Valuing Urban Wetlands: A Property Price Approach

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ABSTRACT. *This study estimates the value of wetland amenities in the Portland, Oregon, metropolitan area using the hedonic property price model. Residential housing and wetland data are used to relate the sales price of a property to structural characteristics, neighborhood attributes, and amenities of wetlands and other environmental characteristics. Measures of interest are distance to and size of wetlands, including distance to four different wetland types; open water, emergent vegetation, scrub-shrub, and forested. Other environmental variables include proximity to parks, lakes, streams, and rivers. Results indicate that wetlands influence the value of residential property and that wetlands influence property values differently than other amenities. Increasing the size of the nearest wetland to a residence by one acre increased the residence's value by $24. Similarly, reducing the distance to the nearest wetland by 1,000 feet increased the value by $436. Home values were not influenced by wetland type.* (JEL Q25)

I. INTRODUCTION

Wetlands provide many valuable services such as improved water quality, groundwater recharge, shoreline anchoring, flood control, and support a diverse variety of fish, wildlife, and plants. Despite a growing recognition of the importance of wetlands, recent losses of wetlands have been significant. Between 1970 and 1990, the total net loss of wetlands in the United States was 2.6 million acres (Frayer 1991). The continuing loss led to the Federal wetland policy of "no net loss." (White House Office on Environmental Policy 1993).

Wetlands, like other natural resources such as streams and lakes, can provide positive amenity values for nearby residents. These include open space, enhanced views, increased wildlife, and a buffer against noise and other forms of pollution. Conversely, wetlands can produce disamenities such as odors and insect and animal annoyances. Wetlands vary, from primarily open water to forest and grassland that is wet only part of the year. The characteristics of a wetland (e.g., vegetative cover, size, shape, location, and soil conditions) determine whether the wetland outputs are amenities or disamenities to nearby property owners. To date, limited research has been conducted which links wetland ecosystem characteristics and functions to the amenity values of wetlands. As a result, most wetland valuation research has used indirect measures of wetland amenities. In this paper, we use the hedonic property price method to estimate the value of various wetland characteristics and amenities using data from Portland, Oregon. These amenity values of wetlands have important policy implications in deciding whether wetlands should be preserved or converted to other uses, and whether alternative wetlands are roughly equivalent in some sense.

Estimating the value of wetland characteristics is difficult because many of the services provided by wetlands are not traded in a market. A number of non-market valuation techniques are available to estimate the value of such unpriced goods. One of these techniques, the hedonic property price method, uses observations on property values, typically residential properties, to infer values for non-traded goods such as wetland services. Residential properties are composite goods that contain different amounts of a variety of

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characteristics. The price of the property, which is observable, thus represents the value of the collection of characteristics. Observing how property values change as the level of various characteristics change, such as wetland amenities, provides a way of estimating the marginal value of these characteristics.

The hedonic property price method has an advantage over other assessment techniques of using observed market prices to build estimates of various non-market goods and services. There is, however, an important limitation of the method in this application. Specifically, the method provides only a limited measure of total economic benefits. For example, in this study, the hedonic property price method measures only the amenity value of proximity to wetlands perceived by owner-occupied, single family residence purchasers. Urban wetlands provide many other services to society, such as water quality improvements, biodiversity, ground water recharge and discharge, and recreation. The value of these services may not be fully reflected in property values if either they are not fully perceived by residents, or the services provided are public goods. In the case of public goods, only part of the value of wetland services will accrue to owners of residences.

The results of this study indicate that wetlands influence nearby residential property values, which confirms the results of two previous studies (Doss and Taff 1996; Lupi, Graham-Tomasi, and Taff 1991). We found that increasing the size of the nearest wetland by one acre increased a property's value by $24.39, and decreasing the distance to the nearest wetland by 1,000 feet increases a property's value by $436.17. The type of wetland does not appear to matter to nearby residents. We also found that wetlands influence property values differently than lakes, rivers, streams, and parks. Finally, going beyond previous studies, we attempted to estimate the willingness-to-pay function for nearest wetland size using second-stage regression analysis. The results were problematic, confirming the inherent difficulties in using the hedonic property price model to estimate demand parameters.

II. PROPERTY PRICE METHODS IN WATER RESOURCES VALUATION

The hedonic property price method has been used to estimate the value of selected water resources, including lakes and reservoirs on nearby property values (Brown and Pollakowski 1976; d'Arge and Shogren 1989; Daring 1973; David 1968; Feather, Pettit, and Ventikos 1992; Knetsch 1964; Lansford and Jones 1995; Reynolds et al. 1973; Young and Teti 1984). A common finding across these studies is that lake frontage and lake proximity increase property values. Some studies also evaluate the influence of water quality on property value in addition to shorefront and proximity (d'Arge and Shogren 1989; David 1968; Feather, Pettit, and Ventikos 1992; Young and Teti 1984); improved water quality increases property values. Other applications of the hedonic property price method for valuing water resources include reservoir level changes (Khairi-Chetri and Hite 1990), river views (Kulshreshtha and Gillies 1993), and restoration of urban streams (Streiner and Loomis 1995).

There are two prior hedonic studies that estimate the value of wetlands. Lupi et al. (1991) estimate the relationship between the number of wetland acres in a given area and the price of a house in that area. The study shows that changes in wetland acreage are relatively more valuable in areas where wetland acreage is low than in areas where wetland acreage is higher. Doss and Taff (1996) assess the value of different types of wetlands and the willingness to pay for proximity to wetlands in Minnesota. Their results show a preference by homeowners for scrub-shrub and open-water wetlands, over forested and emergent-vegetation types of wetlands.

This study uses an extensive data set representing over 14,000 home sales in Portland, Oregon, to measure the value of different wetland types. The data include a number of attributes that affect purchase decisions, which have not been available for use in previous hedonic studies. Examples include view quality, property slope and elevation, distances to commercial and industrial areas, and distances to geographic features that lie beyond the residential housing study area. The wetland categories used by Doss and Taff (1996) are employed here, with the added differentiation of shape and size. The data include controls for other amenity generating features such as streams, rivers, lakes, and parks. Such detailed data are critical in measuring the subtle valuation differences among alternative wetland types and other kinds of green spaces.

III. THE HEDONIC PRICE FUNCTION

Most research using hedonic pricing to value environmental goods is based on a theoretical model presented in Rosen's 1974 article. Freeman (1993) provides a useful summary of the theoretical aspects of the hedonic property pricing model. A very brief discussion of key theoretical features is presented below.

Assume that each individual's utility function depends upon X, a composite commodity representing all goods other than housing; $\mathbf{Q}$, a vector of environmental amenities associated with a specific location; $\mathbf{S}$, a vector of structural characteristics (e.g., square footage, number of rooms, lot size) of the individual's residence; and $\mathbf{N}$, a vector of neighborhood characteristics: $u(X, \mathbf{Q}, \mathbf{S}, \mathbf{N})$. Assume that preferences are weakly separable in housing characteristics and other goods, which allows the demand for characteristics to be independent from the prices of other goods.

The housing market is assumed to be in equilibrium, which requires that individuals optimize their residential choice based on the prices of alternative locations. Prices are assumed to be market-clearing, given the existing inventory of housing choices and their characteristics. With these assumptions, the price of any residence can be described as a function of the environmental, structural, and neighborhood characteristics of the residence location:

$$P_h = P_h(\mathbf{S}, \mathbf{N}, \mathbf{Q}) \qquad [1]$$

Equation [1] is referred to as the hedonic price function.

Each individual maximizes utility subject to a budget constraint given by $M - P_h - X = 0$, where M is income. The price of X is implicitly scaled to \$1. The first order conditions that characterize a solution for the optimal level of the jth environmental amenity, q_j, can be written as:

$$\frac{\partial u / q_j}{\partial u / \partial X} = \frac{\partial P_h}{\partial q_j} \qquad [2]$$

The left-hand side of equation [2] represents the marginal rate of substitution between the environmental attribute and the composite (numeraire) good, that is, the marginal willingness to pay for the environmental attribute. The right hand side of equation [2] is the implicit marginal price of a characteristic. The partial derivative of the hedonic price function with respect to any characteristic yields its marginal implicit price. For example, if q_j is the distance to an open-water wetland, then the first partial derivative represents the additional amount that must be paid (received) to be located an additional unit closer to the wetland. It is important to note that while implicit price and marginal willingness-to-pay information for environmental characteristics at the optimal choice is estimated under this method, the entire willingness-to-pay function for the individual is not directly revealed (Freeman 1993).

IV. STUDY AREA AND DATA

The residential housing study area is that portion of Multnomah County that lies within the Portland urban growth boundary. Multnomah County encompasses the city of Portland, Oregon's largest city, with a population of about 509,000. Wetlands (and other geographical variables) located in the counties surrounding Multnomah are included since they may effect housing prices in the study area. Given its location in the maritime Pacific Northwest, the area enjoys significant water resources including two major rivers, several lakes, numerous streams, and many wetlands. The study area has over 4,500 wetlands and deepwater habitats. Two principal data sources were used in this study: MetroScan, Sacramento, California, which collects real estate data from assessor's records for numerous U.S. cities, provided real estate data for Multnomah County; and Metro Regional Services, a directly elected regional government agency for the greater Portland area, provided digital neighborhood and environmental characteristics for each residential property that was sold. Metro's Arc/Info geographic information system, (GIS), was employed to generate the data. Distance calculations were made using a raster system where all data are arranged in grid cells. Each cell is 52-feet square. Distances were measured as the Euclidean distance in feet from the centroid of the tax lot to the nearest edge of a feature.

The dependent variable of the hedonic price function is the sales price of a residence. Actual sales prices of individual properties are preferred to other forms of data on property values such as assessed, appraised, or census tract estimates because sales come closest to reflecting equilibrium prices. A total of 14,485 market-based residential sales for Multnomah County occurred between June 1992 and May 1994. Sales prices were adjusted by a price index for the Multnomah County residential housing market to a May 1994 price level. The average sales price for a residence was $123,109; the median price was $104,240. The most expensive home sold for $1,913,814, while the least expensive sold for $9,656. Ninety percent of the residences had market values between $55,000 and $250,000.

For each home sale there is a set of associated explanatory variables that are used to explain the sales price of the home. These variables consist of structural, neighborhood, and environmental characteristics linked to each property in the data set. The explanatory variables, their definitions, and their expected relationship to the dependent variable, sales price, are shown in Table 1. Descriptive statistics for the variables are given in Table 2. Wetland characteristics are based on the U.S. Fish and Wildlife Service's National Wetlands Inventory in Oregon (Oregon Division of State Lands 1990). The inventory uses the Cowardin classification system (Cowardin et al. 1979). The system is hierarchical, allowing for various levels of detail and consists of system, subsystem, class, subclass, and modifier designators.

Doss and Taff (1996) aggregated the Cowardin system, subsystem, and class designators into six major categories related to visual aesthetics which are expected to influence home purchasers willingness to pay. The major categories include forested, scrub-shrub, emergent-vegetation, and open-water wetlands, and lakes and rivers or streams. Forested wetlands are characterized by woody vegetation that exceeds a height of 20-feet and includes wooded swamps and bogs. There are 840 wetlands of this type in study area. They tend to be the least visually open. Scrub-shrub wetlands are dominated by woody vegetation less than 20-feet tall. The study area has about 680 scrub-shrub wetlands. Emergent-vegetation wetlands have the greatest incidence in the study area, with 1,700 sites. These wetlands include marshes, meadows, fens, and sloughs. Open-water wetlands (790 in number) are the most visually open and provide high quality habitat for waterfowl. They are usually less than 10-feet deep and include shallow ponds and reservoirs. Riverine habitats include rivers and streams contained within a channel of which there are 430 in the study area. They are usually, but not always, flowing. Lakes, which total 68, including deep reservoirs and ponds, typically have a large area of deep, open water with wave action. The average size of a wetland (excluding lakes, rivers, and streams) nearest to a residence is about 41 acres. The largest is 358 acres, while the smallest is 1 acre. The median and the mode size is 29 acres. About 25% of the homes that sold during the study period were located one-quarter mile or less from a wetland and 47% were within a distance of one-half mile. The average distance was two-thirds of a mile from a wetland site.

Metro's GIS database allowed an additional designation for each type based on its geographical shape. Wetlands that are narrow in one dimension, but relatively long in the other dimension are considered linear features. An example would be a long narrow scrub-shrub wetland adjacent to a stream. Alternatively, a polygonal-shaped wetland is considered an areal feature. All wetland vari-

TABLE 1
EXPLANATORY VARIABLES: NAMES AND DEFINITIONS

Variable Name	Description	Expected Relationship to Dependent Variable
	Structural Variables	
BATHTOT	Number of bathrooms. Partial bathrooms were not specified in the data	Positive
FIREPLCE	Number of fireplaces	Positive
DGAS	Dummy variable for gas heating source (1 if gas heat, 0 otherwise)	Positive
DHARDWD	Dummy variable for hardwood flooring (1 if hardwood floor, 0 otherwise)	Positive
DPOOL	Dummy variable for swimming pool (1 if pool, 0 otherwise)	Positive
DSIDEWALK	Dummy variable for sidewalk (1 if sidewalk, 0 otherwise)	Positive
TOTALSF	Total structure square footage	Positive
GARAGESF	Garage square footage	Positive
LOTSQFT	Lot square footage	Positive
AGE	Year house was built subtracted from 1994	Negative
	Neighborhood Variables	
MILLRATE	Mill rate which indicates the tax rate	Negative
LNCBD	Distance to central business district	Negative[a]
DLTTRAF	Dummy variable for light traffic (1 if light traffic, 0 otherwise)	Positive
ELEV	Elevation of property above sea level	Positive
SLOPE	Slope of property as a percent	Positive
LNINDUS	Natural log of the distance in feet to nearest industrial zone	Positive[a]
LNCOMM	Natural log of the distance in feet to nearest commercial zone	Negative[a]
VIEWQLTY	Quality of view as indicated by county assessor (range 0–9, 0 if no view)	Positive
	Wetland Variables	
WTLDSIZE	Size in acres of nearest wetland of any type	Positive
LNDIST	Natural log of distance in feet to nearest wetland of any type	Negative[a]
DOPWTR_A	Dummy variable for nearest wetland type (1 if open water areal, 0 otherwise)	Unknown
DEMRVG_L	Dummy variable for nearest wetland type (1 if emergent vegetation linear, 0 otherwise)	Unknown
DEMRVG_A	Dummy variable for nearest wetland type (1 if emergent vegetation areal, 0 otherwise)	Unknown
DFORST_L	Dummy variable for nearest wetland type (1 if forested linear, 0 otherwise)	Unknown
DFORST_A	Dummy variable for nearest wetland type (1 if forested areal, 0 otherwise)	Unknown
DSCRSB_L	Dummy variable for nearest wetland type (1 if scrub-shrub linear, 0 otherwise)	Unknown
DSCRSB_A	Dummy variable for nearest wetland type (1 if scrub-shrub areal, 0 otherwise)	Unknown
LNOP_L	Natural log of distance in feet to nearest open water linear wetland	Unknown
LNOP_A	Natural log of distance in feet to nearest open water areal wetland	Unknown
LNEM_L	Natural log of distance in feet to nearest emergent vegetation linear wetland	Unknown
LNEM_A	Natural log of distance in feet to nearest emergent vegetation areal wetland	Unknown
LNFO_L	Natural log of distance in feet to nearest forested linear wetland	Unknown
LNFO_A	Natural log of distance in feet to nearest forested areal wetland	Unknown
LNSC_L	Natural log of distance in feet to nearest scrub-shrub linear wetland	Unknown
LNSC_A	Natural log of distance in feet to nearest scrub-shrub areal wetland	Unknown
	Other Environmental Variables	
LNSTREAM	Natural log of distance in feet to nearest stream	Negative[a]
LNRIVER	Natural log of distance in feet to nearest river	Negative[a]
LNLAKE	Natural log of distance in feet to nearest lake	Negative[a]
LNPARK	Natural log of distance in feet to nearest improved public park	Negative[a]
	Market Segment Variables (reference location is North Portland)	
DSTHWST	Dummy variable for property location (1 if located in southwest Multnomah Co., 0 otherwise)	Positive
DNTHWST	Dummy variable for property location (1 if located in northwest Multnomah Co., 0 otherwise)	Positive
DSTHEST	Dummy variable for property location (1 if located in southeast Multnomah Co., 0 otherwise)	Positive
DNTHEST	Dummy variable for property location (1 if located in northwest Multnomah Co., 0 otherwise)	Positive

[a] For proximity variables such as distance to central business district, (LNCBD), and distance to nearest lake, (LNLAKE), a negative (positive) relationship to the dependent variable means residents are willing to pay more (less) to live closer to the feature. That is, the lesser (greater) the distance value, the more (less) the residence is worth.

TABLE 2
DESCRIPTIVE STATISTICS OF THE VARIABLES

Variable Name	Mean	Standard Deviation	Minimum	Maximum
		Structural Variables		
LNPRICE	122,570.00	79,158.00	9,656.00	1,913,800.00
BATHTOT	1.40	0.59	0.00	6.00
FIREPLCE	0.95	0.70	0.00	15.00
TOTALSF	1,426.10	573.89	364.00	8,099.00
GARAGESF	301.70	213.72	0.00	7,757.00
LOTSQFT	7,612.60	6,546.40	963.00	439,520.00
AGE	44.52	26.94	0.00	114.00
		Neighborhood Variables		
MILLRATE	18.04	0.54	13.73	19.31
LNCBD	31,658.00	17,968.00	4,060.00	79,206.00
ELEV	265.33	142.45	9.00	1,200.00
SLOPE	4.26	6.78	0.00	171.00
LNINDUS	3,691.60	2,986.30	0.00	15,321.00
LNCOMM	1,228.50	1,009.50	0.00	7,636.00
VIEWQLTY	0.15	0.78	0.00	9.00
		Wetland Variables		
WTLDSIZE	40.80	52.55	1.00	358.00
LNDIST	3,580.50	2,485.10	0.00	11,930.00
LNOP_L	21,032.00	13,417.00	773.00	59,312.00
LNOP_A	4,921.80	2,580.20	104.00	12,843.00
LNEM_L	9,292.90	4,485.90	104.00	23,913.00
LNEM_A	10,350.00	5,426.00	0.00	28,525.00
LNFO_L	9,087.20	6,348.00	0.00	23,423.00
LNFO_A	7,780.20	3,916.30	0.00	17,952.00
LNSC_L	12,149.00	5,887.30	0.00	27,253.00
LNSC_A	8,392.20	4,220.70	73.00	19,697.00
		Other Environmental Variables		
LNSTREAM	7,608.70	4,327.50	0.00	18,484.00
LNRIVER	11,738.00	6,618.10	0.00	28,838.00
LNLAKE	17,695.00	6,790.10	0.00	35,535.00
LNPARK	1,347.90	870.56	0.00	5,553.00

Notes: Number of observations equal 14,233. Values for natural logarithmic variables are shown prior to conversion. Dummy variables have been excluded. Distance variables with a minimum value of zero are within 52 feet of the edge of the feature.

ables, except size, are measured as distance in feet.

The explanatory variables for the 14,485 home sales were checked for unusable observations using histograms, maximums, minimums, and means for quantitative variables and occurrence counts for qualitative variables. Examples of variables with unrealistic or unusable values include: blank values for bedrooms, bathrooms, and lot square footage; zero values for house square footage and an $80,000 residence with 74 bathrooms. There were 252 observations deleted from the data set, resulting in a final sample size of 14,233, with a mean value of $122,570.

The housing market was divided into five segments, north (reference segment), northeast, northwest, southeast, and southwest, based on conversations with the assessors office and several home buyers. Many residents perceive the segments as being distinctly different in character. The highest to lowest ranking of average property values for Portland submarkets is northwest or southwest, southeast, northeast, and north. Table 1 describes the variables used in defining the market segments.

V. PROCEDURES

We used least squares regression analysis to estimate the hedonic price function. This function relates sales price to the structural characteristics of the property, neighborhood attributes in which the property is located, and characteristics of nearby wetlands and other environmental characteristics. The econometric model can be written as:

$$\ln P_{hi} = \beta_0 + \Sigma\, \beta_j \mathbf{S}_{ji} + \Sigma\, \beta_k \mathbf{Q}_{ki} + \Sigma\, \beta_l \mathbf{N}_{li} + \varepsilon_i \quad \text{for } i = 1, 2, \ldots, n \qquad [3]$$

where $\ln P_{hi}$ is the natural log of the sales price of a residence i, S_{ji} is the quantity of the jth structural variable for residence i, Q_{ki} is the measure of the kth environmental amenity, N_{li} is the measure of the lth neighborhood characteristic, and ε_i is the observation specific error term. For variables accounting for distance to some attribute, such as distance to a wetland or distance to the central business district, we define the distance variable used in the regression equation as the natural log of the distance. It seems reasonable to expect that the effect of distance on property value declines with distance rather than being constant. Dummy (categorical) variables are used to estimate the effects of qualitative characteristics, such as whether a residence has hardwood floors, and to include the effects of a residence being located in different Portland housing submarkets.

We checked for heteroskedasticity in the data. Specifically, we regressed the square of the residuals on four explanatory variables: total square feet, garage square feet, lot square feet, and size of nearest wetland. The resulting Breusch-Pagan test statistic was significant at the 1% level.[1] Because we did not know the exact form of the heteroskedasticity, consistent estimates of the standard errors of the coefficients (and the associated t-statistics) are generated using White's method (White 1980).

VI. RESULTS AND IMPLICATIONS

The results of the analysis are presented in Tables 3 and 4. We estimate two models, each based on different assumptions about the influence of wetlands on property values. In Model I, the natural log of the distance to the nearest wetland, the size of the nearest wetland, and dummy variables for the type of the nearest wetland are included, along with structural and neighborhood characteristics. Model I assumes that it is the characteristics of the nearest wetland (size, distance, type) that affect property value. In Model II, the size of the nearest wetland and the natural log of the distance to each type of wetland were included, along with structural and neighborhood characteristics. Model II assumes that it is the distance to the nearest wetland *of each type* that influences property values. Doss and Taff's (1996) analysis is based implicitly on the same premise.

The results of the estimation of Model I are reported in Table 3. All of the structural and neighborhood variables are statistically significant at the .05% level. Coefficient signs are generally as expected; the only exception is distance to commercial zone (LNCOMM). We expected the variable to represent ease of access to shopping, but the positive coefficient (distance away from commercial zones increases property value) may more strongly reflect congestion and noise associated with commercial areas.

The coefficients on the wetland variables (WTLDSIZE, LNDIST) are of the predicted sign. Increasing the size of the nearest wetland and decreasing the distance to the nearest wetland increases house values. The marginal implicit price of increasing the nearest wetland size by one acre, evaluated at the mean house value ($122,570), yields an estimate of $24.39 in increased house value. The marginal implicit price for reducing the distance to the nearest wetland by 1,000 feet,

[1] The test statistics was 754.4. The critical value of the test statistic at the 1% level of significance is 13.28.

TABLE 3
REGRESSION RESULTS: MODEL I

Variable Name	Estimated Coefficient	Standard Error	t-statistic d.f. = 14,196	Prob[$t_n > x$]
		Structural Variables		
INTERCEPT	12.760216	0.14335552	89.011	0.00000
BATHTOT	0.040898	0.004912881	8.3246	0.00000
FIREPLCE	0.092406	0.005361884	17.234	0.00000
DGAS	0.028255	0.004398227	6.4242	1.3679E-10
DHARDWD	0.034779	0.005077598	6.8495	7.7156E-12
DPOOL	0.056218	0.023494489	2.3928	0.0167332
DSIDEWALK	0.059674	0.005051653	11.813	0.00000
TOTALSF	0.000396	6.72E-06	58.929	0.00000
GARAGESF	0.000149	2.78E-05	5.3597	8.4E-08
LOTSQFT	3.856E-06	7.94E-07	4.8564	1.208E-06
AGE	−0.001908	0.000150665	−12.664	0.00000
		Neighborhood Variables		
MILLRATE	−0.016282	0.005636763	−2.8885	0.0038766
LNCBD	−0.13673	0.007820026	−17.485	0.00000
DLTTRAF	0.037897	0.007241133	5.2336	1.68608E-07
ELEV	0.000256	3.45E-05	7.4203	1.23456E-13
SLOPE	0.005249	0.000556776	9.4275	0.00000
LNINDUS	0.017574	0.002491987	7.0522	1.84252E-12
LNCOMM	0.005351	0.000824015	6.4938	8.6482E-11
VIEWQLTY	0.035037	0.003866394	9.0619	0.00000
		Wetland Variables		
WTLDSIZE	0.000199	3.92E-05	5.0765	3.8932E-07
LNDIST	−0.018789	0.00255147	−7.364	1.88294E-13
DOPWTR_A	0.008933	0.033069503	0.2701	0.78708
DEMRVG_L	−0.004088	0.035771106	−0.1143	0.909
DEMRVG_A	0.00266	0.034555998	0.077	0.93862
DFORST_L	0.01139	0.035385407	0.3219	0.74754
DFORST_A	−0.013114	0.034418469	−0.381	0.7032
DSCRSB_L	−0.00697	0.038325657	−0.1819	0.85566
DSCRSB_A	−0.000848	0.034689134	−0.0244	0.98054
		Other Environmental Variables		
LNSTREAM	−0.011149	0.002694439	−4.1378	3.5268E-05
LNRIVER	0.013893	0.011172421	1.2435	0.2137
LNLAKE	−0.07081	0.017185168	−4.1204	3.8036E-05
LNPARK	−0.001432	0.001783255	−0.803	0.42198
		Market Segment Variables (reference location is North Portland)		
DSTHWST	0.303002	0.017214035	17.602	0.00000
DNTHWST	0.385616	0.028882625	13.351	0.00000
DSTHEST	0.258256	0.012210856	21.15	0.00000
DNTHEST	0.290208	0.010929135	26.554	0.00000

R^2: .7565.
Adjusted R^2: .7559.
F value: 1260.492.

TABLE 4
REGRESSION RESULTS: MODEL II

Variable Name	Estimated Coefficient	Standard Error	t-statistic d.f. = 14,196	Prob$[t_n > x]$
		Structural Variables		
INTERCEP	12.423899	0.11999281	103.539	0.00000
BATHTOT	0.040274	0.00487629	8.25915	0.00000
FIREPLCE	0.091825	0.00526026	17.4564	0.00000
DGAS	0.02445	0.0043388	5.6352	1.7818E-08
DHARDWD	0.033294	0.00499836	6.66098	2.8202E-11
DPOOL	0.056243	0.0235539	2.38784	0.0169608
DSIDEWALK	0.05111	0.0047599	10.7376	0.00000
TOTALSF	0.000391	6.74E-06	58.0119	0.00000
GARAGESF	0.000148	2.74E-05	5.40146	6.7166E-08
LOTSQFT	3.939E-06	7.84E-07	5.02423	5.116E-07
AGE	−0.001922	0.00014939	−12.866	0.00000
		Neighborhood Variables		
MILLRATE	−0.018603	0.00570683	−3.2598	0.00111754
LNCBD	−0.15439	0.01033239	−14.942	0.00000
DLTTRAF	0.041844	0.00717983	5.82799	5.7316E-09
ELEV	0.000191	3.27E-05	5.84098	5.303E-09
SLOPE	0.00492	0.00053696	9.16274	0.00000
LNINDUS	0.01786	0.00231151	7.72656	1.17684E-14
LNCOMM	0.005785	0.00082584	7.00503	2.5806E-12
VIEWQLTY	0.033538	0.00379298	8.84212	0.00000
		Wetland Variables		
WTLDSIZE	0.000257	3.69E-05	6.96477	3.4342E-12
LNOP_L	0.053801	0.00708118	7.59775	3.1974E-14
LNOP_A	−0.042785	0.00353576	−12.101	0.00000
LNEM_L	0.035433	0.00445908	7.94626	2.2204E-15
LNEM_A	−0.001576	0.00487291	−0.3234	0.7464
LNFO_L	−0.000586	0.00128326	−0.4566	0.64796
LNFO_A	−0.004097	0.0032015	−1.2797	0.20068
LNSC_L	−0.007983	0.00462192	−1.7272	0.084154
LNSC_A	0.00934	0.00416499	2.24251	0.024944
		Other Environmental Variables		
LNSTREAM	−0.018577	0.00384896	−4.8265	1.404E-06
LNRIVER	0.006586	0.01007537	0.65367	0.51334
LNLAKE	−0.057896	0.01456669	−3.9745	7.0876E-05
LNPARK	0.00225	0.00176301	1.27623	0.2019
		Market Segment Variables (reference location is North Portland)		
DSTHWST	0.332771	0.01591785	20.9055	0.00000
DNTHWST	0.353886	0.029012	12.1979	0.00000
DSTHEST	0.224162	0.01098962	20.3976	0.00000
DNTHEST	0.264029	0.01169284	22.5804	0.00000

R^2: .7605.
Adjusted R^2: .7599.
F value: 1288.156.

evaluated at the mean house value and an initial distance of one mile yields a $436.17 increase in house value.[2] In Model I, the dummy variables for all wetland types are statistically insignificant. While there is a preference to be closer to wetlands, the type of wetland does not seem to matter.

The results on the coefficients of the other environmental variables have the expected sign with the exception of the coefficients on distance to the nearest river and distance to nearest park, which are insignificant. Living closer to streams and lakes increases house values. The marginal implicit price for reducing the distance to the nearest stream or lake by 1,000 feet, evaluated at the mean house value and an initial distance of one mile, indicates an increase in house value of $258.81 for streams and $1,643.78 for lakes. According to our results, wetlands are not as desirable to live near as are lakes but somewhat more desirable to live near than are streams.

In addition to the results reported for Model I, we also estimated this model with interaction terms among the wetland characteristics. We included a variable for size-distance interaction, as well as variables for size-type, and distance-type interactions. While not reported here, all of the interaction terms were statistically insignificant and did not have much influence on other estimated coefficients.

The second set of results, Model II, include the variables from Model I, except the dummy variables for type of nearest wetland and the natural log of distance to the nearest wetland, but add the natural log of distance for each of the four wetland types distinguished by geographic shape. For the variables common to both models, Model II results are similar to those of Model I with one exception, the coefficient on distance to nearest park, (LNPARK), switched signs, though again the coefficient was not statistically significant.

Coefficients on four of the specific wetland variables are significant at the .05 level: open water linear and areal, (LNOP_L, LNOP_A), emergent vegetation linear, (LNEM_L), and scrub-shrub areal, (LNSC_A). Living closer to open water areal, (LNOP_A), wetlands increased house value, while living closer to open water linear, emergent vegetation linear, and scrub-shrub areal decreased house value. Distances to the remaining four wetland types had no statistically significant effect on sales price. The coefficients on the wetland variables can be translated as changes in values for wetland characteristics. Using open water areal wetlands, (LNOP_A), for example, for two otherwise identical houses, a house that is 1% closer to a open water areal wetland would have a .04% greater value. Moving 1,000 feet closer to an open water areal wetland results in a $993.21 increase in home value, when evaluating the marginal implicit price at the mean house value and an initial distance of one mile. Conversely, moving 1,000 feet closer to an open water linear wetland decreases the value by $1,248.94. For emergent vegetation linear and scrub-shrub areal house values decrease by $822.54 and $216.82, respectively, for moving 1,000 feet closer.

In addition to the significant wetland *t*-statistics, which indicate that wetlands influence property values in Portland, we conducted two other tests to examine the role of wetlands and other attributes on prices. Using Model I, separate paired tests were conducted to examine whether the marginal price of wetlands differs from the marginal price of streams, rivers, lakes, or parks. At the .05 level of significance, the marginal implicit price for wetlands is significantly distinct from the marginal implicit prices for each of the other open spaces, except streams. With Model II, we tested whether the coefficients on each of the wetland types are equal. The results indicate that, at the

[2] The marginal implicit price for wetland size is ∂price/∂size which is equal to price times the wetland size coefficient. Using the data mean for house price, the marginal implicit price is .00199 × $122,570 = $24.39. This approach applies to all non-logged variables. Similarly, the marginal implicit price for a distance variable is equal to price × the distance coefficient/distance. Using the data mean for house price and an initial distance to nearest wetland of one mile, the marginal implicit price is (.018789 × $122,570)/5,280 = $.43617. Moving 1,000 ft closer increases the average house value by $436, ceteris paribus.

.05% level of significance, the coefficient on at least one wetland type is different.

The influence of wetland type on house value appears to be inconsistent between Models I and II. Model I focuses on the value of distance to nearest wetland and how that value changes if the nearest wetland is a given type. The inference from the results is that wetland type is not important to the home purchaser, but size and distance are. Model II measures the value of distance to the nearest wetland of each type. This specification assumes that wetland type, in addition to size and distance, matter to home purchasers. The problem with the Model II specification is that a given wetland type may be several wetlands distant from a residence. For example, the closest forested areal wetland may be the tenth wetland from a house and would have little influence on its value. Based on the results of Model II alone, one can not say whether the difference in value relates to wetland characteristics or proximity. The Model I specification seems a more plausible representation of the house-wetland amenity valuation process.

Doss and Taff (1996) used a specification similar to Model II in that they estimated the nearest distance parameters to each of four wetland types, forested, scrub-shrub, emergent vegetation, and open water. While we believe Model I to be a preferred specification for our analysis, the model used by Doss and Taff may be appropriate given that the greatest distance to any wetland type is less that .6 miles. Even though Doss and Taff (1996) used a model similar to Model II, it is difficult to compare the results across the two studies. The wetland types used by Doss and Taff (1996) did not include the geographical designators as used here. Also, Doss and Taff (1996) limited their wetland distances to about six-tenths of a mile, while we included all distances within the study area, which could be as much as several miles. It is, however, interesting to compare the wetland preferences indicated in the two studies, assuming the relative magnitude of the distance coefficients represent preference ordering. Doss and Taff (1996) found the highest preference was for scrub-shrub wetlands, followed by open water, then forested wetlands. Because of the quadratic functional form used by Doss and Taff (1996), emergent vegetation was not strictly more preferred nor less preferred to the other types. Using Model II and focusing on the significant wetland types only, our study found open water areal wetlands to be most preferred, followed by scrub-shrub areal wetlands, then emergent vegetation wetlands. Open water linear wetlands were least preferred.

VII. SECOND-STAGE ANALYSIS—THE WILLINGNESS-TO-PAY FUNCTION

In most cases, if a policy change or project is non-marginal (i.e., results in large changes in the resource being valued) then the value of the change cannot be measured by the first derivative of the hedonic price function, the marginal implicit price. In such cases, a second-stage analysis is required to estimate short-run, non-marginal changes by estimating the willingness-to-pay function. The willingness-to-pay function can then be used to evaluate policies and projects in terms of their influence on aggregate welfare.

For wetlands, it is plausible that some policies would only affect properties in close proximity to and/or a few wetlands. As Palmquist shows in such cases, the first-stage equation is sufficient to capture total benefits (Palmquist 1992). For completeness, we attempted to estimate a willingness-to-pay function for the study area by combining the quantity and price information obtained from the first-stage and adding demand characteristics of the home purchasers.

No water resources studies using the hedonic property approach were found to have estimated willingness-to-pay functions. The lack of empirical estimation of willingness-to-pay functions arises from the serious identification problem in estimating the function. The first-stage estimation yields an individual's marginal willingness to pay at one point. Though the hedonic price function traces out equilibrium points over a range of prices, observations at different prices come from different individuals. To overcome the identification problem and estimate the individual willingness-to-pay function, it is necessary to impose further restrictions. (Palmquist 1991)

Freeman (1993) suggests that the most reliable method for addressing the identification issue is the use of segmented markets from within a city or from different cities. This study uses the former, dividing the Portland housing market into five different sections. With segmented markets, households with the same preferences, incomes, etc., face different marginal implicit prices for characteristics. Assuming that the underlying demand structure is the same across all the submarkets (i.e., the differences in the determinants of the willingness to pay are controlled) this approach may allow the willingness-to-pay function to be identified.

The second-stage analysis consisted of estimating the willingness-to-pay function for size of nearest wetland to a residence, (WTLDSIZE). This function may be used to estimate the benefits of a wetland project by integrating under the willingness-to-pay curve, with and without the project. The determinants of an individual's willingness to pay for an acre of wetland include the wetland's size and other demand-shift variables. Exogenous demand-shift variables include income of the home purchaser (median income of residents in census block group), and preferences of the purchaser, which are indirectly described by age (median age of residents in census block group), race (percent of population nonwhite in the census block group), and number of occupants per residence (percent of homes in census block group with 1 or fewer persons per room).

Our first step was to evaluate the coefficients on the market segment dummy variables from the first-stage analysis. The coefficients on the market segment variables show how each submarket compares to the reference location, north Portland. The regression results for both models indicate northwest Portland has the greatest value, followed by southwest, northeast, southeast and north. We examined the hypotheses that all market segment coefficients are equal to the reference segment (north Portland), against the alternative that at least one coefficient was not equal to the reference segment. Using an F-test, we rejected the hypothesis. This result supports the conclusion of at least two different values for otherwise similar houses in different market segments. It is important to note that while the test results may indicate market segmentation, there is no a priori reason to expect separate markets within a single urban area. The dummy variable for market segments could be explaining variation in sales price correlated with different areas that is not otherwise captured in the model.

Next, the complete data set of 14,233 observations was divided by market segment and separate regressions were estimated for each segment while keeping the specification constant across all segments. This was done using both Models I and II absent the market segment dummy variables. Hedonic price functions were generated for each of the five housing markets. Each homebuyer's marginal implicit price for size of nearest wetland was then computed by calculating the first partial derivative with respect to wetland size from the hedonic price functions for each observation. Finally, the computed marginal implicit prices for the combined housing market were regressed on the observed quantities of wetland size and exogenous demand shifters (socio-economic variables) in an attempt to produce the willingness-to-pay function.

The expectation of the stage-two results was that residents would prefer larger wetlands to smaller ones, but that they would have a relatively small and diminishing willingness to pay for additional wetland acreages. However, the estimated coefficient on the variable of interest, wetland size, is .1776 (t-statistic: 11.28) using the model I specification and .1429 (t-statistic: 9.36) using model II. The positive coefficient indicates a positively sloped inverse demand curve, an unexpected and troubling result. The failure of the stage-two model, despite the market segmentation within this large data set confirm the problematic aspects of using the hedonic approach to estimate demand parameters. In particular, it is not clear that the assumption of separate submarkets within a single metropolitan area is valid nor that the chosen instrumental variables are uncorrelated with unobserved preference parameters (see Bartik 1987; Epple 1987; McConnell and Phipps 1987; and Palmquist 1991).

VIII. CONCLUSIONS

The results of this study show that wetlands proximity and size significantly influence residential property values. Further, proximity to wetlands is valued differently from other urban open spaces.

The first-stage analysis yields estimates of the marginal willingness to pay or price for environmental attributes. We found that increasing the size of the nearest wetland and decreasing the distance to the nearest wetland increases house values. The marginal implicit price of increasing the nearest wetland size by one acre, evaluated at the mean house value ($122,570), yields an estimate of $24.39 in increased house value. The marginal implicit price for reducing the distance to the nearest wetland by 1,000 feet, evaluated at the mean house value and an initial distance of one mile yields a $436.17 increase in house value. While there is a preference to be closer to wetlands, the type of wetland does not seem to matter. The marginal implicit price for reducing the distance to the nearest stream or lake by 1,000 feet, evaluated at the mean house value and an initial distance of one mile, indicates an increase in house value of $258.81 for streams and $1,643.78 for lakes. According to our results, wetlands are not as desirable to live near as lakes but somewhat more desirable to live near than streams.

Under certain conditions margin implicit prices may be used to construct upper or lower bounds on welfare changes for non-marginal changes in environmental attributes. Bartik (1988) and Freeman (1993) give explanations of the issues involved in estimating welfare changes from non-marginal changes in environmental attributes using the hedonic method. We were unable to obtain meaningful second-stage results, even when using what we feel is an excellent data set. It is unclear whether separate markets truly exist and the inherent difficulty in overcoming endogeneity remains.

While the hedonic property price method has an advantage over other assessment techniques of using observed market prices to estimate the value of various non-market goods and services, it is important to remember the method provides only a limited measure of total economic benefits. Examples for this study include the following. Urban wetlands provide many services in addition to positive and negative amenities. They may include water quality improvements, biodiversity, ground water recharge and discharge, and recreation. The value of these services may not be fully reflected in property values if either they are not fully perceived by residents or the services provided are public goods. The approach does not measure the benefits received by others in the area such as businesses, renters and visitors. Because the benefits are partial and site specific, the method does not readily address the issue of how a wetland project in Portland benefits society relative to a wetland project in some other location. Finally, the hedonic property price approach only provides a limited means of comparing amenities provided by wetlands to those provided by other natural and human resources.

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