. The results of this study suggest that in some cases hedonic price analyses should take into consideration how the actors in a market consider the good of interest. In this case, homebuyers near the Pike National Forest appear to discount living close to noisy activities on a national forest. This recognition in our analysis allows us to provide managers at the Pike National Forest with better information about how people value the benefits (or costs) associated with the different land uses for incorporation in land management planning.

We also found that the amenity values for houses near the Pike National Forest are positive and significant across models when considering houses throughout the entire county. However, disaggregating the Pike National Forest by use rather than assuming the forest is homogeneous provides a clearer picture of the values homebuyers place on actual land uses. In particular, treating the Pike National Forest as a homogenous land type overstates the benefits for houses located within two miles of noisy land uses. Thus, treating the national forest as one homogeneous land use by owner or manager is a misspecification and can have misleading policy implications. Future research can address whether these land use effects are observed on other national forests and public lands.

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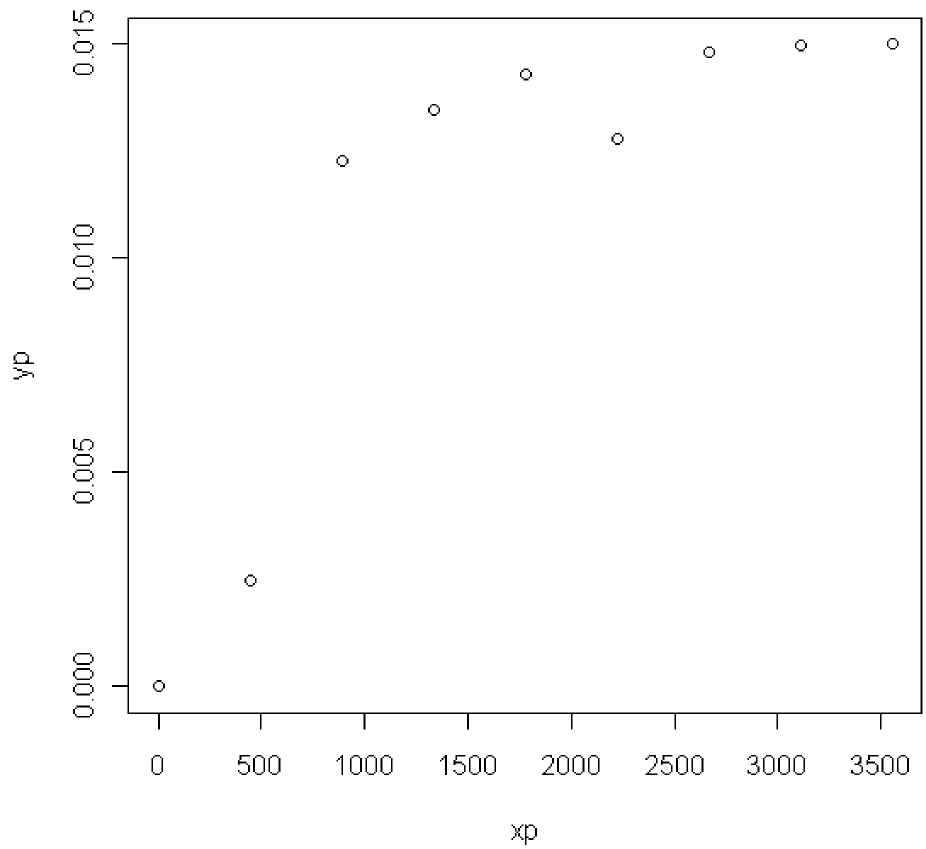

SEMIVARIOGRAM OF OLS RESIDUALS (FEET)

COMPARISON ACROSS SPATIAL WEIGHT MATRICES

	Model 1						Model 2					
	100 meters			200 meters			100 meters			200 meters		
Variable	Coefficier	Std Err		Coefficient	Std Err		Coefficien	Std Err		Est Coef	Std Err	
CONSTANT	5.7059	0.2471	***	5.7426	0.2567	***	5.7352	0.2469	***	5.7666	0.2563	***
HOUSE AGE	-0.0084	0.0006	***	-0.0085	0.0006	***	-0.0084	0.0006	***	-0.0085	0.0006	***
AGE_2	0.0001	<0.0001	***	0.0001	<0.0001	***	0.0001	<0.0001	***	0.0001	<0.0001	***
BATHROOMS	0.0148	0.0068	**	0.0153	0.0067	**	0.0148	0.0068	**	0.0152	0.0067	**
ln (LOT AREA)	0.1009	0.0117	***	0.1049	0.0118	***	0.1003	0.0117	***	0.1049	0.0118	***
ln (HOUSE AREA)	0.3194	0.0187	***	0.318	0.0187	***	0.3192	0.0187	***	0.3177	0.0187	***
BASEMENT AREA	0.0002	<0.0001	***	0.0002	<0.0001	***	0.0002	<0.0001	***	0.0002	<0.0001	***
GARAGE AREA	0.0002	<0.0001	***	0.0002	<0.0001	***	0.0002	<0.0001	***	0.0002	<0.0001	***
2006	0.0889	0.0089	***	0.0884	0.0088	***	0.0893	0.0088	***	0.0887	0.0088	***
2007	0.1254	0.0107	***	0.1255	0.0106	***	0.1261	0.0107	***	0.1263	0.0106	***
ln (MEDIAN INCOME)	0.3092	0.0211	***	0.3053	0.022	***	0.3116	0.0211	***	0.3076	0.022	***
TIME TO WORK	-0.0121	0.0014	***	-0.0126	0.0015	***	-0.0124	0.0014	***	-0.0129	0.0015	***
ln (PIKE distance)	-0.0617	0.0108	***	-0.0635	0.0115	***	-0.0638	0.0108	***	-0.0654	0.0115	***
PIKE within 2 miles	-0.0126	0.0257		-0.0073	0.0269							
PIKE NOISE within 2 miles							-0.0716	0.0328	**	-0.0711	0.0342	**
PIKE RECREATION within 2 miles							0.0214	0.0299		0.0255	0.0312	
RHO	-0.0004	0.0007		-0.0002	0.0005		-0.0004	0.0007		-0.0002	0.0005	
LAMBDA	0.2058	0.0337	***	0.2059	0.0259	***	0.2012	0.0338		0.2019	0.0259	***
VARIANCE	0.0236	0.0009		0.0231	0.0008		0.0235	0.0009		0.023	0.0008	
Model statistics												
AIC	-2881.01			-2903.758			-2883.75			-2906.044		
Residual standard error	0.1543			0.1526			0.1541			0.1525		
FIT	0.8369			0.8405			0.8373			0.8408		
		p -value			*p* -value			*p* -value			*p* -value	
Likelihood Ratio	31.2015	<0.0001		53.9534	<0.0001		29.3528	<0.0001		51.6457	<0.0001	
Moran's I	0.042779	0.47478		0.017965	0.611944		0.042471	0.47792		0.018098	0.60941	
Lagrange Multiplier	0.4958	0.4813		0.2409	0.6236		0.4887	0.4845		0.2444	0.6211	

***,**,* indicate 0.01, 0.05, and 0.1 significance level, respectively

N=1536

COMPARISON ACROSS MODELS (MODEL 1)

Variables	OLS			Spatial Lag			Spatial AR			Joint Spatial	
	Coef Est	Std Err		Coef Est	Std Err		Coef Est	Std Err		Coef Est	Std Err
CONSTANT	5.7373	0.2427	a	5.7307	0.2434	a	5.771	0.2638	a	5.7426	0.2567
HOUSE AGE	-0.0085	0.0006	a	-0.0085	0.0006	a	-0.0086	0.0006	a	-0.0085	0.0006
AGE_2	0.0001	<0.0001	a	0.0001	<0.0001	a	0.0001	<0.0001	a	0.0001	<0.0001
BATHROOMS	0.0156	0.0069	b	0.0156	0.0068	b	0.0154	0.0066	b	0.0153	0.0067
ln (LOT AREA)	0.1015	0.0117	a	0.102	0.0119	a	0.1042	0.0119	a	0.1049	0.0118
ln (HOUSE AREA)	0.3255	0.0189	a	0.3256	0.0189	a	0.314	0.0187	a	0.318	0.0187
BASEMENT AREA	0.0002	<0.0001	a	0.0002	<0.0001	a	0.0002	<0.0001	a	0.0002	<0.0001
GARAGE AREA	0.0002	<0.0001	a	0.0002	<0.0001	a	0.0002	<0.0001	a	0.0002	<0.0001
2006	0.0923	0.009	a	0.0923	0.009	a	0.087	0.0087	a	0.0884	0.0088
2007	0.125	0.011	a	0.125	0.0109	a	0.1255	0.0104	a	0.1255	0.0106
ln (MEDIAN INCOME)	0.3013	0.0205	a	0.3013	0.0204	a	0.307	0.0227	a	0.3053	0.022
TIME TO WORK	-0.0125	0.0013	a	-0.0125	0.0013	a	-0.0126	0.0015	a	-0.0126	0.0015
ln (PIKE distance)	-0.0606	0.0106	a	-0.0607	0.0105	a	-0.0644	0.012	a	-0.0635	0.0115
PIKE within 2 miles	-0.0066	0.0249		-0.0067	0.0248		-0.007	0.0279		-0.0073	0.0269
RHO				0.0002	0.0007					-0.0002	0.0005
LAMBDA							0.2849	0.0245	a	0.2059	0.0259
VARIANCE				0.0243	0.0009		0.0228	0.0008		0.0231	0.0008
Model statistics											
Residual Standard Error	0.1566			0.1566			0.1518			0.1526	
R-Square	0.8317			0.8317			0.8352			0.8405	
AIC	-1321.806			-1092.093			-1365.187			-2903.758	
	statistic	p-value		statistic	p-value		statistic	p-value		statistic	p-value
Likelihood Ratio				0.0594	0.8074		522.7783	<0.0001		53.9534	<0.0001
Moran's I	0.2574	0.2824		0.257242	<0.0001		-0.072161	0.051343		0.017965	0.6119
Lagrange Multiplier	49.1429	<0.0001		49.0666	<0.0001		3.8605	0.0494		0.2409	0.6236

[a] indicates significance at the 0.01 levels

[b] indicates significance at the 0.05 levels

[c] indicates significance at the 0.1 levels

COMPARISON ACROSS MODELS (MODEL 2)

Variables	OLS			Spatial Lag			Spatial AR			Joint Spatial		
	Coef Est	Std Err		Coef Est	Std Err		Coef Est	Std Err		Coef Est	Std Err	
CONSTANT	5.7701	0.2426	a	5.7634	0.2432	a	5.7939	0.2644	a	5.7666	0.2563	a
HOUSE AGE	-0.0085	0.0006	a	-0.0085	0.0006	a	-0.0086	0.0006	a	-0.0085	0.0006	a
AGE_2	0.0001	<0.0001	a	0.0001	<0.0001	a	0.0001	<0.0001	a	0.0001	<0.0001	a
BATHROOMS	0.0154	0.0069	b	0.0154	0.0068	b	0.0154	0.0066	b	0.0152	0.0067	b
ln (LOT AREA)	0.1008	0.0117	a	0.1014	0.0119	a	0.1045	0.0119	a	0.1049	0.0118	a
ln (HOUSE AREA)	0.3251	0.0189	a	0.3252	0.0188	a	0.3133	0.0187	a	0.3177	0.0187	a
BASEMENT AREA	0.0002	<0.0001	a	0.0002	<0.0001	a	0.0002	<0.0001	a	0.0002	<0.0001	a
GARAGE AREA	0.0002	<0.0001	a	0.0002	<0.0001	a	0.0001	<0.0001	a	0.0002	<0.0001	a
2006	0.0927	0.009	a	0.0927	0.009	a	0.087	0.0087	a	0.0887	0.0088	a
2007	0.1262	0.011	a	0.1263	0.0109	a	0.126	0.0104	a	0.1263	0.0106	a
ln (MEDIAN INCOME)	0.3042	0.0205	a	0.3042	0.0204	a	0.3094	0.0228	a	0.3076	0.022	a
TIME TO WORK	-0.0129	0.0013	a	-0.0129	0.0013	a	-0.0129	0.0015	a	-0.0129	0.0015	a
ln (PIKE distance)	-0.063	0.0106	a	-0.0631	0.0106	a	-0.0662	0.012	a	-0.0654	0.0115	a
PIKE NOISE within 2 miles	-0.0814	0.0318	b	-0.0814	0.0317	b	-0.0655	0.0356	c	-0.0711	0.0342	b
PIKE RECREATION within 2 miles	0.0303	0.0288		0.0302	0.0286		0.0236	0.0325		0.0255	0.0312	
RHO				0.0002	0.0007					-0.0002	0.0005	
LAMBDA							0.2915	0.0244	a	0.2019	0.0259	a
VARIANCE				0.0242	0.0009		0.0227	0.0008		0.023	0.0008	
Model statistics												
Residual Standard Error	0.1564			0.1564			0.1516			0.1525		
R-Square	0.8324			0.8324			0.8357			0.8408		
AIC	-1326.399			-1324.461			-1365.083			-2906.044		
	statistic	p-value		statistic	p-value		statistic	p-value		statistic	p-value	
Likelihood Ratio				0.0625	0.8026		538.3739	<0.0001		51.6457	<0.0001	
Moran's I	0.2514	0.2714		0.25117	<0.0001		-0.083481	0.024004		0.0181	0.6094	
Lagrange Multiplier	46.8448	<0.0001		46.7778	<0.0001		5.1671	0.023		0.2444	0.6211	

[a] indicates significance at the 0.01 levels
[b] indicates significance at the 0.05 levels
[c] indicates significance at the 0.1 levels

CHAPTER FIVE

Concluding Remarks

The amenity value of federal land proximity was analyzed from three perspectives to see how estimates of marginal benefits vary based on the empirical specification and estimation techniques. Results across studies indicate there is a price premium for homes in the west and south near Pike National Forest and Cheyenne Mountain (NORAD); while there is a price discount for homes in the east near Peterson Air Force Base and northeast of Fort Carson; and no statistically significant effect near the center of the city and the U.S. Air Force Academy.

Chapter two addressed whether homes adjacent or in close proximity to federal lands convey a price premium (discount) by using three different distance representations, (1) continuous distance, (2) within half mile, and (3) between 0-1, 1-2, 2-3 miles for each federal land in the study area. The first model that measures open space proximity based on the natural log of distance indicates there is a price premium for a 1% change in the mean distance closer increases house prices for Pike National Forest (2.9% premium), NORAD (4.4%), and natural area/wildlife habitat (3.4%). Non-linear effects are pronounced for Pike NF ranging from an approximate 20% premium for the first half mile in the second model to 10% for the first mile and 5% for the second mile in the third model. The premium for the first mile was 14% and the second was 15% for NORAD. Price discounts of approximately 4% were found for homes near Fort Carson and

Peterson Air Force Base. There were no statistically significant price effects for homes near the U.S. Air Force Academy.

In chapter three the objective of the analysis was to examine the differences in estimates of marginal values for housing attributes across scales using local and global regression techniques, particularly with respect to federal land proximity. Results from the ordinary least squares estimation indicate that on average federal lands do not affect house prices. Then, the geographically weighted regression provides valuable information about how the marginal values vary across the landscape. The results are similar to those in the second chapter because homes in the west and southwest nearer to the Pike National Forest, NORAD and Fort Carson experience price premiums while homes closer Peterson Air Force Base sell for less. The distribution is 43% of the homes exhibit the premium, 11% the discount and 46% experience no statistically significant price effects. The marginal value of federal land proximity is between five and six times higher in the local models. The difference is evidence that much variation exists in marginal values across the landscape such that the global models illustrate averages, not distributions. Finally, the characteristic length of the bandwidth selection in the geographically weighted models included 94 neighbors or homes within approximately 200 meters similar to the results from the first study.

In the fourth chapter, the direction, magnitude and significance of the price effects for being closer to the Pike National Forest were examined to determine if specifying the land by use rather than just ownership provides more information about marginal values that is useful for planners and policy-makers. In this case, homebuyers near the Pike National Forest appear to discount living close to noisy activities on a national forest. A clearer picture of the values homebuyers place on actual land uses demonstrates that specifying the federal land as homogenous land type overstates the benefits for houses located within two miles of noisy land uses.

There are two primary lessons learned. The first is that when evaluating the marginal benefits from environmental amenities that cover large areas of land (Pike National Forest and Fort Carson), geographically weighted regressions provide important information on how the benefits vary across the landscape. In the third chapter proximity to federal lands appears to be insignificant in the OLS estimation; however the geographically weighted regressions produce a continuous surface that relays information about where there are significant price effects for proximity. This is extremely valuable in determining the winners and losers of various land use scenarios. Second, it is important to include information about the characteristics of the land uses on federal lands in the models of housing prices not just ownership.

Next steps that build on this foundation include: (1) estimating the geographically weighted regressions to see how marginal values for local parks vary in the Colorado Springs area and (2) using the marginal implicit prices from the geographically weighted regression, along with other demand shifters, to estimate second stage demand to get non-marginal changes for environmental amenities.

In closing, a study such as this has limitations. Some are related to hedonic property method's assumptions about information availability and mobility. For example, the method can only be applied to goods whose characteristics and alternatives are known, i.e. sufficient information. Second is the assumption that mobility within the real estate market is not a limiting factor in the decision to buy a particular house. A third limitation is that this is a case study based on relative factors and therefore the results may not be generally applied to other populations. An interesting extension would be to perform the same analysis for 2008 or after to see which locations hold their value during the housing market adjustment.

APPENDIX

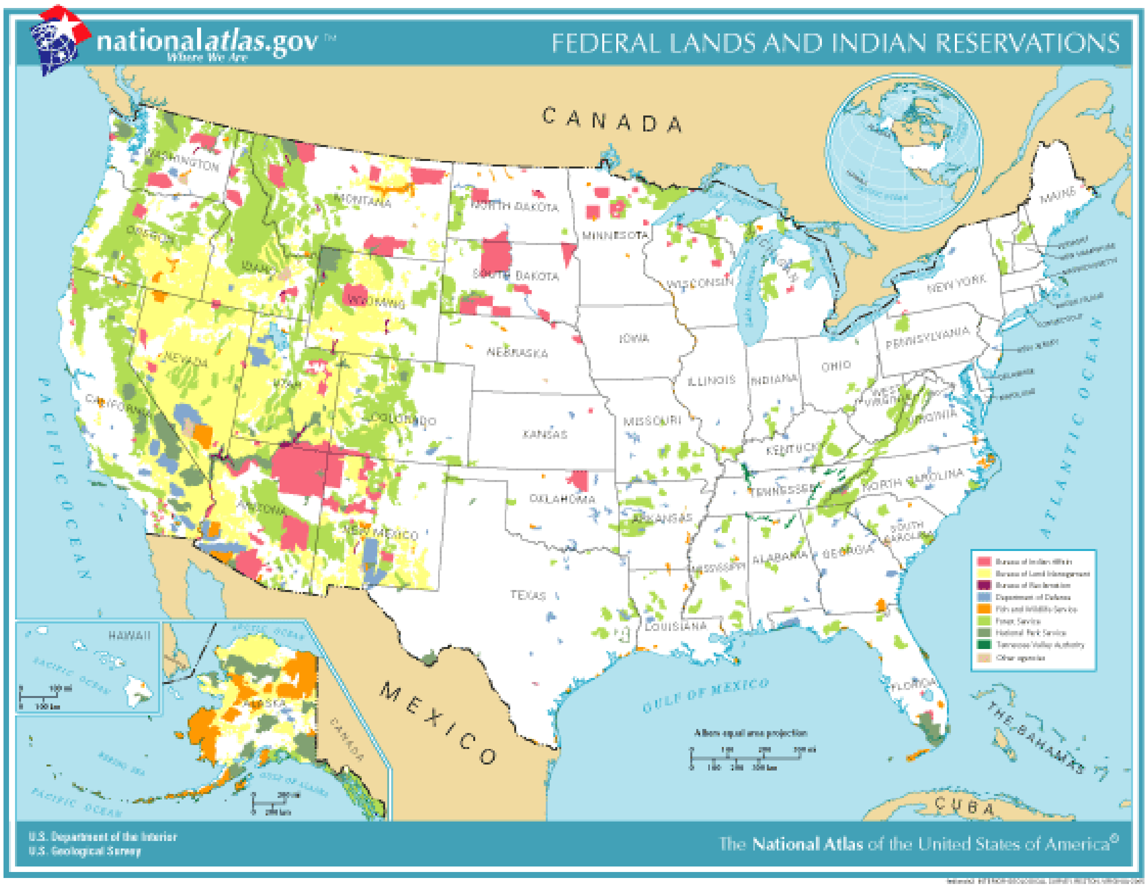

FIGURE A1. FEDERAL LANDS AND INDIAN RESERVATIONS, NATIONAL ATLAS

http://www.nationalatlas.gov/printable/fedlands.html#list

4/5/2011

Natural Resource Council of Maine for federal and state breakdown.

http://www.nrcm.org/documents/publiclandownership.pdf 4/5/2011

Revision of map from nwo.org 1995

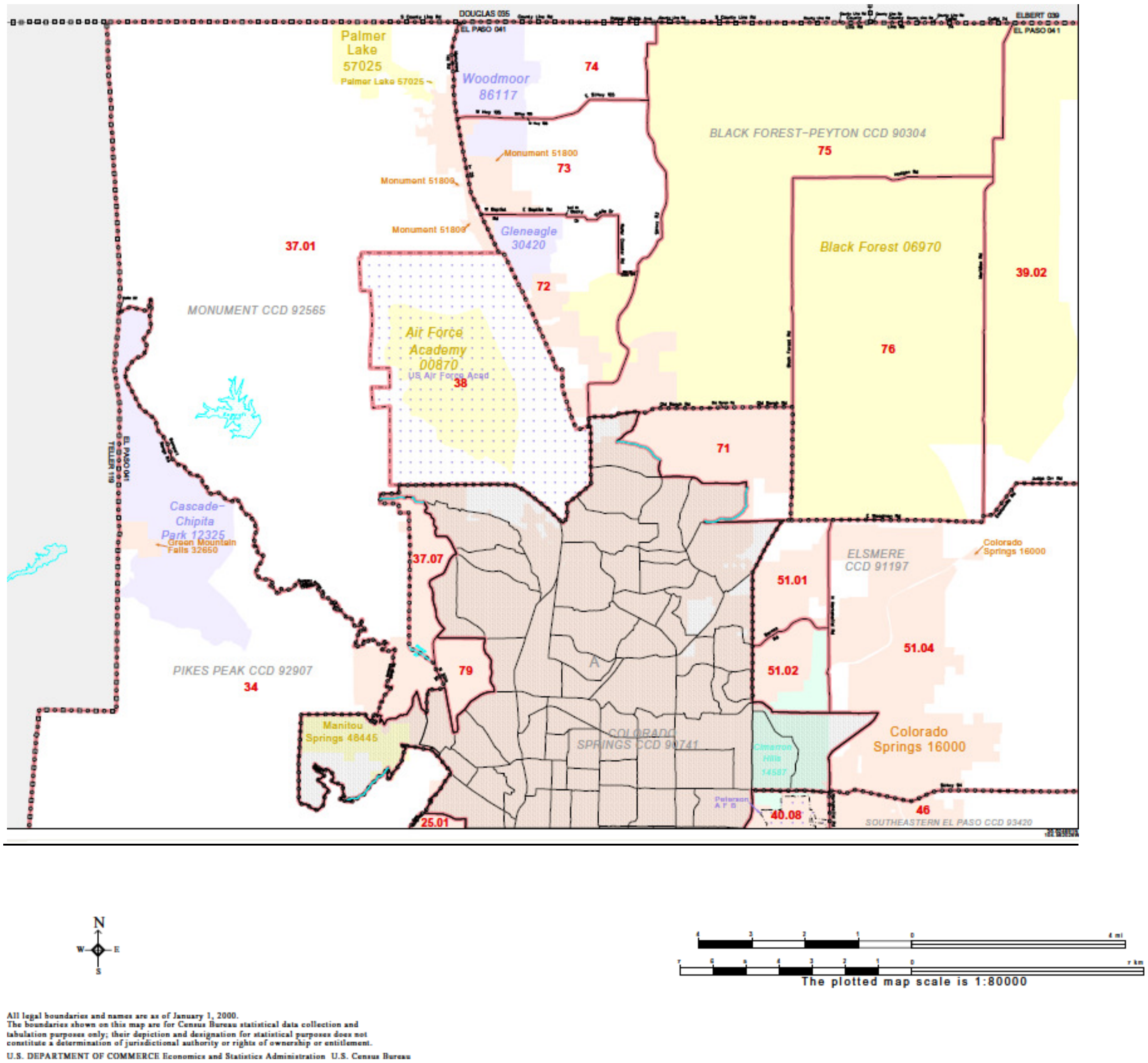

FIGURE A2. CENSUS TRACTS NORTHWESTERN CORNER OF STUDY AREA

http://www2.census.gov/plmap/pl_trt/st08_Colorado/c08041_ElPaso/CT08041_001.pdf

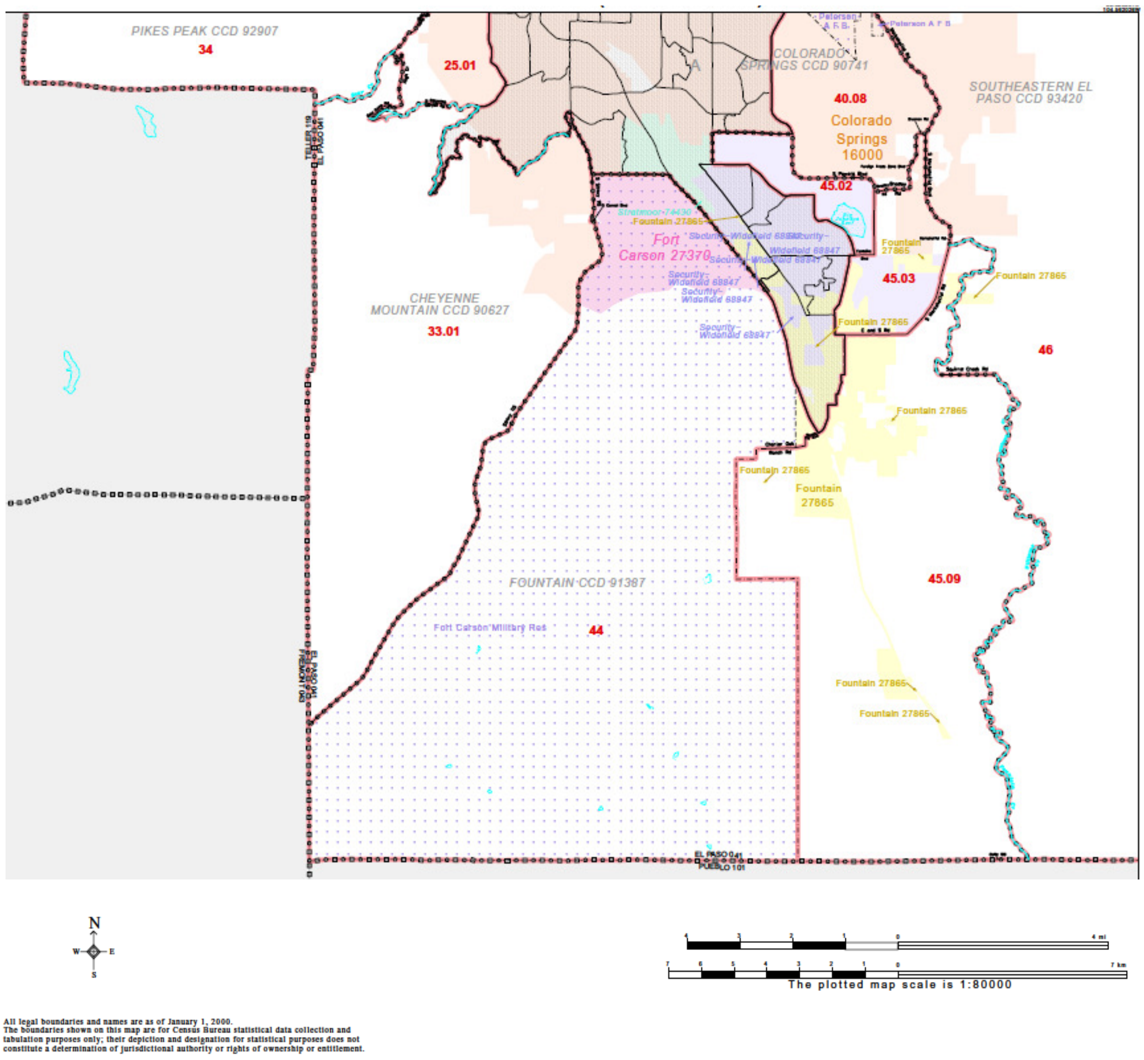

FIGURE A3. CENSUS TRACTS SOUTHWESTERN CORNER OF STUDY AREA

http://www2.census.gov/plmap/pl_trt/st08_Colorado/c08041_ElPaso/CT08041_003.pdf

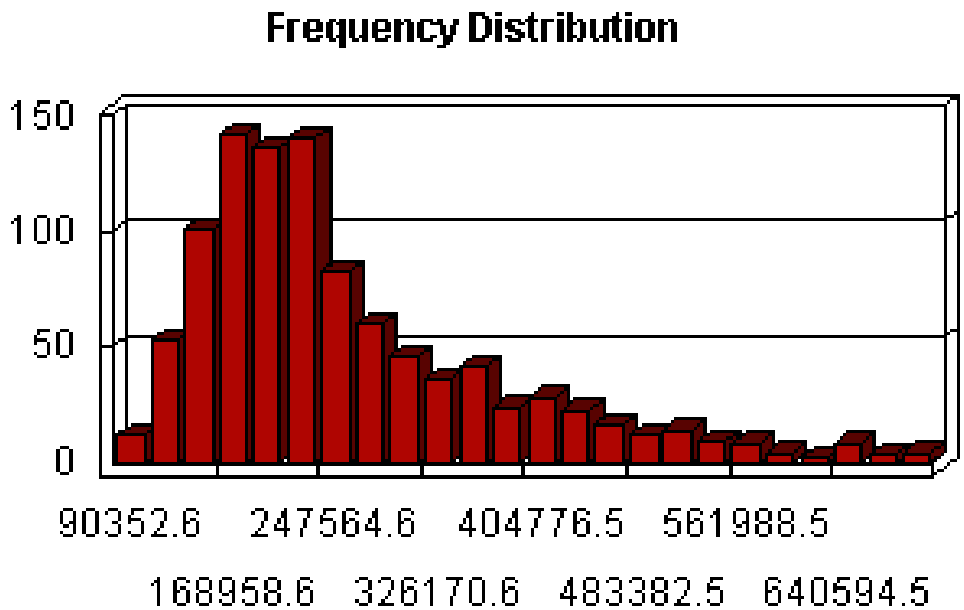

FIGURE A4. HOUSE SALES PRICES

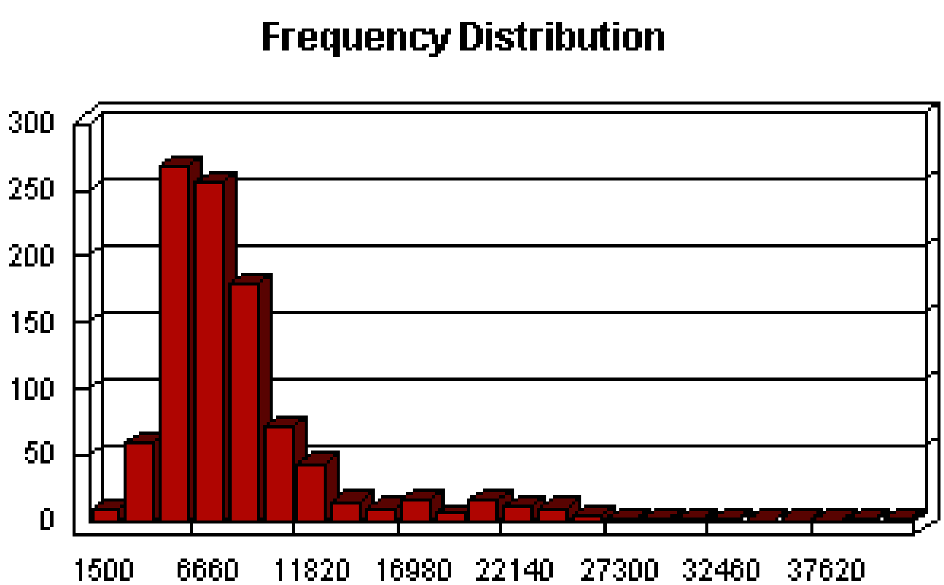

FIGURE A5. HOUSE SQUARE FOOTAGE

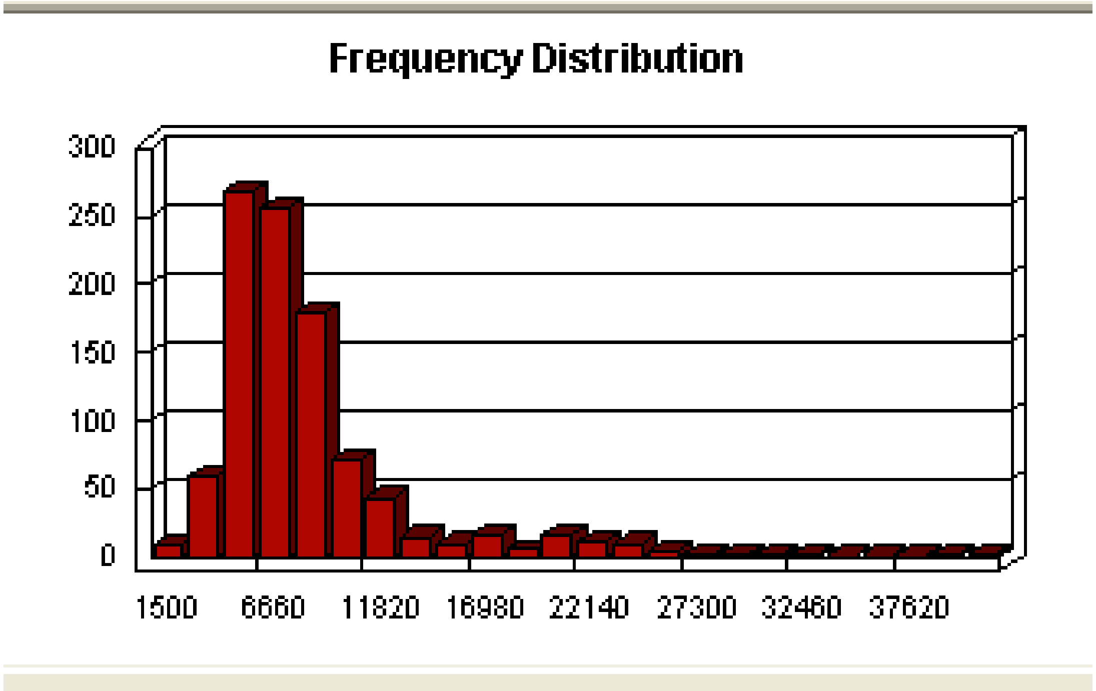

FIGURE A6. LOT SQUARE FOOTAGE

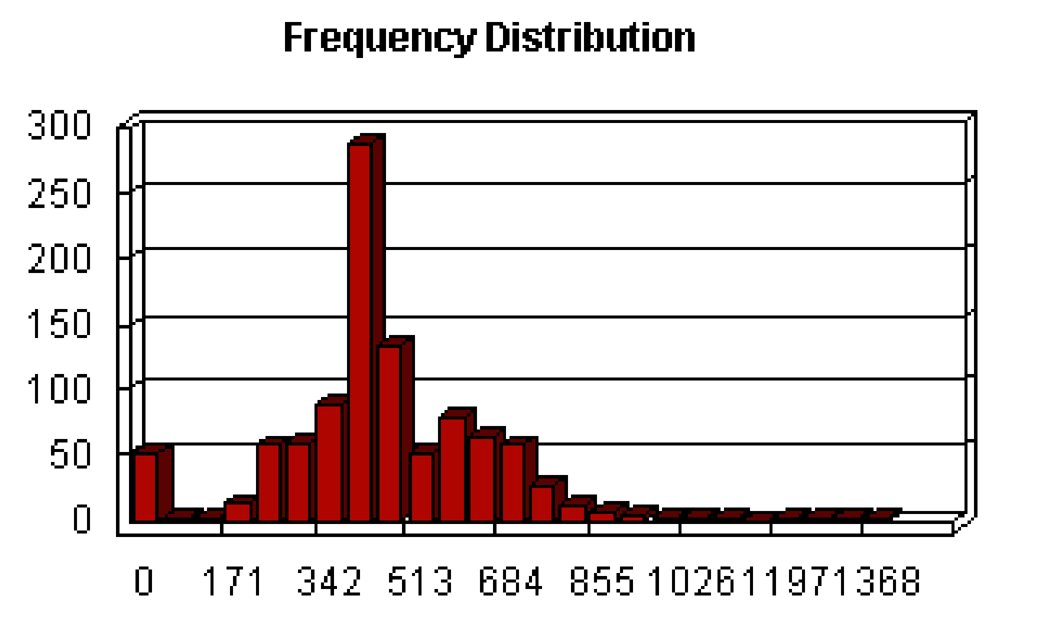

FIGURE A7. GARAGE SQUARE FOOTAGE

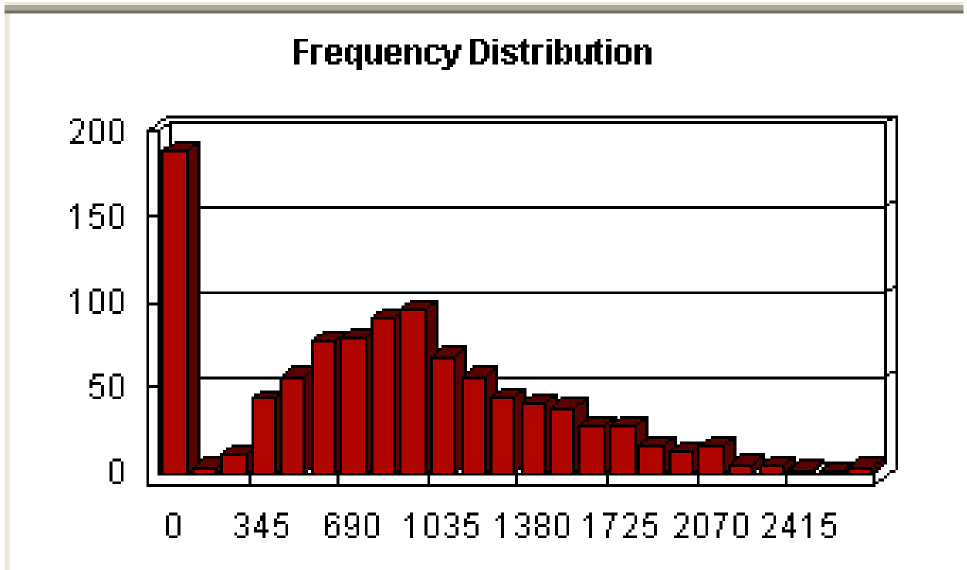

FIGURE A8. BASEMENT SQUARE FOOTAGE

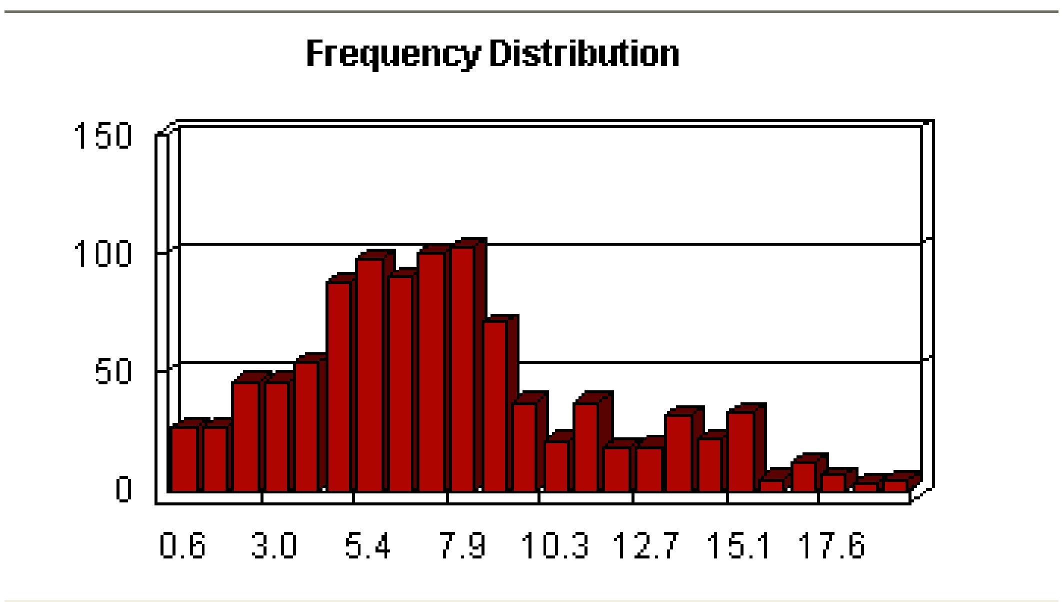

FIGURE A9. MILES TO CITY CENTER

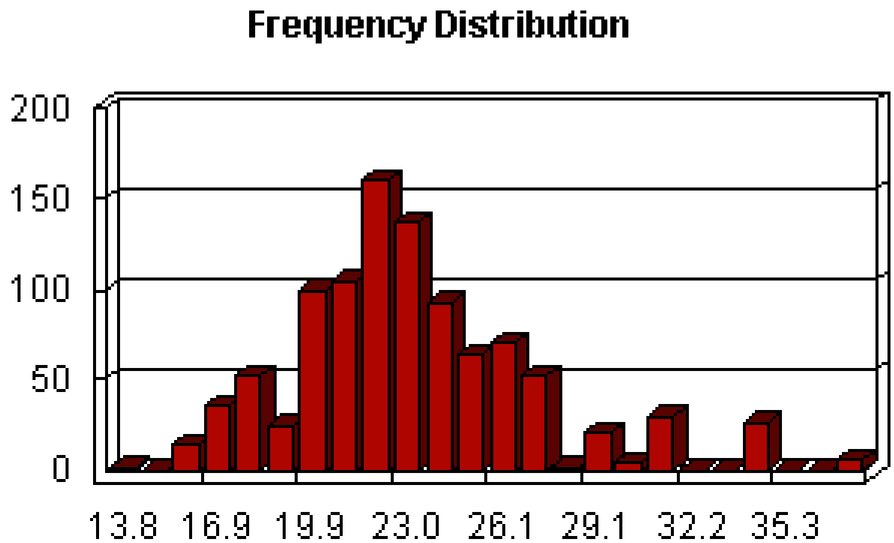

FIGURE A10. TRAVEL TIME TO WORK

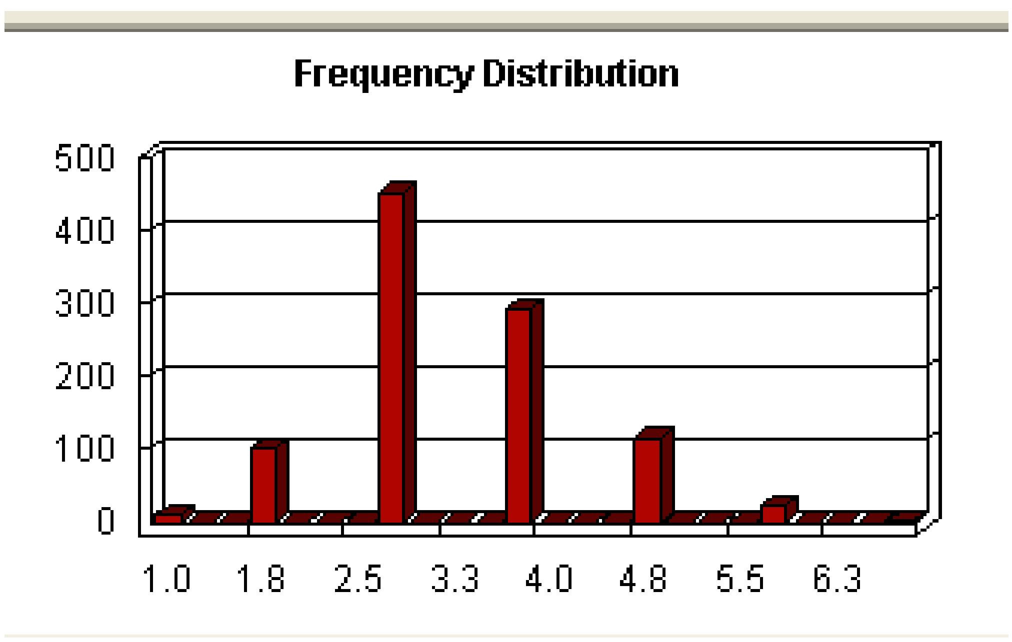

FIGURE A11. NUMBER OF BEDROOMS

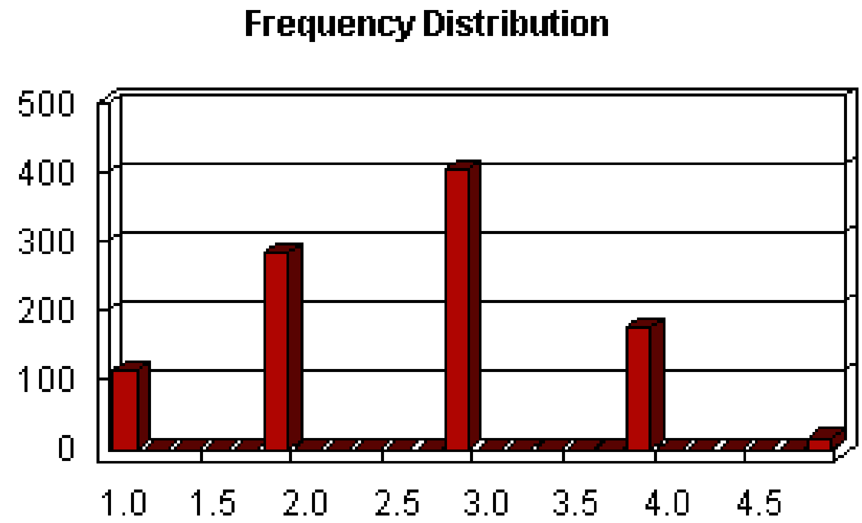

FIGURE A12. NUMBER OF BATHROOMS

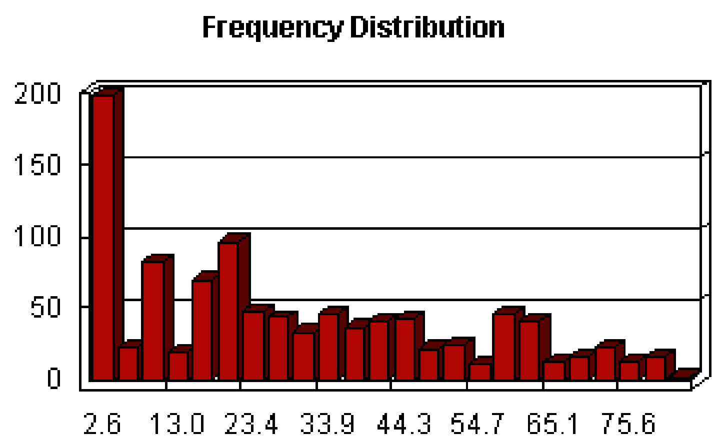

FIGURE A13. RENTALS AS A PERCENTAGE BY CENSUS TRACT

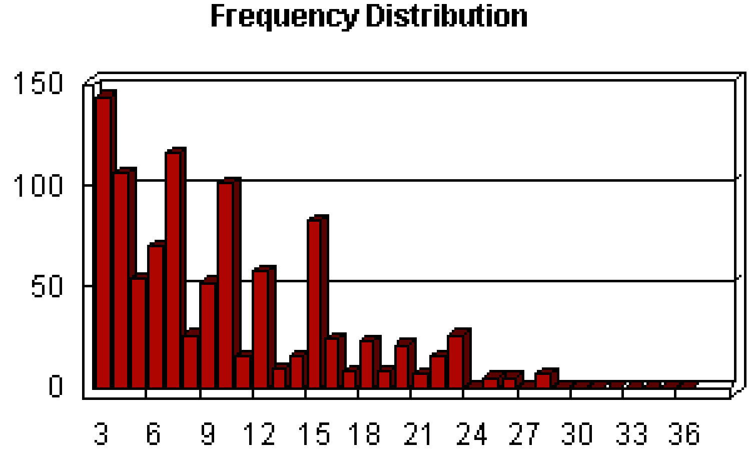

FIGURE A14. PERCENTAGE OF PERSONS OVER 60 BY CENSUS TRACT

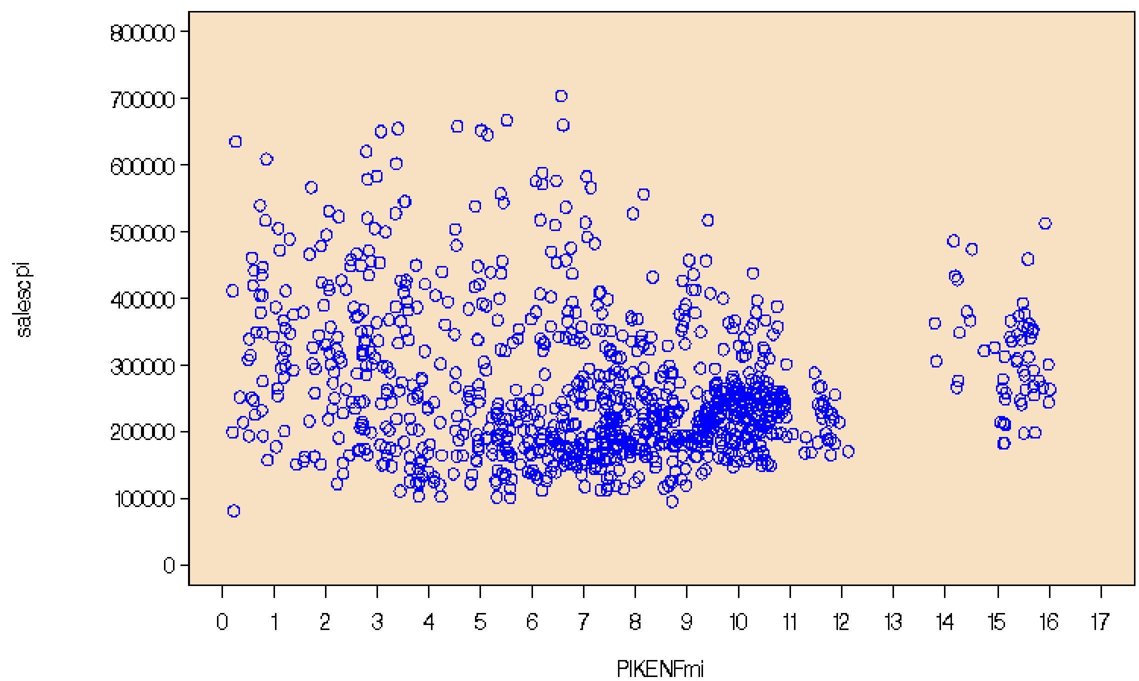

FIGURE A15. HOUSE SALE PRICE (IN 2005$) AS A FUNCTION OF DISTANCE (IN MILES) FROM THE PIKE NATIONAL FOREST

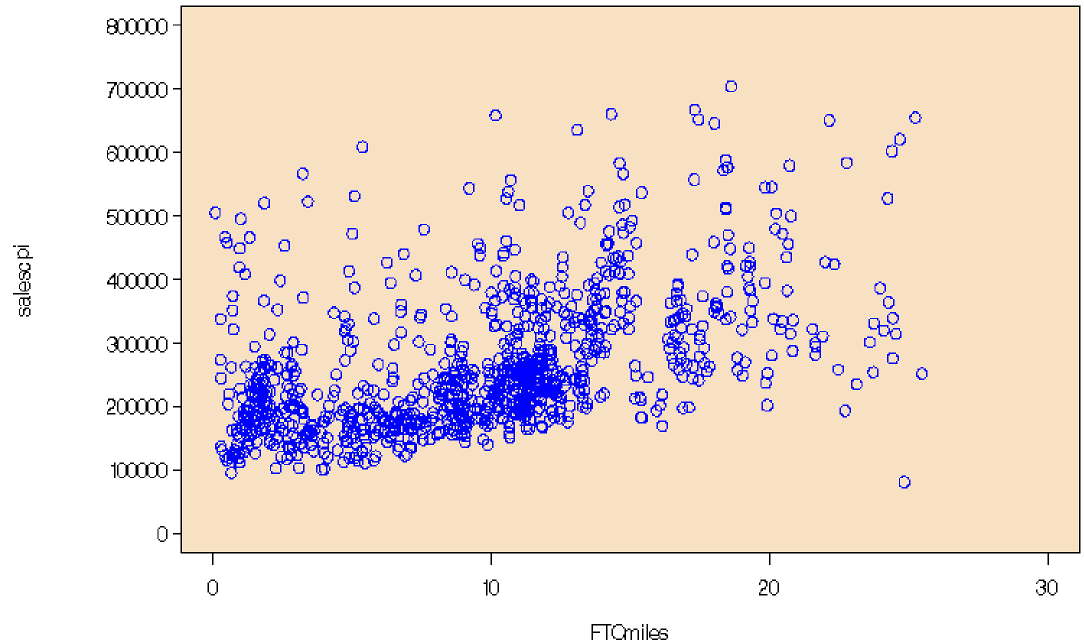

FIGURE A16. HOUSE SALE PRICE (IN 2005$) AS A FUNCTION OF DISTANCE (IN MILES) FROM FORT CARSON

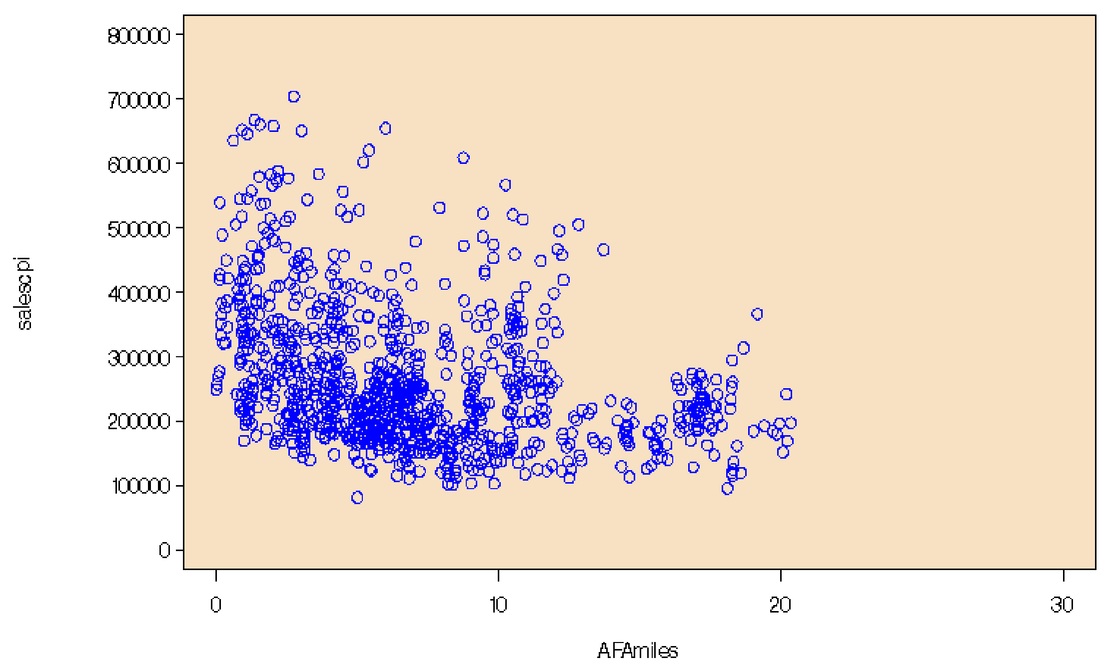

FIGURE A17. HOUSE SALE PRICE (IN 2005$) AS A FUNCTION OF DISTANCE (IN MILES) FROM THE U.S. AIR FORCE ACADEMY

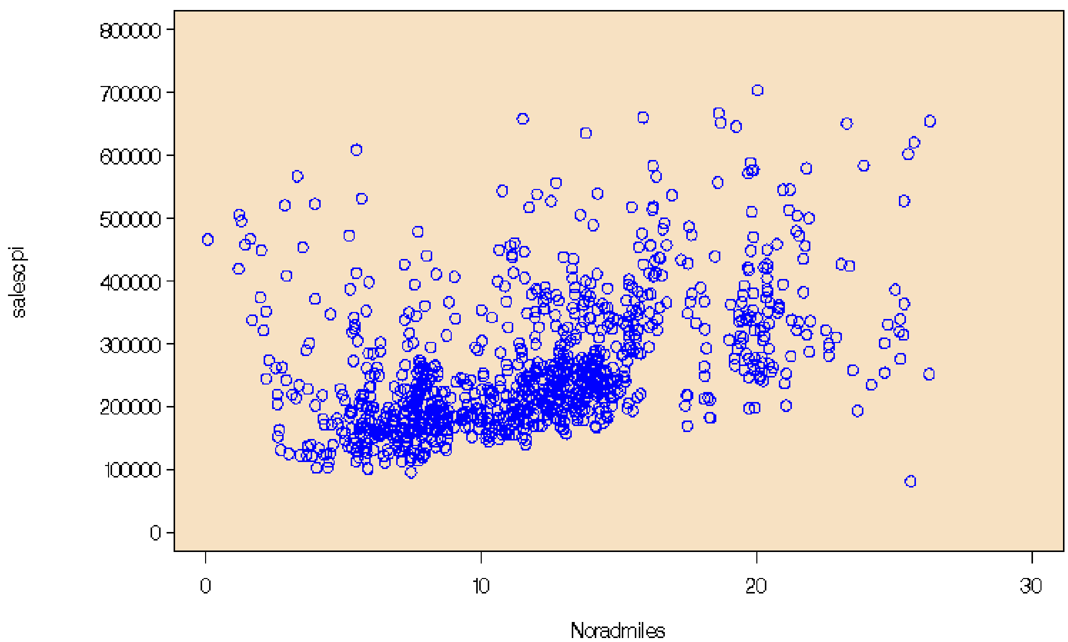

FIGURE A18. HOUSE SALE PRICE (IN 2005$) AS A FUNCTION OF DISTANCE (IN MILES) FROM CHEYENNE MOUNTAIN AIR FORCE STATION (NORAD)

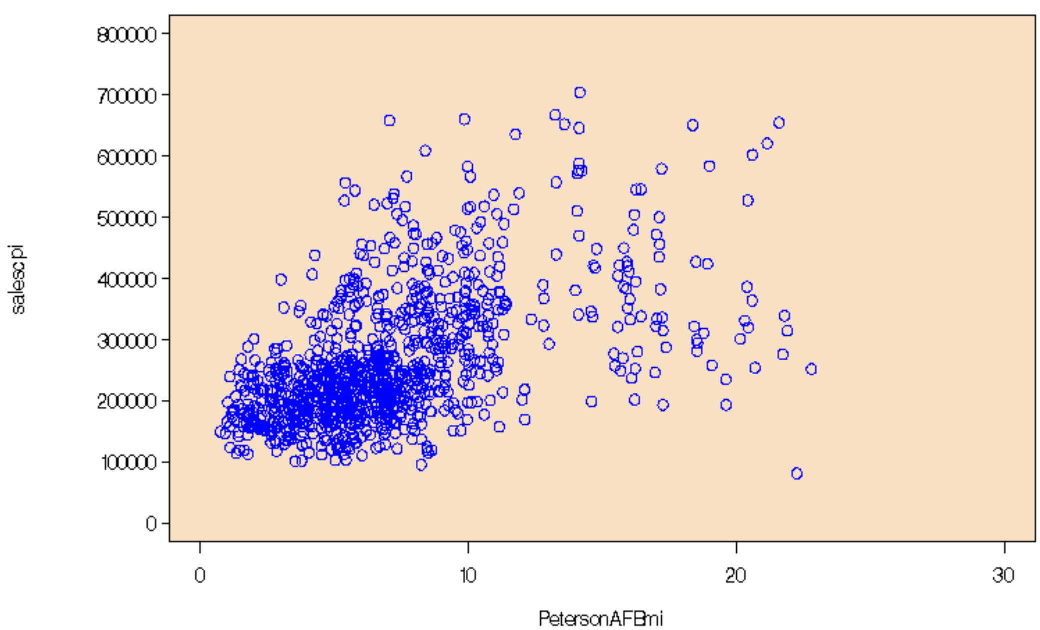

FIGURE A19. HOUSE SALE PRICE (IN 2005$) AS A FUNCTION OF DISTANCE (IN MILES) FROM PETERSON AIR FORCE BASE

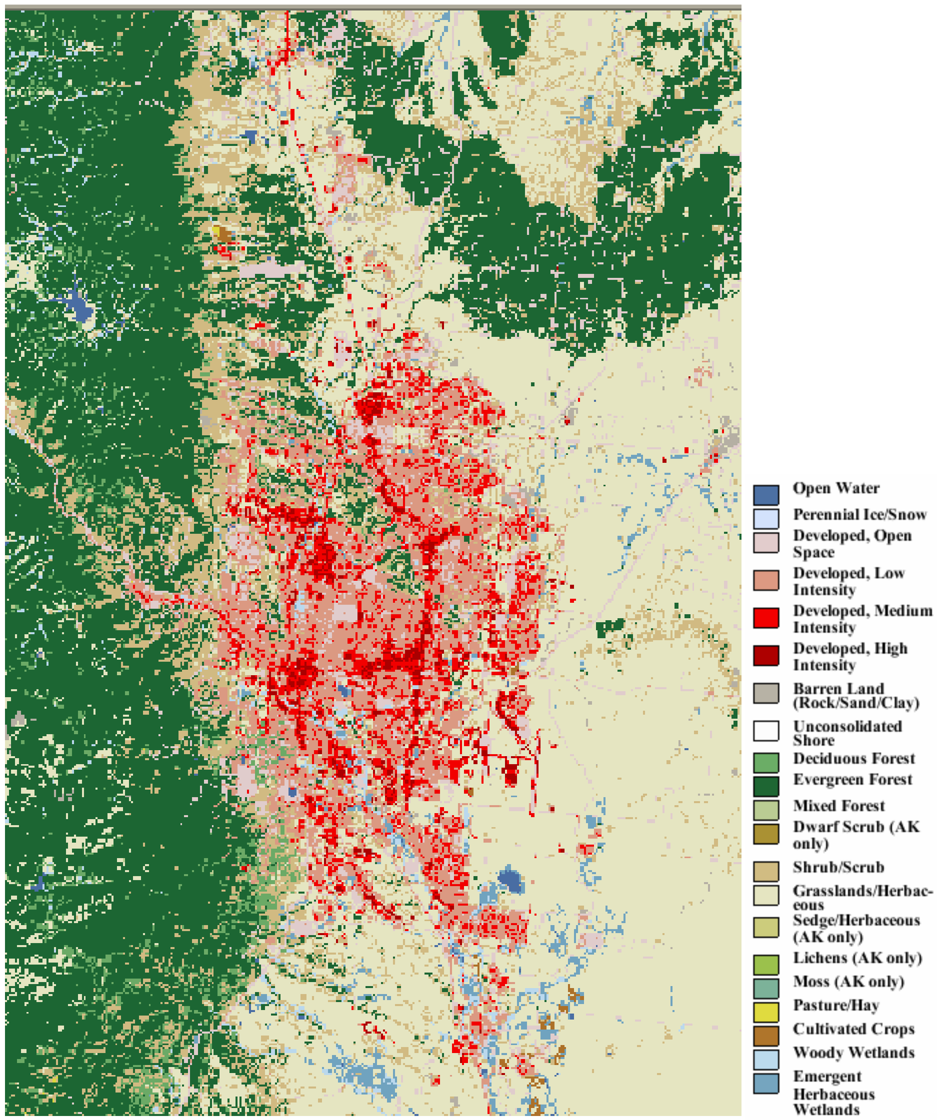

FIGURE A20. NATIONAL LAND COVER FOR STUDY AREA

National Land Cover Database (NLCD 2001)

http://eros.usgs.gov/#/Science/Landscape_Dynamics/Land_Cover-Land_Use/National_Land_Cover

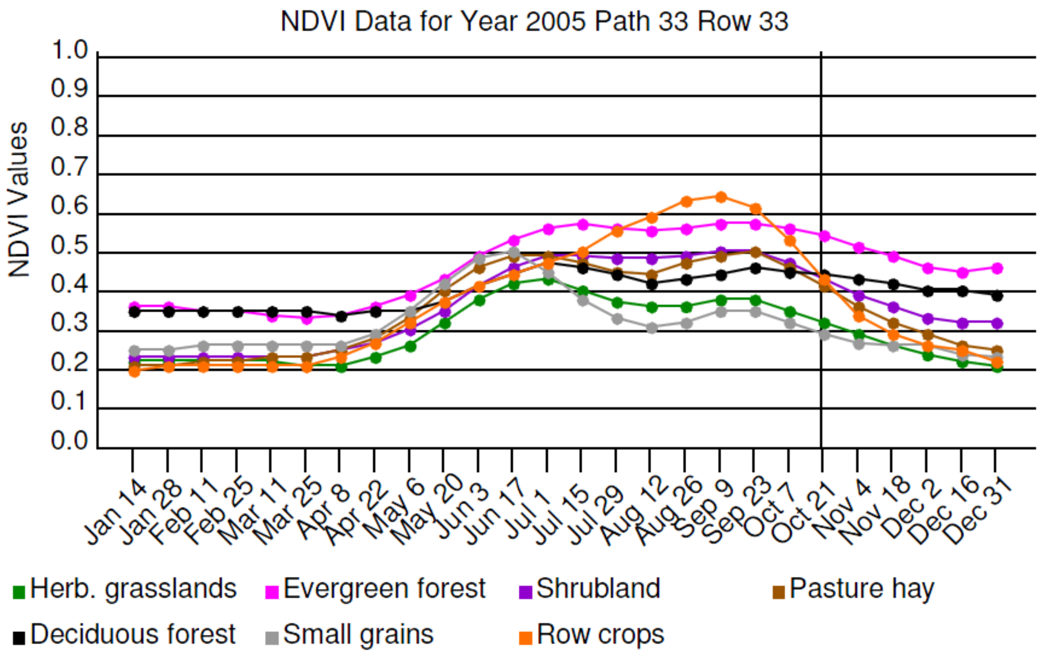

FIGURE A21. NORMALIZED DIFFERENCE VEGETATION INDEX 2005

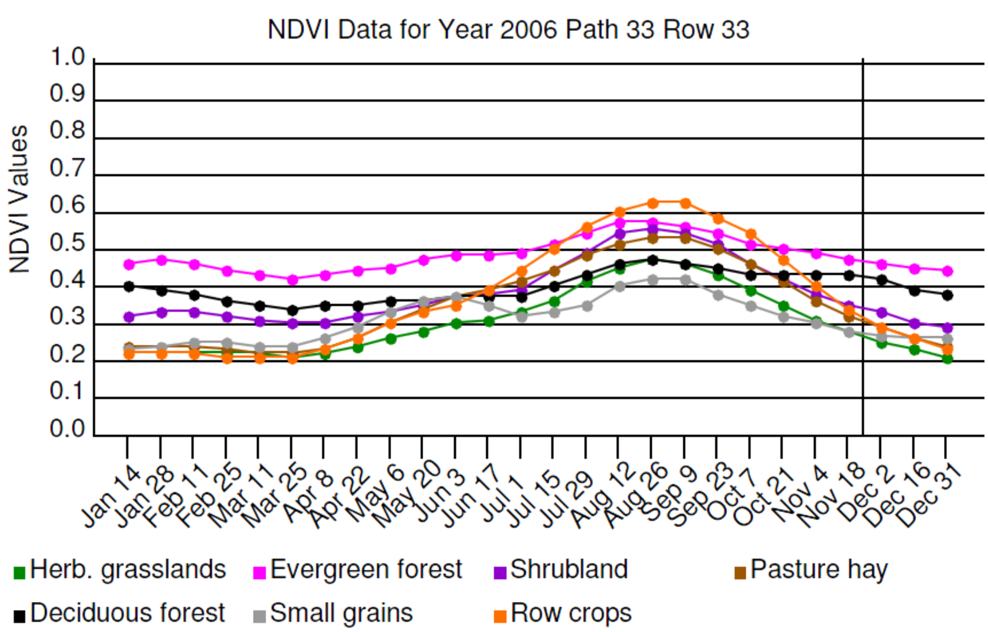

FIGURE A22. NORMALIZED DIFFERENCE VEGETATION INDEX 2006

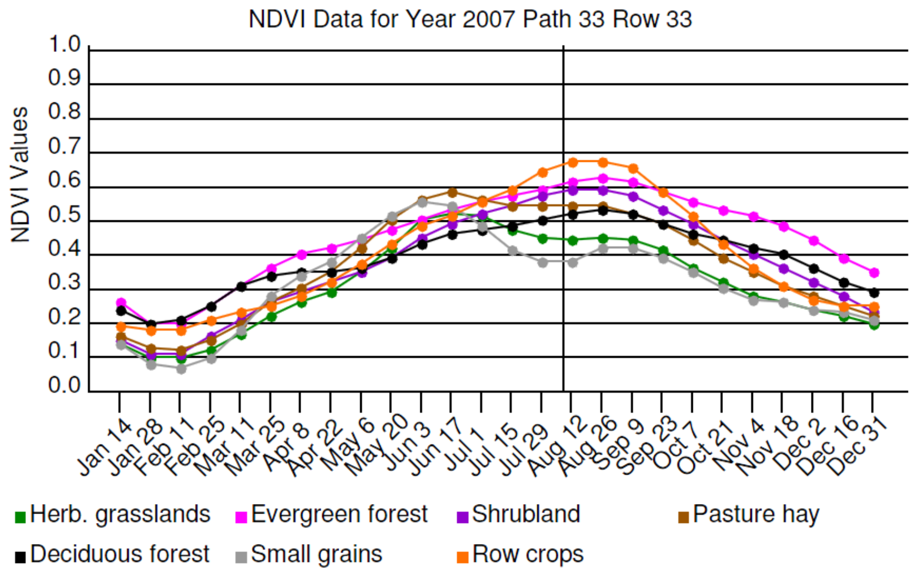

FIGURE A23. NORMALIZED DIFFERENCE VEGETATION INDEX 2007