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

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ABSTRACT Open space lands are provided by a variety of entities from private individuals to the federal government and these entities make management decisions based on a very broad range of priorities. The net benefits of additional open space depend on the number, quality, and composition of existing open space in the vicinity. In areas where open space is abundant and there is a significant proportion that is federally owned, the net benefits are not well understood. In this study, the marginal willingness to pay for proximity to public open space is estimated using the hedonic property method and home sales transactions in 2007 for El Paso County Colorado, a location that boasts of having over 150,000 acres of open space. Results from a generalized spatial two-stage least squares regression indicate that homes in close proximity to open space provided locally by city, county, and state governments sell for a premium, but larger premiums are associated with proximity to the Pike National Forest and Cheyenne Mountain Air Force Station likely at least partially due to the natural amenities of the Rocky Mountains. In contrast, proximity to Fort Carson Army Installation is found to negatively affect house sales prices likely due to undesirable activities that occur on and around the installation. As for the other area of federal lands, proximity to the U.S. Air Force Academy and to Peterson Air Force Base was found to negatively affect house prices; however, these effects were not statistically significant.

Introduction

An assessment of the net benefits provided locally by open space is needed when conducting benefit cost analysis of land management options and evaluating growth plans among communities and different levels of government. There are many areas in the U.S. where open space is provided by multiple agencies and there is a need to understand the values associated with these open space lands within the broader context of all the types of open space land provided. Federal lands such as national forests and military bases are 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, direct, indirect, and induced effects on income and employment accrue regionally (Deger 1983). Another benefit is the provision of open space. While the former contributions are measurable directly from market interactions (Maki and Lichty 2000), the benefits of open space are usually measured through the application of nonmarket valuation methods (Freeman 2003). In particular, the hedonic property method is commonly used to

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examine housing market transactions for property price effects associated with proximity to open space (see McConnell and Walls 2005). House prices incorporate the value homeowners are willing to pay to live in a particular location. If there is a property price premium associated with proximity to open space, local governments benefit from the additional tax revenue and homeowners benefit from the increase in property value. Conversely, it is also possible that there may be a property price discount associated with less desirable externalities. However, these net benefits are only a part of the total benefit of open space; other benefits include recreational opportunities and water quality effects (Cline and Seidl 2009), as well as passive value and the reduced likelihood of irreversible development effects.

The primary function of the military is to supply the forces needed for national security and military lands are managed to ensure necessary operations can occur to deliver the service which is a public good. To do so, the military lands are allocated to housing and training for soldiers as well as weapons and equipment testing. These activities occur at Fort Carson Army Installation (FTC) and Peterson Air Force Base (PAFB). Unfortunately, local by-products 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, Timlin, and Goran 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 often established that, in addition to reducing noise or hazard impacts outside installation boundaries (Eerkens 1999), yield wildlife viewing opportunities and provide other ecosystem benefits (Armsworth et al. 2006). Proactive management for threatened and endangered species and species at risk within these buffer zones is required to minimize the threat of restrictions to the military's mission (Department of the Army 2006; Efroymson et al. 2009).

Similarly, there are trade-offs when managing national forests and grasslands for multiple uses as is required of the USDA Forest Service. The USDA Forest Service was established by Congress in 1905 to provide quality water and timber. Other ecosystem services include public goods such as wildlife habitat and diversity, watershed services, carbon storage, and scenic landscapes. Additionally, the demand for recreational uses on national forest land has grown rapidly in recent years as the population has increased in surrounding areas (White, Alig, and Stein 2010). As a result, forest plans prioritize locating recreation adjacent to neighborhoods as urban growth approaches national forest boundaries (Stein et al. 2007). The Pike National Forest (PIKE) covers the entire western boundary of the study area and it contains both noise-intensive activities, such as off-road vehicle use, and timber management activities, as well as quieter activities such as recreational trails and picnic areas.

In this study, the marginal implicit prices attributable to proximity to open space on neighboring residential properties are estimated using the hedonic property method. The study area is El Paso County, Colorado, home to Colorado Springs and suburbs, as well as abundant open space provided by many sources. The multitude of open space types allows us to examine the relative net benefits of proximity to different types of open space although the focus is on the effects of proximity to federal lands on house sales prices. Federal lands in the area are the PIKE and several military installations including FTC, the United States Air Force Academy (USAFA), Cheyenne Mountain Air Force Station, and PAFB. A geodatabase was created by combining county assessor information on property structural characteristics with neighborhood attributes from the census, as well as a geodatabase containing open space boundaries and ownership information. Euclidean distance measures were calculated from each house to various open space types (each of the federal, state, county, and city open spaces), as well as the primary North-South transportation artery, Interstate 25. Proximity to open space is captured through 1 mi intervals for 3 mi. Residuals for the ordinary least squares (OLS) regression hedonic price model are examined for spatial autocorrelation and the appropriate model specification is selected using Lagrange multiplier (LM) tests. Direct, indirect, and total impacts are then calculated to determine how the spatial autocorrelation influences the proportion of the price effect attributable to direct versus spatial spillovers throughout the study area. Improved estimation of net benefits is vital for policies aimed at open space preservation and land use conflict resolution.

Hedonic Studies of Open Space Values from Federal Lands

There are many different types and ownership of open space including private lands with conservation easements, greenways, city parks, county, state, and federal lands. Most of these are well studied (see McConnell and Walls 2005). However, relatively few open space studies have focused on the value of open space amenities and disamenities provided by federal lands.

With respect to military lands, Irwin (2002) examined the proximity effects of open space on residential property values in central Maryland and found the only effects, in this case positive, from neighboring military lands occurred for the largest of the installations, Fort Meade, while the other military land proximity measures were insignificant. Neumann, Boyle, and Bell (2009) estimated relative amenity values for the National Wildlife Refuge in Massachusetts and found homes within 100 m of the wildlife refuge sold for a premium similar to golf courses and sport/recreation parks ($1,093 in 2012 dollars) and more than agricultural land, cemeteries, and conservation land. In a national study, Taylor, Liu, and Hamilton (2012) found homes within a half mile of National Wildlife Refuges exhibit a price premium.

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). However, some studies have found negative or negligible effects (Kim and Johnson 2002; Kling et al. 2007). In Oregon, a study of national forest land amenity effects found that property values are higher closer to McDonald Dunn Research Forest but proximity to a visible clear cut decreased the average property price by 13.3 percent ($24,761 in 2012 dollars) (Kim and Johnson 2002). No price effect was found for homes proximate to the Arapaho-Roosevelt National Forest proposed to be due to uncertainty about potential negative externalities from national forest land uses and the relative abundance of substitutes at the rural–urban fringe in Larimer County, Colorado (Kling et al. 2007). Comparability across studies is challenging because real estate markets are unique with varying preferences for open space and availability of substitutes. Furthermore, the variation in proximity measures used in these different studies may be representing values from different service flows. By considering federal and local open space within the same model, this study identifies the individual contribution of different types of public lands to house sales prices.

Hedonic Price Method

The hedonic price method is a revealed preference approach that uses information from actual market transactions to infer the values consumers place on attributes of a differentiated good (Rosen 1974). Applications of the hedonic price method to housing (hedonic property method) are common and often applied to estimate values of open space for inclusion in policy analysis (see McConnell and Walls 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. Market participants are assumed to be informed, mobile, and able to select from a broad range of characteristics. The house sales price 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). Cohen and Coughlin (2009) demonstrate an application to value airport noise and Kim, Phipps, and Anselin (2003) quantify the value of improved air quality.

The theoretical specification for the hedonic property price function defines the house price vector (**P**) as a function of the individual characteristics of the property according to categories in matrix form: structural components of the house (**S**), neighborhood variables (**N**), and location such as proximity to open space amenities/disamenities (**L**):

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

$$\mathbf{P} = \alpha\mathbf{S} + \beta\mathbf{N} + \gamma\mathbf{L} + \varepsilon$$

where the estimated parameters (α,β,γ) describe the relationships between house prices and the measures included within the three categories. The value and significance of γ indicate whether proximity to open space is an amenity ($\gamma > 0$) or a disamenity ($\gamma < 0$). Assumptions about the independence, normality, and variance of the error term are addressed in the empirical modeling section.

Using the estimated parameters, marginal implicit prices associated with each attribute are calculated to get a marginal value for each characteristic included in the price function (Taylor 2003). 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 exact implicit price calculation depends on the functional form of the dependent and independent variables, along with any adjustments for spatial dependence if needed. In this study, the log transformation of the dependent variable is selected because the sales data are skewed left such that most sales occur in lower to middle price ranges with less in the upper range, i.e., a long right side tail (Wooldridge 2003). Additionally, independent variables measured as continuous are similarly transformed (logged) to estimate the elasticity relationships for the variables in the model. For dummy variables that represent discrete characteristics, such as the primary variables of interest that relate to proximity to open space, the percentage effect is calculated as 100 multiplied by the exponential value of the coefficient (γ) minus 1 (Kennedy 1982). Then one can calculate the marginal implicit price as the percentage effect times the average house price ($\bar{P}$):

$$100 \times \left(\exp^{\beta} - 1\right) \times \bar{P} \tag{1}$$

With the estimated implicit prices, the net benefit of each variable included in the model can be stated as a percentage of the total house price to indicate the relative importance of that variable to the total value of the house.

Study Area and Data

El Paso County, Colorado, is an ideal area to evaluate the net benefits of federal and local open space because of the abundance in the area supplied by multiple sources. A significant proportion of the study area is federal land including the PIKE, USAFA, FTC, PAFB, Schriever Air Force Base,[1]

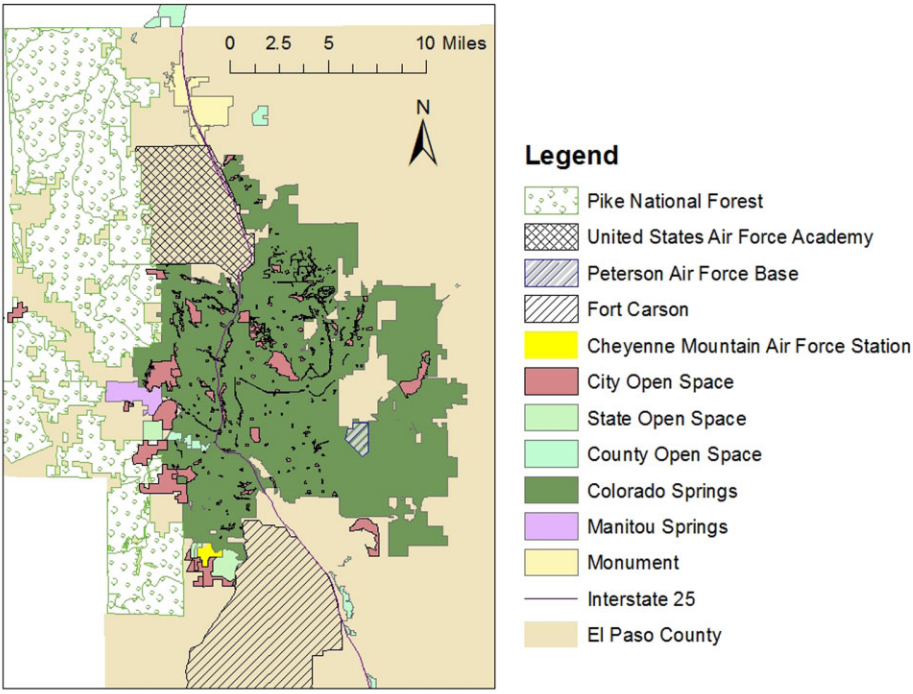

FIGURE 1. MAP OF FEDERAL LANDS AND OTHER OPEN SPACE TYPES FOR THE STUDY AREA.

and Cheyenne Mountain Air Force Station (North American Aerospace Defense Command [NORAD]). These military installations play a strategic and critical role in the national defense of the U.S. and the sustained economic vitality of El Paso County and state of Colorado. El Paso County is approximately 2,158 mi^2 with a population of 576,884 according to 2006 Census data. Our study area is only the western portion of the county which contains the cities of Colorado Springs, Fountain, Manitou Springs, and the towns of Monument, Palmer Lake, and Green Mountain Falls (Figure 1). All areas are within 15 mi of Colorado Springs city center and therefore considered one market in the analysis.

The activities and land uses on each of the military installations differ significantly from one another. The USAFA is primarily an educational facility with scenic views, recreational trails, and relatively few noisy aircraft activities on the campus. Conversely, flight training and military maneuvers are the primary purposes of PAFB and FTC. Cheyenne Mountain Air Force Station was the home to the NORAD which is a joint operation between the U.S. and Canada that provides intelligence on air sovereignty, aerospace warning, and defense for the two countries but very little flight activity. Cheyenne Mountain Air Force Station is unique in that the facility is relatively unnoticeable because it is underground in the side of a mountain and the surrounding lands are preserved.

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. The number of bedrooms was found to be highly correlated with the square footage of the house; therefore, just the house square footage variable was used in the model. The total number of house sale transactions from 2007 was 6,498. Because the sales price of a home is decided when the buyer enters the contract approximately 2 months prior to the sales date, the decision date is calculated by subtracting 60 days from the sales date for the year the contract was entered. For example, if a house sale closed in January of 2008, then 2007 is the year the contract was entered. Then the age of the house when sold is calculated as the difference between the year of the decision and the year the house was built. Because homes on more than an acre are potentially developable, only homes on 1 acre or less are included (Heimlich and Anderson 2001; Lewis, Bohlen, and Wilson 2008). Additionally, the bottom and top 1 percent of sales were trimmed to remove outliers and transactions that are not considered arms length, such as transactions among family members at less than fair market price.

Variable definitions and descriptive statistics are found in Tables 1 and 2, respectively. House sales prices ranged from $103,732 to $870,126 with an average of $318,533 (Figure 2). The average house was 23 years old and had house, lot, basement, and garage square footage of 1,598, 9,115, 816, and 447, respectively. Median income by census tract was $72,750 and was the primary demographic measure selected for the final model because many of the other demographic measures, such as the percentage of students with no high school degree, the percentage nonwhite, and crime rates, are highly correlated with income. Furthermore, travel time to work by census tract (average 23 min) is included; however, it is highly correlated with Euclidean distance to city center, so the measure that accounts for multiple employment centers was selected for the final model.

Distance to Interstate 25 and various open space types was calculated based on as the crow flies measurement (Euclidean distance) using ArcGIS (ESRI, Redlands, CA, USA). The average distance of homes to Interstate 25 was 3 mi. The percentages of the homes within the first mile, between 1 and 2 mi, and between 2 and 3 mi for each federal land are as follows: 3, 5, and 7 percent for the PIKE; 4, 8, and 9 percent for the USAFA; 4, 9, and 6 percent for Fort Carson; 0.5, 5, and 12 percent for PAFB; and 1, 1, and 3 percent for Cheyenne Mountain Air Force Station. The percentages of homes within similar 1 mi intervals are 77, 9, and 3 percent for city open space and 10, 15, and 15 percent for county and state (combined) open space. Dummy variables were created to represent homes within the different city boundaries: Manitou Springs (1 percent), Monument (2 percent), Colorado Springs (68 percent), Fountain (6 percent), Palmer Lake and Green Mountain Falls (combined 0.01 percent), and rural areas (23 percent). However, only Manitou Springs, Monument, and rural areas have significantly different effects on prices relative to Colorado Springs.

The El Paso County Assessor website was the source for the shapefiles of the boundaries for the county, cities, school districts, military lands, national forest land, and roads.[2] The second data source was the Colorado Ownership, Management, and Protection Project (COMaP) spatial database that provided comprehensive information about Colorado open spaces including land ownership and levels of protection (Theobald et al. 2008). City open space types in El Paso County include community separators, greenway/stream, local parks, natural areas/wildlife habitat, and urban open space managed by the City of Colorado Springs Parks, Recreation, and Cultural Services; the City of Colorado Springs; and Manitou Springs; as well as parks owned by the school districts but managed by the City of Colorado Springs. State open space is provided by Colorado State Parks and the Colorado State Land Board. County open space is managed by El Paso County Parks and Leisure Services, El Paso County, and Douglas County. Douglas County borders El Paso County to the North and portions were included if within the 3 mi buffer of homes that were sold in El Paso County.

TABLE 1. VARIABLES IN HEDONIC REGRESSIONS.

Name	Definition
Dependent variable	
Price	Sale price of house adjusted to 2013 dollars using the consumer price index
Housing structural	
Age	Age of house in years at time of sale
Bathrooms	Number of bathrooms
Houseft	Square footage of house
Lotft	Square footage of lot
Baseft	Square footage of basement
Garageft	Square footage of garage
Neighborhood	
Interstate 25	Distance in miles from house to Interstate 25
Income	Median income by census tract in 2013 dollars
Work travel time	Mean travel time to work by census tract in minutes
City	
Manitou Springs	Dummy variable equal to one for houses within Manitou Springs city limits
Monument	Dummy variable equal to one for houses within Monument city limits
Rural	Dummy variable equal to one for houses outside of city limits
Open space	
PIKE_0to1	Dummy variable equal to one for houses within first mile of the Pike National Forest
PIKE_1to2	Dummy variable equal to one for houses between first and second miles of the Pike National Forest
PIKE_2to3	Dummy variable equal to one for houses between second and third miles of the Pike National Forest
USAFA_0to1	Dummy variable equal to one for houses within first mile of the U.S. Air Force Academy
USAFA_1to2	Dummy variable equal to one for houses between first and second miles of the U.S. Air Force Academy
USAFA_2to3	Dummy variable equal to one for houses between second and third miles of the U.S. Air Force Academy
FTC_0to1	Dummy variable equal to one for houses within first mile of Fort Carson
FTC_1to2	Dummy variable equal to one for houses between first and second miles of Fort Carson
FTC_2to3	Dummy variable equal to one for houses between second and third miles of Fort Carson
PAFB_1to2	Dummy variable equal to one for houses between first and second miles of Peterson Air Force Base

TABLE 1. (CONTINUED)

Name	Definition
PAFB_2to3	Dummy variable equal to one for houses between second and third miles of Peterson Air Force Base
NORAD_0to1	Dummy variable equal to one for houses within first mile of Cheyenne Mountain Air Force Station
NORAD_1to2	Dummy variable equal to one for houses between first and second miles of Cheyenne Mountain Air Force Station
NORAD_2to3	Dummy variable equal to one for houses between second and third miles of Cheyenne Mountain Air Force Station
CityOS_0to1	Dummy variable equal to one for houses within first mile of city open space
CityOS_1to2	Dummy variable equal to one for houses between first and second miles of city open space
CityOS_2to3	Dummy variable equal to one for houses between second and third miles of city open space
CountyStateOS_0to1	Dummy variable equal to one for houses within first mile of county and state open space
CountyStateOS_1to2	Dummy variable equal to one for houses between first and second miles of county and state open space
CountyStateOS_2to3	Dummy variable equal to one for houses between second and third miles of county and state open space

Empirical Model

OLS regression is often used to estimate the baseline model in hedonic property analysis. The model is specified as:

$$y = \mathbf{X}\beta + \varepsilon$$

where y denotes an N by 1 vector consisting of one observation on the dependent variable for every unit in the sample (i = 1, . . . , N), X denotes an N by K matrix of exogenous explanatory variables, with the associated parameters β contained in a K by 1 vector, and $\varepsilon = (\varepsilon_1, \ldots, \varepsilon_N)$ is a vector of disturbance terms, where ε_i are independently and identically distributed error terms for all i with zero mean and constant variance σ^2. However, the assumptions of independence in the error term, as well as constant variance, are likely not to hold in practice. Rather, an empirical model that allows for spatial interactions (autocorrelations) may be more appropriate. The empirical Cliff and Ord-type model that incorporates a spatially lagged dependent variable and a spatially lagged error term is specified as:

$$y = \mathbf{X}\beta + \lambda\mathbf{W}y + \varepsilon$$

$$\varepsilon = \rho\mathbf{W}\varepsilon + \xi$$

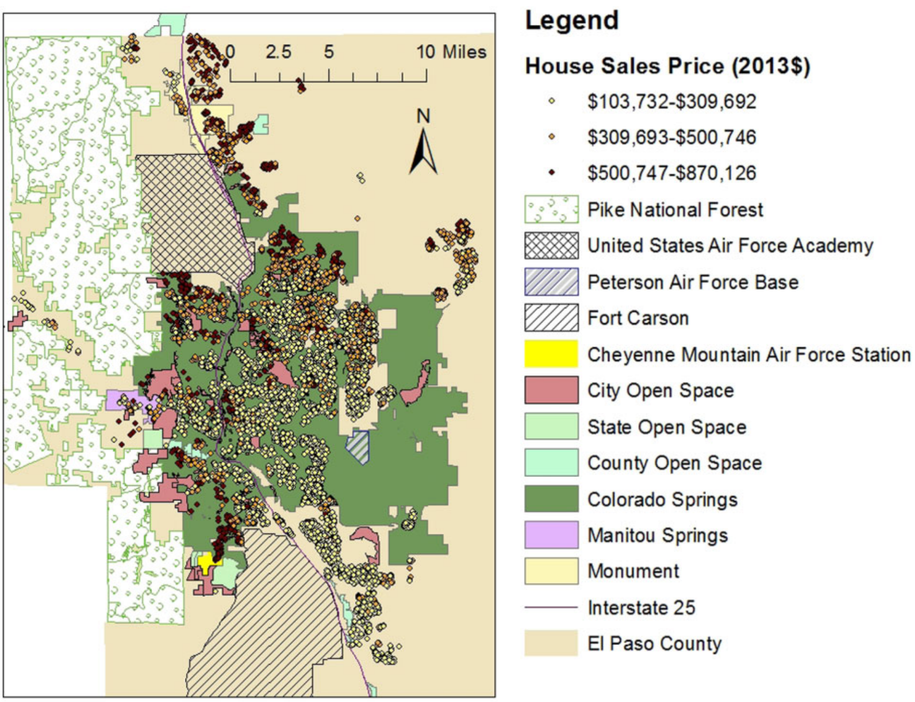

FIGURE 2. MAP OF HOUSE VALUES (2013 DOLLAR), FEDERAL LANDS, AND OTHER OPEN SPACE TYPES FOR THE STUDY AREA.

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 captures the interconnection in house prices via a spatially lagged dependent variable to incorporate the effects of house prices in close proximity; otherwise, coefficient estimates will be biased. The spatially lagged dependent variable is composed of a spatial lag parameter, λ, and a spatial weighting matrix, $\mathbf{W}$. The spatial weight matrix, $\mathbf{W}$, is created to account for the expected spatial relationship of which there are many possible formulations, such as inverse distance to the nearest neighbor that tapers the impact of neighbors as distance between them increases. However, to more closely resemble the practice of estimating prices based on neighborhood comparables, the spatial weight matrix in this study is created using the eight nearest neighbors' homes that were sold in 2007. The matrix is row standardized and the main diagonals are set to zero.

Homes in close proximity may also share location-specific amenities and disamenities that can be hard to measure resulting in omitted variables or error in measurement that manifests as a systematic spatial error which has the effect of reducing estimation efficiency. One approach to incorporating the spatial error is to model the disturbance term, ε, as a first-order autoregressive process ($\rho\mathbf{W}\varepsilon$) separate from innovations, ξ, that are assumed independent, do not need to be normally distributed, and may have nonconstant variance which are more realistic assumptions. If no spatial autocorrelation exists based on the Wald test, $\rho = \lambda = 0$, then the reduced form of the model is appropriate which is the OLS specification.

To determine if spatial autocorrelation is present, the residuals from the OLS regression are examined using test statistics. LM statistics are used to provide information about the spatial

TABLE 2. DESCRIPTIVE STATISTICS.

	Mean	Standard deviation		Count	Frequency (%)
Dependent variable			Open space		
Price	$318,533	$133,024	PIKE_0to1	164	2.52
			PIKE_1to2	321	4.94
Housing structural			PIKE_2to3	481	7.40
Age	22.67	23.26	USAFA_0to1	231	3.55
Bathrooms	2.64	0.93	USAFA_1to2	497	7.65
Houseft	1,598	585	USAFA_2to3	562	8.65
Lotft	9,115	5,558	FTC_0to1	271	4.17
Baseft	817	560	FTC_1to2	584	8.99
Garageft	447	179	FTC_2to3	414	6.37
			PAFB_0to1	30	0.46
Neighborhood			PAFB_1to2	332	5.11
Work travel time	23	4	PAFB_2to3	808	12.43
Interstate 25	3.38	2.62	NORAD_0to1	40	0.62
Income	$72,750	$20,315	NORAD_1to2	54	0.83
City	Count	Frequency	NORAD_2to3	207	3.19
Colorado Springs	4,418	67.99%	CityOS_0to1	5,026	77.35
Monument	135	2.08%	CityOS_1to2	593	9.13
Manitou Springs	50	0.77%	CityOS_2to3	205	3.15
Rural	1,472	22.65%	CountyStateOS_0to1	648	9.97
Other	423	6.51%	CountyStateOS_1to2	1,004	15.45
$N=$	6,498	100.00%	CountyStateOS_2to3	955	14.70

structure of the data (Anselin 1988). The statistics include the simple LM test for error dependence (LMerr), the simple LM test for a missing spatially lagged dependent variable (LMlag), the robust test for error dependence (RLMerr) in the possible presence of a missing lagged dependent variable, the robust test for a spatially lagged dependent variable (RLMlag) in the presence of a missing error dependence, and a portmanteau test (SARMA, which is equivalent to LMerr + RLMlag). Additionally, the OLS residuals can be examined for heteroscedasticity using the Breusch–Pagan test. The results from examining the residuals from the OLS model herein indicate that the SARMA is most appropriate and heteroskedasticity is present, therefore the general spatial two-stage least squares (GS2SLS) regression developed by Kelejian and Prucha (2010) is the method selected to consistently and efficiently estimate the spatial parameters.[3]

GS2SLS procedure consists of two steps alternating generalized moments (GMs) and instrumental variable estimators. First, $\delta = [\beta', \lambda]'$ is estimated by two-stage least squares and the residuals are used to obtain an initial GM estimator of ρ that is consistent but not efficient until a consistent and efficient estimator (involving the variance-covariance matrix of the limiting distribution of the normalized sample moments). Second, the GS2SLS procedure uses 2SLS to estimate the transformed spatial Cochrane–Orcutt model and the residuals are used to obtain a consistent and efficient GM estimator for ρ (Piras 2010).

If spatial autocorrelation is present through the form of the spatially lagged dependent variable, then measures can be calculated to delineate the direct, indirect, and total impact of changes in the open space measures of interest based on the effects of own (direct impact) and cross (indirect impact) derivatives based on the known dependency between observations (LeSage and Pace 2009). Assuming technological externalities (Small and Steimetz 2006), the indirect effects of proximity to open space variables can be calculated using the spatial multiplier:

$$\gamma \times [I - \lambda \mathbf{W}]^{-1} \tag{2}$$

Then the direct impact in terms of willingness to pay is calculated using equation (1); the indirect impact calculated in equation (2) is transformed similarly ($100 \times$ exponentiated (indirect effect) minus $1 \times$ mean house price); then the sum of the direct and indirect impacts is the total impact.[4] Kim, Phipps, and Anselin (2003) demonstrate the use of the spatial multiplier when estimating the benefits of air quality improvements using a spatial lag model. For more on spatial econometrics, see McMillen (2010) and Pinske and Slade (2010).

Results

Results from the model estimation steps are presented first. Then there is a brief comparison of the two regression results, OLS and GS2SLS. Finally, the direct, indirect, and total impacts for proximity to open space measures are described.

The results from the model specification tests are presented in Table 3. LM tests for spatial dependence indicate that the SARMA specification which combines the error and robust spatial lag components has the largest test statistic and is therefore the most appropriate representation of the spatial structure to the data. Further support is found because the Wald test statistic was highly significant, indicating that both λ and ρ do not equal zero. The Bruesch–Pagan test indicates the presence of heteroscedasticity.

A comparison of the regression results between OLS and the spatial model is presented in Table 4 in terms of the coefficient estimates, standard errors, significance levels, and model pseudo R^2 values. The pseudo R^2 value for both the OLS and spatial models is calculated as the square of the correlation of the estimated and actual house sales prices since the standard R^2 measure requires error independence. The actual R^2 for the OLS model is 0.825 and the pseudo R^2 is 0.829, so very close; however, both are less than that for the spatial model, 0.862.

TABLE 3. STATISTICS FOR MODEL SELECTION.

	Test statistic	p-value
Lagrange multiplier error	2,516	0.0001
Lagrange multiplier lag	1,774	0.0001
Robust Lagrange multiplier error	1,029	0.0001
Robust Lagrange multiplier lag	286	0.0001
SARMA (LMerr+RLMlag)	2,802	0.0001
Bruesh–Pagen	412	0.0001
Wald	985	0.0001

TABLE 4. REGRESSION RESULTS.

	OLS		Spatial	
	Estimate	Standard error	Estimate	Standard error
Intercept	5.2203	0.1489***	3.7425	0.2566***
*ln*Age	−0.0709	0.0022***	−0.0465	0.0034***
*ln*Bath	0.0405	0.0077***	0.0571	0.0075***
*ln*Basesqft	0.0092	0.0004***	0.0081	0.0004***
*ln*Garagesqft	0.0026	0.0006***	0.0035	0.0009***
*ln*Housesqft	0.4443	0.0088***	0.3587	0.0103***
*ln*Lotsqft	0.1580	0.0053***	0.1286	0.0077***
*ln*Interstate 25	−0.0382	0.0038***	−0.0257	0.0059***
ln Work Travel Time	−0.3021	0.0220***	−0.2216	0.0348***
*ln*Income	0.3254	0.0121***	0.1571	0.0227***
Manitou Springs	0.1806	0.0244***	0.1624	0.0521**
Monument	−0.0891	0.0182***	−0.0705	0.0241**
Rural	−0.0330	0.0067***	−0.0226	0.0086**
PIKE_0to1	0.1030	0.0131***	0.0976	0.0209***
PIKE_1to2	0.0386	0.0110***	0.0475	0.0173**
PIKE_2to3	0.0150	0.0091	0.0150	0.0158
USAFA_0to1	−0.0159	0.0131	−0.0258	0.0184
USAFA_1to2	−0.0045	0.0094	−0.0067	0.0130
USAFA_2to3	0.0094	0.0080	0.0062	0.0096
FTC_0to1	−0.2374	0.0155***	−0.1287	0.0244***
FTC_1to2	−0.1673	0.0100***	−0.0995	0.0151***
FTC_2to3	−0.0879	0.0090***	−0.0523	0.0126***
NORAD_0to1	0.2612	0.0292***	0.1167	0.0427**
NORAD_1to2	0.2759	0.0274***	0.1271	0.0399**
NORAD_2to3	0.0750	0.0195***	0.0303	0.0294
PAFB_0to1	−0.0338	0.0293	−0.0414	0.0382
PAFB_1to2	−0.0279	0.0104**	−0.0174	0.0123
PAFB_2to3	−0.0165	0.0083*	−0.0139	0.0096
CityOS_0to1	0.0276	0.0101**	0.0215	0.0145
CityOS_1to2	0.0632	0.0104***	0.0421	0.0143**
CityOS_2to3	0.0823	0.0145***	0.0479	0.0185**
CountyStateOS_0to1	0.0963	0.0083***	0.0538	0.0128***
CountyStateOS_1to2	0.0636	0.0068***	0.0350	0.0109**
CountyStateOS_2to3	0.0902	0.0071***	0.0605	0.0111***
Lambda	—	—	0.3130	0.0201***
Rho	—	—	0.40871	0.027338***
Pseudo R^2	0.825		0.862	

* $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$.

The housing structural and neighborhood variables had the expected sign and significance in both models, although the magnitude of the coefficients tended to be higher in the OLS model (exceptions are bath and garage square footage). House prices are positively related to bathrooms, median income, and square footage of the basement, garage, lot, and house. House prices are negatively related to house age, the distance to Interstate 25, and travel time to work. Homes in Manitou Springs have the highest selling prices, while homes in rural areas and monument sell for less. The coefficients on the open space measures have the same sign in both models giving consistent support for whether proximity is an amenity or disamenity, but the statistical significance and magnitude differ, although the tendency for OLS to have higher values holds. The magnitude of the coefficients from OLS more closely resembles the total impacts from summing the direct and indirect effects in the spatial model. More of the open space measures are found to be statistically significant in the OLS model that does not account for spatial autocorrelation, specifically the exceptions are the 2–3 mi interval from Cheyenne Mountain Air Force Station, the one to 3 mi intervals from PAFB, and the first mile from city open space. However, both models found statistically significant positive effects for homes within the first 2 mi adjacent to the PIKE and Cheyenne Mountain Air Force Station; for homes within the second and third miles from city open space; and for homes within 3 mi adjacent to state and county open space. Both models also found statistically significant negative effects for homes within the first 3 mi of Fort Carson.

Estimated marginal willingness to pay measures in terms of the percentage of the house price for open space proximity by direct, indirect, and total impact is presented in Table 5. The direct, indirect, and total effects are as follows: within 1 mi of the PIKE, 10, 4, and 14 percent; between 1 and 2 mi of the Pike, 5, 2, and 7 percent; within the first mile of Fort Carson, −12, −6, and −18 percent; between 1 and 2 mi of Fort Carson, −10, −4, and −14 percent; from 2 to 3 mi of Fort Carson, −5, −2, and −7 percent; within 1 mi of Cheyenne Mountain Air Force Station, 13, 5, and 18 percent; and between 1 and 2 mi of Cheyenne Mountain Air Force Station, 14, 6, and 20 percent. As for the nonfederal open space proximity, the direct, indirect, and total impacts are: between 1 and 2 mi of city open space, 4, 2, and 6 percent; between 2 and 3 mi of city open space, 5, 2, and 7 percent; within the first mile of state and county open space, 6, 2, and 8 percent; between 1 and 2 mi of state and county open space, 4, 2, and 6 percent; and between 2 and 3 mi of state and county open space, 6, 3, and 9 percent.

Summary and Conclusions

The objective of this study was to determine if proximity to national forest and military lands affects house prices in El Paso County, Colorado, and how these effects compare to other publically supplied open space. Results indicate that proximity to the PIKE and Cheyenne Mountain Air Force Station increases house prices while proximity to FTC decreases house prices. Proximity to open space provided by state, county, and city also increases house sales prices, although to a smaller degree than the effect of the federal land proximity.

The results from this study indicate that proximity to federal lands impacts local house prices and therefore property taxes both directly and indirectly through proximity effects on neighboring residential property values. For example, assuming a property tax mill rate of $10 per $1,000, a property within the first mile of the PIKE generates approximately $446 more in property tax revenue while homes between 1 and 2 mi generate approximately $228 more than properties not within these distance ranges. A similar story can be told with respect to proximity to Cheyenne Mountain Air Force Station while the effect of proximity to Fort Carson decreases property tax revenues.

TABLE 5. MARGINAL IMPLICIT PRICES FOR DIRECT, INDIRECT, AND TOTAL IMPACTS OF PROXIMITY TO OPEN SPACE.

	Direct (%)	Indirect (%)	Total (%)	Direct ($)	Indirect ($)	Total ($)
PIKE_0to1	10	4	14***	33,066	14,074	44,595
PIKE_1to2	5	2	7**	15,680	6,772	22,785
PIKE_2to3	2	1	2	4,859	2,118	7,009
USAFA_0to1	−3	−1	−4	−8,219	−3,625	−11,751
USAFA_1to2	−1	0	−1	−2,149	−942	−3,085
USAFA_2to3	1	0	1	2,002	875	2,882
FTC_0to1	−12	−6	18***	−38,913	−17,661	57,336
FTC_1to2	−10	−4	14***	−30,521	−13,740	44,595
FTC_2to3	−5	−2	−7***	−16,425	−7,297	−23,346
NORAD_0to1	13	5	18**	39,952	16,911	57,336
NORAD_1to2	14	6	20**	43,739	18,457	64,730
NORAD_2to3	3	1	5	9,930	4,310	14,374
PAFB_0to1	−4	−2	−6	−13,088	−5,797	−18,646
PAFB_1to2	−2	−1	−3	−5,562	−2,447	−7,967
PAFB_2to3	−1	−1	−2	−4,442	−1,952	−6,368
CityOS_0to1	2	1	3	7,023	3,056	10,147
CityOS_1to2	4	2	6**	13,856	5,993	20,111
CityOS_2to3	5	2	7**	15,821	6,832	22,992
CountyStateOS_0to1	6	2	8***	17,834	7,688	25,952
CountyStateOS_1to2	4	2	6**	11,504	4,986	19,112
CountyStateOS_2to3	6	3	9***	20,131	8,661	29,339

* $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$.
Note: Evaluated at the mean house price, $318,533.

In conclusion, the results from this case study suggest that the property price effects of proximity to federal lands are dependent on the types of federal lands. While national forest land proximity positively influenced house sales prices and property tax revenues, military lands appeared to be valued differently. Further research is needed at multiple sites to determine if these results are consistent across settings.

NOTES

1. Schriever Air Force Base is located to the east of Peterson Air Force Base away from the homes in the study area and therefore is not included in this analysis.
2. http://adm.elpasoco.com/InformationTechnologies/GeographicInformationSystems/Pages/default.aspx
3. The gstslshet function from the sphet package was used to estimate the regression using R software (http://cran.r-project.org/web/packages/sphet/vignettes/sphet.pdf)
4. The impact command from the spdep package was used to estimate the direct, indirect, and total impacts (http://cran.r-project.org/web/packages/spdep/spdep.pdf)

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