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# Untangling the Value of Open Space: Adjacent vs. Neighborhood Area

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# Untangling the Value of Open Space: Adjacent vs. Neighborhood Area

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## Abstract

This paper examines the effect of proximity to different types of open space on a home's sale price using data from the Denver-Boulder metropolitan area. Proximity measures are varied to examine the differing spatial values of open space. Types of open space are varied by protection and level of access. Open space adjacency (within 30 feet) for any type has a positive and significant impact on home sale price, and adjacency to protected land is valued three times more than unprotected land. An additional acre of protected land at ¼ mile is ten times more valuable than at 1 mile, indicating a rapid decline in value over distance greater than ¼ mile. Irrespective of the spatial measure, protected/yes access is valued highest, followed closely by protected/no access, with unprotected/no access coming in a distant third. Protected lands with or without access perform quite similarly in all spatial measures except one. An additional acre of protected land with access at 1 mile is one and a half times more valuable than protected land without access. This result suggests for policy makers that in low-density areas, where the difference between the number of homes ¼ and 1 mile from open space is quite small, a private conservation easement can provide a similar value to home owners as a public park. On the other hand, in high-density areas, a public park may be preferred to a private conservation easement.

## Introduction

Over the past 20 years, several studies have used hedonic theory to value open space land near a home. These studies have shown that open space such as parks, golf courses, conservation land and farm land provide value to nearby residents. As land becomes scarce in urban and suburban areas, local governments, city planners, and housing developers are interested in the value that open space provides, as they strive to best serve their residents. Open space value is inherently tied to distance for residents, so an understanding of how open space value changes with distance is of the utmost importance for land use decisions in planning housing communities and cities.

This paper examines the value of open space capitalized into home prices, and is specifically concerned with the differing spatial measures of open space that residents value. This issue is addressed by asking the questions: What is the premium for homes adjacent (within 30 feet) to open space? What is the value of open space in a neighborhood area near a home? And finally does the adjacent and neighborhood value differ based on the type of open space? The literature looks at many different types of open space, and each paper defines open space differently. The broad common definition of open space is land that consists mostly of nature and is void of man-made structures. For this study, open space is divided into categories based on two key characteristics: protection level and access. And each of these has two categories: protected or unprotected, and public or restricted access. The issue of protection involves whether or not the land that is open space today has the possibility of being developed into man-made structures in the future. Access refers to whether or not the land is publicly accessible. While there are many types of open space, all are defined by these two basic characteristics. This paper uses the three categories listed in Table 1 to group the open space data and perform analysis.

### Table 1: Categorized open space based on protection and access

| | Public Access | Restricted Access |
|---|---|---|
| **Protected** | parks, cemeteries, national parks, lakes, river, golf courses | private conservation land, private parks |
| **Unprotected** | ---------------- | agricultural, vacant |

To answer these questions, the paper constructs a unique and large data set of home price transactions and open space measures for the Denver-Boulder metropolitan area. The study utilizes several specifications including a nearest neighbor matching technique to examine the spatial value of open space by the categories in Table 1. The study finds adjacency to any type of open space has a positive and significant impact on home sale price, and adjacency to protected land is valued three times more than unprotected land. Unprotected land only adds value to adjacent homes and otherwise has no significant impact on home sale price. An additional acre of protected land at ¼ mile is ten times more valuable than at 1 mile, indicating a rapid decline in value over distance greater than ¼ mile. Irrespective of the specification or spatial measure, protected/yes access is valued highest, followed closely by protected/no access, with unprotected/no access coming in a distant third. The results of this paper give planners a better understanding of how residents value open space over distance, and this allows for proper land use policies in the future.

There is quite a great deal of literature estimating open space's effect on residential property values. Several papers focus on measuring how the value changes with distance to different open space types. The categories into which previous literature fits based on distance measures, and types of open space is presented in Table 2.

**Table 2: Categorized open space literature focused on distance measures**

| | Value % open space in buffer (1/4 -1/2 mile) from home | Value distance to open space from home | Value home adjacency to open space | Study protected lands with public access | Study protected lands with restricted access | Study unprotected lands with restricted access | Control for neighborhood unobservables |
|---|---|---|---|---|---|---|---|
| Bolitzer and Netusil (2000), Lutz and Netusil (2001) | | X | | X | | | |
| Anderson and West (2006) | | X | | X | | | X |
| Irwin (2002), Geoghegan et. al. (2003) | X | | | X | X | X | |
| Chesire and Sheppard (1995) | X | | | X | X | | |
| Do and Grudnitski (1995) | | | X | X | | | |
| Metz (2010) | X | X | X | X | X | X | X |

Some papers focus on protected open space, but are unconcerned with the value of unprotected lands (Bolitzer and Netusil 2000; Lutzenhiser and Netusil 2001; Anderson and West 2006). These studies look at how the value changes with distance, along with different demographic variables, but none considers the adjacent value of open space. Other literature looks at the differences in value between protected and unprotected land (Irwin 2002; Geoghegan et. al. 2003). These studies look at the value of open space in an area surrounding a home, and look at how a percentage increase in open space within a ¼ to ½ mile radius affects a home's value. Their research also does not include the value of adjacent open space. Another study (Chesire and Sheppard 1995) focuses on determining the difference in value between protected lands that allow access and protected lands that do not allow access; again, they only measure this value as a percentage of land in a ½ mile radius. A study that explicitly considers an adjacency premium (Do and Grudnitski 1995) focuses on how homes located next to a golf course are valued much higher than homes just across the street.

Previous research has returned unexpected results for different types of open space. In many cases it finds a much higher value for permanently undeveloped open space that restricts access (private conservation land) compared with land that has public access (Irwin 2002). Researchers argue that a negative externality from congestion occurs at public access space, leading to a lower value compared with restricted access land. The magnitude of the difference in these values cannot be explained solely by congestion; in one study (Irwin 2002), conservation land is valued nearly four times more highly than public protected land.

Although previous research has studied the three categories of open space mentioned above, each paper appears to exclude some category and so would bias the results. Although all papers use the hedonic pricing method to estimate the value for open space through home prices, the various studies' research designs vary dramatically. Some previous literature uses a ½ mile (or shorter) buffer around a home and determines the comparative value for types of open space against a baseline land use. The observations for a ½ mile buffer cannot inform one if the open space is adjacent to a home or ½ mile away, and also if the adjacent value is quite large and dissipates over that ½ mile dramatically. Other literature looks only at the distance from open space in a linear fashion, and it could miss the importance of the adjacent value, which is expected to be quite large.

One econometric issue in estimating the value of open space is correlated omitted variables. Previous research has attempted to control for this issue by using fixed effects at fine geographic scales (Anderson and West 2006), looking at variation within a census block group. Census block groups are quite small in urban areas, and are often one block in size. It is difficult to see how there is much variation of open space properties in such a small area.[1]

This paper contributes in several ways to the wider literature on valuing open space. First, it untangles the value of being adjacent to open space and the value of open space at a neighborhood level. Most previous work only examines the value of open space at the neighborhood level (not adjacent). The only exception is (Do and Grudnitski 1995), which examines adjacency to golf courses on a small scale. This current paper examines all types of open space and on a much larger scale. This paper contends that the adjacent value is quite important. For example, a house with a property line bordering a public park (distance of 0ft to open space), as opposed to a house across the street from the park (distance of 60ft to open space), could have very different values for open space as a result of this small change in distance, where congestion and view have changed. Second, this paper simplifies the categories of open space into the two most salient properties: access and level of protection. Previous papers separate open space into each individual category (e.g. public park, natural park, conservation land, or agricultural), and this paper's simplification of the categories is an attempt to get at the basic properties that drive the value differences in open space lands. Each open space land is inherently unique, so without being able to value each land separately, this paper's category breakdown reflects the base decision a planner or housing

[1] Their study used straight line distance to the nearest types of open space; this could provide some variation if a block group is 1,000 ft in length and the mean distance to open space is quite short, such as 2,000 ft.

developer makes, based on what type of open space is near homes. Third, the size of our sample is larger than any other open space study to my knowledge, based on housing sample size and number of open space lands. Also, the study area is the Denver-Boulder metro area, whose governments take great care in preserving and allocating land for open space. This abundance of open space lands allows for a wide amount of variation and provides us with many observations through which to investigate the adjacency premium. Fourth, this paper uses a larger level for fixed effects than previous literature, census tracts which consist of multiple block groups. While still small enough to believe that omitted variables are being controlled for, this allows for a wider variation in open space measures. And finally, this paper uses a nearest neighbor matching technique, not used previously in the literature. This technique is an improved control for neighborhood effects and unobservable quality of home build. Nearest neighbor matching is used to obtain an accurate estimate for the adjacency premium and how this premium changes with distance to matching homes.

## Conceptual Framework

This section provides a brief theoretical model incorporating all three categories of open space along with their breakdown between adjacent and neighborhood level value. The section ends with a detailed construction of the econometric model.

The model uses standard hedonic theory (Rosen 1974); a home is viewed as having a bundle of attributes that consist of several different characteristics, and the combination of these characteristics determines the sale price of the home. The hedonic price schedule is based on households maximizing their utility facing a budget constraint. Household $i$ maximizes utility subject to the budget constraint:

(1) $$u^i = U^i(c, \boldsymbol{z}) \quad \text{s.t. } y^i = P(\boldsymbol{z}) + c$$

Where $y$ is income, $c$ is a numeraire good with price normalized to 1, and $\boldsymbol{z}$ is a vector of housing characteristics. The relationship between a home's sale price and its characteristics is represented by the hedonic price function:

(2) $$P(\boldsymbol{z}) = P(\boldsymbol{S}, \boldsymbol{N}, \boldsymbol{OS})$$

Where $\boldsymbol{S}$ is a vector of structural housing characteristics, $\boldsymbol{N}$ is a vector of neighborhood characteristics, and $\boldsymbol{OS}$ is a vector of open space characteristics. $\boldsymbol{OS}$ vector decomposed contains open space adjacency characteristics, $adj$ and open space neighborhood area characteristics, $area$. The variable, $adj$, is a dummy equal to 1 if a home's lot is within 30ft of open space. The variable, $area$, is continuous and equal to the percentage of open space within a radius (1/4 or 1 mile) of the home. The open space price function is represented by a linear function:

(3) $$P(\boldsymbol{OS}) = \sum_{t=1}^{3} \rho_t \, adj_t + \sum_{t=1}^{3} \gamma_t area_t$$

Where $t = 1$ represents a home's open space properties in relation to protected lands with access ($P/A$); $t = 2$ represents a home's open space properties in relation to protected lands with no access ($P/NA$); and $t = 3$ represents a home's open space properties in relation to unprotected lands with no access ($UNP/NA$). At the optimum, the partial derivative of the hedonic price function with respect to a specific attribute represents the marginal implicit price of that attribute; this is the marginal willingness to pay for an attribute.

$$(4) \qquad \frac{\partial P(\boldsymbol{OS})}{\partial adj_t} = \rho_t, t = 1{,}2{,}3. \ and \ \frac{\partial P(\boldsymbol{OS})}{\partial area_t} = \gamma_t, t = 1{,}2{,}3.$$

From this model, there are several testable implications based on the properties of the open space land and the channels ($adj\ vs.\ area$) through which value is added to the home's price. First, expectations for the adjacency premium are as follows: $\rho_t > 0\ for\ all\ t$, $\rho_{P/A} > \rho_{UNP/NA}$, $\rho_{P/NA} > \rho_{UNP/NA}$ and $\rho_{P/A} =?\ \rho_{P/NA}$. Homes adjacent to open space plausibly gain their value from having a view of undeveloped land without any other property between the home and open space, and for this reason adjacency to any type of open space is expected to positively impact a home's value. Homes adjacent to protected lands should have a higher premium than that for unprotected lands, as the latter has a possibility of being developed in the future and the adjacent property will lose the view of undeveloped land. The effect of access to protected lands on the adjacency premium is ambiguous. On the one hand, lands with access may have a higher value than those with no access simply because the homeowner can use the land for recreation, and on the other hand, this access may include noise and congestion that reduces the value of homes adjacent to accessible lands.

Next, expectations for the neighborhood area value are as follows: $\gamma_{P/A} > \gamma_{P/NA} > \gamma_{UNP/NA}$ and $\gamma_{UNP/NA} =?\ 0$. Homes with open space in their neighborhood plausibly gain value by having access to nearby land and to protected land that reduces future population density. Protected lands with access are expected to have the highest value in a neighborhood, because they provide proximity to recreation and create lower density neighborhoods, which homeowners value. Protected land without access is expected to have a slightly lower value, because it cannot provide recreation amenities to its nearby residents. Unprotected lands without access are expected to have the lowest value and possibly no value at all, because the land will plausibly be developed in the future, increasing density and having no recreation value.

Theory does not provide guidance for selecting an appropriate functional form for the hedonic price function. Several forms are seen in the literature: linear, semi-log, log-log, and Box-Cox. The form for each paper appears to be chosen by the authors to best fit their data and study objectives. This paper uses a semi-log form in order to examine the effect of housing characteristics on the percentage change in house price. A hedonic function with the following form is estimated:

$$(5) \qquad lnP_{ic} = \alpha\ ln\boldsymbol{X}_{ic} + \beta\boldsymbol{Y}_{ic} + \sum_{a\in A}(\rho_a\boldsymbol{W}_{a,ic}) + \sum_{b\in B}(\gamma_b\boldsymbol{Z}_{b,ic}) + \delta_c + \varphi_q + \theta_t + \varepsilon_{ic}$$

Where $P_{ic}$ is the sale price of home *i,* in census tract *c*. $\boldsymbol{X}_{ic}$ is a vector of continuous home structural characteristics. $\boldsymbol{Y}_{ic}$ is a vector of dummy and discrete home structural characteristics. $\alpha$ and $\beta$ are parameter vectors for home characteristics to be estimated. *A* is the set of adjacent open space variables, $\boldsymbol{W}_{a,ic}$ is a vector of adjacent open space characteristics of category $a$, and $\rho_a$ is a parameter vector of adjacent open space characteristics of category $a$. $B$ is the set of neighborhood open space variables, $\boldsymbol{Z}_{b,ic}$ is a vector of neighborhood open space characteristics of category $b$, and $\gamma_b$ is a parameter vector of neighborhood open space characteristics of category $b$. $\delta_c$ is a census tract fixed effect, $\varphi_q$ is a quarter of year sale fixed effect, and $\theta_t$ is a year of sale fixed effect.

The variables of interest are those for open space characteristics. For the first model, open space in a neighborhood surrounding a home is measured with an adjacency dummy variable for each category of open space adjacent to a home, along with interaction terms for homes adjacent to multiple categories of open space, and with percentage of open space land for each category within a fixed radius (1/4 mile or 1 mile) of the home. For the second model, distance dummies to the nearest piece of open space land are estimated and divided into separate regressions by open space category nearest the home.

## Data

The study area, Figure 1, consist of most of the Denver-Aurora-Boulder combined statistical area. The area of study includes seven counties: Adams, Arapahoe, Broomfield, Boulder, Denver, Douglas and Weld. The housing price data consists of 115,627 single family home sales from Metrolist, Inc. for 2002-2008 and includes several home characteristics. The summary statistics are provided in Table 3.

**Table 3**

Summary Statistics for Housing Characteristics

| Variable | Mean | Standard Deviation | Min | Max |
|---|---|---|---|---|
| Sale Price (2002 dollars) | 263,602 | 123,639 | 11,909 | 1,000,000 |
| Lot Size (acres) | 0.216 | 0.287 | 0.014 | 9.656 |
| # of Baths | 2.39 | 0.853 | 0.5 | 9 |
| Home Size (sqft) | 1,771 | 750.7 | 273 | 11,794 |
| Age of House (years) | 22.63 | 26.81 | 0 | 137 |
| Garage Attached to Home | 0.801 | 0.399 | 0 | 1 |
| Garage not Attached to Home | 0.00884 | 0.0936 | 0 | 1 |
| A/C in Home | 0.858 | 0.349 | 0 | 1 |
| Fireplace | 0.491 | 0.5 | 0 | 1 |
| Basement | 0.804 | 0.397 | 0 | 1 |

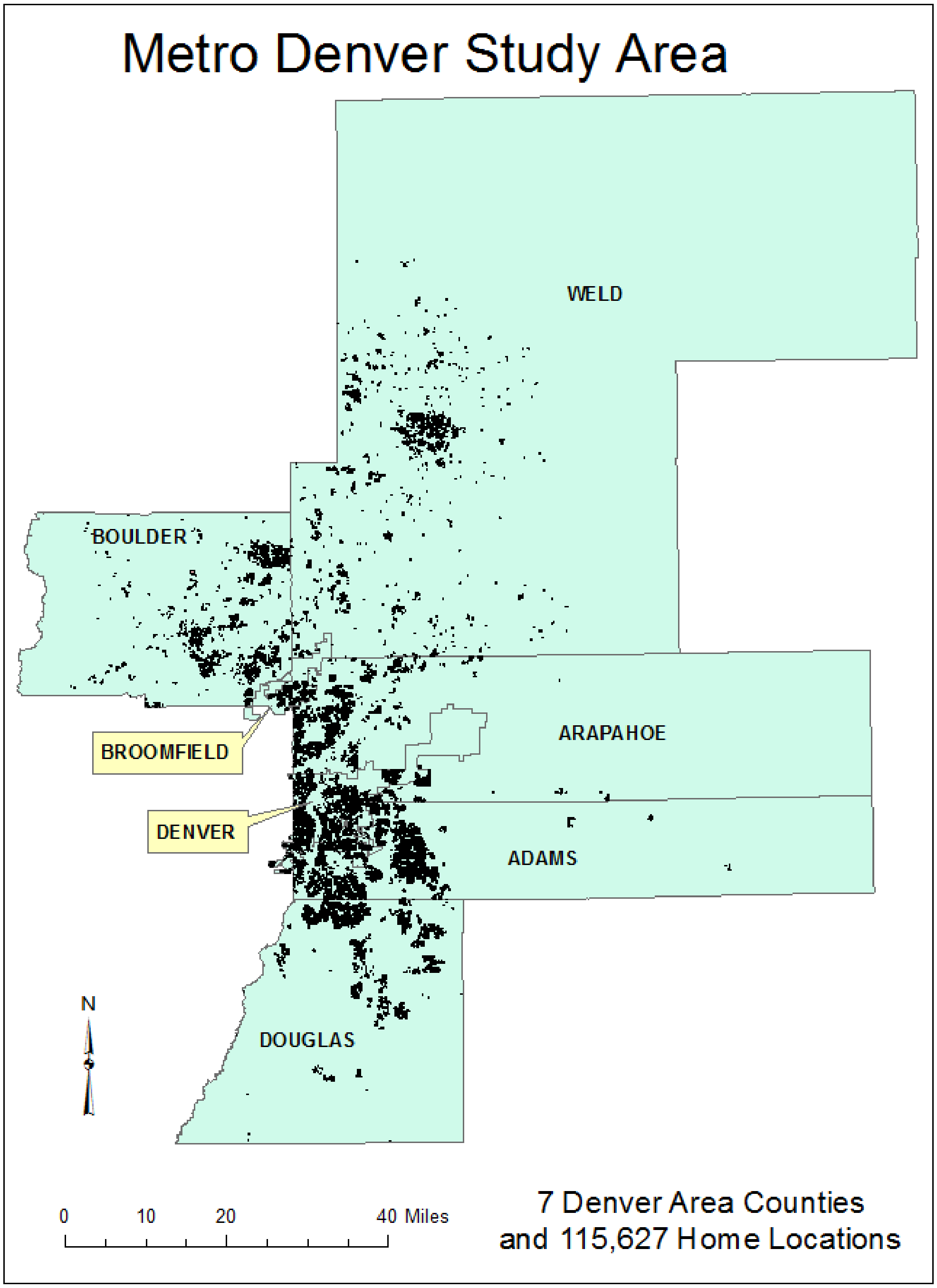



**Figure 1: Location of 115,627 homes in the study area. Bolded names are counties.**

The open space data come from several sources. The majority of the data are from Colorado Ownership, Management and Protection (COMAP) v7 database from Colorado State University, this data set contains protected open space lands and their level of access. The remaining open space data come from the GIS departments of the counties in the study area, and these data contain protected lands with their level of access not included in the COMAP data set and unprotected open space lands that do not have access. Combining these open space data sets, we obtain a comprehensive set of 7,497 protected and 108,901 unprotected open space lands along with their level of access. For the purposes of the study, open space is assigned to one of three categories: protected/access, protected/no access, and unprotected/no access. These three categories are selected to divide open space into the most salient features of open space that affect their value, level of protection and level of access. Protected/access includes golf courses, rivers, lakes, public parks, and recreation facilities. Protected/no access includes conservation easements, city and county protected land, and private parks.[2] Unprotected/no access includes agricultural and vacant land; there is no category for unprotected/access, because no open space land fits into this category. The summary statistics for open space are provided in Table 4. Open space by category in the study area is shown in Figure 2.

**Table 4**

Summary Statistics for Open Space Characteristics

| Open Space Category | Number of Open Spaces | Mean OS Acreage | Standard Deviation (acres) | Min (acres) | Max (acres) |
|---|---|---|---|---|---|
| Protected/Access | 4,093 | 263 | 4223 | 0 | 238335 |
| Protected/No Access | 3,404 | 69 | 352 | 0 | 10099 |
| Unprotected/No Access | 108,901 | 26 | 86 | 0 | 4153 |

[2] The COMAP database indicates 1,363 lands that are protected but have an unknown level of access. These lands are put into the category of protected/no access. Lands with unknown access are most likely conservation land or government protected land where the level of access is not reported. Local governments are very likely to report the access level for protected lands that have access, such as parks and recreation facilities. For this reason, the assumption is made that protected lands of unknown access most likely do not have access.

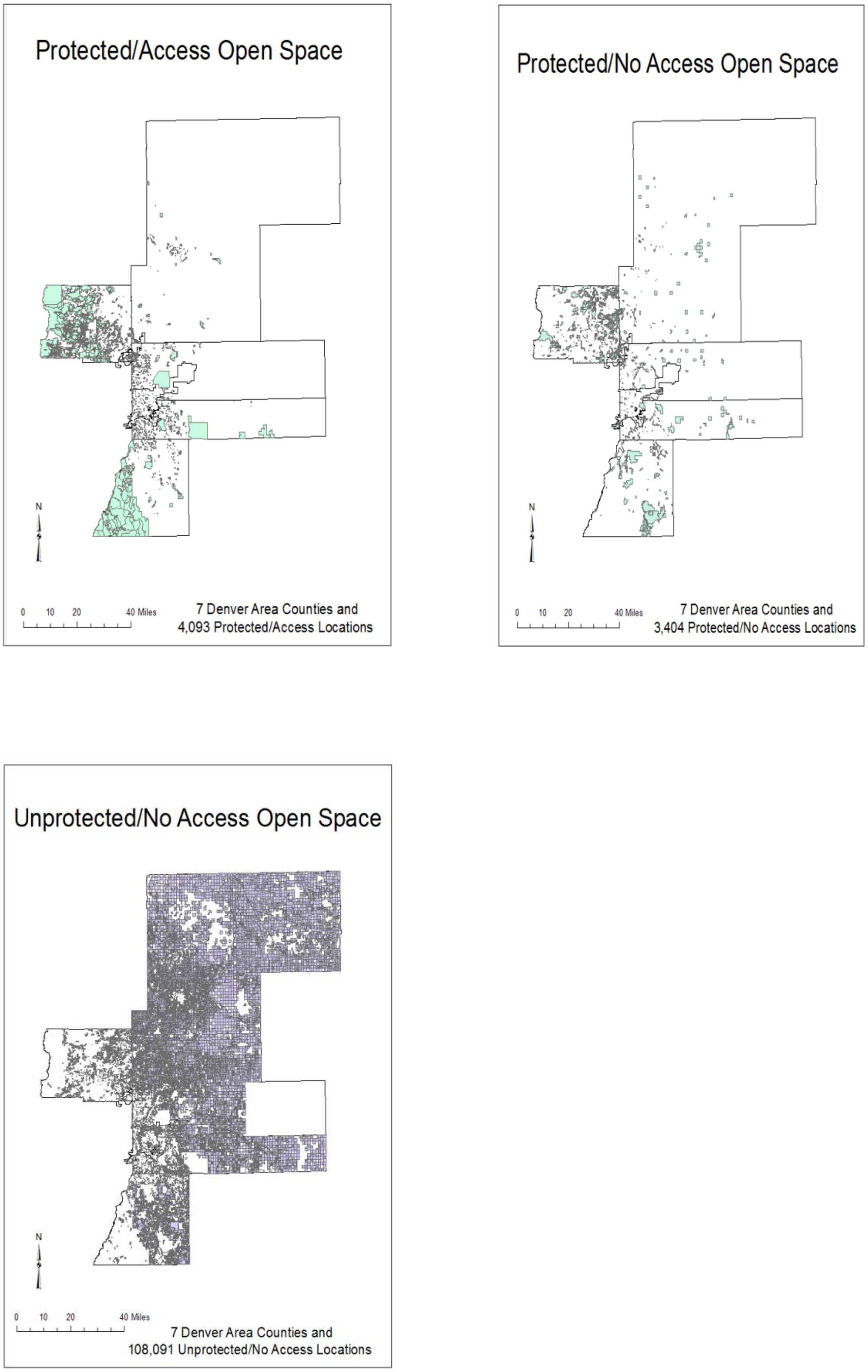



**Figure 2: Open space by category in study area**

From the home and open space data, GIS software is used to construct a spatial data set of a home's relationship to open space land. Three types of open space relationships are constructed: adjacent to a category of open space, percentage of open space category within a 1 mile radius, and the distance to the nearest category of open space.[3]

A home is considered adjacent to open space if the perimeter of the home lot is within 30ft of an open space land. A 30 ft buffer is chosen as the breakpoint to account for small errors in the GIS spatial data, because this study is bringing together GIS data from several sources that can be a few feet from matching exactly. The data also have slight discrepancies in the line work defining the perimeters of land parcels; an urban road is suggested to be minimally 32 ft in width, and so a buffer of 30 ft is selected to avoid considering an open space land across the street from a home as adjacent.[4] Summary statistics for homes adjacent to open space are provided in Table 5.

**Table 5**

Summary Statistics for Homes Adjacent to Open Space

| Adjacent to Open Space Categories | Number of Homes | % of Adjacent Homes | % of Total Homes |
|---|---|---|---|
| Protected/Access | 4,014 | 21.1 | 3.5 |
| Protected/No Access | 2,827 | 14.9 | 2.4 |
| Unprotected/No Access | 11,512 | 60.6 | 9.9 |
| Protected/Access and Protected/No Access | 110 | 0.6 | 0.1 |
| Protected/Access and Unprotected/No Access | 250 | 1.3 | 0.2 |
| Protected/No Access and Unprotected/No Access | 280 | 1.5 | 0.2 |
| Total | 18,993 | 100.0 | 16.4 |

The percent of open space within a 1 mile radius captures the area for types of open space in a distance near a home. This variable treats open space area adjacent to the home the same as open space area 1 mile away. For this reason buffers of different radii (1/4 mile, 1 mile) can be created to see how open space area changes value at different distances from the home. Summary statistics for percentage of open space within a 1 mile radius from the home are provided in Table 6.

[3] Percentage of open space within a 1 mile radius is calculated as follows. A circle with a radius of 1 mile is constructed with the home at the center of the circle. The area of open space within this circle is calculated and is divided by the total area of the circle to obtain the percentage of open space.

[4] 30 ft is selected to differentiate between houses directly next to open space and those across the street. From inspection, a mass of homes is located 45 ft and 62 ft from open space, and these distances are the same as the widths of most typical roads. A buffer of 30 ft ensures that our adjacent variable is only considering homes directly next to open space and not across the street.

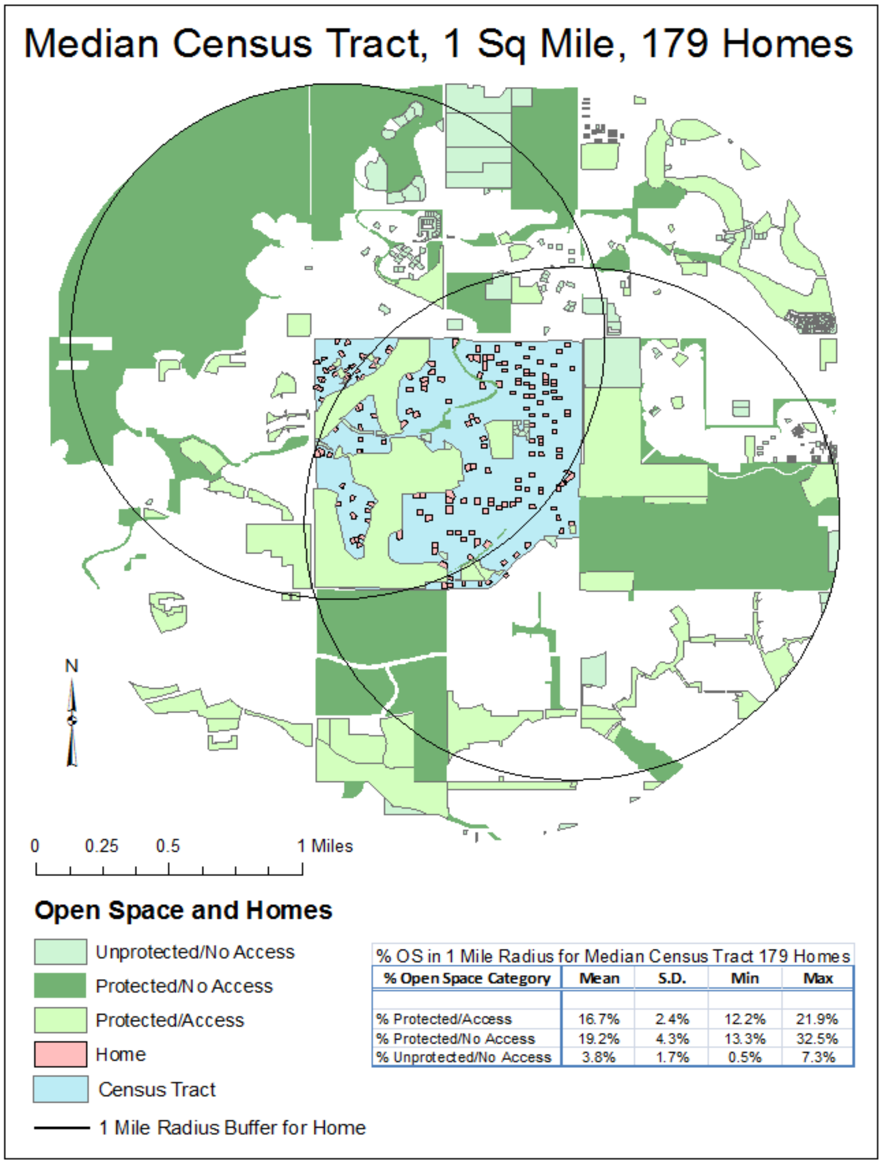
| Table 6 | | | | |
|---|---|---|---|---|
| Summary Statistics for % Open Space 1 Mile Radius from Home | | | | |
| **% Open Space Category** | **Mean** | **Standard Deviation** | **Min** | **Max** |
| | | | | |
| % Protected/Access | 7.0% | 7.8% | 0.0% | 99.1% |
| % Protected/No Access | 5.2% | 8.4% | 0.0% | 83.2% |
| % Unprotected/No Access | 16.1% | 18.6% | 0.0% | 99.7% |

The distance variable for homes to open space only measures the distance to the open space category that is closest to a home. This variable does not measure the distance to the nearest category of open space for all categories, but only a single distance to the open space that is nearest to a home.[5] The variable is constructed in this way to capture the change in value over distance isolated for each category of open space. Summary statistics for distance from home to nearest category of open space are provided in Table 7.

| Table 7 | | | | | |
|---|---|---|---|---|---|
| Summary Statistics for Distance from Home to Nearest Category of Open Space | | | | | |
| **Distance to Nearest Open Space Category** | **Number of Homes Nearest** | **Mean (1000ft)** | **Standard Deviation (1000ft)** | **Min (1000ft)** | **Max (1000ft)** |
| | | | | | |
| Distance to Protected/Access | 32,355 | 0.45 | 0.39 | 0.00 | 2.39 |
| Distance to Protected/No Access | 10,867 | 0.32 | 0.35 | 0.00 | 2.40 |
| Distance to Unprotected/No Access | 72,405 | 0.39 | 0.38 | 0.00 | 2.98 |

The main model uses fixed effects at the census tract level. Figure 3 shows a map of the median census tract with locations of homes and open space that is approximately 1 sq mile and contains 179 homes. This figure of a median census tract illustrates variation in the open space variables within a census tract. Figure 4 shows a map of homes inside the median census tract from Figure 3, illustrating the difference in prices of similar homes based on adjacency to open space.

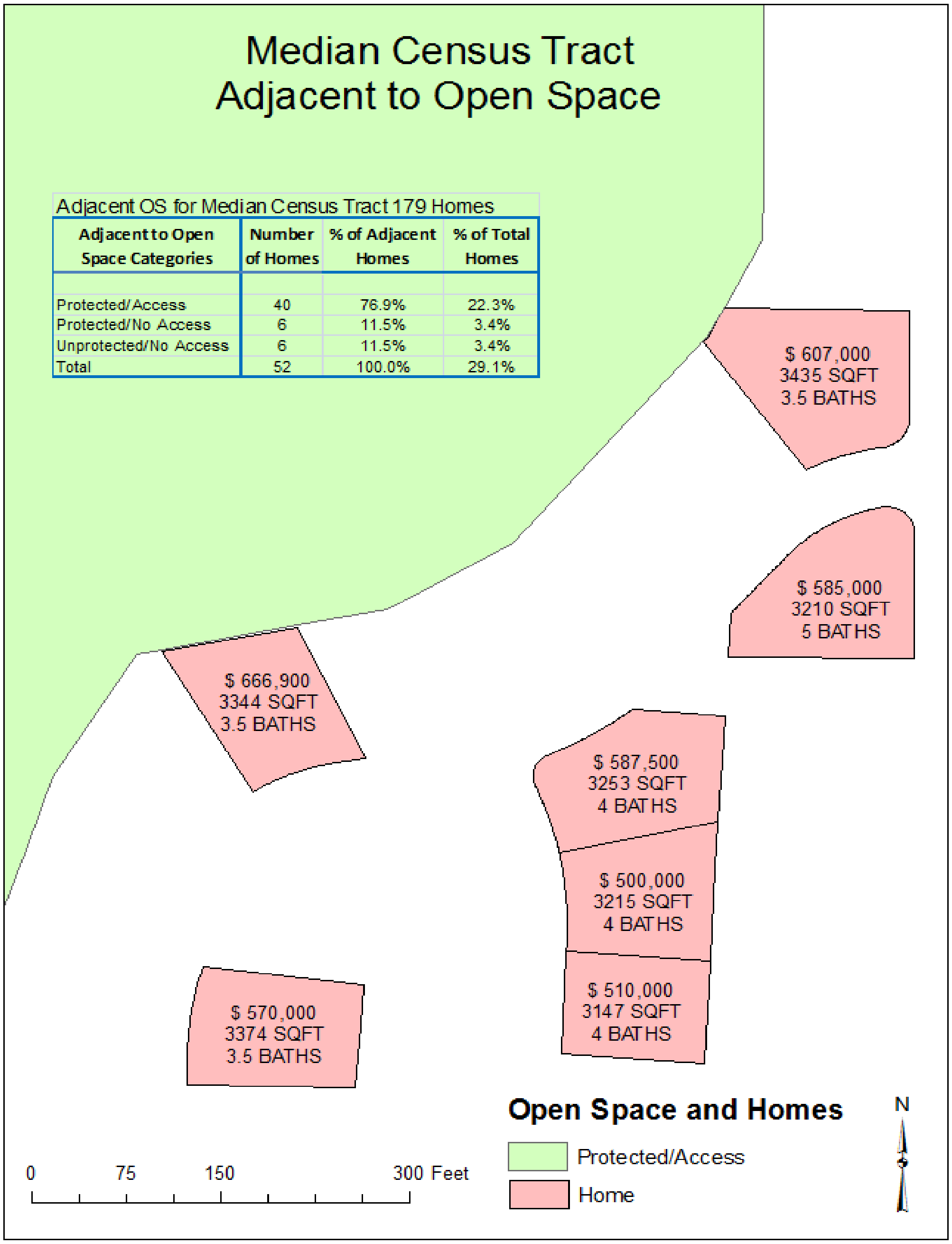
[5] Previous research includes the distance to all types of open space in one single regression. If the majority of a home's value for open space is from the nearest land as opposed to lands further away, then breaking up regressions based on the open space category closest to a home may give a better understanding of how distance to each category of open space affects the value of a home.




% OS in 1 Mile Radius for Median Census Tract 179 Homes

| % Open Space Category | Mean | S.D. | Min | Max |
|---|---|---|---|---|
| % Protected/Access | 16.7% | 2.4% | 12.2% | 21.9% |
| % Protected/No Access | 19.2% | 4.3% | 13.3% | 32.5% |
| % Unprotected/No Access | 3.8% | 1.7% | 0.5% | 7.3% |

**Figure 3: Median census tract, approximately 1 sq mile, containing 179 homes. Circles show the 1 mile radius buffer for a home at the NW corner of the census tract compared to a home at the SE corner.**




Adjacent OS for Median Census Tract 179 Homes

| Adjacent to Open Space Categories | Number of Homes | % of Adjacent Homes | % of Total Homes |
|---|---|---|---|
| Protected/Access | 40 | 76.9% | 22.3% |
| Protected/No Access | 6 | 11.5% | 3.4% |
| Unprotected/No Access | 6 | 11.5% | 3.4% |
| Total | 52 | 100.0% | 29.1% |

**Figure 4: Zoom in of Median census tract, showing difference in prices for similar homes based on adjacency to open space.**

## Results

Several models are estimated to explore the relationship between open space and home price. The first model is estimated using a semi-log model with a fixed effects approach at the census tract level. The equation for estimation includes housing characteristic variables, dummies for adjacency to categories of open space, and interaction terms for homes that are adjacent to multiple categories of open space, and the percentage of land within a 1 mile radius for each open space category. The results are provided in Table 8.

### *OLS with Census Tract FE for Adjacency and Neighborhood Area Value*

| Table 8 | | |
|---|---|---|
| Estimated Coeffients - Model 1 (1 Mile Buffer Radius) | | |
| **VARIABLES** | **log_saleprice** | **standard error** |
| | | |
| Ln of Lot Size (acres) | 0.122* | 0.00248 |
| # of Baths | 0.0450* | 0.00127 |
| Ln of Home Size (sqft) | 0.448* | 0.00256 |
| Age of House (years) | -0.00121* | 7.00E-05 |
| Garage Attached to Home | 0.0143* | 0.00247 |
| Garage not Attached to Home | 0.0305** | 0.00931 |
| A/C in Home | -0.0128* | 0.00328 |
| Fireplace | 0.0223* | 0.00121 |
| Basement | 0.106* | 0.00158 |
| Adjacent Protected/Access | 0.0493* | 0.00306 |
| Adjacent Protected/No Access | 0.0406* | 0.00412 |
| Adjacent Unprotected/No Access | 0.00773** | 0.0026 |
| % Protected/Access | 0.199* | 0.0117 |
| % Protected/No Access | 0.0924* | 0.0104 |
| % Unprotected/No Access | 0.0166 | 0.0102 |
| Adjacent Protected/Access * Adjacent Protected/No Access | -0.0584** | 0.0185 |
| Adjacent Protected/Access * Adjacent Unprotected/No Access | 0.0186 | 0.016 |
| Adjacent Protected/No Access * Adjacent Unprotected/No Access | 0.0145 | 0.0187 |
| Ln of Block Mean Lot Size (acres) | 0.0549* | 0.00408 |
| | | |
| Observations | 115627 | |
| R-squared | 0.818 | |
| Year and Quarter Dummies | YES | |
| Census Tract FE | YES | |
| *P=0.001; **P=0.01; ***P=0.05 | | |

The coefficients for the housing characteristics are as expected and very similar to results from previous literature. The only coefficient that is somewhat surprising is the negative sign for air conditioning (A/C). This could be explained by the climate of the Denver area coupled with the fact that older homes are more likely to not have A/C and those older homes of a high quality have not been replaced with new housing that would most likely have A/C. Therefore, not having A/C may represent a higher quality build for the home and thus have a negative coefficient. Also included as an explanatory variable is the mean size of neighborhood lots, this term is significant and positive as expected.[6]

A home being adjacent to an unprotected/no access open space land is estimated to increase a home's sale price by 0.77%. The sale price increases for homes adjacent to protected/no access and protected/access land are 4.06% and 4.93%, respectively.[7] These estimates match expectations; there is a much larger value for being adjacent to protected land compared with unprotected land, and this is most likely because of the fact that unprotected land can be developed in the future, which diminishes its value. Also, the difference in value between protected with and without access is quite small, which suggests that the level of access does not matter when valuing open space next a home, and having permanently undeveloped land is creating the majority of the value. Using the mean sale price for a home in the data set to interpret the coefficients, a home adjacent to unprotected/no access increases in value by $2,030, a home adjacent to protected/no access increases in value by $10,702, and a home adjacent to protected/access increases in value by $12,995.

F-tests are conducted to determine whether the estimated coefficients for open space category adjacency are statistically different from each other. The null hypothesis of equal values for adjacent unprotected/no access and adjacent protected/no access can be rejected (P=0.000). Also, the null hypothesis of equal values for adjacent unprotected/no access and adjacent protected/access can be rejected (P=0.000). However, the null hypothesis of equal values for adjacent protected/no access and adjacent protected/access cannot be rejected (P=0.0891).

The results for the interaction terms indicate that being adjacent to both protected with and without access is close in value to being adjacent to one category of protected open space; this result is to be expected. The two other interaction terms are positive but are not significant. The interaction terms between the different categories of open space all have quite large standard errors, most likely because of the small number of homes adjacent to multiple categories of open space, as seen in Table 5.

The coefficients for the categories of percentage open space within a 1 mile radius match our expectations. At a radius of 1 mile, one expects lands with access to be valued most highly, as people can enjoy the recreational benefits of an open space land with access. We can interpret a 10% increase in protected/access land results in a 1.99% increase in a home's sale price. Next in value is protected/no access, a 10% increase in its

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[6] Inclusion of this variable in the regression reduces the coefficients on the percentage open space variables; this suggests that large neighborhood lot sizes substitute for open space in a home's neighborhood.

[7] As a check, homes less than 62 ft were considered as adjacent. Including these additional homes from 30 to 62 ft reduces the adjacency premium from the regression results more than 20% as compared to the 30 ft buffer. This indicates an important difference in being directly next to open space and across the street.

land results in a 0.92% increase and a 10% increase in unprotected/no access results in a 0.17% increase in value.[8] These coefficients are significant except for unprotected/no access. This is expected because unprotected land 1 mile from a home should not have much impact on its value. A discussion of the monetary value related to these coefficients is saved for the next sections comparison with a buffer radius of ¼ mile.

F-tests are conducted to determine whether the estimated coefficients for percentage open space category within a 1 mile radius are statistically different from each other. The null hypothesis of equal values can be rejected (P=0.0000) for all three tests between the categories.

Next, we take a look at the same model but now use a buffer radius of ¼ mile, and the results are provided in Table 9. Here we are concerned with comparisons against the 1 mile buffer radius.

**Table 9**

Estimated Coeffients - Model 1 (1/4 mile Buffer Radius)

| VARIABLES | log_saleprice | standard error |
|---|---|---|
| | | |
| Ln of Lot Size (acres) | 0.123* | 0.00247 |
| # of Baths | 0.0448* | 0.00127 |
| Ln of Home Size (sqft) | 0.448* | 0.00256 |
| Age of House (years) | -0.00128* | 7.00E-05 |
| Garage Attached to Home | 0.0127* | 0.00247 |
| Garage not Attached to Home | 0.0282** | 0.0093 |
| A/C in Home | -0.0132* | 0.00328 |
| Fireplace | 0.0221* | 0.00122 |
| Basement | 0.106* | 0.00159 |
| Adjacent Protected/Access | 0.0425* | 0.00301 |
| Adjacent Protected/No Access | 0.0360* | 0.00415 |
| Adjacent Unprotected/No Access | 0.0134* | 0.00257 |
| % Protected/Access | 0.0765* | 0.00878 |
| % Protected/No Access | 0.0414* | 0.00854 |
| % Unprotected/No Access | -0.0767* | 0.00845 |
| Adjacent Protected/Access * Adjacent Protected/No Access | -0.0478** | 0.0182 |
| Adjacent Protected/Access * Adjacent Unprotected/No Access | 0.0167 | 0.0159 |
| Adjacent Protected/No Access * Adjacent Unprotected/No Access | 0.0118 | 0.0188 |
| Ln of Block Mean Lot Size (acres) | 0.0600* | 0.00408 |
| | | |
| Observations | 115627 | |
| R-squared | 0.818 | |
| Year and Quarter Dummies | YES | |
| Census Tract FE | YES | |
| *P=0.001; **P=0.01; ***P=0.05 | | |

[8] Removal of adjacency dummies from the regression raises the coefficients for the percentage of open space variables which translates into approximately a 0.1% increase in the interpretations. Although, this is a small amount, the absence of adjacency dummies does bias the results upward as expected.

Examining the coefficients for adjacent to open space, we obtain similar results for a ¼ mile radius as we do with a 1 mile radius; this is to be expected. F-tests have the same results as well. The concern here is how the percentage of land category coefficient varies between the ¼ and 1 mile radius.

F-tests are conducted to determine whether the estimated coefficients for the percentage of open space within a ¼ mile radius category are statistically different from each other. The null hypothesis of equal values can be rejected (P=0.0000) for tests between unprotected/no access and both protected categories open space. Although, the null hypothesis of equal values for protected/no access and protected/access cannot be rejected (P=0. 2009), at this very close distance an increase in percentage of protected lands has a very similar impact.

The coefficients for the categories of percentage open space within a ¼ mile radius still have the same rank, but their values change quite substantially. It is important to note that a circle with a radius of 1 mile has an area of 2,010 acres, whereas that of a ¼ mile radius is 126 acres. Given this difference, it is difficult to make comparisons between the regression results of these different radii. We must equate these percentage regression results into equal area changes. Table 10 presents the interpretation of the percentage open space regression results for the two radii.

**Table 10**

Interpreation of Regression Coefficients from Tables 8 and 9

| | | | 10% Increase in Open Space Land | | 1 Acre Increase in Open Space Land | |
|---|---|---|---|---|---|---|
| **Open Space Type** | **Reg. Coeff.** | **Mean % Open Space** | **Acreage** | **$ Value** | **% Value** | **$ Value** |
| **1 Mile Buffer** | | | | | | |
| % Protected/Access | 0.199* | 7.01% | 14.09 | $5,246 | 0.14% | $370 |
| % Protected/No Access | 0.0924* | 5.17% | 10.39 | $2,436 | 0.09% | $237 |
| % Unprotected/No Access | 0.0166 | 16.11% | 32.38 | $448 | 0.01% | $26 |
| **1/4 Mile Buffer** | | | | | | |
| % Protected/Access | 0.0765* | 5.15% | 0.65 | $2,017 | 1.18% | $3,110 |
| % Protected/No Access | 0.0414* | 2.85% | 0.36 | $1,091 | 1.15% | $3,031 |
| % Unprotected/No Access | -0.0767* | 8.47% | 1.07 | -$2,022 | -0.72% | -$1,898 |

A straight forward interpretation of the regression results looks at how a 10% increase in open space land affects a home's value. This is not a good choice of interpretation for comparison purposes between the different radii, because the acreage increase for a 1 mile buffer as opposed to ¼ mile is quite large, as seen in Table 10. For policy purposes, decisions for open space are not made by changes in percentages of land but rather by actual land size. The last columns of Table 10 look at the effect of a 1 acre increase in open space land. As expected for protected lands, the addition of 1 acre at ¼ mile is more valuable than at 1 mile. Slightly surprising is that at ¼ mile, an acre is almost 10 times more valuable than at 1 mile. This result shows how the value of additional protected open space land declines quite rapidly with distance. Also interesting, at ¼ mile the value difference for level of access is very small. This has important policy impacts, if a housing development is being created near farmland; a conservation easement will provide as much value as turning the farmland into a park. This is important, because a conservation easement will most likely be cheaper than a park. Table 10 also shows that the addition of unprotected land at 1 mile has almost no impact, whereas at ¼ mile it has a sizable negative impact. This negative value is most likely because vacant land very near a home has a greater chance of being developed in the future compared with vacant land at a distance further away.

## ***OLS with Census Tract FE for Adjacency and Distance to Nearest Open Space Value***

A second group of models is estimated to determine how distance to the nearest category of open space impacts the value of a home. In the first model we examined adjacency, and while approximately 15% of the sample is adjacent to some category of open space, the rest of the sample is a measure away from the nearest piece of open space; we are interested in how this value changes over distance. Previous studies have a distance variable to the nearest open space for all categories. Relating to our variables, this would mean that each home would have a distance to the nearest protected/access land, a distance to the nearest protected/no access land and a distance to the nearest unprotected/no access land. These three variables would go into one regression, and although this is telling us how home value changes with distance to open space, it is giving us a general feel of how open space land is valued in a neighborhood around a home, much like the percentage of open space land in a radius from the previous section.

This section takes a different approach; here the focus is the piece of open space. A home most likely gets the bulk of its value from the single closest piece of open space land. For example, if home A is 100 ft from the nearest protected/no access land, 1,000 ft from the nearest protected/access land, and 500 ft from the nearest unprotected/no access land, most plausibly the protected/no access land 100 ft away will contribute the majority of added home value. Also, if home B is 1,000 ft from the nearest protected/no access land, 1,000 ft from the nearest protected/access land, and 1,000 ft from the nearest unprotected/no access land, home A and home B are the same distance from the nearest protected/access, but holding everything else constant except these distances to other open space categories, one would expect a different value between the homes for distance to nearest protected/access even though the distance is exactly the same. For this reason, the piece of open space land becomes the focus, and if we were able to run an experiment, we would place each category of open space at the center of a bulls eye and place homes at distances around the open space. This would give an understanding of how value changes for each category of open space as the distance to a home increases.[9]

The large data set for this study allows us to examine the issue of distance in the approach stated above; we have a much larger number of open space lands and home transactions than any other previous open space

[9] This method is an attempt to examine how the value of a home varies with respect to its distance from the nearest open space type. Although this method makes a restrictive assumption that homes do not gain value from the next closest piece of open space land. If one believes the closest piece of open space will have the largest effect on a home's value compared to land further away, then perhaps separating the regressions into types is preferred to having one single regression with all types.

study. When we restrict the distance measures as stated above, we still have 10,867 homes that have protected/no access as their nearest category of open space, 32,355 homes nearest to protected/access and 72,405 homes nearest unprotected/no access. The results are provided in Table 11. The housing characteristics estimates are omitted from the table, because they are very close to the estimates seen in Tables 8 and 9. Dummy variables for distance were used in the model; this was done as the study's main focus of is adjacency, and estimation of the adjacency premium is not possible with a continuous distance variable. Also, the value over distance is not expected to behave linearly, so dummies give some flexibility. The adjacency coefficients from Tables 8 and 9 are interpreted as the difference in value between homes adjacent and those not adjacent. Here the adjacency coefficients are interpreted as the difference in value between homes adjacent and homes greater than 700 ft away from open space. In the Data section, Table 7 shows most homes are within 1,500 ft of an open space type, so for practical purposes the coefficients for the dummy distance variables can be considered a comparison with homes 700-1,500 ft from their open space type. Also included as an explanatory variable is the census block mean lot size, and we expect results similar to those found in Table 8 and 9. The size of the nearest open space land is included, holding other factors constant. As the size of the nearest open space land increases one would expect the value of homes to increase. The results of the three open space categories are presented in Table 11.

**Table 11**

Estimated Coeffients - Model 2

| VARIABLES | log_saleprice | standard error | log_saleprice | standard error | log_saleprice | standard error |
|---|---|---|---|---|---|---|
| Adjacent Protected/Access | 0.0511* | 0.00331 | | | | |
| (30ft-100ft) Protected/Access | 0.00204 | 0.0037 | | | | |
| (100ft-300ft) Protected/Access | 0.00334 | 0.00235 | | | | |
| (300ft-700ft) Protected/Access | 0.0032 | 0.00206 | | | | |
| Ln of Block Mean Lot Size (acres) | 0.0608* | 0.00958 | | | | |
| Ln of Nearest Protected/Access Size (acres) | 0.00703* | 0.000811 | | | | |
| | | | | | | |
| Adjacent Protected/No Access | | | 0.0287* | 0.00542 | | |
| (30ft-100ft) Protected/No Access | | | -0.00414 | 0.00603 | | |
| (100ft-300ft) Protected/No Access | | | -0.0107*** | 0.00454 | | |
| (300ft-700ft) Protected/No Access | | | -0.0077 | 0.00428 | | |
| Ln of Block Mean Lot Size (acres) | | | 0.0360** | 0.0138 | | |
| Ln of Nearest Protected/No Access Size (acres) | | | 0.00413* | 0.00106 | | |
| | | | | | | |
| Adjacent Unprotected/No Access | | | | | 0.0181* | 0.00299 |
| (30ft-100ft) Unprotected/No Access | | | | | 0.00857** | 0.0031 |
| (100ft-300ft) Unprotected/No Access | | | | | 0.00595** | 0.00208 |
| (300ft-700ft) Unprotected/No Access | | | | | 0.00764* | 0.00182 |
| Ln of Block Mean Lot Size (acres) | | | | | 0.0587* | 0.00491 |
| Ln of Nearest Unprotected/No Access Size (acres) | | | | | -0.00276* | 0.000405 |
| | | | | | | |
| Observations | 32355 | | 10867 | | 72405 | |
| R-squared | 0.878 | | 0.872 | | 0.798 | |
| Year and Quarter Dummies | YES | | YES | | YES | |
| Census Tract FE | YES | | YES | | YES | |
| *P=0.001; **P=0.01; ***P=0.05 | | | | | | |

The adjacency coefficients for all open space category regressions are significant, and they have the same rank and a similar magnitude as previous results from Tables 8 and 9. Mean size of block group lot is significant and performs similarly to Tables 8 and 9 for all regressions.

Estimates for unprotected/no access show significant results for all dummies. The value is greatest for homes adjacent to unprotected/no access, it is positive and trends smaller as the distance from the land increases. F-tests are conducted to determine whether the estimated coefficients for the distance dummies are statistically different from each other. The null hypotheses of equal values between adjacency and the other distance dummies can be rejected, but the null hypothesis of the equal values between the other distance dummies cannot be rejected. A negative coefficient for the size of the nearest unprotected/no access land supports the negative coefficient results from Table 9 for percentage unprotected/no access land in a ¼ mile buffer. Each regression in Table 11 is comparing homes that are roughly within ¼ mile of open space. The results for each open space category are of the same rank as percentage land variables within a ¼ mile, as shown in Table 9, and have a similar magnitude.

Distance dummy estimates for protected/access lands are all very small positive values that are insignificant, except for adjacency. As seen in Table 9, there is a positive value for being near protected/access land, but Table 11 indicates it doesn't matter whether the home is 30 or 1,500 ft from the land, the value is very similar. Table 11 also shows adjacency has a premium and its value is similar to the results from Table 8 and 9.

Distance dummy estimates for protected/no access lands are small negative values that are mostly insignificant, except for adjacency. Once again adjacency performs quite similarly to results from Tables 8 and 9. Perplexingly, houses from 30 to700 ft are valued lower than homes 700 to 1,500 ft from protected/no access. Still, given this strange result, adjacency is a clear way in which a home gains value, and being located 30 ft or 1,500 ft from protected/no access does not have a large effect on the home's value.

In general, the results of Table 11 show that adjacency is an important and distinct way in which home value is increased by open space. Also, changing the distance between 30 ft and 1,500 ft to the nearest open space category does not have much effect on changing the home's value.

## ***Nearest Neighbor Matching***

This section focuses on estimating the premium associated with homes adjacent to open space. Also, does this premium difference between treated (adjacent) and non-treated (non-adjacent) vary with distance and type of open space? Nearest neighbor matching technique can answer these questions and provides advantages over the standard OLS hedonic regression. Matching estimators make no assumptions about the linearity between the home price and the house's characteristics. In this paper's context, a non-parametric strategy makes sense, given the previous literature on valuing distance to open space in which the selection of functional form (linear, semi-log, Box-Cox) is quite arbitrary. Intuitively, the relationship between price and distance to open space is not linear. Comparing a home adjacent to open space with a home 100 ft away, one expects a large price difference, whereas comparing a home 100 ft from open space with a home 200 ft away, one expects a much smaller price difference. The OLS strategy described previously uses a census tract fixed effect in an attempt to control for neighborhood effects. The median census tract is 1 sq mile. At this level there is still enough variation in the covariates to identify the parameters, but plausibly neighborhood effects are typically concentrated at a smaller level. Using a finer geographic level for fixed effects results in little variation of the covariates, which is a problem for linear regression. Matching allows for comparison of homes on a finer scale, because we can compare a home adjacent to open space with a home across the street that has matching home structural characteristics.

Treated and untreated homes are matched on bathrooms, home size (sq ft), and lot size (acres). These home characteristics are continuous, so exact matches between homes are not possible. A bandwidth for acceptable matches is set at: +/- 0.5 baths, +/- 300 sq ft, and +/- .04 acres. Matching requires common support for treated and untreated homes. They must have similar values for observable structural housing characteristics, and a representative example is shown in Figure 5. If a treated home does not have matches that fall within this range, it is eliminated from the sample, and this technique is used to ensure "good" matches. For the base model, treated homes are only matched with a single untreated home within 1,500ft (approx. ¼ mile) and within the acceptable bandwidth. For example, the entire sample has 2,827 homes adjacent to protected/no access land. Once narrowed by the bandwidth; the sample is reduced to 1,684 treated homes. The main identifying assumption is that given "good" matches the only factor affecting house price differences between treated and untreated homes is adjacency to open space. Following (Abadie and Imbens 2006), the matching estimation uses a regression-based bias adjustment, to eliminate bias introduced by poor match quality given continuous covariates. Table 12 displays the results for the average treatment effect on the treated (ATT) for protected/no access.

**Table 12**

Matching Homes Adjacent to Protected No Access on Baths, Sqft, and Lot Size

| **VARIABLES** | **log_saleprice** | **standard error** |
|---|---|---|
| | | |
| ATT, Using Control Homes within 1500ft of Treated | 0.0256 | 0.0048 |
| | | |
| | | |
| Treated Observations | 1684 | |
| # of Matches | 1 | |
| Treated Obs. Excluded with Matches Outside Bandwidth (Bath Diff > .5, Sqft Diff > 300sqft, and Lot Size Diff >.04 Acres) | | |

Figure 5 shows how a 1,500 ft buffer around a treated home is a much smaller area for comparison than a 1 sq mile census tract. The objective is to control for neighborhood effects and achieve a more accurate estimate for the adjacency premium. Comparing the results from Table 12 for matching 2.56% and OLS for a ¼ mile buffer 3.60%, one can see that the matching estimator is lower than the OLS estimate. This makes sense given the geographic level on which comparisons are being made. At this finer level (1,500ft) homes are most likely in the same housing sub-division and have a similar quality. At the census tract level, a majority of the houses used for comparison will not be in the same subdivision and most likely will have differing levels of quality. Most plausibly the neighborhood with open space will have higher quality homes, whereas a neighborhood ½ mile away which does not have open space will have lower quality homes. OLS with census tract fixed effects have estimates that include all these lower quality homes for comparisons, thus resulting in a larger adjacency premium. Matching estimates only use comparison homes of a similar quality; thus, better control of neighborhood quality results in a smaller adjacency premium.

Also of interest is how this adjacency premium changes with distance. If the allowable distance from a treated observation to its control match is varied, this should give insight on how the value of open space changes with distance. A buffer distance of 300 ft is used to divide the control matches, and so only treated homes with an acceptable match inside of 300 ft are used. These treated homes will first be compared with control matches within 300 ft, and then these same treated homes will be compared with control matches between 300 ft and 1,500 ft. This matching procedure only allows the estimation of the treatment effect on the treated, but the difference in the parameter estimates should give an idea of how the value of open space changes over distance. Table 13 displays the results.

| **Table 13** | | |
|---|---|---|
| Matching Homes Adjacent to Protected No Access on Baths, Sqft, and Lot Size | | |
| **VARIABLES** | **log_saleprice** | **standard error** |
| | | |
| ATT, Using Control Homes within 300ft of Treated | 0.017 | 0.0054 |
| ATT, Using Control Homes 300ft-1500ft of Treated | 0.0226 | 0.0096 |
| | | |
| Treated Observations | 499 | |
| # of Matches | 1 | |
| Treated Obs. Excluded with Matches Outside Bandwidth (Bath Diff > .5, Sqft Diff > 300sqft, and Lot Size Diff >.04 Acres) | | |

The standard errors are quite large. The small number of observations is the most likely cause, and the treated observations were reduced so dramatically because they had to have a match inside of 300 ft and another match from 300 to 1,500 ft. The table shows that treated homes matched with control homes inside a 300 ft buffer have a smaller premium for adjacency 1.70% than those same treated homes matched with controls between 300 and 1,500 ft, 2.26%. An increase in the ATT suggests a larger home price difference for control homes further away. This result suggests that as distance to protected/no access increases, home price decreases, all else held constant.

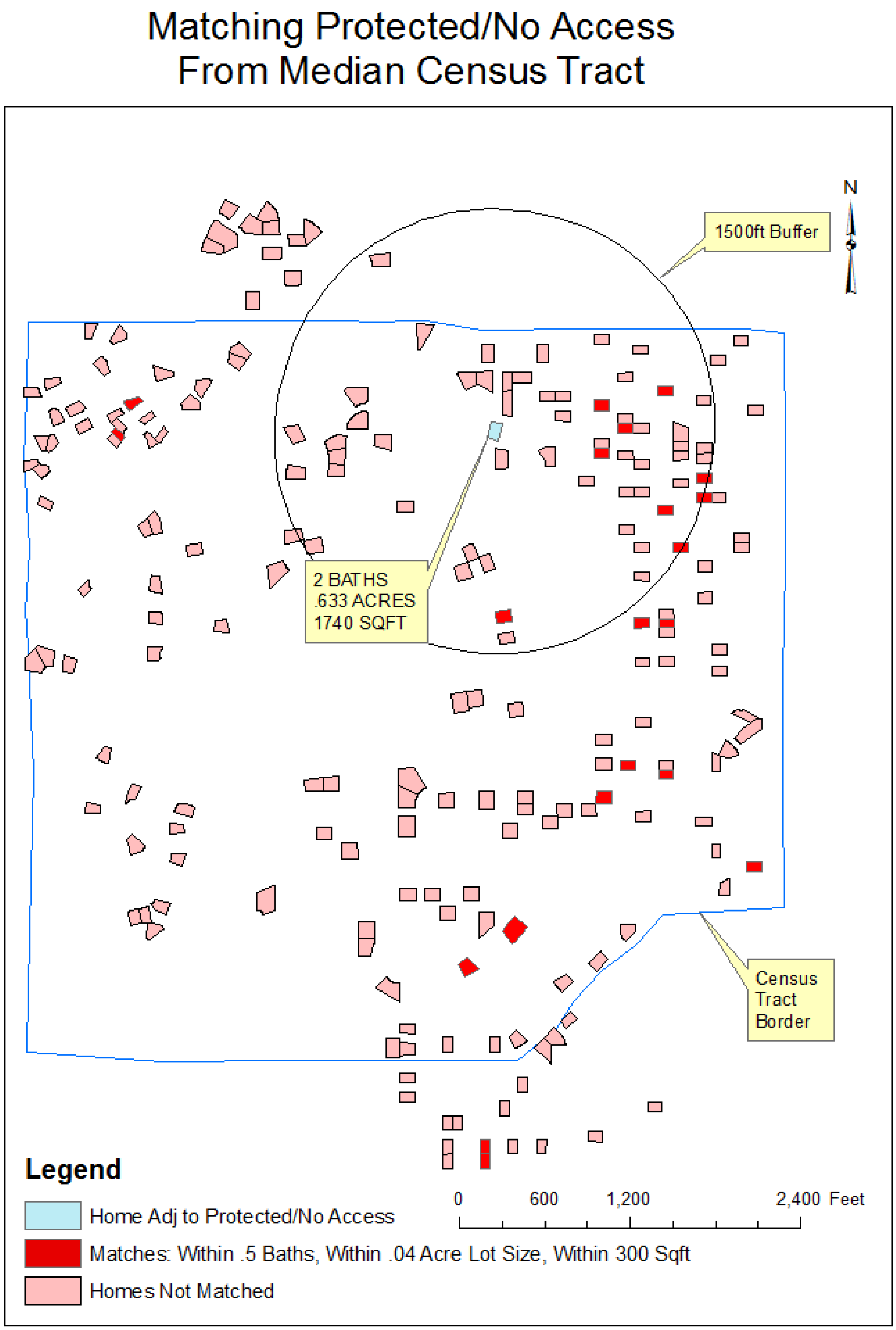


**Figure 5: Median census tract, a representative home is selected showing all possible matches within the acceptable bandwidth.**

This same matching strategy is used for the other two types of open space, protected/yes access and unprotected/no access, and the results are presented in Tables 14 and 15 respectively.

| **Table 14** | | | | |
|---|---|---|---|---|
| Matching Homes Adjacent to Protected Yes Access on Baths, Sqft, and Lot Size | | | | |
| **VARIABLES** | **log_saleprice** | **standard error** | **log_saleprice** | **standard error** |
| | | | | |
| ATT, Using Control Homes within 1500ft of Treated | 0.0417 | 0.0033 | | |
| ATT, Using Control Homes within 300ft of Treated | | | 0.0353 | 0.0047 |
| ATT, Using Control Homes 300ft-1500ft of Treated | | | 0.0329 | 0.0054 |
| | | | | |
| Treated Observations | 2625 | | 729 | |
| # of Matches | 1 | | 1 | |
| Treated Obs. Excluded with Matches Outside Bandwidth (Bath Diff > .5, Sqft Diff > 300sqft, and Lot Size Diff >.04 Acres) | | | | |

Examining protected/yes access results shows that as the control matches move from less than 300 ft to the 300 to 1,500 ft range, the premium for adjacency changes very little, from 3.53 to 3.29%. This indicates that the change in value over distance for protected/yes access is very small for houses not adjacent. The premium for adjacency also drops slightly, which makes the argument that homes not adjacent to protected/yes access but very close (less than 300 ft) have lower values than homes further away (300-1,500 ft) due to congestion and traffic from the publicly accessible open space. As noted previously, the number of treated observations for protected/yes access drops substantially from 2,625 to 729 when the sample is limited to treated observations, which must have an acceptable match under 300 ft and between 300 and 1,500 ft. The same is true for unprotected/no access as the treated observations drop from 6,799 to 1,582. The premium for being adjacent to protected/yes access using controls in a 300 ft radius is 3.53%, which as expected is greater than both protected/no access 1.70% and unprotected/no access 0.36%.

| **Table 15** | | | | |
|---|---|---|---|---|
| Matching Homes Adjacent to Unprotected No Access on Baths, Sqft, and Lot Size | | | | |
| **VARIABLES** | **log_saleprice** | **standard error** | **log_saleprice** | **standard error** |
| | | | | |
| ATT, Using Control Homes within 1500ft of Treated | 0.0071 | 0.0036 | | |
| ATT, Using Control Homes within 300ft of Treated | | | 0.0036 | 0.0049 |
| ATT, Using Control Homes 300ft-1500ft of Treated | | | -0.0056 | 0.0071 |
| | | | | |
| Treated Observations | 6799 | | 1582 | |
| # of Matches | 1 | | 1 | |
| Treated Obs. Excluded with Matches Outside Bandwidth (Bath Diff > .5, Sqft Diff > 300sqft, and Lot Size Diff >.04 Acres) | | | | |

Examining unprotected/no access results shows that as the control matches move from less than 300 ft to the 300 to 1,500 ft range, the premium for adjacency changes a small amount, from 0.36 to -0.56%, and is not significantly different from zero. This result indicates that being adjacent to undeveloped land provides no real benefit for home owners. Also, the premium drops as control homes are located further away, indicating that home owner's benefit from being further away from unprotected/no access. Homeowners most likely believe this land will be developed in the future and wish to be further away, given the uncertainty of the type of development and the possible future negative externality associated with it.

## Conclusion

This paper uses hedonic analysis of home transactions in the Denver-Boulder metro area to estimate the effect of open space on sales price. This paper considers three categories of open space, unprotected/no access, protected/access and protected/no access, and each type of open space fits into one of these three categories. The effects of open space are also allowed to vary by adjacency and neighborhood area. For OLS, census tract fixed effects are used to control for neighborhood characteristics along with unobserved quality of home build. As a robustness check, a nearest neighbor matching estimator is used to better control for neighborhood effects and to allow for flexibility from the linear assumptions of OLS.

The results yield several important insights. First, there is an important difference between the adjacent and neighborhood value for open space. The distinction between homes directly adjacent and across the street from protected open space is important; adjacency to protected open space provides a substantial premium. A home's value for adjacent protected land is more than three times the value for an additional acre of protected land ¼ mile from the home. Results indicate that if the distance to the nearest open space varies between 30 and 1,500 ft, there is no effect on home price. At distances beyond ¼ mile the value for protected open space drops off dramatically. An additional acre of protected open space at ¼ mile is almost 10 times more valuable than at 1 mile.

Second, the category of open space is important to differences in home values. Protected/access land is valued slightly higher than protected/no access for both adjacency and neighborhood value; this indicates that access is a valuable property of open space. These results go against previous literature, which indicates protected/access lands may have a lower value at close proximity because of a noise/congestion effect. Unprotected/no access adjacency provides a small positive value almost three times less than protected lands. Also of note, an additional acre of unprotected/no access land at ¼ mile reduces the value of a home. Generally speaking, unprotected/no access land does not provide value to nearby homes.

Finally, controlling for unobservable neighborhood characteristics is important in obtaining accurate estimates for open space value. Nearest neighbor matching allows for a finer control of unobserved quality of home build compared with OLS fixed effects. Matching obtains smaller adjacent values for all categories of open space while still maintaining positive significant coefficients. This result indicates that unobserved spatial differences occur at a very fine geographic scale, possibly less than ½ mile.

These results have important policy implications. Unprotected lands provide a small adjacency premium but in a neighborhood area may reduce home values. Protected lands provide a sizeable adjacency premium and in a neighborhood area increase home prices. This result suggests that government protection of open space lands is valuable and important. However, protected/access lands have a larger value than protected/no access lands for adjacency, and for an additional acre at ¼ mile, the difference is not substantial. This result suggests that if farmland is going to be converted into protected open space, access may not be important to providing additional value. A government may choose to create private conservation land over a public park, as it most likely costs less. At a radius of 1 mile, an additional acre of protected/yes access land provides 1.5 times more value than protected/no access. Combining this result with similar values for an additional acre at ¼ mile suggests that if there is high population density within 1 mile of proposed protected land, then a public park may be favored. If there is low population density within 1 mile, private conservation land may be preferred. The Denver-Boulder metro area has an ample amount of protected open space land for this study. This relatively high amount of protected open space as compared to other areas in the United States may lead to some concern in the absolute value of the results being applicable to an area with a lower amount of protected open space. On the other hand, one may expect the relative results found in the Denver-Boulder area to persist in other communities. Urban areas most likely value protected/yes access highest, followed closely by protected/no access, with unprotected/no access coming in a distant third.

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