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Recreational and Aesthetic Value of Water Using Hedonic Price Analysis

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Historically, water allocation focused on quantities demanded by consumptive uses. As quantity demand grows, efficient allocation among consumptive and nonconsumptive uses becomes more critical. This hedonic approach provides information regarding recreational and aesthetic (RA) value for a central Texas lake. The model indicates several statistically significant RA characteristics of housing; proximity is the most important. Waterfront properties command a premium, but marginal RA price falls rapidly with increasing distance. Marginal RA values are estimated for selected water levels and are found to have a lower marginal price per acre-foot than many agricultural uses.

Key words: aesthetic, hedonic, property, proximity, recreation, value, water

Introduction

Economic theory suggests that resources be allocated such that marginal value product or benefits are equated across uses to maximize total returns or social welfare (Gibbons, p.2). Since water has public good characteristics and nonmarket uses, efficient water allocation is difficult. Water is an input not only in agricultural and industrial activities but also as an input in the household production function of consumers. Among other things, households use water in production of meals, personal hygiene, and recreation. Marginal prices of water in recreational use can be estimated with nonmarket valuation methods such as the contingent valuation or travel cost approaches. The hedonic approach, however, uses actual market transactions.

A hedonic study of shoreline and "near-the-lake" properties will capture an important component of the recreational and "amenity" (aesthetic) values that are provided by the existence of such a lake. This article illustrates this component of in-stream water's value. To estimate the total recreational and aesthetic value, other components must be added. These include the following: (*a*) the value to persons living outside the immediate area who travel to the lake to enjoy its benefits and (*b*) components for existence, bequest, and option value by those who never visit the lake yet believe it to be beneficial. Without these components, this study may place a lower boundary on the total recreational and aesthetic value of a lake.

Water within the Colorado River basin of Texas has historically been allocated based on quantity demanded by traditional consumptive uses such as municipal, industrial, and agricultural. As the demand by users grows, efficient allocation of water among competing consumptive and nonconsumptive uses becomes more critical [Lower Colorado River Authority (LCRAa)]. Recreational and aesthetic services provided by the river and lake waters are among the nonconsumptive uses.

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The hedonic price approach is used to determine components of the recreational and aesthetic (RA) value of a lake in the central Texas chain called the "Highland Lakes." Specifically, the implicit recreational and aesthetic price placed on Lake Travis by homeowners living near it is investigated. The hypothesis is that within a certain proximity around a lake, residential property values reflect the recreational and aesthetic benefits received from the lake by the residents. The study attempts to isolate this RA value from the numerous valuable attributes and amenities that compose the total value of a residential property. The primary objectives are to do the following: (*a*) estimate the marginal value of proximity to a lake through the hedonic pricing method; (*b*) estimate the total nonmarket, implicit price of recreational and aesthetic (RA) benefits to residential properties relatively close to the lake; and (*c*) estimate the marginal RA value of water.

This article is organized as follows. Hedonic theory and application is briefly reviewed, followed by a description of the methods and data. Next, resulting marginal price estimates and aggregate market price of lake recreation and aesthetics are presented. The marginal value of water for varying lake levels is estimated. Finally, some implications for lake management are presented in addition to other conclusions. This study takes steps toward rounding out the small body of literature on recreational and aesthetic lake value.

Hedonic Price Theory and Application

"Hedonic prices are defined as the implicit prices of attributes and are revealed to economic agents from observed prices of differentiated products and the specific amounts of characteristics associated with them" (Rosen, p. 34). Thus, the nonmarket, implicit price of each characteristic is imbedded in the price of the composite good. This is especially true of goods that have some public good characteristics. Air quality, for example, is the focus of the classic hedonic study by Harrison and Rubinfeld.

A hedonic price equation may be represented as where P_x is the price of composite good, X; and Z_i is a vector of individual characteristics of the good. The first partial derivative of P_x with respect to Z_i is the marginal price of the characteristic. Marginal prices for individual components of composite goods or services are of interest for the relative contribution made to the composite price of the good, even when it is not possible to examine nonmarginal changes in price for lack of a demand function. For example, Pope and Stoll use the hedonic price equation to discover which components of a hunting lease are most important.

Selection of an appropriate functional form is the subject of several analyses (Bender, Gronberg, and Hwang; Halvorsen and Pollakowski; Milon, Gressel, and Mulkey). "A hedonic price equation is a reduced-form equation reflecting both supply and demand influences. Therefore, the appropriate functional form. . . cannot, in general, be specified on theoretical grounds" (Halvorsen and Pollakowski, p. 37). Studies comparing goodness of fit and measures of error often reject the traditional functional forms in favor of Box-Cox transformations (Cropper, Deck, and McConnell; Goodman; Halvorsen and Pollakowski). Cropper, Deck, and McConnell also show the linear Box-Cox to be more robust than the quadratic Box-Cox. Although there is, in general, no a priori expectation of the functional form of the hedonic function, there may be a priori reasons to expect it to have a negative second derivative with respect to some characteristics (Freeman). For example, as the number of heated square feet in a house becomes larger, the marginal price should decline, ceteris paribus. Housing characteristics examined here should also reflect this trend.

Demand studies for various housing characteristics, including water recreation, have been performed. Witte, Sumka, and Erekson apply the Rosen model to estimate supply and demand of housing attributes in four nonmetropolitan cities. Palmquist implements the Brown and Rosen model to estimate demand for several important housing characteristics in seven standard metropolitan statistical areas. Useful recreational studies pertaining to lakes (Brown and Pollakowski; David; McConnell) and coastal waters (Milon, Gressel, and Mulkey; Wilman) help guide the current work.

Procedures

The hedonic model used in this study is specified as a linear Box-Cox transformation. Its general form is given by:

$$(1)\qquad \frac{Y^{\lambda}-1}{\lambda}=B_0+\sum_{i=1}^{k}B_i\frac{X_i^{\theta}-1}{\theta}+\sum_{j=1}^{m}\delta_j D_j+\varepsilon,$$

where λ and θ are Box-Cox transformation parameters to be estimated; B_0, B_i, and δ_j are parameter estimates; ε is the residual; Y is the selling price of a residence; the X_i are nonnegative, continuous variables; and the D_j are dummy variables or discretely measured characteristics of housing. ε is assumed to be normally distributed with mean, zero, and variance, σ^2.

Using iterative ordinary least squares (IOLS), a computer program (SAS Proc Matrix) performs a grid search over specified ranges of λ and θ to find the maximum likelihood estimator (Ozuna). The computational ease of IOLS is offset by the underestimate of the true standard errors of the *B*s (Spitzer). This problem is circumvented by using the Hessian of second-order conditions to obtain consistent estimates of the true, unconditional covariance matrix (Ozuna, p. 30; Spitzer). This solution also provides the true standard errors of λ and θ allowing valid hypothesis testing by *t*-tests. The nonlinear functional form causes marginal prices to depend upon every independent variable. The marginal prices of X_j are given by:

$$(2)\qquad \frac{\partial Y}{\partial X_i}=\frac{1}{\lambda}[\lambda(B_0+\sum_{i=1}^{k}B_i\frac{X_i^{\theta}-1}{\theta}+\sum_{j=1}^{m}\delta_j D_j)+1]^{\frac{1}{\lambda}-1}\lambda B_i X_i^{\theta-1}.$$

Although this nonlinear form makes interpretation more cumbersome, it may also supply more accurate marginal price estimates.

Following estimation of the hedonic price model and marginal prices of characteristics, the total market price of RA amenities is estimated using the estimated hedonic price model and the Travis County Appraisal District inventory of single-family dwellings within the study area. Since RA value is directly related to proximity to the lake, the RA price component of each residence may be determined by estimating the total market price of the residence with and without RA benefits. The difference between the two is the RA price component of the residence. Estimating the price of a home, absent the RA benefits, is accomplished by increasing the "distance-to-lake" variable (*LDIST*) to that distance at which the characteristic, distance to lake, is no longer important ($LDIST_{max}$). This is the distance at which homeowners no longer attribute any value to their proximity to the lake. They are simply too far away to feel they gain any appreciable RA benefit. The estimated hedonic price equation is used to estimate the market price at $LDIST_{actual}$ and again at

$LDIST_{max}$. The difference between (1), the status quo market price at $LDIST_{actual}$, and (2), the estimated market price of an otherwise identical home located at $LDIST_{max}$ provides a market price estimate of the RA benefits to that home. (Lake level and view characteristics are held constant.)[1] Previous work (Dornbusch and Barrager; Brown and Pollakowski; Milon, Gressel, and Mulkey) and conversation with local Travis County officials and appraisers (Corey; Welcome; Nuckles) indicate a potential range for $LDIST_{max}$ of a few hundred feet to 4,000 feet.

Finally, if water level has a significant affect on housing price, it is possible to measure the marginal value of lake water to surrounding homeowners. The following is a new approach not found in the literature. A positively signed, significant regression coefficient on lake level implies that larger sale prices are directly attributable to RA benefits provided by the additional lake water. Since the quantity of water at varying lake levels is known and the aggregate price of housing may be computed at alternative lake levels, the marginal value of water may be estimated. The study analysis is restricted to lake levels at the sample mean (667 feet), plus approximately one and two standard deviations above and below the mean. The aggregate market price of all houses within $LDIST_{max}$ of Lake Travis is estimated for lake levels of 679, 673, 667, 661, and 655 feet. To estimate marginal changes in RA value, the aggregate housing price is estimated again for lake level corresponding to 680, 674, 668, 662, and 656 feet, each of these being a one-foot increase in lake level with respect to the first set of levels. The difference in aggregate price at each level, divided by the change in quantity of lake water at each level, provides an estimate of the marginal RA value per acre-foot. These marginal value estimates are capitalized values of water for RA use by the homeowners. Using an appropriate discount rate, an estimate is made of the annual marginal value.

Sample Data

A fully specified hedonic pricing model for housing includes all the important characteristics of that housing—physical characteristics, as well as, neighborhood and environmental characteristics of the area must be considered. Selection of variables included was based on conversations with realtors, real estate appraisers, and ad valorem tax appraisers, plus personal inspection of the area. The primary source of data on sales of single-family residences and the characteristics of those residences is the Travis Central Appraisal District (TCAD).[2] These sales data were supplemented with information provided by an Austin, Texas, realty and appraisal company.[3] Elevation of lakefront properties was obtained from deed records in the Travis County Courthouse. Water level of the lake at the time of sale was obtained from the Lower Colorado River Authority (LCRAb). Sales information for all residential sales, from waterfront homes to homes a mile away (and in some instances up to two and one-half miles) from the lake, for January 1988 through December 1990, are included in the data set.

Many physical and financial variables were considered. Pretesting of the model, including variables such as house age, number of baths, various other interior and exterior features,

[1] Lake view is not considered since the data are unavailable to differentiate lake views from other views for all homes.

[2] Travis Central Appraisal District is responsible for recording all property transactions within Travis County. Therefore, it has a comprehensive list of residential sales.

[3] At the time of data collection, TCAD had not completed recording sales data for the last four months of 1990. Therefore, Appraisal Builders Realty (ABR) provided additional sales for these months. ABR has access to all sales information sources such as realtors' multiple listing service.

type of financing, interest rate, and cove location, led to deletion of several potential variables. Several caused collinearity problems with other variables. Some had insignificant parameter estimates and added virtually no explanatory power to the model. This may be attributed to the relatively homogeneous nature of the sample properties in terms of features. Finally, terms of financing available in TCAD records are of insufficient detail to be useful.

Descriptive Statistics

Five hundred ninety-three sales are included in the data set. Twenty-seven variables are listed and defined in table 1. Month of sale is numbered sequentially from 1 for January 1988 to 36 for December 1990. Table 2 shows the average time of sale as April 1989 (*TIME* = 16.61). Square feet of living area (*IMPSF*) and sale price (*SPRICE*) vary over a relatively large range. Most of the sampled houses are in average physical condition (*ACON*) with some being superior (*HCON*) and others below average (*LCON*). According to TCAD, few residences show any obsolescence (*PCNTGOOD* = 0.99). Forty homes are on the waterfront. Waterfront homes are grouped by elevation of the property line adjacent to the lake. Properties at an elevation of 715 feet mean sea level (msl) are designated *WFHIGH*. Properties extending below 670 feet in elevation are designated *WFLOW*. *WFMED* designates observations lying between 670 and 715 feet msl. The long-term average lake level (*LEVEL*) is 673 feet. Hence, *WFHIGH* properties (≥ 715 msl) have limited direct access.

Many of the 593 residences have a scenic view (*LVIEW* or *OVIEW*). Ninety-two observations have lake views and 27 others have views of the countryside but not the lake. The average distance (*LDIST*) to the lake is about 3,700 feet and the distance to the central business district (*CDIST*) ranges approximately from ten to twenty miles (table 2). *LDUM4* is a slope dummy variable intended to capture any change in slope of the hedonic function beginning at 4,000 feet from the lake.

Sales are divided among three school districts: Lago Vista (*LVISD*), Lake Travis (*LTISD*), and Leander Independent School Districts (*LISD*). Sixty-nine percent of the sales are located within municipalities (*CITY*) with 52% of these located in the Village of Lakeway (*VOLW*).

Finally, lake-level deviation (*LLDEV*) indicates the difference between the water level at the time the parties agreed to a sale price and the long-term average water level. (*LLDEV* equals the average level of the three months prior to sale minus the long-term average lake level.) Three months was selected because it is representative of the time period lapsed between beginning the search for a home and the sale (closing) date. Lake Travis is a flood control lake, and as such, its water level (*LEVEL*) is quite variable. Table 2 shows a mean level of 667 feet above sea level and standard deviation of seven feet. The range in level is 22 feet.

Results

Estimated Hedonic Price Function

The estimated hedonic price function for housing around Lake Travis fits the data well (table 3). Using the log-likelihood function value (LLF), the likelihood ratio test indicates the estimated transformation parameters ($\lambda = 0.22$ and $\theta = 0.77$) differ significantly from the log-log ($\lambda = 0$, $\theta = 0$) and semi-log ($\lambda = 0$, $\theta = 1$) forms. Thus, it is inappropriate to reduce this nonlinear function to a simpler, traditional form. More than one-half of the parameter

Table 1. Variable Names and Definitions

Variable	Definition
TIME	Month of sale; January 1988–December 1990; numbered 1–36
SPRICE	Sale price
IMPSF	Improved area square feet or heated area (excluding garage and porches, etc.)
GARAGS	Garage spaces: 1, 2, 3, or 4
CPORTS	Carport spaces: 1, 2, 3, or 4
FRONTFT	Linear feet of street frontage
CQUAL	Construction quality; ratings range: 1 (poorest) to 7 (best)
HCON	High condition: houses in excellent condition (near new)
ACON	Average condition: houses in average condition
LCON	Low condition: houses in poor condition (poorly maintained)
PCNTGOOD	Percent good: 1.00 minus any functional or economic obsolescence found by TCAD
WATFRT	Waterfront: value = 1 for waterfront property; zero otherwise
BLUFF	Bluff location: value = 1 for waterfront property on bluff; zero otherwise
VIEW	Scenic view: value = 1 for scenic view; zero otherwise
LDIST	Lake distance: feet from property to lake
LDUM4	Lake distance dummy variable: *LDIST* < 4,000 feet, value = 0.1; otherwise = *LDIST*
CDIST	Central city distance: feet from property to downtown Austin
LTISD	Lake Travis Independent School District
LISD	Leander Independent School District
LVISD	Lago Vista Independent School District
CITY	City location indicator: value = 1 for property within city; zero otherwise
VOLW	Village of Lakeway
COJT	City of Jonestown
COLV	City of Lago Vista
GOLF	Property located on golf course fairway: value = 1; zero otherwise
LLDEV	Lake-level deviation; deviation from average water level at time of sale

estimates are significant at the 0.05 level. Furthermore, the signs on the parameters are as expected.

Zarembka shows that the Box-Cox procedure is not robust with respect to heteroskedasticity. Attempts to estimate unbiased coefficients with a weighted least-squares routine developed by Ozuna failed to converge.

The Harvey and Breusch-Pagan and Godfrey tests reject the null hypothesis of homoskedasticity. White's heteroskedasticity consistent covariance matrix is used to estimate standard errors. Through this mechanism standard errors are adjusted, but the parameter estimates are unchanged. Table 3 shows the adjusted standard errors. All parameter estimates reflecting RA value except one are significant at the level (waterfront location, lake distance, and view coefficients) (table 3). The coefficient on *LLDEV* (lake level) is significant at $\alpha = 0.10$.

Table 2. Descriptive Statistics of Sample Residences Located on and around Lake Travis

Variable	Mean	Standard Deviation	Variable	Mean	Standard Deviation
TIME	16.61	8.350	*OVIEW*	0.046	0.209
SPRICE[a]	125.320	85.091	*LDIST*[a]	3.715	3.182
IMPSF[a]	2.169	0.790	*LDUM4*[a]	2.879	3.715
GARAGS	1.783	1.065	*CDIST*[a]	84.540	11.308
CPORTS	0.283	0.745	*LISD*	0.164	0.370
FRONTFT	95.58	38.38	*LVISD*	0.147	0.354
CQUAL	4.64	0.75	*LTISD*	0.690	0.463
HCON	0.008	0.092	*CITY*	0.690	0.463
ACON	0.966	0.181	*VOLW*	0.516	0.500
LCON	0.025	0.157	*COJT*	0.051	0.219
PCNTGOOD	0.994	0.034	*COLV*	0.123	0.329
WFHIGH	0.017	0.129	*GOLF*	0.125	0.331
WFMED	0.032	0.176	*LLDEV*	– 6.225	6.207
WFLOW	0.019	0.135	*LEVEL*	666.70	7.00
LVIEW	0.155	0.362			

[a]Expressed in thousands ('000).

Waterfront location is hypothesized to be of considerable value since it offers immediate access to the lake. The variability of Lake Travis's water level, combined with the variability in deeded property elevation, lead to the hypothesis that these waterfront properties may increase in value with decreasing lot elevation. Yet the coefficient on *WFMED* is larger than the coefficients for *WFHIGH* and *WFLOW* (table 3). One reason may be that *WFLOW* properties are partially submerged during part of each year making them less desirable. Without more detailed study of the characteristics of waterfront properties (and perhaps a larger number of waterfront sales), it is impossible to definitively explain the relative size of the waterfront coefficients.

Scenic view (*LVIEW* and *OVIEW*) also reflects RA value. Parameter estimates for both "lake" view and "other" view are significant at the 95% level (table 3). Further study is needed to determine whether lake view is more desirable than other scenic views.

Distance from the lake (*LDIST*) reflects RA value. *LDIST* is negatively signed, indicating the expected inverse relationship between RA value and distance to the lake. The positively signed lake distance dummy variable (*LDUM4*) indicates that housing prices continue to diminish at distances greater than 4,000 feet but at a greatly reduced rate. That is, the proximity to water has little influence on homes beyond this distance.

Lake-level deviation from the long-term average level (*LLDEV*) is the final housing characteristic reflecting a portion of the RA value of lake area housing (table 3). Buyers are willing to pay higher prices for higher lake levels, presumably due to greater accessibility and greater aesthetic value when the lake level is up.

Table 3. Estimated Hedonic Price Function for Lake Travis with Box-Cox Model

Independent Variable	Coefficient	Standard Error	Independent Variable	Coefficient	Standard Error
WFHIGH	1.3582[b]	0.26967	*GOLF*	0.17654[a]	0.10351
WFMED	1.5564[b]	0.20971	*OBSOL*	1.6423[a]	0.95704
WFLOW	1.2940[b]	0.26047	*LLDEV*	0.01655[a]	0.00870
LVIEW	0.32251[b]	0.09236	*IMPSF*	0.20305[a]	0.01221
OVIEW	0.30542[b]	0.15375	*CDIST*	– 0.01041[b]	0.00203
LTISD	0.19092[a]	0.11596	*LDIST*	– 0.03130[c]	0.00805
LISD	– 0.23515	0.15787	*CQUAL*	0.85076[b]	0.09863
CITY	– 0.02180	0.08381	*TIME*	– 0.00965	0.01188
HCON	0.44594	0.34918	*FRONTFT*	0.06652[b]	0.01593
LCON	0.11443	0.22732	*LDUM4*	0.02230[b]	0.00608
GARAGS	0.17981[b]	0.04009	*CONSTANT*	3.4663[b]	1.15760
CPORTS	0.11620[b]	0.05047			
λ	0.22	0.00137			
θ	0.77	0.00			
LLF[c]	– 2,825.17				
adj R^2	0.7855				
F[d]	99.55				

[a]Denotes significance at the $\alpha = 0.10$ level.
[b]Denotes significance at the $\alpha = 0.05$ level.
[c]LLF denotes log-likelihood function value.
[d]Null hypothesis.

Well-informed buyers and sellers in a competitive market would not be expected to be affected by normal fluctuations in lake level. It is well known that Lake Travis varies throughout the year. The water level generally rises in the spring and early summer, followed by decreasing level through the remainder of the summer as downstream irrigation increases. Fall rains sometimes raise the water level following the summer draw down. However, there does not appear to be any clear seasonal pattern (Lansford, pp. 151–54). Since sale price does vary with water level, does this imply that buyers are uninformed? It seems unlikely that local buyers are uninformed. However, Travis County has a dynamic economy with many people moving into and out of the area. Real estate practitioners report incidences of out-of-town buyers paying substantially higher prices for real estate than the normal market level.

Home buyers may also be influenced more by what they see than what they know. That is, even an informed buyer may be influenced by the appearance of the property and the neighborhood at the time the contract is signed. If the lake is relatively low, lakefront properties look less appealing compared with times when the lake is at its normal level. A broad, barren shoreline strewn with the debris that is normally covered with water has a negative influence on many consumers. Likewise, even those planning to purchase a home away from the waterfront may be negatively influenced by such a view of the shore, especially if the subdivision has a common property park, boat ramp, or marina which they intend to use.

In summary, all estimated coefficients for variables affecting RA value are significant and perhaps the most interesting is the significance of lake-level deviation. The meaning of these results becomes clearer when the resulting marginal prices are examined.

Marginal Price Estimates

Marginal prices are the implicit prices of individual housing characteristics obtained from the first partial derivatives of the hedonic price function with respect to each characteristic (5). To simplify analysis, discussion is focused on marginal prices of a typical (hypothetical) residence. The marginal price estimates shown in table 4 are for a typical 2,200 square-foot house with a two-car garage on a 100 front-foot lot inside a municipality. The house is of construction quality level five, has no obsolescence, and is in average condition. The time of sale is December 1990. The house (described in table 4) is 84,500 feet from downtown Austin, is located in the Lake Travis Independent School District (*LTISD*), and is 2,000 feet from the lake. (Marginal values for *WFHIGH*, *WFMED*, and *WFLOW* in table 4 are estimated at $LDIST = 1$.)

Local realtors estimated the premium for a house on the waterfront typically ranges from $60,000 to $100,000. The model's estimate of premium paid for waterfront property—$79,000 to $102,000—conforms to the expected range. It was expected that waterfront lots extending to lower elevations would reflect higher prices. As discussed earlier, the model provides mixed results and does not confirm the original hypothesis.

A key component of recreational lake value is proximity to the lake. Recreational value declines at the rate of $6.19 per foot at $LDIST = 2{,}000$ feet (table 4). The marginal price of proximity falls at a decreasing rate throughout the range. At the waterfront the marginal price is about $56 per foot but declines rapidly to $12 per foot at 150 feet and becomes $5.41 per foot at a distance of 3,000 feet. There is little change beyond approximately 2,000 feet, ceteris paribus.

Total Market Price of Residential Recreational Benefits

Inspection of the marginal prices of *LDIST* from the model suggests that somewhere between 1,000 and 4,000 feet from the lake, home buyers cease paying for "proximity" to the lake. That is, beyond some point, the distance-to-lake characteristic is of no consequence to buyers. Based on the literature cited earlier and the estimated marginal prices, a distance of 2,000 feet was selected for $LDIST_{max}$. The marginal price of proximity changes little beyond this distance. In fact, if a distance a few hundred feet more or less is chosen, the following results change very little.

Estimated total market price of recreational benefits is $49,164,089 (table 5). Approximately 3,672 single-family residences located within 2,000 feet of the shore have an average RA price of $13,389. On average, RA price is estimated to be 15% of the current location price. Further investigation shows that within 2,000 feet of Lake Travis, 75% of the estimated RA market price is captured in the price of waterfront properties. Eighteen percent of the affected residences are on the water. By way of contrast, for residences located 1,001 to

Table 4. Estimated Marginal Values of Housing Characteristics for Residences in Proximity to Lake Travis

Characteristic	Marginal Value ($)	Characteristic	Marginal Value ($)
WFHIGH	84,545	*GOLF*	6,953/lot
WFMED	101,635	*LLDEV*	652/foot
WFLOW	79,297	*CDIST*	– 0.87/foot
LVIEW	12,702	*LDIST*	– 6.19/foot
OVIEW	12,029	*CQUAL*	23,141/increment
CITY	– 859	*TIME*	– 167/month
GARAGS	7,082/space	*FRONTFT*	154.27/foot
CPORTS	4,577/space	*IMPSF*	39.28/sq.ft.

2,000 feet from the water's edge, the percentage of sale price attributable to RA price is only 6%.

Estimating Marginal RA Value

Water level (*LLDEV*) having a significant affect on housing prices allows measuring the marginal value of lake water to surrounding homeowners. The estimated total market price of all houses within 2,000 feet of Lake Travis for each of five pairs of lake levels is presented in table 6. The marginal RA value per acre-foot and a confidence interval is also presented for each pair. The indicated marginal values of RA benefits appear to be reasonable. The decline in marginal price from $136 per acre-foot to $110 per acre-foot as the water level increases may be attributed to diminishing marginal returns and the increasing capacity of the lake at higher elevations.

These marginal prices of Lake Travis RA benefits are generally smaller than the marginal value product of water used in municipal, industrial, and many agricultural uses. The marginal price estimates presented in table 6 are the capitalized value of homeowners' perceived future benefits, precluding direct comparison to annual marginal value products (MVPs) of water use. Chang and Griffin, however, report water purchases by municipalities in the lower Rio Grande valley of Texas. These market transactions are at prices of $500 to $600 per acre-foot. Chang and Griffin also estimate the net present value (NPV) of water in cotton production in the same region.[4] Depending upon the price and yield of cotton, NPVs of water range from $306.58 to $2,336.29 per acre-foot under one scenario and from –$72.41 to $1,600.60 per acre-foot under a second. Hence, a comparison with their analysis suggests that the marginal price of water in RA use is lower than that in municipal use and may also be less than that in cotton production depending upon the set of variables and assumptions used.

Because estimates of the marginal value of water are often expressed in terms of annual amounts, comparison can be facilitated by restating the capitalized marginal value estimates presented in table 6. Discount rates of 2, 4, 6, 8, and 10% and time periods of 10, 30, and 50 years provide a matrix of annualized marginal RA values ranging from $3.69 to $20.99 per acre-foot for water levels one standard deviation above and below the sample mean (table

[4]The net present value computations are based on a fifty-year period and 6% discount rate.

Table 5. Marginal Value of Recreational and Aesthetic Uses for Lake Travis Residences within 2,000 Feet of the Lake

Variable	N	Mean Price ($)	Standard Deviation ($)	Max. Value ($)	Min. Value ($)	Sum of RA[a] Market Prices ($)
Current location	3,672	87,964	62,777	596,592	5,566	323,003,316
At 2,000 feet	3,672	74,575	52,691	539,349	5,516	273,839,227
Estimated RA[a] price	3,672	13,389	24,127	189,110	0	49,164,089

[a] Recreational and aesthetic

Table 6. Estimated Marginal Value of Water in Recreational and Aesthetic Use Reflected in Housing Values around lake Travis

	Lake Level (Feet)	Predicted Aggregate Housing Price ($)	Volume of Water in Lake Travis (Acre-Feet)	Price ($/Ac.-Ft.)	95% Confidence Interval ($/Ac.-Ft.)
	680	348,813,660	1,151,854		
	679	346,771,842	1,133,289		
Change:		2,041,818	18,565	109.98	−15.69 to 235.65
	674	336,704,899	1,044,154		
	673	334,719,713	1,027,044		
Change:		1,985,186	17,110	116.02	−13.29 to 245.34
	668	324,933,028	944,914		
	667	323,003,316	929,151		
Change:		1,929,712	15,763	122.42	−10.54 to 255.38
	662	313,491,130	853,473		
	661	311,615,747	838,940		
Change:		1,875,383	14,533	129.04	−7.38 to 265.46
	656	302,372,374	769,088		
	655	300,550,189	755,648		
Change:		1,822,185	13,440	135.58	−3.77 to 274.93

Table 7. Estimated Annual Marginal RA Values per Acre-Foot for Selected Periods of Time and Discount Rates

	Standard Deviations from Mean Sample Water Level ($)					
Discount	50 Years		30 Years		10 Years	
Rate	+1	-1	+1	-1	+1	-1
2	3.69	4.11	5.18	5.76	12.91	14.36
4	5.40	6.00	6.71	7.46	14.30	15.90
6	7.36	8.18	8.43	9.37	15.76	17.53
8	9.48	10.54	10.30	11.46	17.29	19.22
10	11.70	13.01	12.31	13.68	18.88	90.99

7).[5] Gibbons cites several studies of annual marginal value product of water in crop production throughout the United States. The MVPs per acre-foot range from less than $15 per acre-foot for grain sorghum in New Mexico to $698 per acre-foot for potatoes in Idaho. Water in cotton and corn production is indicated to have MVPs of $56 to $129 per acre-foot for cotton and $52 to $57 per acre-foot for corn.

In summary, the annual MVPs of water in municipal and agricultural uses generally exceed the recreational and aesthetic MVPs found here. Yet the RA benefits examined in this study do not reflect all recreational and aesthetic use of the lake. A complete assessment of recreational and aesthetic value includes the value to persons traveling to the lake from remote areas plus the value of the lake to those who may never visit the lake but place value on the benefits offered (option and existence values). Thus, a proper comparison of marginal value among water uses requires the addition of other components of recreational and aesthetic value to the housing RA component estimated in this study.

Implications for Lake-Level Management

Since it is a stated goal of LCRA to give due weight to all demands upon the water it manages, LCRA managers should be aware of the affect of water allocation decisions. The average-size Lake Travis residence (2,200 square feet) located on the waterfront is estimated to be worth $6,800 more if the lake is at its long-term average level rather than six feet below normal at the time of sale. For the majority of waterfront residences, prices are $3,200 to $8,000 higher under this scenario. Hence, a relatively small change in water level is indicated to be worth thousands of dollars per home. Higher lake level results in greater demand, not only for lakefront properties, but also for those within relatively close proximity. In other words, keeping the water level an average of six feet higher would add thousands of dollars in RA benefits to lakefront homes and hundreds, if not thousands, to each home within reasonable proximity. This assertion is validated by estimating the coefficient on lake-level

[5]The range of discount rates and time periods gives consideration to both private and social rates and similar variance in the projected lifetime of RA Benefits.

deviation while excluding lakefront properties and finding continued statistical significance.[6]

Furthermore, it is reasonable to believe that water management to reduce the range of fluctuation in water level would result in larger market values due to greater RA benefits. Water-level fluctuations exceeding 20 feet per year require docks and marinas designed for extremes. "Waterfront" lots with insufficient depth of property rights occasionally become "land-locked" lots when the water level falls below the property line. Maintaining a higher average level and reducing the range of fluctuation are actions that will increase RA lake value.

Therefore, the results presented in table 5 imply that maintaining higher water levels in Lake Travis adds value to homes surrounding the lake. If this is true, individual property owners and local officials interested in economic growth will likely want more water kept in Lake Travis. Homeowners seek to maximize their benefits in terms of RA returns and housing value. Local officials realize that greater local wealth tends to stimulate the local economy. Likewise, they realize that greater property values provide a larger tax base.

Conversely, it is likely that downstream users will object to such action. Downstream users may use the same or similar arguments for maintaining the volume of river flow. LCRA, as manager of these waters, will need to weigh the benefits and costs of water-level policy for the entire region. In the same way that government policies, such as zoning, affect private property values, LCRA can positively or negatively affect the residential property values both around the lakes and downstream.

If past trends continue, residential development will continue and will have the effect of adding to total RA value around Lake Travis. As more land is converted to commercial and residential use, the demand for water for RA use is expected to increase.

Summary and Conclusions

The hedonic price approach is used to estimate the implicit price of recreational and aesthetic benefits. The estimated residential price equation indicates several statistically significant characteristics of housing, among which are distance to the lake, scenic view, waterfront location, and water level. Analysis of marginal values indicates that proximity to the lake is the most important component of recreational and aesthetic value. Waterfront properties command a premium price for the private access they offer for enjoyment of public lake waters. Beyond the waterfront, the marginal recreational and aesthetic price falls rapidly with increasing distance. An aggregation of RA prices for all homes within 2,000 feet of the lake indicates 75% of total RA price resides in lakefront property and composes 15% of the total market price of housing.

Consumer preference for higher water levels is indicated by the significant, positive relationship with sale prices. This finding allows estimation of homeowners' marginal RA value of lake water. The marginal RA value estimates ranged from $110 to $136 per acre-foot, depending on lake level.

The study has several limitations. It considers one of several lakes and many miles of river flow. It is limited to RA value expressed by homeowners. It is limited by the assumptions and constraints of the Box-Cox model selected. And, finally, the method, rather

[6]Another question is possible correlation between seasons and lake level. Testing with seasonal dummy variables shows no significant relationship (Lansford, pp. 151–54).

than the results, are transferable. These limitations indicate ample room for further research.

This hedonic price analysis of Lake Travis leads to several conclusions. First, variation in lake level affects RA value; this is reflected in corresponding variation in price of housing. Hence, lake management practices influence housing prices and RA benefits.

Second, there are probably two lake management factors at work here—degree of variability and normal water level. Less variability over time and relatively higher water level are both of value to homeowners. Higher water level implies greater RA value within a certain range. Note again the finding of diminishing marginal value of water. Homeowners generally seem to desire a higher, more stable water level but do not want water in their homes.

Third, the estimated range of RA marginal value product of water is similar to, but generally less than, MVP of water in cited agricultural uses. However, as lake water level falls, the marginal value of RA use rises. At some point, optimal water allocation in the Colorado River system will require trade-offs among current uses. As RA demand increases with increasing population and development, more pressure will be placed on the Lower Colorado River Authority to retain relatively higher water level in Lake Travis and decrease water-level variability.

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References

Bender, B., T. Gronberg, and H-S. Hwang. "Choice of Functional Form and the Demand for Air Quality." *Rev. Econ. Statis.* 62(1980):638–43.

Box, G., and D. Cox. "An Analysis of Transformations." *J. Royal Statis. Soc.* Ser. B 26(1964):211–43.

Breusch, T. S., and A. R. Pagan. "A Simple Test for Heteroskedasticity and Random Coefficient Variation." *Econometrica* 47(1979):1287–294.

Brown, G. M., and H. O. Pollakowski. "Economic Valuation of Shoreline." *Rev. Econ. Statis.* 59(1977):272–78.

Brown, J. N., and H. S. Rosen. "On the Estimation of Structural Hedonic Price Models." *Econometrica* 50(1982):765–68.

Chang, C., and R. C. Griffin. "Economic Evaluation of Water Marketing: Agricultural Costs and Municipal Benefits in the Lower Rio Grande Valley." Paper presented at the Southwest Economics Association meeting, San Antonio TX, March 1991.

Corey, A., Chief Appraiser, Travis Central Appraisal District, Austin TX. Personal communication, 1991.

Cropper, M. L., L. B. Deck, and K. E. McConnell. "On the Choice of Functional Form for Hedonic Price Functions." *Rev. Econ. Statis.* 70(1988):668–75.

David, E. L. "Lakeshore Property Values: A Guide to Public Investment in Recreation." *Water Resour. Res.* 4(1968):697–707.

Dornbusch, D. M., and S. M. Barrager. "Benefit of Water Pollution Control on Property Values." EPA-600/5-73-005, U.S. Environmental Protection Agency, Washington DC, October 1973.

Freeman, M., III. *The Benefits of Environmental Improvement.* Baltimore MD:John Hopkins University Press for Resources for the Future, 1979.

Gibbons, D. C. *The Economic Value of Water.* Washington DC: John Hopkins University Press for Resources for the Future, 1987.

Godfrey, L. G. "Testing for Multiplicative Heteroskedasticity." *J. Econometrics* 8(1978):227–36.

Goodman, A. C. "Hedonic Prices, Price Indices, and Housing Markets." *J. Urban Econ.* 5(1978):471–84.

Griliches, Z. "Introduction: Hedonic Price Indexes Revisited." *Price Indexes and Quality Change.* Cambridge MA:Harvard University Press, 1971.

Halvorsen, R., and H. O. Pollakowski. "Choice of Functional Form for Hedonic Price Equations." *J. Urban Econ.* 10(1981):37–49.

Harrison, D., Jr., and D. L. Rubinfeld. "Hedonic Housing Prices and the Demand for Clean Air." *J. Environ. Econ. and Manage.* 5(1978):81–102.

Harvey, A. C. "Estimating Regression Models with Multiplicative Heteroscedasticity." *Econometrica* 44(1976):461–65.

Hoehn, J. P., and D. Krieger. "The Hedonic Housing Approach." *Review of Techniques for Weighing or Valuing the Benefits Associated with Environmental Quality Improvements—Economics*, pp. 68–89. Proj. Rep. Contract No. OSE84-00321, submitted to Scientific Authority of the International Joint Commission, March 1986.

Lansford, N. H, Jr. "Recreational and Aesthetic Value of Lakes Reflected by Housing Prices: An Hedonic Approach." Publ. Ph.D. diss., Dept. of Agri. Econ., Texas A&M University, 1991.

Lower Colorado River Authority (LCRAa). Water Management Plan for the Lower Colorado River, Volume I, Policy and Operations, Austin TX, n.d.

———. (LCRAb). Lake Travis Average Elevations, Austin TX, n.d.

McConnell, K. E. "Double Counting in Hedonic and Travel Cost Models." *Land Econ.* 66(1990):121–27.

Milon, J. W., J. Gressel, and D. Mulkey. "Hedonic Amenity Valuation and Functional Form Specification." *Land Econ.* 60(1984):378–87.

Nuckles, J. Director of Real Property Appraisal, Travis Central Appraisal District, Austin TX. Personal communication, 1991.

Ozuna, T., Jr. "Functional Form and Welfare Measures in Truncated Recreation Demand Models." Publ. Ph.D. diss., Dept. of Agri. Econ., Texas A&M University, 1989.

Palmquist, R. B. "Estimating the Demand for the Characteristics of Housing." *Rev. Econ. Statis.* 66(1984):394–404.

Pope, C. A., III, and J. R. Stoll. "The Market Value of Ingress Rights for White-Tailed Deer Hunting in Texas." *S. J. Agr. Econ.* 17(1985):177–82.

Rosen, S. "Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition." *J. Polit. Econ.* 82(1974):34–55.

Spitzer, J. J. "Variance Estimates in Models with the Box-Cox Transformation: Implications for Estimation and Hypothesis Testing." *Rev. Econ. Statis.* 66(1984):645–52.

Welcome, P. Deputy Chief Appraiser, Travis Central Appraisal District, Austin TX. Personal communication, 1991.

White, H. "A Heteroskedasticity-Consistent Covariance Matrix Estimator and a Direct Test for Heteroskedasticity." *Econometrica* 48(1980):817–38.

Wilman, E. A. "Hedonic Prices and Beach Recreational Values." *Advances in Applied Microeconomics* 1(1981): 77–103.

Witte, A. D., H. J. Sumka, and H. Erekson. "An Estimate of a Structural Hedonic Price Model of the Housing Market: An Application of Rosen's Theory of Implicit Markets." *Econometrica* 47(1979):1151–173.

Zarembka, P., ed. *Economic Theory and Mathematical Economics*. New York: Academic Press, 1974.