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Property price effects of a national wildlife refuge: Great Meadows National Wildlife Refuge in Massachusetts

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ABSTRACT

The amenity value of proximity to a National Wildlife Refuge (NWR) in central Middlesex County, Massachusetts is estimated and compared to the values of proximity to five other open space types, including agricultural land, cemeteries, conservation land, golf courses, and sport/recreation parks. A hedonic model is used to explore the relationships among residential property values and proximity to these distinct types of open space. Open space characteristics in the empirical model include measures of continuous distance from each property to the nearest open space of each type and an index describing the diversity of open space types within neighborhoods of 100 and 1000 meters around a home. Results reveal that a property located 100 meters closer to the NWR than a neighboring property has a price premium of $984. Further, proximity to the NWR is valued more than proximity to agricultural land, cemeteries, and conservation land. No significant differences are found among the values of proximity to the NWR, golf courses, and sport/recreation parks.

1. Introduction

Economic evidence suggests there are positive price effects associated with open space that are capitalized into land values of neighboring properties (e.g. Knetsch, 1962; Correll et al., 1978; Beasley et al., 1986; Garrod and Willis, 1992; Geoghegan, 2002; and others). Compton (2005) argues that this price relationship was the rationale for the first publicly funded park in Birkenhead, England in 1847. Open spaces can provide a host of services, such as recreational opportunities, privacy, aesthetics, and numerous ecosystem services including flood control, water purification and wildlife habitat, for which nearby homeowners may be willing to pay a price premium to live near. Variations in these potential price premiums across different types of open space have been the focus of several studies (e.g. Lutzenhiser and Netusil, 2001; Shultz and King, 2001; Irwin, 2002; Smith et al., 2002; Anderson and West, 2006).

National Wildlife Refuges (NWRs) provide a unique type of open space (National Wildlife Refuge System Administration Act of 1966, amended Public Law 105-57).[2] The refuge lands are permanently designated to protect bird habitat with a special emphasis on migratory bird habitat (U.S. Fish and Wildlife Service, 2007b). Thus, the vast majority of lands within NWRs are covered by natural vegetation. There are over 500 national wildlife refuges in the United States and they account for nearly 100 million acres of open space managed as wildlife habitat. Nearly 50% of this acreage is classified as wetlands.[3]

Investigating the extent to which a NWR enhances the values of adjacent and nearby properties is important because the publicly owned land is not subject to local property taxes, and local officials may be concerned about the impact of refuges on property tax revenues (U.S. Fish and Wildlife Service, 2001). National Wildlife Refuges do make payments in lieu of taxes and the current payment is the greater of $1.65 per acre or an alternative formula amount for all federally owned land in a community (P.L. 97–258, as amended, §6903).[4] Despite these payments, some members of communities may believe that if refuge lands were used for commercial or residential development the property tax revenues might exceed the payments in lieu of taxes. Some of these concerns might be lessened if a NWR were shown to increase values of nearby properties and thereby the property tax revenue collected by the community.

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[3] See: http://www.fws.gov/refuges/.
[4] See: http://www.doi.gov/pilt/chapter69.html.

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This study investigates the property price effects of the Great Meadows National Wildlife Refuge in Massachusetts while controlling for other types of open space in the surrounding communities. To our knowledge no published studies have examined the price effects of a national wildlife refuge on property values. Thus, this research contributes to the established and growing literature focused on valuing open space lands (see McConnell and Walls (2005) for a recent review).

Some studies have assessed the price effects of open space lands with similar attributes to the Great Meadows National Wildlife Refuge. The refuge is a natural open space, located approximately 20 miles northwest of Boston, and consists of 3626 acres of wetlands along the Concord and Sudbury Rivers that are managed for migratory waterfowl habitat. It shares attributes with the natural area parks studied in hedonic price studies conducted by Lutzenhiser and Netusil (2001), the urban wetlands studied by Mahan et al. (2000), and the Class I and II wildlife habitat studied by Shultz and King (2001). Collectively, these studies provide a useful benchmark to assess our findings.

Our empirical research focuses on two questions. First, we examine whether or not proximity to the Great Meadows National Wildlife Refuge conveys a price premium on single-family residential units in the surrounding communities. Second, we explore the extent to which the Great Meadows National Wildlife Refuge generates a unique price premium relative to other types of open space. Proximity to the refuge is investigated in the context of five other types of open space in the study area: agricultural land, cemeteries, conservation land, golf courses, and sport/recreation parks.

2. Hedonic studies of open space values

McConnell and Walls (2005) review over 40 hedonic price studies of open space values published between 1967 and 2003. They document considerable diversity in the empirical measurement and description of open space lands and the services they provide, including discrete, continuous, and area-based proximity measures, shape and size characteristics, and categorization of open space by land cover, ownership, and use. They emphasize the importance of jointly examining multiple types of open space lands and carefully distinguishing among types of open space.

Table 1 summarizes key design features from 13 recent (published since 2000) hedonic studies of open space values. Eight of these studies were reviewed by McConnell and Walls (2005). The remaining five studies were published after the completion of their review. The intent here is not to present a complete overview of the literature as was done by McConnell and Walls (2005), but to present a synthesis of how these recent contributions to the literature influenced the research presented in this paper.

Of the 13 studies summarized in Table 1, eight used a semi-log specification [ln(sale price)] as the dependent variable, one estimated a Box-Cox transformation of the dependent variable, and the other four studies used linear dependent variables. Most of the studies considered multiple types of open space, recognizing the need to include 'substitute' lands and avoid potential econometric issues by omitting relevant lands.

Interestingly, there does not appear to be any explicit or implicit consensus in the literature on how the units of open space variables are measured in hedonic price equations. Measures of open space included distance to the nearest site, size of parcel, percent of land within a specified buffer, binary variables designating the presence or immediate adjacency of open space, indices of land diversity, and zoning. Distance, whether actual distance (seven studies) or buffer measurements (five studies), has played a central role in characterizing open space within these recent hedonic models.

As noted in our introduction, three of the studies summarized in Table 1 value open space with similar attributes to the Great Meadows National Wildlife Refuge. The Lutzenhiser and Netusil (2001) study found the presence of a natural area park (>50% natural or native vegetation land cover) increased property values when located within 1500 feet of a residence. Mahan et al. (2000) found property values increased at locations closer to an urban wetland. Shultz and King (2001) found property values decreased with proximity to Class I wildlife habitat and increased with proximity to Class II wildlife habitat. Class II habitat is composed of riparian areas along rivers.

Table 1
Recent hedonic studies of open space.

Authors	Application	Open space variables
Acharya and Bennett (2001)	Urban open space	Percent of open space with 1.25 miles, distance to lake and ocean, and diversity index of land use
Anderson and West (2006)	Urban open space	Distance[a] (meters) to and size (acres) of neighborhood park, special park, golf course, cemetery, lake and river
Geoghegan (2002)	Open space	Percent of land developable and in permanent open space within 1600 meters
Irwin (2002)	Open space	Percent of land within 400 meters that is cropland, forest, private conservation lands and public land
King and Anderson (2004)	Conservation easements/transfer of development rights	Acres conserved in town, lagged one, two and three years
Lutzenhiser and Netusil (2001)	Urban open space	Presence and acreage of urban parks, natural areas, golf courses, specialty parks, and cemeteries
Mahan et al. (2000)	Urban wetlands	Distance (feet), size (acres) and type of wetland (binary), and distance (feet) to stream, river, lake or park
Ready and Abdalla (2005)	Agricultural land	Zoned agricultural or conservation (binary)
Shultz and King (2001)	Open space	Distance (miles) to protected resource area, undeveloped park, regional park, neighborhood park, public or private golf course, and Class I or II wildlife habitat
Smith et al. (2002)	Urban open space	Distance (feet) to and adjacent (binary) to vacant land, golf course, public land, agricultural land and forest
Song and Knaap (2004)	Mixed land uses	Distance (feet) to nearest public park and percentage of parks within Travel Analysis Zone
Thorsnes (2002)	Suburban forest preserve	Borders preserve or across from preserve (both binary)
White and Leffers (2007)	Rural, natural amenities	<400 feet from lake, distance to Lake Mitchell, nearest public land, National Scenic River and nearest stream

[a] Distance is typically the measure to the nearest occurrence of the specified land use.

Geoghegan (2002) and Irwin (2002) demonstrate the permanency of open space protection is a crucial element in the valuation of open space in hedonic models because of endogeneity issues. The communities abutting the Great Meadows refuge are largely built out and open space is either publicly owned or under some type of permanent conservation easement or other deed restriction, which lessens endogeneity concerns.

Building on the approaches and findings of previous studies, we:

- employ a semi-log linear specification where the dependent variable is the natural log of sale price,
- include six types of open space that reflect the types of open space in the study area, and
- employ two types of measures for open space (distances and diversity indices) to investigate the effects on sale prices of open space.

The empirical results suggest people do place a price premium on properties nearer to the Great Meadows refuge, but that this price premium might not be greater than that of other types of open space included in the model.

3. Hedonic property value model

Application of the hedonic method for valuing open space as a characteristic of residential properties is well established (Taylor, 2003; McConnell and Walls, 2005). A hedonic price function is assumed to exist, representing the locus of equilibrium points of arms-length transactions between utility maximizing consumers and profit maximizing sellers. As such, the price (P) of the *ith* residential property can be explained by its differentiated characteristics:

$$P_i = f(L_i, S_i, N_i, E_i) \tag{1}$$

where L is a vector of land characteristics, S is a vector of structural characteristics, N is a vector of neighborhood characteristics, and E is a vector of environmental characteristics. The latter category is especially relevant to this research, incorporating the open space variables.

There is limited theoretical guidance for choice of functional form for a hedonic price equation and we followed guidance from the literature in choosing a specification. Costs associated with reassembling or repackaging certain housing characteristics favor a nonlinear hedonic price function (Rosen, 1974). Simulation evidence suggests using simpler forms (linear, semi-log, double log, and linear Box-Cox) when some property characteristics are missing or proxy variables are employed (Cropper et al., 1988). Because we are not able to observe all property characteristics and the previous open space studies have favored the semi-log specification, the specification used is:

$$\ln P_i = \beta_0 + \sum_{j=1}^{k} \beta_j X_{ij} + \varepsilon_i \tag{2}$$

where $\ln P_i$ is the natural logarithm of the sale price of property i, β_0 is the intercept, β_j are k parameters to be estimated associated with the vectors of property characteristics (L, S, N, and E), and ε_i is the observation specific error term.

The partial derivative of [2] with respect to a particular characteristic of interest (e.g. distance to Great Meadows (X_1)) gives the

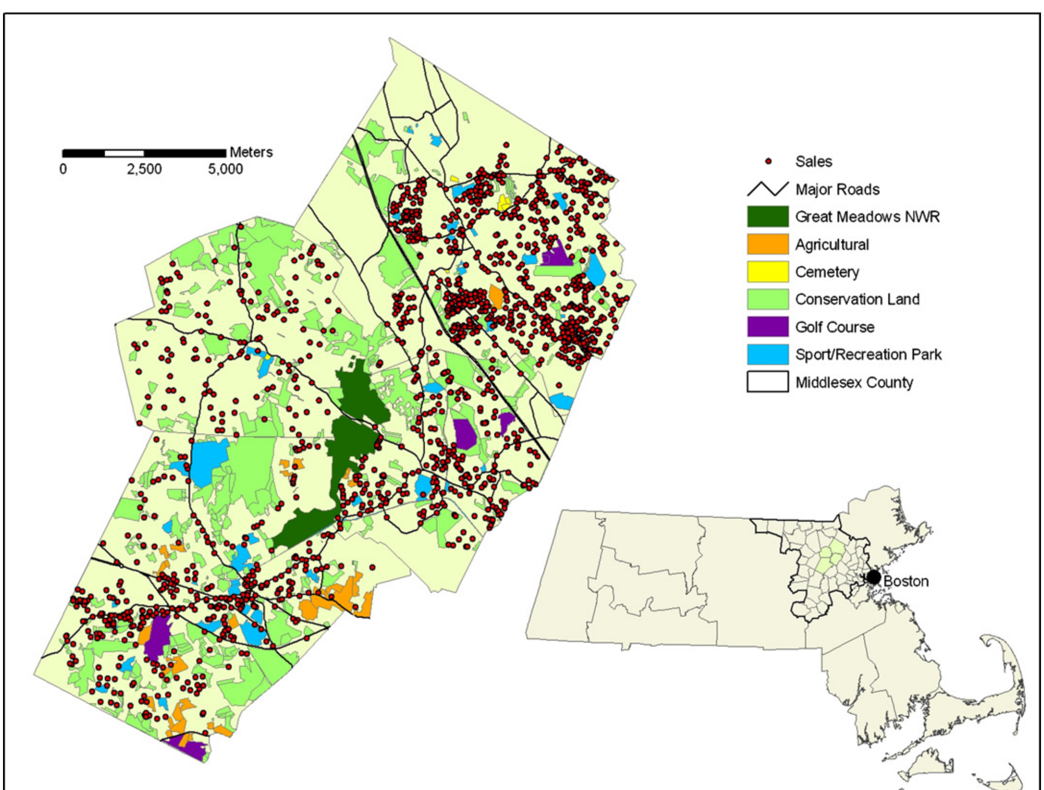

Fig. 1. Study Area and location of property sales. Open space in the concentric ring of towns surrounding the four-town study area was also included in the hedonic model, but was not included in this figure.

Table 2
Open space descriptive statistics.

Type of open space in study area	Number of parcels[a]	Smallest (acres)	Largest (acres)	Total area in parcels (acres)
Agricultural	70	0.8	230	2,332
Cemetery	30	0.5	87	681
Conservation land	1049	0.1	791	22,314
Golf course	11	11.6	192	991
Sport/recreation park	232	0.1	347	4,143
Great Meadows NWR[b]	1	3,506	3506	3,506[c]

[a] The numbers in this column represent spatially distinct parcels of land under the same type of protection. If two parcels are adjacent and under the same type of protection, say agricultural easements, then they are treated as a single parcel of open space.

[b] The Great Meadows NWR is collectively composed of 35 parcels of land that range in size from 1 to 546 acres, and most are contiguous to another like parcel. The refuge lands are treated as one parcel in the hedonic analysis.

[c] Some of the Great Meadows NWR publications cite the refuge's total acreage as 3626 acres. The 3506 acres represents the GIS data used in the hedonic analysis.

marginal implicit price, evaluated at a particular value of P (P^*),

$$\frac{\partial P}{\partial X_1} = \beta_{X_1} \exp\{\beta_0 + \sum_{j=1}^{k} \beta_{xj} X_j\} = \beta_{X_1} P^* \tag{3}$$

The marginal implicit price of an environmental attribute, such as proximity to the Great Meadows NWR, represents the change in the price of a home (e.g. the average sale price) that would result from an additional unit increase in the distance to the refuge, holding all other property characteristics constant. Within this first stage of a hedonic analysis, calculation of an attribute's marginal implicit price only reveals information about a small, marginal change in consumers' willingness-to-pay function, with the demand function itself remaining unidentified (Taylor, 2003; Palmquist, 2005). However, policy debates about National Wildlife Refuges may only require marginal analyses, focusing on the sign, magnitude, and significance of the estimated parameters (β) associated with the refuge.

4. Study area and data

The study area for this research is centered on the Great Meadows National Wildlife Refuge in Massachusetts. The refuge is composed of two units, the northern Concord unit and the southern Sudbury unit (Fig. 1). Approximately 90% of the Great Meadows refuge is comprised of wetlands that serve as a permanent or transient home to as many as 200 bird species, including many neotropical migratory birds (U.S. Fish and Wildlife Service, 2000). In addition to the protection of migratory bird habitat, Great Meadows also serves as a natural environment for wildlife viewing and recreation. Ornithologists refer to Great Meadows as one of the best inland birding areas in Massachusetts (U.S. Fish and Wildlife Service, 2007a). As a large tract of open space in a predominantly developed area, the refuge also provides permanently undeveloped land in a high-density residential area.

Property sales data were obtained for the towns of Billerica, Bedford, Concord, and Carlisle, Massachusetts–the four communities adjacent to the Great Meadows National Wildlife Refuge. The abundance of property sales in the communities adjacent to the refuge make the suburban location of this refuge a promising area for investigating the price effects of a national wildlife refuge. Many wildlife refuges are located in rural areas where there are a limited number of property sales. Few and uneven spatially distributed sales could complicate assessments of the value of proximity to a refuge (Bell et al., 2001). The Great Meadows National Wildlife Refuge is also convenient for examining the price effects of a refuge relative to other types of open space because the communities are nearly completely built out and all types of open space in the communities have some type of protection from development. Table 2 provides descriptive data on the open space within the communities of Billerica, Bedford, Concord, and Carlisle.

The property sales data obtained for this analysis consisted of 2983 residential, market transactions occurring between January 1993 and December 1998.[5] Property data included land, structural, and latitude and longitude coordinates information for most properties, which made spatial reference of each property in the Geographic Information System (GIS) possible. Observations without latitude and longitude coordinates were geo-coded in the GIS by performing an interactive address match to a 2000 U.S. Census Bureau Topologically Integrated Geographic Encoding and Referencing (TIGER) file. During the matching process, potential matches were simultaneously ground-truthed using street atlases complete with address numbering.[6]

Observations with unadjusted sales prices below 85% of the unadjusted assessed prices were omitted from analysis.[7] Extremely high, outlying sale prices were also removed from the data.[8] Additionally, observations with lot sizes less than 0.05 acres (2178 ft^2) were removed from analysis because these properties are not legal for residential construction based on current zoning regulations in the study area and are likely recording errors. Finally, observations with missing data and recording errors were removed. The sales prices of the remaining 1594 observations were adjusted to 1990 dollars using the Consumer Price Index for housing costs within the Boston–Brockton–Nashua area.[9]

The sole land variable in the equation is the acreage of the lot (ACRES). It is expected that sale prices will increase as lot size increases (Table 3).

The age (AGE), squared age (AGE2), interior square footage (INTSF), and number of bathrooms (BATH) in a house are included to measure the size and quality of the structures on the properties.

[5] The communities surrounding the refuge are well established (Billerica, Bedford, Concord and Carlisle) and the refuge was established in 1947. Thus, while the data are from the mid-1990s it is unlikely that physical changes in the communities or the refuge would affect the premium that home buyers might place on a residence located near the refuge. However, the active housing market in the early 2000s may have included people moving into these communities who place a higher value on living near the refuge, which would result in an increase in the estimated implicit price for proximity to the refuge.

[6] A dummy variable indicating if the analyses were systematically affected by observations that were address matched was included in the initial estimation. This variable is omitted in the results here as the parameter estimates on the open space variables were robust to differing treatments of address-matched observations.

[7] Home prices in the Greater Boston housing market decreased over the first half of the 1990s as a result of the area's recession and began to climb after 1995 (Allen et al., 2002).

[8] Observations with sale prices over 3.34 standard deviations from the mean were omitted.

[9] The deflation factor for 1993 sales is 1.069; 1994: 1.08; 1995: 1.107; 1996: 1.148; 1997: 1.186; 1998: 1.21. U.S. Bureau of Labor Statistics, "Consumer Price Index-All Urban Consumers (Current Series): Boston–Brockton–Nashua, Housing" (http://www.bls.gov/cpi/home.htm#data).

Table 3
Explanatory variable definitions and expected signs.

Name	Description	Expected sign
Land		
ACRES	Size of the lot (acres)	Positive
Structural		
AGE	Age of the house at the time of sale (years)	Negative
AGE2	Squared age of the house at the time of sale	Positive
INTSF	Interior size of the house (square feet)	Positive
BATH	Number of bathrooms (including half baths)	Positive
Neighborhood		
TOWN 1	Dummy indicating property located in Carlisle	Unknown
T0WN2	Dummy indicating property located in Bedford	Unknown
T0WN3	Dummy indicating property located in Concord	Unknown
P_EDUC	% in census tract with some college education	Positive
P_AGE65	% in census tract over the age of 65	Unknown
DIST_TSTOP	Distance (meters) to closest commuter train	Negative
DIST_MJRD	Distance (meters) to closest major road	Positive
DIST_COMRC	Distance (meters) to closest commercial land	Positive
Environmental		
DIST_AG	Distance (meters) to closest agricultural land	Unknown
DIST_CEM	Distance (meters) to closest cemetery	Unknown
DIST_CONS	Distance (meters) to closest conservation land	Negative
DIST_GOLF	Distance (meters) to closest golf course	Negative
DIST_SPRT	Distance (meters) to closest sport/recreation park	Negative
DIST_GRM	Distance (meters) to Great Meadows NWR	Negative
DIVIND_SM	Index of open space diversity within 100 meters	Unknown
DIVIND_LG	Index of open space diversity within 1000 meters	Unknown

Older houses may be a sign of lower quality or outdated technology, which would reduce sales prices. However, the Boston area has many historic homes that are valued for this quality and may increase sale prices. We expect property values to decrease with age up to some point at which age becomes a premium for high-quality, historic homes. Property values are expected to increase with the size of and number of bathrooms in a home.[10]

Neighborhood characteristics include dummy variables representing the towns in which properties are located within the study area and the education level (percent with some college education) and age (percent over 65) of residents of the neighborhoods surrounding the properties. Census tracts from the 1990 U.S. Census of Population and Housing were used to assign the education (P_EDUC) and age (P_AGE65) variables to property sales. We are uncertain whether the town dummy variables will indicate a premium of homes in one jurisdiction relative to the others. Property prices are expected to increase with higher educated neighborhoods, but the effect of older age-group neighborhoods is indeterminate.

Neighborhood variables were also created to measure the proximity of each property sale to the closest Massachusetts Bay Transportation Authority commuter rail station (DIST_TSTOP), major road (DIST_MJRD), and commercial land use (DIST_COMRC). Theses variables were created in the GIS with data obtained from the Massachusetts Office of Geographic and Environmental Information. We expect property prices may decrease with distance from a T-stop (convenience of public transportation) and increase with distance from a major road or commercial land use (avoidance of noise and other unpleasant aesthetics).

Open space data for this study were also obtained from the Massachusetts Office of Geographic and Environmental Information for the four towns of Billerica, Bedford, Carlisle, and Concord, and for the concentric ring of towns surrounding the four-town study area. This was done to ensure that property sales on the periphery of the four-community study area had accurate measures of distance to the nearest open space. Open space was assigned one of six different codes based on whether the open space is agricultural land (DIST_AG), a cemetery (DIST_CEM), conservation land (DIST_CONS), a golf course (DIST_GOLF), a sport/recreation park (DIST_SPRT), or the Great Meadows National Wildlife Refuge (DIST_GRM).[11] These categories encompass nearly all types of open space in the communities that surround the Great Meadows refuge. Agricultural lands are private farmlands where the development rights have been purchased by the Massachusetts Agricultural Preservation Restriction Program. The majority of these agricultural lands are operated by farms producing vegetables and hay. Conservation lands are areas of habitat protected by conservation easements that often have minimal recreation, such as walking trails. Golf courses include both public and private courses in the study area.[12] Sport/recreation park refers to neighborhood, urban, or specialty parks that are municipally owned.

Measures of the distance from each property sale to the closest open space of each type were recorded in meters. Considering the proverbial phrase ‘location, location, location’, proximity is expected to be an important measure for estimating open space spillovers that are capitalized into neighboring properties. Based on existing literature we can hypothesize certain relationships between property values and proximity to each open space type. We expect the relationship between property values and open space proximity to be negative for conservation land (Lutzenhiser and Netusil, 2001; Irwin, 2002; Shultz and King, 2001) and the Great Meadows refuge (Mahan et al., 2000), indicating that property values decrease with distance from these types of open space. Similarly, we expect the relationship to be negative for golf courses (Lutzenhiser and Netusil, 2001; Shultz and King, 2001; Smith et al., 2002; Anderson and West, 2006) and sport/recreation parks (Lutzenhiser and Netusil, 2001; Song and Knaap, 2004). Our expectations of the signs of the coefficients for cemeteries and agricultural land are uncertain. Johnston et al. (2001) and Smith et al. (2002) found a positive relationship between agricultural land and home prices, while Irwin (2002) found no significant relationship between the two. Similarly, Anderson and West (2006) found a positive relationship between house price and distance to cemeteries, while Lutzenhiser and Netusil (2001) found cemeteries did not affect the sales prices of residential properties.

Ecologists have used indices to measure landscape patterns and determine the capacity of various landscapes to support specific ecological processes for decades. Indeed, animals have preferred habitats which govern how they inhabit the landscape in terms of spatial extent and population size, which is the ecological justification for the establishment of National Wildlife Refuges. Economists have used similar arguments to consider how landscape patterns affect human preferences for where we live (Geoghegan et al., 1997; Acharya and Bennett, 2001). We use an open space diversity index similar to Geoghegan et al. (1997) to investigate if the number and sizes of different types of open space (agricultural land, cemeteries, conservation lands, golf courses, sport/recreation parks, and the Great Meadows refuge) near a

[10] Other structural characteristics were considered, but not included because missing observations would substantially reduce the usable sample. There is no reason to expect that missing omitted structural characteristics are correlated with proximity to any of the types of open space in the model and thus, their omission is not expected to bias proximity coefficient estimates.

[11] In addition to referencing the attributes of the open space GIS data, digital aerial photographs were used as a base layer in the GIS to examine the land cover associated with each open space polygon. The color, 0.5-meter resolution orthophotos were originally collected on film in April 2001 by Keystone Aerial Surveys, Inc. of Philadelphia, Pennsylvania.

[12] Public golf courses in the study area are not necessarily protected from development by easements or other deed restrictions, but are municipally owned. Many private golf course developments are permanently protected by restrictions in the master deeds.

property influence sale prices (see also Turner, 1990).[13] The open space diversity indices were calculated as:

$$D_i = -\sum_{k=1}^{6} (Pr_{ik}) \ln(Pr_{ik}) \quad (4)$$

where D_i is the diversity index for the *ith* property, Pr_{ik} is the proportion of the landscape surrounding the i^{th} property in open space type k, and ln is the natural logarithm. The diversity index associated with a specific observation increases with the proportion and number of open space categories within the specified zone around the property. A small diversity index zone, at 100 meters (DIVIND_SM), encompasses open space that is adjacent or in the immediate neighborhood of a property and a large diversity index zone, at 1000 meters (DIVIND_LG), encompasses much of the area of the community where homeowners live and carryout day-to-day activities.

A priori, it is difficult to know if the coefficients for the diversity indices will be positive or negative. A positive coefficient would suggest that the more diverse the open space in a given neighborhood, the more expensive the residential properties in that neighborhood, whereas a negative coefficient would suggest just the opposite. While greater diversity of open space in a neighborhood increases the choice set of individuals seeking recreation and potentially limits the extent of the residential-commercial/industrial interface, it also may be accompanied by greater nuisance as a result of outsiders seeking to enjoy the recreational diversity of the area and noise from locals using these areas.

Descriptive statistics of all variables in the hedonic equation are summarized in Table 4.

Table 4
Descriptive statistics of variables (n = 1594).

Name	Mean	S.D.	Minimum	Maximum
PRICE	214,809	186,133	18,067	2,024,793
Land				
ACRES	0.85	1.24	0.05	19.50
Structural				
AGE	44	35	0	313
AGE2	3,194	6,963	0	97,969
INTSF	1,825	965	372	9,483
BATH	1.5	0.77	1	7
Neighborhood				
TOWN1	0.07	0.25	0	1
TOWN2	0.18	0.38	0	1
TOWN3	0.22	0.41	0	1
P_EDUC	0.59	0.13	0.38	0.82
P_AGE65	0.16	0.07	0.08	0.31
DIST_TSTOP	4,816	2,271	108	9,261
DIST_MJRD	426	422	1	1,991
DIST_COMRC	732	534	0	3,129
Environmental				
DIST_AG	2,097	1,340	0	6,067
DIST_CEM	2,479	1,489	13	7,271
DIST_CONS	351	264	0	1,269
DIST_GOLF	2,299	1,361	0	6,673
DIST_SPRT	622	453	0	2,805
DIST_GRM	3,711	1,920	28	8,199
DIVIND_SM	0.05	0.12	0.00	0.72
DIVIND_LG	0.38	0.18	0.01	0.99

5. Empirical results

Equation [2] was first estimated by ordinary least squares (OLS) and corrected for heteroskedasticity by a second weighted least squares (WLS) estimation (see Table 5).[14] Statistical and diagnostic testing (Moran's I and various Lagrange Multiplier tests) was then undertaken to investigate if spatial dependence was present (Bell and Bockstael, 2000). Lagrange Multiplier tests identified spatial autocorrelation as the dominant form of spatial dependence.[15] Spatially correlated residuals can be caused by measurement error or omitted variables (Anselin, 1988). For example, if relevant, unobserved property characteristics exhibit spatial patterns, these patterns can result in spatially correlated residuals. In the presence of this form of spatial dependence, OLS and WLS parameter estimates are inefficient, compromising hypothesis testing based on these parameters.

In response to these findings, we re-estimated the model accounting for the spatial autocorrelation using maximum likelihood methods. We assumed a first-order spatial autoregressive form (Cliff and Ord, 1973) and employed a row-standardized binary contiguity spatial weights matrix with a cutoff distance of 200 meters. This weights matrix is therefore picking up relatively localized effects and may represent neighborhood or block-specific attributes omitted from our analysis. We conducted a sensitivity analysis to examine the responsiveness of results to alternative specifications of the spatial weights matrix (cutoff distances of 200, 400, 800, and 981 meters).[16] Few differences in results emerged. We maintained the cutoff distance of 200 meters because of our interest in capturing these local effects and because of ordering of test statistics supporting this specification (Wald > Likelihood Ratio > Lagrange Multiplier (Anselin, 1988)).

The maximum likelihood estimates are presented in Table 5. All of the land, structural, and neighborhood variables (with the exception of DIST_COMRC, which is insignificant) have coefficients that are significant with the expected signs (see Table 3). The dummy variables representing the town in which properties are located within the study area are all positive indicating that properties located in Carlisle (TOWN1), Bedford (TOWN2), and Concord (TOWN3) have premiums over properties in Billerica. The percent of residents in census tracts over the age of 65 (P_AGE65) is positive indicating neighborhoods with older populations tend to have higher property values.

Focusing on the open space distance variables, three of the six coefficients are significant at the 10% level. The coefficients for distance to agricultural land (DIST_AG) and distance to cemeteries (DIST_CEM) are insignificant. This result is not surprising considering the literature's mixed findings for these two types of open space.

A surprising finding is the insignificant price effect of proximity to conservation lands (DIST_CONS), the other type of 'natural' open space in the model. There are a number of potential explanations for this result. Federally protected natural land may be more important to homeowners than natural land protected by local groups because the federal designation exudes a greater sense of permanence than does locally protected land or private land with conservation easements. Alternatively, households may be less aware of privately conserved lands; for instance, private conservation easements may not be well publicized. Finally, if public access is limited to these

[13] This diversity index is based on information theory developed by Shannon and Weaver (1975). A version of the index was first applied to landscape ecology by O'Neil et al. (1988).

[14] In the OLS model, a Breusch-Pagan test leads to the rejection of the null hypothesis of homeskedasticity at the 5% level ($49.18 > \chi^2(0.05, 21) = 32.67$). In the WLS model, we fail to reject the null hypothesis at the 5% level ($30.75 < \chi^2(0.05, 21) = 32.67$).

[15] Both LM-Error and LM-Lag test statistics were examined (each distributed as χ^2 with one degree of freedom). The LM-Error statistic is most significant (equal to 6.84, p-value = 0.0089), identifying spatial autocorrelation as the dominant form of spatial dependence.

[16] 981 meters is the minimum distance such that every observation in the data has at least one neighbor.

Table 5
Estimation results.

Variables	OLS estimates $R^2=0.70$ Estimates (Standard errors)	WLS estimates $R^2=0.69$; AIC = 4617 Estimates (Standard errors)	Maximum likelihood estimates AIC = 4610[a] Estimates (Standard errors)	Implicit prices[b]
CONSTANT	11.330030***[c]	11.281810***	11.307770***	NA[d]
	(0.168870)	(0.164230)	(0.174277)	
ACRES	0.046100***	0.053970***	0.053196***	11,426.98
	(0.008950)	(0.012810)	(0.012806)	
AGE	−0.004640***	−0.004410***	−0.004502***	−967.07
	(0.000675)	(0.000667)	(0.000669)	
AGE2	0.000017***	0.000016***	0.000016***	3.44
	(0.000003)	(0.000003)	(0.000003)	
INTSF	0.000226***	0.000224***	0.000219***	47.04
	(0.000015)	(0.000015)	(0.000015)	
BATH	0.046070**	0.045630***	0.044866***	9,637.62
	(0.018270)	(0.017490)	(0.017357)	
TOWN1	0.513110***	0.449090***	0.460825***	98,989.36
	(0.113740)	(0.111350)	(0.118108)	
TOWN2	0.293430***	0.264050***	0.269719***	57,938.07
	(0.079190)	(0.076690)	(0.081559)	
TOWN3	0.461270***	0.341290***	0.351404***	75,484.74
	(0.122670)	(0.118200)	(0.125452)	
P_EDUC	0.545840*	0.720840**	0.695062**	149,305.57
	(0.309590)	(0.299240)	(0.318402)	
P_AGE65	0.878730***	0.928750***	0.921758***	198,001.91
	(0.274700)	(0.265780)	(0.281490)	
DIST_TSTOP	−0.000018*	−0.000024**	−0.000024**	−5.16
	(0.000010)	(0.000010)	(0.000010)	
DIST_MJRD	0.000076***	0.000058**	0.000061**	13.10
	(0.000029)	(0.000028)	(0.000030)	
DIST_COMRC	−0.000007	0.000007	0.000008	1.72
	(0.000025)	(0.000025)	(0.000026)	
DIST_AG	0.000014	0.000008	0.000008	1.72
	(0.000013)	(0.000013)	(0.000013)	
DIST_CEM	0.000012	0.000013	0.000013	2.79
	(0.000009)	(0.000009)	(0.000010)	
DIST_CONS	−0.000057	−0.000066	−0.000063	−13.53
	(0.000045)	(0.000044)	(0.000046)	
DIST_GOLF	−0.000025**	−0.000023**	−0.000023*	−4.94
	(0.000012)	(0.000012)	(0.000012)	
DIST_SPRT	−0.000058**	−0.000056**	−0.000056**	−12.03
	(0.000027)	(0.000026)	(0.000028)	
DIST_GRM	−0.000030***	−0.000028***	−0.000029***	−6.23
	(0.000010)	(0.000010)	(0.000010)	
DIVIND_SM	−0.071410	−0.110520	−0.108571	−23,322.03
	(0.084680)	(0.081540)	(0.083940)	
DIVIND_LG	−0.197190**	−0.210740**	−0.209168**	−44,931.17
	(0.091700)	(0.089490)	(0.094411)	
RHO	NA	NA	0.080799***	NA
			(0.029916)	

[a] A proper measure of fit in spatial regression models is the AIC (Akaike information criterion), which decreases relative to the WLS model, suggesting an improvement in fit for the spatial error model.
[b] Implicit prices are evaluated at the mean sale price, calculated as $\partial \ln(\text{price})/\partial X_j = \beta_j P^*$.
[c] Asterisks denote: (*) significance at the 10% level, (**) significance at 5%, and (***) significance at 1%.
[d] NA indicates not applicable.

conservation lands the public may be indifferent, or care less about their presence.

The coefficients for distance to golf courses (DIST_GOLF), distance to sport/recreation parks (DIST_SPRT), and distance to Great Meadows (DIST_GRM) are significant and have negative signs, indicating property owners prefer residential locations proximate to these types of open space. Shultz and King (2001), Smith et al. (2002), and Anderson and West (2006) found similar results for golf courses. Lutzenhiser and Netusil (2001) and Anderson and West (2006) found similar results for special and urban parks, while Shultz and King (2001) found the opposite result for neighborhood parks. This disparity is not surprising as these types of parks provide open space that may not provide many natural or aesthetic amenities and may be associated with noise or other undesirable factors. Pair-wise likelihood ratio tests of the restriction that the Great Meadows coefficient is equal to the coefficients on golf courses and sport/recreation parks cannot be rejected at the 5% level.[17] This suggests that Great Meadows is not valued differently than golf courses or sports parks.

The coefficient on the small diversity index (DIVIND_SM) is insignificant while the large diversity index (DIVIND_LG) is significant with a negative coefficient. This result suggests that property owners prefer less diversity of open space in the 1000 meter neigh-

[17] Given the single restriction under each null hypothesis and a 5% significance level, the critical value is distributed as $\chi^2_{(1,0.05)}$ and equal to 3.84. The LR statistics are 0.36 (H_0: $\beta_{DIST\_GRM} - \beta_{DIST\_GOLF} = 0$, vs. H_1: $\beta_{DIST\_GRM} - \beta_{DIST\_GOLF} \neq 0$) and 1.82 ($H_0$: $\beta_{DIST\_GRM} - \beta_{DIST\_SPRT} = 0$, vs. H_1: $\beta_{DIST\_GRM} - \beta_{DIST\_SPRT} \neq 0$). A joint test was also conducted. Given two restrictions, the critical value is 5.99 and the test statistic is 2.82. The test fails to reject the null hypothesis at the 5% level of significance.

borhoods around their homes. Acharya and Bennett (2001) found similar results for landscape diversity, concluding that homeowners prefer neighborhoods with more homogeneous land uses. Our results suggest that home buyers prefer locations with large areas of homogenous open space nearby, such as the Great Meadows National Wildlife Refuge.

6. Discussion and conclusions

Revisiting our two research questions, we find proximity to the Great Meadows National Wildlife Refuge conveys a price premium and this premium is statistically equivalent to the price premiums for two other forms of open space (golf courses and sport/recreation parks). The estimated implicit price for proximity to the Great Meadows refuge is $623 per 100 meters of proximity.[18] This is $984 in 2007 dollars.

While differences in real estate markets and purchaser preferences complicate straight-on comparisons of different hedonic studies, we do qualitatively compare the estimated implicit price for proximity to Great Meadows with the implicit prices for other hedonic price studies with attributes similar to Great Meadows.[19] All comparisons are made in 2007 dollars.[20] Using buffers, Lutzenhiser and Netusil (2001) found properties located within 1500 meters of a natural area park are valued $16,838 (16%) more than properties located farther away. A similar price effect cannot be reported for proximity to Great Meadows due to different independent variable specifications. However, a property located adjacent to the refuge is valued $14,760 (6.9%) more than a property located 1500 meters distant, all else being equal. Mahan et al. (2000) found a price effect of $452 (<1%) for a property located 200 meters closer to a wetland, and Shultz and King (2001) found that a property located 200 meters closer to a Class II wildlife habitat will have an increased sale price of $678. A property located 200 meters closer to the Great Meadows refuge increases the sale price of the average property by $1968 ($\sim$1%). These results give the impression that the Great Meadows National Wildlife Refuge price premium is in the same range as the price premiums for open spaces that only provide some of the attributes of the refuge. Such a conclusion must be tempered by the fact that the results are from different real estate markets where preferences for open space, substitutes, and market conditions can vary substantially.

The estimation results do indicate that the Great Meadows refuge is valued differently from some other types of open space in the study area. Residents of Billerica, Bedford, Concord, and Carlisle, Massachusetts prefer living in proximity to the Great Meadows National Wildlife Refuge than in proximity to agricultural land, cemeteries, and conservation land.

The results for the open space diversity index suggest that people in the communities of Billerica, Bedford, Concord, and Carlisle, Massachusetts prefer large tracts of homogeneous open space to numerous small tracts of diverse open space. Great Meadows provides one, large track in this index. There may be an endogeneity issue related to this finding, with people who prefer large tracks of homogenous open space choosing to move to this area and those preferring to live proximate to a variety of (heterogeneous) open space types choosing to move to other communities (Walsh, 2007). Interpretation of the diversity variable could also be complicated by the pure size of the refuge dominating the index.

The results of our study indicate that the Great Meadows National Wildlife Refuge contributes directly and indirectly to local property tax revenues. The refuge contributes directly through the payments in lieu of taxes made by the U.S. government and indirectly through enhanced values of residential properties in the adjacent communities. If the property tax mill rate is $10 per $1000 of valuation, then two average properties, one located adjacent to the refuge and the other located at the periphery of the study communities, about 8000 meters distant, will generate substantially different property tax revenues. The property adjacent to the refuge will generate about $787 in additional property tax revenue each year. This does not answer the question of whether a wildlife refuge will generate more tax income than if the land were developed, but it does indicate that a national wildlife refuge is not a dead-weight loss in property tax revenues. Also, a national wildlife refuge does not require infrastructure investment and maintenance such as is required for residential and commercial developments in communities.

The general results of this study likely apply qualitatively to the open space provided by other national wildlife refuges located in suburban areas. In these areas, the presence of a national wildlife refuge is likely to increase the values of nearby properties. However, the specific parameter estimates for the different types of open space and their relative magnitudes may change from one refuge application to another. The consistency of sign, significance and implicit price of the Great Meadows effect with similar coefficient estimates from previous hedonic studies provides an external validity check that supports the portability of the results to other suburban wildlife refuges.

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[18] The marginal implicit price for open space proximity is calculated as $\partial\ln(\text{price})/\partial\text{distance}$ which is equal to price times the open space distance coefficient. Using the mean property price, the marginal implicit price is −$6.23 (=−0.000029 × $214,809).

[19] To maintain consistency with other implicit price comparisons, we use the same changes in proximity that McConnell and Walls (2005) used (Table 1, p. 31 and 32) in their survey of the literature on hedonic price studies of open space.

[20] The adjustment factor for our study, Lutzenhiser and Netusil (2001), and Shultz and King (2001) is 1.58 (1990 to 2007 dollars). The adjustment factor for the Mahan et al. (2000) study is 1.41 (1994 to 2007 dollars). U.S. Bureau of Labor Statistics, "Databases, Tables & Calculators by Subject - CPI Inflation Calculator" (http://www.bls.gov/data/inflation_calculator.htm).

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