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Hedonic Valuation of Proximity to Natural Areas and Farmland in Dakota County, Minnesota

by
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ABSTRACT

Open space may provide a variety of environmental services, such as flood control, prevention of soil erosion, storage and recycling of wastes, and scenic views, which do not have traditional market values. This study assesses the value of these amenities in Dakota County, Minnesota, by estimating the marginal price of open space proximity to housing, with the hedonic property price method. Utilizing residential housing and open space data, a property's structural, neighborhood, regional, and environmental characteristics are related to its sale price. Key environmental characteristics are distances between a property and particular types of natural areas and farmland.

The marginal price of proximity to open space was estimated with three models that illustrate the relationship between open space proximity and property price. The estimation results suggest that Dakota County homeowners pay, ceteris paribus, a higher property price ($115) to live 100 feet closer to any type of open space. Upon categorization of open space into natural areas and farmland, an interesting distinction was discovered: homebuyers paid more ($111) to live 100 feet closer to natural areas and less (-$53) to live the same distance closer to farmland. Further classification of open space into public lands, forests, prairies, wetlands, and water bodies, yielded varying marginal prices for proximity to these features. Proximity to public lands and forests had a positive relationship with property price ($80 and $70 respectively), while the marginal price for proximity to farmland remained negative (-$66). Living marginally closer to prairies also had a negative association with property price (-$48), while nearness to wetlands and water did not have a statistically significant effect. These last three marginal prices are unreliable due to the presence of multicollinearity.

Finally, splitting the observations into urban and rural-urban fringe zones showed regional distinctions in the relationship of open space proximity to property price. In urban areas, proximity to publicly owned natural spaces and forests yielded a positive marginal price ($127 and $62 respectively). In the rural-urban fringe, proximity to forests and water features yielded positive marginal prices ($91 and $66 respectively). While proximity to farmland, prairies and wetlands was considered undesirable in the urban zone (with marginal prices -$102, -$55, -$63), nearness to these same features in the rural-urban fringe has a statistically insignificant relationship to property price.

Introduction

Over half of the population of the state of Minnesota lives in the Twin Cities seven-county region. In the past two decades, this region has experienced marked population growth. There has also been a pronounced geographic shift of households from the central cities and inner suburbs to the outer suburbs. Dakota County, which is located in the southeast section of the Twin Cities, is one of the region's fastest growing areas. It experienced a 29.3 percent increase in population from 1990 to 2000 (U.S. Census Bureau). In addition, during the first two decades of the 21st century, 105,000 new residents (or 57,500 households) are expected to move into Dakota County. As a result of growth in population and related businesses, and the necessary infrastructure to support it, 27,000 acres of undeveloped land in Dakota County are expected to be converted to other uses in the next twenty years (Dakota County).

Some Twin Cities' residents are concerned about how economic and population growth, resulting in low-density residential or commercial/industrial development, will impact farmland and natural areas in the region. A public opinion survey of registered voters in the Twin Cities seven-county area, sponsored by the Metropolitan Council and conducted by American Viewpoint, indicated that 96 percent of those surveyed consider natural areas to be an important part of the metro region's quality of life (Hohmann). In a 1997 survey, 98% of Dakota County residents stated their overwhelming support for the protection of Dakota County's natural resources, such as lakes, wooded areas, and wetlands (Cohn). Furthermore, the 2001 Dakota County Residential Survey found that over 90% of respondents believe it is important for Dakota County to take an active role in protecting farmland and natural areas (DCOP).

While it is clear from surveys that residents appreciate their open spaces and the environmental amenities they provide, the economic value that they place on them is not known.

Though planners know that residents desire the inclusion of natural areas in new development schemes, the amount, type, and placement of these areas would be better devised with economic values as inputs to the decision-making process. This paper estimates economic values for certain types of open space in order to improve the development process.

The hedonic property price method, which uses existing markets to estimate marginal values, was used to estimate the economic value of open space proximity. The hedonic pricing method is based upon the idea that environmental characteristics, such as air or water quality, will affect the productivity, and thus the rent, of a given parcel of land (Freeman). The value obtained through this study is not a complete economic value for open space; specifically, some use values are not measured. Since markets already exist for some of the environmental goods that individuals obtain from open spaces (such as timber and minerals), the hedonic method is not necessary to estimate their value. Also, because these estimates are based on housing prices in Dakota County, only the value to residents who live in Dakota County are observed; non-residents' values are not taken into account.

The variables that are used to estimate the value of open space to homebuyers in Dakota County are distances to the nearest feature of certain types of open space. An initial evaluation of how the distance to open space in general affects property price precedes an analysis based upon the categorization of open space into natural areas and farmland. Then, the marginal prices of proximity to privately owned wetlands, water, forests, and prairies, publicly owned natural areas of all types, and farmland, are estimated. Finally, differences in marginal prices between the urban and fringe regions of Dakota County are examined.

Natural Resource Valuations in Recent Literature

Several authors have conducted similar hedonic studies. For instance, Mahan, Polasky and Adams (2000) utilized the hedonic property price method to estimate the value of wetland amenities in the Portland, Oregon metropolitan region. The authors suggest that the amenity values of wetlands provide useful policy tools for making decisions regarding the preservation of wetlands versus their conversion to other uses. To estimate these amenity values, the study used a hedonic model of property prices, with distance to and size of wetlands as the key variables. Through this analysis, they observed that decreasing the distance from a house to a wetland positively impacted property price, by roughly $436 per 1,000 feet of reduced distance. In addition, increasing the size of the nearest wetland to the residence by one acre augmented the property value by $24. Mahan, Polasky and Adams (2000) also estimated that the implicit price for reducing the distance to a lake by 1,000 feet (with an initial distance of one mile) indicated an increase of $1,643.78 in house value. The same change in distance to streams yielded a $258.81 increase in house value.

Tyrvainen and Miettinen (1999) found that forest proximity positively impacted property values in the district of Salo in Finland. The authors estimated that a one kilometer increase in the distance from a residential property to the nearest forested land implied an average 5.9 percent decrease in the property price. Correspondingly, properties with a view of forested lands were on average 4.9 percent more expensive than properties lacking a view.

Very few studies have been conducted to estimate the value of open space amenities provided by prairie ecosystems. This is an area of research that deserves increased attention in future studies, particularly those related to the preservation of open spaces near urban areas and in the rural-urban fringe.

A study related to the valuation of amenities on public land was conducted by Espey and Owusu-Edusei (2001), who analyzed the impact of the proximity of different types of parks to residential houses in Greenville, South Carolina. The results of this study were more varied. While estimates showed that there was a positive impact (about 15%) on housing prices for homes between 300 and 500 feet of small neighborhood parks, there was a negative impact (about 14%) for homes within 300 feet of a park. The authors suggest that this initial negative impact for close park proximity may be due to park disamenities, such as noise and bright lights. In addition, there was a smaller positive impact (about 6.5%) on property values for homes within 500 and 1500 feet of small neighborhood parks.

McLeod et al. (1999) found that agricultural land values are determined by environmental amenities as well as production characteristics. Though this study measured the effect of amenities on the property containing them, the benefits of these amenities may accrue to surrounding properties as well. GIS software was used to determine the level of characteristic amenities on each property observed in the study. The amenity variables that were measured, in terms of abundance and quality, for the hedonic model included 1) wildlife habitat (specifically elk, which were chosen for their popularity in hunting and viewing), 2) trout habitat, and 3) scenery. All three variables were found to have a positive and significant impact on the property sale price. The authors thus suggest that agricultural lands that have a diverse set of these characteristics, command higher prices than parcels of comparable size which only offer production opportunities.

The Hedonic Property Price Method

Rosen (1974) is often credited with the formalization of the hedonic property price framework. His theory describes the underlying market for heterogeneous goods, suggesting that the price of a quality-differentiated good is a function of the levels of characteristics composing the good. Hedonic prices are the implicit prices of the good's utility-bearing attributes, represented by the slope of the hedonic function with respect to the characteristics. If the hedonic price function is accurately estimated, its partial derivative represents the individual's marginal WTP for the characteristic (Leggett and Bockstael).

The valuation of proximity to farmland and natural areas in Dakota County was based upon a traditional cross-sectional hedonic property value model. It is assumed that the housing market is in equilibrium, because producers and consumers are small relative to the market so that prices are given. Additional assumptions require that individuals have made utility-maximizing choices given the prices of alternative housing locations and that the prices just clear the market. As a result, one can express the price of a residential location as a function of the characteristics of that location. The hedonic price equation, an inverse demand function for a particular residential property, is:

$$P= \beta_j (S) + \beta_k (N) + \beta_l (R) + \beta_m (E) + \varepsilon$$

where P is the sale price, S is a vector of structural characteristics, N is a vector of neighborhood characteristics, R is a vector of regional characteristics, and E is a vector of environmental characteristics (which, in this study, are the distances to open space). The betas each represent a vector of coefficients relating the independent variables to the dependent variable, property price. Epsilon represents an additive error term for each observation.

Taking the partial derivative with respect to each argument in the hedonic model yields the marginal price of each characteristic (Freeman). Assuming utility maximizing behavior, each consumer will try to equate marginal cost of that characteristic with marginal WTP. If the housing market is in equilibrium, the calculation of the marginal cost of a given characteristic through regression analysis will provide an estimate of the consumer's marginal WTP for that characteristic (McLeod). The marginal price (β_m) represents the additional payment that an individual is willing to make for a marginal change in the distance to the closest open space.

One major weakness of the hedonic price method is its fundamental assumption that consumers of residential property have complete information. Because consumers may not be aware of all of the environmental services provided by an environmental entity, their marginal WTP for a particular open space may not reflect the true economic benefits of the resource. Another problem with the hedonic method is that by only measuring the marginal value of residents with access to an environmental good, the benefits received by non-homeowners (e.g., businesses, renters and visitors) are not taken into account. Therefore, the resulting estimates provide only a subset of the values in which one may be interested (Perman, Ma and McGilvray).

Despite these disadvantages, the hedonic method was preferable for this study for several reasons. Its estimates are unbiased because they are based on observation of economic behavior, not stated preferences (as with the contingent valuation method, for example). Also, because it is based on existing housing data, surveys, which can be costly and time-consuming, are not necessary. Finally, the hedonic method makes it possible to observe the marginal prices of several environmental amenity values simultaneously.

Case Study Area and Data

The main data sources for this study were the Dakota County Office of Planning and Office of Survey and Land Information. Dakota County provided digitized maps including property parcels, buildings, farmland and natural areas. The parcel and building data included housing prices and characteristics. Neighborhood characteristics are drawn from U.S. Census

Bureau data including demographic and housing characteristic information. Regional variables (which serve as proxies for some neighborhood and accessibility characteristics) are defined based upon municipal boundaries and stages of development, as defined by the Dakota County Office of Planning. Environmental characteristics are derived from housing, parcel, farmland and natural area maps.

The data used in this hedonic analysis consists of housing sales (*saleprice*) within Dakota County, Minnesota, that occurred between October 2000 and September 2001. The housing sales information (unadjusted for time) was combined with structural variables that are commonly found in hedonic models, including house age (*age*), finished square footage ($fnshdft^2$), garage square footage ($garageft^2$), architectural style (*arch1*-*arch7*), additional buildings (*addbldg*), and property area (*acres*). The neighborhood characteristic, household density (*density*), was found using the U.S. Census Bureau web page, bounded by Dakota County zip codes. These characteristics were organized into the proper format using Arc View geographical information systems (GIS) software.

GIS was used to measure distances, which quantify the environmental attributes of each house. These attributes are essentially locational externalities; the public goods that they provide are not part of the housing market, but they may affect property owners, whether it is in a positive or negative way. The proximity of open space features to a house can serve as a measure of environmental attributes, making it possible to estimate this impact. Using an extension[1] for Arc View, it was possible to measure the distance from the edge of each house to the edge of the closest polygon of each land use type.

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[1] Extension provided by Jenness Enterprises. Accessed online at: http://www.jennessent.com/arcview/arcview_extensions.htm.

Distances to open space were measured in three stages. First, the distance between each property and the nearest open space (*openspace*), of any kind, was calculated in Arc View. Then, these open spaces were divided into natural areas and farmland; distance measures to the closest feature of each were determined (*naturalarea* and *farm*). Finally, natural areas were divided into different types: public lands (*public*), privately owned wetlands (*wetland*), water (*water*), forests (*forest*), and prairies (*prairie*). The distance between each property and the closest open space feature of each category (including farmland) was then measured.

Since distance variables are so important to this analysis, it was desirable to remove any distortions that could be caused by house proximity to the Dakota County border. The natural area and farmland datasets did not include features from surrounding counties, so it was necessary to eliminate all houses that fell too close to the edge of Dakota County. To do this, the mean distance and standard deviation for each open space were calculated for all observations. The largest mean distance was observed in the wetland variable, which equaled 7,855 feet, with a standard deviation of 5,119. The mean distance plus two standard deviations yielded the buffer distance from the Dakota County boundary, which is approximately 3.4 miles. Observations within this distance of the border were eliminated from the dataset, yielding a dataset with 1,464 records. This method ensures that 95% of the records are an acceptable distance from the border.

Following the measurement of environmental characteristics, two more variables were added to the dataset. The first, *ownspace*, was added in order to separate open spaces that are within property boundaries and those that belonged to other property owners. By adding this categorical variable, it may be possible to separate the private good value from the public good value of open space amenities. However, because there are only eighteen properties including open space, this relationship may be difficult to measure statistically. The second variable, *priority*, was added in order to distinguish whether the closest farmland to each property was priority or ineligible farmland, in terms of its preservation potential.[2] Only thirty-four of the houses in the sample are closer to priority farmlands, as opposed to farmland that is ineligible for the Dakota County protection plan.

Finally, three variables indicating the region in which each property is located were created based upon the description of development boundaries provided by the Dakota County Office of Planning. *Zone1* and *zone3* represent the fringe and urban zones respectively, while *zone2* represents rural areas. Most observations fall within the urban and fringe regions. The lack of rural data points is mainly a result of the fact that most housing sales within the given time frame took place in the urban and fringe regions.

Table 1 gives a description of the independent variables, which represent the level of characteristics for each property. The third column in this table shows how many observations are in each category for dummy variables (e.g., there are 99 houses in the dataset that have extra buildings located on the property). Table 2 includes descriptive statistics (including mean, standard deviation, and minimum and maximum values) for continuous variables.

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[2] Eligibility for preservation was defined by an open space protection task force made up of Dakota County government representatives, environmental organizations, and citizens.

Table 1. Description of Explanatory Variables

Variable Name	Description	Indicator Count	Expected Impact
	Structural Variables		
$fnshdft^2$	Total structure square footage	-	positive
$garageft^2$	Garage square footage	-	positive
acres	Area of land parcel	-	positive
age	Age of building	-	negative
addbldg	Dummy variable for additional building	99	positive
ownspace	Dummy variable for presence of open space	18	positive
arch1	Dummy variable for structure (1 ½ stories)	12	positive
arch2	Dummy variable for structure (1 ¼ stories)	8	positive
arch3	Dummy variable for structure (1 ¾ stories)	10	positive
arch4	Dummy variable for structure (1 story)	262	positive
arch5	Dummy variable for structure (split level)	875	positive
arch6	Dummy variable for structure (2 stories)	294	positive
arch7	Dummy variable for structure (2+ stories)	3	positive
	Neighborhood Variables		
density	Density (houses per square mile)	-	positive
	Environmental Variables		
openspace	Distance to nearest open space (ft)	-	negative
naturalarea	Distance to nearest natural area (ft)	-	negative
public	Distance to nearest public land (ft)	-	negative
farm	Distance to nearest farm (ft)	-	negative
forest	Distance to nearest forest (ft)	-	negative
prairie	Distance to nearest prairie (ft)	-	negative
wetland	Distance to nearest wetland (ft)	-	negative
water	Distance to nearest water (ft)	-	negative
priority	Dummy variable for prioritized farm	34	positive
	Regional Variables		
zone1	Dummy variable for rural-urban fringe zone	667	negative
zone2	Dummy variable for rural zone	11	negative
zone3	Dummy variable for urban zone	786	positive

Note: Italicized variables are base indicators. The number of observations for each dummy variable is shown in the third column, "Indicator Count." There are 1,464 observations in the dataset.

Table 2. Descriptive Statistics of Variables

Variable Name	Mean	Standard Deviation	Minimum	Maximum
		Structural Variables		
saleprice ($)	212,265	66,767	66,500	915,000
$fnshdft^2$	2,058	668	420	5,893
$garageft^2$	523	180	0	2,032
acres	0.42	0.78	0.12	18
age (years)	18	13	2	126
		Neighborhood Variables		
density ($hshlds/mile^2$)	531	388	15	1,387
		Environmental Variables		
openspace (ft)	1,439	1,163	0	5,094
naturalarea (ft)	2,381	2,132	19	15,513
public (ft)	2,824	2,567	27	20,207
forest (ft)	7,104	4,555	44	17,096
prairie (ft)	6,089	4,442	43	17,169
wetland (ft)	7,468	4,854	19	26,132
water (ft)	7,033	4,977	122	26,282
farm (ft)	2,944	2,645	0	12,525

Notes: Number of observations equals 1,464. Environmental variables are measured as the distance to the nearest open space feature. The variable *openspace* indicates distance to the nearest open space of any kind (including all natural areas and farmland), while *naturalarea* indicates distance to the nearest natural area of any kind (public or private), excluding farmland. Minimum distances of zero indicate that the house is located within the boundaries of an open space feature.

Estimation Results

The property sale value was related to the independent variables listed in Table 1. Three separate models were estimated, the first (referred to as the Simple Model) measuring the impact of distance to any open space on property price, the second (Intermediate Model) comparing the impact of natural areas and farmland, and the final (Complex Model) comparing the impact of each type of natural area (wetlands, water, forests, prairie, and public land) and farmland (priority and ineligible). Finally, using the Complex Model, the data set was divided into two regions: urban and fringe. The rural region was eliminated from this part of the analysis because there are only eleven rural observations (the number of observations would be fewer than the regressors). The urban-fringe division was made to discover if there were any differences in the impact of proximity to open space features between urban and fringe areas. In each estimation, the structural, neighborhood, and regional variables stayed the same.

Interpreting the relationship between each of the characteristics and property price depends upon the functional form that is chosen for the hedonic model. One important distinction is whether the function should be linear or non-linear. Though the linear function (represented by the hedonic equation shown previously) provides the most readily explainable results, Rosen (1974) suggests that there is no reason to expect that this is the appropriate functional form. It is more likely that the functional form will be non-linear because individual housing characteristics are not separable; an individual cannot mix characteristics in any other form than is available in each house (Garrod and Willis 1992).

The results of the linear, semi-log, and double-log model estimations using the Complex Model, which disaggregates the open space distance variables, are reported for the environmental variables in Table 3. In the linear model, all variables remain untransformed. In the semi-log model, only distances to open spaces underwent log transformation. In the double-log model, property price and the environmental variables are all log transformed. The R^2 measurements are slightly larger for the double-log functional form, which suggests a better fit. In addition, the double-log model is common in hedonic property price studies, such as Mahan, Polasky and Adams (2000). Therefore, the double-log functional form was chosen for this study.

Table 3. Results with Different Functional Forms

Criteria	Linear	Semi-Log	Double-Log
R^2	0.781	0.801	0.816
R^2 (adjusted)	0.778	0.798	0.814
F-value	245	276	291
public	43*	83*	80*
forest	166	80*	70*
prairie	-138	-66*	-48*
wetland	-23	-37	-15
water	37	50	15
farm	-158*	-109*	-66*

Note: An asterisk denotes significant coefficients at the 5% level based on a two-tailed t-test of the null hypothesis that beta equals zero. Results denote change in property price based on decrease of 100 feet to nearest open space feature.

In order to achieve the best possible model fit, further analyses were conducted to determine if other variable transformations were necessary. Based upon Tukey's test of model curvature, three structural and one neighborhood variable were transformed. The range of values for $fnshdft^2$, *age* and *density* were large, suggesting a log transformation would be beneficial to improving model fit. Curvature tests also indicated that the variable *acres* was inversely related to the sale price of property, so this transformation was performed. With these transformations, each of the models (Simple, Intermediate and Complex) was estimated using the double-log functional form.

The estimation results for the Simple and Intermediate Models, using Ordinary Least Squares (OLS) regression, are reported in Tables 4 and 5. The estimation results for the Complex model, which includes distance measures to each type of open space, are reported in Table 6. The results of the urban and fringe zone estimations are displayed in Tables 7 and 8.

Table 4. Simple Model: Proximity to Open Space (OLS)

Variable Name	Estimated Impact	Standard Error	t-statistic d.f.=1445	Prob [$t_n > x$]
constant	9.42	0.13	74.11	0.000
		Structural Variables		
fnshdft^2	0.406	0.014	29.99	0.000
garageft^2	0.0002	0.00002	10.56	0.000
acres	-0.034	0.003	-11.03	0.000
age	-0.138	0.006	-22.33	0.000
addbldg	0.140	0.014	10.06	0.000
ownspace	0.189	0.032	5.94	0.000
arch1	0.109	0.034	3.17	0.002
arch2	0.157	0.045	3.48	0.001
arch3	0.199	0.038	5.25	0.000
arch5	-0.015	0.009	-1.69	0.092
arch6	0.099	0.012	8.45	0.000
arch7	0.307	0.069	4.49	0.000
		Neighborhood Variables		
density	0.025	0.010	2.62	0.009
		Environmental Variables		
openspace	-0.0078	0.003	-2.41	0.016
		Regional Variables		
zone1	-0.041	0.019	-2.19	0.028
zone2	-0.137	0.038	-3.57	0.000

Number of Observations = 1462, F (16, 1445) = 390.22, R-squared = 0.8121, Adjusted R-squared = 0.8100.

Table 5. Intermediate Model: Proximity to Natural Areas and Farmland (OLS)

Variable Name	Estimated Impact	Standard Error	t-statistic d.f.=1444	Prob [t_n > x]
constant	9.45	0.127	74.44	0.000
		Structural Variables		
fnshdft^2	0.401	0.014	29.68	0.000
garageft^2	0.0002	0.00002	10.77	0.000
acres	-0.033	0.003	-10.88	0.000
age	-0.138	0.006	-22.52	0.000
addbldg	0.141	0.014	10.23	0.000
ownspace	0.186	0.032	5.83	0.000
arch1	0.108	0.034	3.17	0.002
arch2	0.159	0.045	3.54	0.000
arch3	0.193	0.038	5.11	0.000
arch5	-0.015	0.009	-1.72	0.086
arch6	0.095	0.012	8.17	0.000
arch7	0.301	0.068	4.41	0.000
		Neighborhood Variables		
density	0.022	0.010	2.22	0.026
		Environmental Variables		
naturalarea	-0.0125	0.003	-4.05	0.000
farm	0.0073	0.004	2.08	0.038
		Regional Variables		
zone1	-0.035	0.019	-1.84	0.066
zone2	-0.101	0.039	-2.63	0.009

Number of Observations = 1462, F (17, 1444) = 371.34, R-squared = 0.8138, Adjusted R-squared = 0.8116.

Table 6. Complex Model: Proximity to All Types of Open Space (OLS)

Variable Name	Estimated Impact	Standard Error	t-statistic d.f.=1439	Prob $[t_n > x]$
constant	9.48	0.13	71.54	0.000
		Structural Variables		
$fnshdft^2$	0.401	0.014	29.51	0.000
$garageft^2$	0.0002	0.00002	10.69	0.000
acres	-0.032	0.003	-10.48	0.000
age	-0.136	0.006	-22.02	0.000
addbldg	0.137	0.014	9.90	0.000
ownspace	0.197	0.032	6.11	0.000
arch1	0.112	0.034	3.28	0.001
arch2	0.161	0.044	3.60	0.000
arch3	0.196	0.038	5.18	0.000
arch5	-0.014	0.009	-1.54	0.124
arch6	0.095	0.012	8.13	0.000
arch7	0.323	0.069	4.72	0.000
		Neighborhood Variables		
density	0.024	0.011	2.20	0.028
		Environmental Variables		
public	-0.0106	0.003	-3.23	0.001
forest	-0.0235	0.006	-3.72	0.000
prairie	0.0139	0.006	2.17	0.030
wetland	0.0051	0.007	0.70	0.483
water	-0.0049	0.007	-0.65	0.515
farm	0.0091	0.004	2.47	0.014
priority	0.0286	0.024	1.21	0.228
		Regional Variables		
zone1	-0.025	0.021	-1.17	0.242
zone2	-0.109	0.041	-2.65	0.008

Number of Observations = 1462, F (22, 1439) = 290.79, R-squared = 0.8164, Adjusted R-squared = 0.8136.

Table 7. Complex Model Estimation for Fringe Zone (OLS)

Variable Name	Estimated Impact ($)	Standard Error	t-statistic d.f.=644	Prob [$t_n > x$]
		Environmental Variables		
public	-0.0002	0.005	-0.03	0.975
forest	-0.0346	0.008	-4.29	0.000
prairie	0.0197	0.012	1.60	0.111
wetland	-0.0010	0.013	-0.08	0.939
water	-0.0221	0.013	-1.65	0.099
farm	-0.0040	0.005	-0.76	0.449
priority	0.0109	0.026	0.41	0.680

Number of Observations = 665, F (20, 644) = 99.42, R-squared = 0.7554, Adjusted R-squared = 0.7478.

Table 8. Complex Model Estimation for Urban Zone (OLS)

Variable Name	Estimated Impact	Standard Error	t-statistic d.f.=767	Prob [$t_n > x$]
		Environmental Variables		
public	-0.0137	0.005	-3.03	0.002
forest	-0.0188	0.011	-1.70	0.089
prairie	0.0156	0.007	2.09	0.037
wetland	0.0246	0.010	2.43	0.015
water	-0.0054	0.009	-0.58	0.561
farm	0.0188	0.005	3.67	0.000
priority	(dropped)			

Number of Observations = 786, F (18, 767) = 222.14, R-squared = 0.8391, Adjusted R-squared = 0.8353.

Results Analysis

While distance to open space is the variable of interest, reasonable estimates with respect to the remaining variables are important in supporting the validity of the study (Leggett and Bockstael). The coefficients of the structural characteristics (finished square footage, garage square footage, acreage, and age of house) had the expected sign and were significant at the 5% level.[3] In general, more house and property space tend to increase the price of the house, while increased age tends to decrease property price.

Architectural style was represented by the indicator variables, *arch1* through *arch7*. The base variable, *arch4*, represents one-story houses. One would expect that each coefficient for the other architectural types would then be positive. Houses that are 1 ¼ stories, 1 ¾ stories, 2 stories, and more than 2 stories are associated with a positive and statistically significant increase in house price, while the difference between house price for split levels and one story houses is not statistically different from zero.

The density variable (*density*) has a positive, statistically significant impact on property prices. Therefore, in areas that have a large number of households within one square mile, property prices are generally higher, all else remaining equal. The presence of open space on a property (*ownspace*) has a positive relationship to property price, though the small number of observations with open space on the property, relative to the sample size, suggests that this assertion is not supported statistically. Finally, an additional building on a property (*addbldg*) also has a positive marginal price.

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[3] Since acreage was included in the model as the inverse of its values, it is expected that its coefficient would be negative, which is supported by the estimation results.

What do the coefficients of the environmental variables suggest about the relationship between open space proximity and house price? It is important to note that, since the dependent and environmental variables have undergone log transformations, the resulting coefficients of these variables are measures of elasticity. A one percent change in the distance to the nearest open space will yield the percentage change in the sale price suggested by the coefficient. For example, a one percent increase in the distance to open space of any kind, as shown in the Simple Model, will yield a 0.0078 percent decrease in the property price.

To make these results more realistic and understandable, the change in property price that results from a 100-foot *decrease* in the distance to the nearest open space was calculated for each of the environmental variables in the Simple, Intermediate and Complex Models. The equation for this calculation is given by:

$$MP_{OPENSPACE} = X_{MARGINAL}/X_{OPENSPACE} * \beta_{OPENSPACE} * Y_{SALEPRICE}$$

where $MP_{OPENSPACE}$ represents the marginal price of proximity to open space, $X_{MARGINAL}/X_{OPENSPACE}$ represents the percent change in distance to open space (100 feet divided by the mean of the environmental variable), $\beta_{OPENSPACE}$ represents the beta coefficient estimated by the model regression, and $Y_{SALEPRICE}$ represents the mean sale price (e.g. $212,265 for all observations) of the houses in the data set. The price changes for each estimation, calculated using this formula, are reported in Table 9.

Table 9. Property Price Change Related to Change in Proximity to Open Space

Variable Name	Estimated Change ($)	95% Confidence Interval
	Simple Model	
openspace	115	(22, 208)
	Intermediate Model	
naturalarea	111	(57, 165)
farm	-53	(-102, -3)
	Complex Model	
public	80	(32, 128)
forest	70	(33, 107)
prairie	-48	(-92, -5)
wetland	-15	(-55, 26)
water	15	(-30, 59)
farm	-66	(-118, -14)
priority	6,071	(-3,800, 15,920)
	Urban Region	
public	127	(45, 210)
forest	62	(10, 134)
prairie	-55	(-107, -4)
wetland	-63	(-114, -12)
water	17	(-40, 73)
farm	-102	(-156, -47)
priority	dropped	
	Fringe Region	
public	1	(-58, 59)
forest	91	(49, 132)
prairie	-68	(-152, 16)
wetland	3	(-83, 89)
water	66	(-13, 144)
farm	54	(-87, 195)
priority	2,069	(-7,763, 11,901)

Note: Change in property price is based upon a 100-foot decrease in distance to the nearest open space feature, calculated at average initial distance with average sale price.

The Simple Model, with the only environmental variable being distance to nearest open space feature of any type, was conducted first to determine whether open space in general effects property price. The estimated impact of proximity to open space was found to be positive and statistically significant (at the 5% level). The estimated increase in property price as a result of decreasing distance to an open space feature by 100 feet is $115. This result supports Dakota County survey findings that its citizens value open space.

In the Intermediate Model, the open space features were separated into natural areas and farmland. Proximity to natural areas had a positive, statistically significant, impact on housing value, while proximity to agricultural land had the opposite, statistically significant effect (at the 5% level). Decreasing the distance to natural areas by 100 feet is associated with an increase in property price of $111, while decreasing the same distance to agricultural features promotes a decrease in property price of $53. This result suggests that only proximity to natural areas is desirable for households in the urban and fringe regions. Proximity to farmland is viewed as a negative environmental characteristic. This result is inconsistent with survey findings that Dakota County citizens positively value their agricultural land. Further information about this contradiction may be provided by the separation of regions, discussed below.

Categorizing open spaces (forests, prairies, wetlands, water, public lands, priority farmland, and ineligible farmland) in the Complex Model tells an even more varied story about the proximity of open space as an environmental characteristic. Holding other housing characteristics constant, a decrease in the distance to open spaces like forests and public lands is associated with an increase in the price of a property. Therefore, the average resident's marginal price for proximity to public land and forests is positive. The coefficient for proximity to water is not significant in this estimation. This lack of explanatory power could be a result of the relative scarcity of water features in the dataset. Proximity to wetlands is also insignificant, which could be due to disamenities (such as odor and insects). Another explanation for these insignificant findings is that some water and wetland features are included in public lands; because public lands are not categorized in terms of the natural area type, it is not possible to determine if there is a difference between proximity to privately and publicly owned water and wetlands.

The implicit marginal price for distance to prairie amenities was unexpected. The impact for this variable was negative and statistically significant for a decrease in distance to a property, suggesting that individuals in the housing market prefer to live farther away from prairies. As very few studies exist that measure the marginal value of prairie ecosystems, there is little to provide an explanation for this result. Once again, further investigation into the impact of prairies on property prices would be beneficial to understanding the value that citizens place on this type of open space resource.

The negative impact that proximity to agricultural land has on property price in the Intermediate and Complex Models may require more investigation also. There are four possible reasons for the negative impact. First, there is no variation of farmland type in the model; a better result could be reached through a study that diversifies the type of farmland located near residential properties.[4] Eligibility of farmland for the protection plan, however, does not appear to influence the sale price of nearby properties. Second, it is possible that the disamenities involved with living near agricultural land (e.g., unpleasant odor, noise pollution, water quality degradation) outweigh the positive open space amenities associated with that property (e.g., scenic view, wildlife habitat, etc.). Third, there is a general lack of data points in the rural

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[4] A study like McLeod et al. (1999) that measures the environmental amenities of farmland may be useful.

region, where most of Dakota County's farmland is found; this means that there is a lack of variation in distance to farmland, since the data points for rural homes are close to agriculture. Finally, the impact of closeness to farmland might also be explained by differences between the urban and fringe regions.

There are some interesting distinctions between the marginal prices for proximity to open space in the urban and fringe areas of Dakota County. First, proximity to public lands does not have a statistically significant impact on sale price in the rural-urban fringe, while in urban areas, it has a positive, statistically significant (at the 5% level) marginal price. One explanation for the insignificant finding in the fringe region is that the Rosemount Experiment Station, a publicly owned open space mostly devoted to agriculture, is located in the fringe. This open space feature makes separation of farmland and public land proximity effects difficult.

Forests appear to be valued positively in both regions, though the impact is only statistically significant at the 10% level for urban areas. This is consistent with the findings for the entire dataset. Urban dwellers are willing to pay, ceteris paribus, a higher price for properties that are farther away from prairies and wetlands, while fringe dwellers do not appear to be influenced by the proximity of these features. Perhaps the disamenities that make proximity to wetlands sometimes undesirable in urban areas are outweighed by their positive amenities in the rural-urban fringe. Water feature proximity has a positive impact on sale price in the fringe (at the 10% significance level), but no effect on sale price in urban areas.

Close proximity to farms has a negative impact on sale price in urban areas, but it is not statistically significant in the fringe. This suggests that households in the rural-urban fringe are less averse to living near farms than households in the urban area. Whether the closest farm is considered priority or ineligible for preservation appears to be unimportant in the regional models, as it was in the Complex Model. In the fringe, the small change of 1% is statistically insignificant. In the urban model, the STATA program dropped the dummy variable for priority farmland; this makes sense intuitively because farms in urban areas were deemed ineligible by the prioritization process. Of course, many of the residential properties that are closer to priority farmlands are located in the rural region of Dakota County. Additional rural observations could be useful in determining whether the criteria that were developed for prioritization are also important in terms of residents' perceptions about the value of different kinds of farmland.

Multicollinearity

As with any regression analysis, statistical issues[5] arose with this estimation. For instance, multicollinearity, a situation in which regressors move with each other, is a common feature of hedonic price functions, making it difficult to produce reliable coefficient estimates for the model's parameters. An informal test for the presence of multicollinearity showed some signs of this relationship between independent variables. The variance inflation factors (VIF) were calculated for each variable included in the model. There is evidence of multicollinearity if the largest VIF measure is greater than 10 and the mean of all the VIFs is considerably larger than 1. The highest variance inflation factor was observed for the natural log of household density (13.21), and the resulting mean variance was 3.11. The VIFs for the variables for wetland, water, forest, and prairie proximity were between 4.21 and 5.32, suggesting that these variables also contribute to the multicollinearity issue.

[5] Heteroscedasticity was apparent in the estimation. In order to correct for this violation of the assumption for constant variance of the disturbances, a weighted least squares (WLS) regression of the Complex Model was run. Most coefficients were not affected, however the coefficient for priority farmland was significant at the 5% level, based on a two-tailed t-test. The Ramsey test showed a high likelihood for the omission of relevant variables. Two variables that could help to explain the impact of open space on property prices, which were not included in the present study due to lack of data, are environmental quality and open space size.

There is strong collinearity between the distances to open space features, particularly wetland, water, forest, and prairie (with correlation factors between 0.7210 and 0.8489). These relationships may have affected the coefficients of these variables. In fact, when a regression analysis was run on each of the environmental variables individually, the relationships between these independent variables and the sale price change. Specifically, the relationship between proximity to prairies and sale price changes from negative and statistically significant to positive and statistically significant at the 10 % level, based on a two-tailed t-test. Proximity to wetlands also becomes positive and statistically significant at the 10% level, while proximity to water features becomes positive and statistically significant at the 5% level. The relationships between public area, forest, and farmland proximity and sale price do not change if they are analyzed separately. Therefore, the results for these variables are more reliable than those for prairie, wetland, and water proximity.

Future Research

One improvement on this hedonic study that was considered, but not done due to constraints of time and our limited knowledge of GIS, is the inclusion of open space variables in the hedonic model as measures of land use within a given radius of a house. Such a model would include one of the omitted variables noted earlier: size of open space area. It may be difficult to define the radius that affects housing market decisions. However, GIS software, like Arc View, would make this measurement of the focus variables possible.

Another beneficial improvement to the study would be increased variation of urban, fringe, and rural observations in order to better understand the different values for open space amenities in these regions. Due to lack of data points in rural areas, little could be said about how the residents in this region perceive the benefits of natural areas and farmland. One way to accomplish this task would be to aggregate data on house sales over a few years, adjusting for time, which would hopefully provide more rural observations. It may also be useful to look at these implicit values over time, as development pressure moves out from the urban core.

Finally, further analysis could have been done with the existing data if ownership of particular open space features had been identified. Because public lands in this study are not separated into different types it is not possible to discern if there is a difference between, for instance, a private forest versus a public forest. A model could be created that measures distances to open space features separated by public and private ownership. If it were discovered that accessible public open space features have a stronger positive relationship with property price, it may suggest that these areas are valued for their recreational attributes as well. This information could be useful in deciding whether it will be appropriate to purchase only the development rights to an open space property or to purchase the land outright.

Conclusion

The estimation results for the Simple Model suggest that Dakota County homeowners pay, ceteris paribus, a higher property price ($115) to live 100 feet closer to open space. However, proximity to different types of open space is not equally valued. Using the Intermediate Model, it was discovered that homebuyers paid more ($111) to live 100 feet closer to natural areas and less (-$53) to live the same distance closer to farmland. Further distinctions in marginal prices were found using the Complex Model, which included variables for distances to public lands, forests, prairies, wetlands, and water bodies. Proximity to public lands and forests had a positive relationship with property price ($80 and $70 respectively), while the marginal price for proximity to farmland remained negative (-$66). Living marginally closer to prairies also had a negative association with property price (-$48), while nearness to wetlands and water did not have a statistically significant effect. However, the marginal prices for proximity to prairies, wetlands and water are unreliable due to the presence of multicollinearity in the Complex Model.

Separate estimations for urban and rural-urban fringe zones showed regional distinctions in the relationship of open space proximity to property price. In urban areas, proximity to publicly owned natural spaces and forests yielded positive marginal prices ($127 and $62 respectively). In the rural-urban fringe, proximity to forests and water features yielded positive marginal prices ($91 and $66 respectively). Finally, while proximity to farmland, prairies and wetlands was considered undesirable in the urban zone (with marginal prices -$102, -$55, -$63), proximity to these same features in the rural-urban fringe has a statistically insignificant relationship to property price.

The results support the hypothesis that the presence of natural areas and farmland near a property influences that property's price. Thus, it seems the average resident in Dakota County has an implicit value for open space amenities, whether it is a positive or negative value. Though multicollinearity makes it difficult to determine the marginal price of proximity to water bodies, wetlands, and prairies, the estimates for public lands and forests are clearly positive. The negative marginal price for proximity to farmland, particularly in urban areas, suggests that residents in this area prefer to live farther away from this type of open space. However, it is important to note that these estimates do not provide a complete economic value for open space amenities. Given the nature of the estimation results for certain variables, further research will likely be needed to more satisfactorily determine the value of open space amenities to Dakota County citizens.

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