Land Use Conflicts in the Coastal Zone: An Approach for the Analysis of the Opportunity Costs of Protecting Coastal Resources

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The implicit price (hedonic) equation for the housing market in a coastal town in southern Rhode Island was estimated using a conditional Box-Cox maximum likelihood procedure. Linear, log-linear, and semi-log functional forms were rejected with 95% confidence. Estimates of marginal implicit prices for water related attributes (view of, frontage on, and proximity to a coastal salt water pond) derived from these rejected models were quite different from those determined from the optimal functional form. This result has important ramifications for public policy, as is shown in an example, since these attributes were found to be highly valued in the housing market.

The management of coastal resources presents a formidable challenge to states and local governments because various uses of the water, shoreline, and lands in the coastal zone are often mutually exclusive. Increasingly, attention has been focused on the conflicts between wetlands preservation and residential development. At least four states (Connecticut, Delaware, New York and North Carolina) have experienced deterioration in the quality of their coastal resources because of sewage leachate associated with residential development (Olsen *et al*. 1982a).

The town of South Kingstown in Southern Rhode Island is presently developing strategies to protect the amenities and environmental services associated with water quality and open space in and around its coastal salt water ponds (hereafter, salt ponds). Currently, more than 70 percent of the land around the salt ponds area is undeveloped. Of the underdeveloped land, 51 percent is prime agricultural land and the remainder consists of wetlands and other open space. Most of the undeveloped land is zoned for residential use.

Although there appears to be an abundance of open space around the salt ponds, rapid residential development in the area has resulted in extensive research on the quality of the salt ponds ecosystems. The Coastal Resources Management Council recently warned that a continuation in recent development trends would eliminate the remaining open space in the salt ponds area within 20 years. Other studies suggest that the quality of ground and surface waters will be adversely affected by residential development.

While there is evidence supporting the need to limit development in the salt pond region, the town expects to encounter resistance because affordable public policy instruments could impose significant costs on current owners of undeveloped land as well as households that would be excluded from residing in the region.[1]

The purpose of this paper is to demonstrate that estimates of the marginal implicit prices for pond-related amenities and services are sensitive to the functional form of the hedonic equation. As a result, estimates of opportunity costs at the margin for potentially excluded households will vary widely. In the following section we discuss the hedonic technique and the procedures for selecting an optimal functional form in light of recent advances in this

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[1] The impact of land use policies which limit development is not limited to opportunity costs for excluded households. Other effects include changes in the values of existing houses, property tax burdens, tax rates, and demand for public services, as well as the benefits of maintaining a potable water supply and pond quality.

field. The results from several estimated hedonic equations are presented in the third section. These results are used in Section IV to derive marginal implicit price equations. Policy implications of these corresponding cost estimates are discussed in the concluding section of the paper.

The Hedonic Technique

The general theoretical framework for the hedonic analysis of multi-attribute products such as housing was developed by Rosen. This technique is used to estimate a hedonic, or implicit price, function which traces the locus of equilibrium points between bid and offer schedules for demanders and suppliers of residential housing. The methodology assumes that consumers maximize utility, producers maximize profits, and the housing market is in short run competitive equilibrium.

The implicit price function can be generalized as:

(1) $P_{h_i} = P_h (S_{i1}, \ldots, S_{ij}, L_{i1}, \ldots, L_{ik}, Q_{i1}, \ldots, Q_{im})$

where P_{h_i} = price of the i^{th} property (and is assumed to be the discounted value),
S_{ij} = vector of site (structural and physical) attributes,
L_{ik} = vector of locational and neighborhood attributes, and
Q_{im} = vector of environment attributes.

The marginal implicit price function of an attribute is found by differentiating the implicit price equation with respect to the attribute. It is interpreted as the marginal benefit (cost) of obtaining (losing) one more unit of the attribute, *ceteris paribus*. For the case when all households have identical incomes and preferences, the marginal implicit price function is also the inverse demand curve for the attribute (Freeman).

Economic theory provides little guidance for selecting the "best" functional form of the hedonic equation (Rosen 1974). Most writers reject a linear specification because constant marginal implicit prices of all attributes would suggest that consumers have the ability to arbitrage bundles of attributes and that the marginal costs of supplying attributes are constant. Several nonlinear specifications are consistent with the inability to arbitrage and with increasing short run marginal costs for producers. Nevertheless, the selection of any one functional form (e.g., log or semi-log) has often been somewhat arbitrary.

Given the limitations of economic theory, some have argued for a statistical criterion whereby the functional form which yields the best fit is selected (Rosen). Others have added that if a statistical selection process is to be used the model should be flexible enough to accommodate functional forms that yield marginal implicit price equations with positive, negative, or constant slopes, and which are concave or convex. Halvorsen and Pollakowski reported on a conditional Box-Cox maximum likelihood procedure for estimating hedonic price equations which satisfies these criteria:

$$(2) \quad P_{h_i}^{(\theta)} = \alpha_0 + \sum_{i=1}^{m} \alpha_i Z_i^{(\lambda)} + (1/2) \sum_{j=1}^{m} \sum_{i=1}^{m} \gamma_{ij} Z_i^{(\lambda)} Z_j^{(\lambda)} + \epsilon_i$$

where $P^{(\theta)}$ = the sales price of the i^{th} unit and

$$(3a) \quad P^{(\theta)} = \begin{cases} (P^{\theta} - 1)/\theta & \text{if } \theta \neq 0 \\ \ln(P) & \text{if } \theta = 0, \end{cases}$$

and $Z_i^{(\lambda)}$ = the value of the i^{th} attribute and

$$(3b) \quad Z_i^{(\lambda)} = \begin{cases} (Z_i^{\lambda} - 1)/\lambda & \text{if } \lambda \neq 0 \\ \ln(Z_i) & \text{if } \lambda = 0, \end{cases}$$

Although their model yields many commonly used functional forms as special cases (e.g. $\theta = \lambda = \gamma_{ij} = 0$ for log-linear; $\theta = \lambda = 1$ and $\gamma_{ij} = 0$ for linear), computer costs to run the procedure can be exorbitant.[2] As a result, other studies which used the Box-Cox methodology have been restricted to iterations over the dependent variable with power transformations of right-hand-side variables set equal to 0 and 1 (Goodman; Linneman).

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[2] For example, a single iteration of the Box-Cox model involving 16 continuous variables (and, therefore, 136 squared and interaction variables) costs about $18 for our data set. The computational costs of running thousands of iterations as done by Halvorsen and Pollakowski (91,200) was prohibitive.

Estimation of the Hedonic Equation

Background

Several authors have investigated the specification of hedonic models. Lot size and structural characteristics of the house are included as explanatory variables in most hedonic studies. Li and Brown and Linneman underscored the need to include locational and neighborhood quality attributes in the specification and suggested that interaction variables may also be important.

Until recently, most of the work involving environmental quality attributes has focused on the impact of air pollution on housing values (Anderson and Crocker; Brookshire *et al.*; Harrison and Rubinfeld; Ridker and Henning). Researchers have only lately begun to investigate the relation between water quality and water-related amenities and property values.

Willis and Foster found that water quality improvements in two rivers in Massachusetts and Vermont did not significantly affect nearby housing values. They raised questions concerning the ability of households to perceive differences in water quality, especially when the water-related amenities are used only infrequently. Brown and Pollakowski, David, and Shabman and Bertelson reported that proximity to water and water views were more important determinants of property values in the housing markets they studied.

The salt ponds area in South Kingstown is situated near a number of water bodies which provide aesthetic and recreational services. The salt ponds are used for swimming, boating and recreational fishing. Nearby ocean beaches are visited by more than a million people each year. In addition, a number of properties afford views of the salt ponds or Block Island Sound, or are situated on these water bodies.

Clearly, many variables and combinations of variables (interaction terms) could be specified in the hedonic equation. However, a number of the variables such as living area and total rooms are likely to be collinear. Butler examined this issue and found that the explanatory power of his model was not reduced significantly when several collinear variables reflecting neighborhood quality were dropped. Nevertheless, while the omission of explanatory variables may reduce computational or data collection costs, one runs the risk of biasing estimates of marginal implicit prices for environmental quality attributes if the later are collinear with any of the excluded variables.

The Data Set

Information on 353 sales of single family houses in South Kingstown was collected for the years 1979, 1980, and 1981. Family sales were omitted from the data set. Sales price data were collected from the tax assessor's office. Data for physical characteristics of the house and land were obtained from the tax assessor's office and Multiple Listing Service records of real estate transactions. Locational characteristics were determined from a street map using a linear mileage recorder. Other property characteristics were determined using a variety of topographical and plat maps. A complete list of variables and their mean values is provided in Table 1.

Results

Estimations of the quadratic Box-Cox model (i.e. equation 2) for values of θ and λ between 0 and 1 (by 0.2) failed to yield credible results. Although the explanatory power of the estimated models tended to be high ($\bar{R}^2 > 0.79$), many of the signs of the estimated coefficients were counterintuitive, thereby precluding an analysis of marginal implicit prices. This problem was caused by severe multicollinearity created by the estimation procedure. A typical estimation with 16 explanatory variables involved 136 squared and interaction terms. Such computations increase the risk of creating nearly linear relationships between two variables or among a group of variables. It was not clear whether the problems that we encountered were peculiar to our data set or whether the procedure will be difficult to apply in general.[3]

As a result of these difficulties, the Halvorsen-Pollakowski model was abandoned in favor of a "linear" Box-Cox model which omits the second expression on the right hand side of equation 2.[4] At first iterations were

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[3] Halvorsen and Pollakowski obtained acceptable results for an application of their procedure. However, their data set included only seven variables (number of rooms, age, lot size and four indices reflecting neighborhood quality and employment accessibility). This may explain why multicollinearity was not a serious problem in their study.

[4] We did include a variable for age of the house-squared, though. We reasoned, *a priori*, that many of the old, historical houses could increase in value with age, *ceteris paribus*.

Table 1. Description and Mean Value of Variable

Variable	Definition	Mean
PRICE	market price adjusted to 1979 values with the national consumer's price index for homeowners	53188
LOTSIZE	lot size (square feet)	22559
WOODED	dummy variable for whether the property is within an overall wooded area; 1 = yes, 0 = no	0.43
MARSH	dummy variable for whether the property is within a marshy area; 1 = yes, 0 = no	0.03
VIEWSW	dummy variable for whether there is a water view of a salt pond or the oceans 1 = yes, 0 = no	0.11
VIEWFW	dummy variable for whether there is a water view of a fresh water pond or river; 1 = yes, 0 = no	0.05
SWFRONTAGE	length of water frontage along a salt pond of the ocean (feet)	150
FWFRONTAGE	length of water frontage along a fresh water pond or river (feet)	333
DBEACH	shortest distance along streets to nearest ocean beach (miles)	7.0
DSALTPOND	shortest distance to the nearest accessible salt pond	1.8
DURI	shortest distance along streets to the University of Rhode Island (miles)	5.9
DSHOP	shortest distance along streets to the major shopping district in town (miles)	5.0
DSCHOOL	shortest distance along streets to the nearest grammar school (miles)	2.5
DENSITY	population density in the area (numbers per square mile)	1138
SQFT	square footage of the house excluding the basement	1264
BATHRM	number of bathrooms including half-baths	1.4
FIREPL	number of fireplaces	0.4
AGE	age of the house (years)	24.5
AGESQ	age squared	1604
SWFTBASE	square footage of finished basement	88.0
SQFTGAR	square footage of garage	188
TIME	month the house sale was recorded. Values are 1 (Jan., 1979) to 36 (Dec., 1981)	18

performed for values of θ and λ ranging from -2 to 2 in intervals of one-tenth in order to close in on the optimal values for θ and λ. Then, increments of one-hundredth were used. The dummy variables MARSHY, WOODED, VIEWSW and VIEWFW entered as intercept shifters. The hedonic equation was also estimated in linear ($\theta = \lambda = 1$), log ($\theta = \lambda = 0$) and semi-log ($\theta = 0; \lambda = 1$) forms for comparisons.

The results of these estimations are summarized in Table 2. Nearly all of the signs of the estimated coefficients in each model were consistent with *a priori* expectations and significant at the 5% level (10 to 11 of the 20 coefficients were significant at the 1% level) and each model had good explanatory power ($\bar{R}^2 \geq 0.73$). The signs on coefficients for AGESW, DENSITY, DSCHOOL and DSHOP were unexpected for certain function forms. These results could be due to the high degree of multicollinearity or could reflect actual market behavior.

The results for the salt pond amenity variables are of particular interest in this analysis. The estimated coefficients on VIEWSW and SWFRONTAGE were positive and significant at the 1% level. Although the estimated coefficient on DSALTPOND also had the expected sign it was less significant. Pairwise correlations between DSALTPOND and the other variables did not suggest that high levels of collinearity were present. However, a regression of DSALTPOND against all other explanatory variables did reveal a significant linear relationship ($\bar{R}^2 = 0.78$), possibly accounting for the high standard error in the implicit price regressions. In this regression, coefficients on LOTSIZE, DBEACH, DURI, DSHOP, DSCHOOL, VIEWSW and WOODED were significant at the 1% level.

The Marginal Implicit Price Equations

The optimal values of θ and λ for the Box-Cox form were 0.32 and 0.66, respectively. The linear, log, and semi-log functional forms lie outside of the 95% confdience region associated with this optimal functional form (Figure 1). This result suggests that using any of the special case models to derive marginal implicit price equations would yield inaccurate estimates of opportunity costs.

The marginal implicit price equations for SWFRONTAGE and DSALTPOND calcu-

Table 2. Estimated Hedonic Equations

	Model							
	Linear		Log		Semi-Log		Box-Cox	
Variable	Coefficient	Standard Error	Coefficient	Standard Error	Coefficient	Standard Error	Coefficient	Stadard Error
Intercept	29003.8*	4186.2	8.43*	0.31	10.47*	0.08	89.59*	3.05
LOTSIZE	0.18*	0.03	0.086*	0.017	0.0000029*	0.0000006	0.0028*	0.00071
SQFT	5.80*	1.19	0.185*	0.031	0.00012*	0.00002	0.052*	0.009
BATHRM	10857.4*	1199.7	0.447*	0.055	0.176*	0.022	6.23*	0.89
AGE	−239.4*	36.5	−0.016	0.033	−0.005*	0.0006	−0.58*	0.10
AGESQ	0.82*	0.22	0.010	0.006	0.000016*	0.000004	0.012*	0.004
SQFTGAR	14.5*	2.61	0.013*	0.003	0.00022*	0.00005	0.046*	0.009
SQFTBASE	1.3	2.1	0.007***	0.004	0.000025	0.000038	0.010	0.008
FIREPL	3839.6*	792.7	0.12*	0.02	0.076*	0.014	1.80*	0.38
DENSITY	−0.11	0.70	0.006	0.012	−0.000005	0.000013	−0.003	0.005
DBEACH	−508.9**	279.1	−0.11*	0.03	−0.013**	0.005	−0.98*	0.30
DURI	380.1	410.7	−0.06**	0.03	−0.011	0.007	−0.53***	0.38
DSCHOOL	−574.1	469.2	−0.046	0.029	0.00054	0.00793	−0.25	0.40
DSHOP	−48.8	435.6	0.025	0.029	−0.012	0.009	−0.40	0.38
SWFRONT-AGE	111.3	13.1	0.052*	0.013	0.0011*	0.0002	0.19*	0.04
FWFRONT-AGE	28.3	26.6	0.013	0.016	0.00026	0.00048	0.05	0.07
VIEWSW	7238.5*	1617.7	0.11*	0.03	0.14*	0.03	3.25*	1.07
VIEWFW	1253.0	2512.7	0.030	0.045	0.021	0.046	1.29	1.60
DSALT-POND	−1008.2***	570.2	−0.028	0.030	−0.016	0.010	−0.40	0.45
WOODED	4140.8*	1292.7	0.079*	0.023	0.081*	0.024	2.68*	0.83
MARSH	−2443.4	3331.7	−0.04	0.06	−0.06	0.06	−4.07**	2.03
TIME	234.2*	47.3	0.077*	0.012	0.0050	0.0009	0.48*	0.08
$\bar{R}^2$	0.75		0.73		0.73		0.73	
observations	353		353		353		353	
(θ, λ)	(1, 1)		(0, 0)		(0, 1)		(0.32, 0.66)	

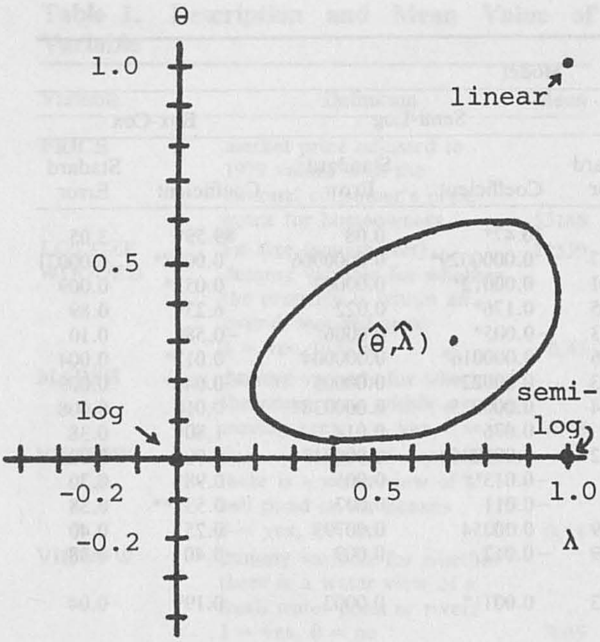
* Significant at the 1% level.
** Significant at the 5% level.
*** Significant at the 10% level.

lated from the Box-Cox model are plotted in Figure 2 for the values of these variables within the range of the data set. Since the Box-Cox model is multiplicative, the values of these functions depend on the values of all other attributes. The mean values of attributes for houses with frontage (Figure 2a) and for houses within one-half mile of a salt pond (Figure 2b) were used for these illustrations. Under these conditions, the marginal implicit benefits of salt pond frontage decrease from \$109/foot for 30 frontage feet to \$53/foot for 650 frontage feet. The marginal implicit costs of locating away from a salt pond decrease from \$1765/mile to \$802/mile for distances ranging from one-twentieth to one-half miles from a salt pond.

VIEWSW cannot be treated in a marginal analysis since it is a discrete variable. The contribution of a water view of a salt pond to the value of a house, *ceteris paribus*, can be directly estimated from the hedonic equation. The value of a water view is estimated to be \$5790 when there is no frontage and the values of all other attributes are once again given by the means for houses within one-half mile of a salt pond.

The marginal implicit prices for SWFRONTAGE, DSALTPOND, and VIEWSW can also be estimated for relevant transactions using the actual values of attributes in the housing bundles selected by households. In this case, the marginal benefits of frontage ranged from \$240/foot to \$737/foot, the marginal implicit costs of living up to one-half mile from a salt pond were \$971/mile to \$1951/mile, and the value of a view of a salt pond ranged from \$5940 to more than \$20,000 for houses with pond frontage.

The estimates of marginal implicit prices and the value of a water view calculated from the Box-Cox model can be compared with es-



Estimates of the optimal values for θ and λ (0.32, 0.66) and the 95% confidence region around this point. Positions for the linear, log, and semi-log models are indicated also.

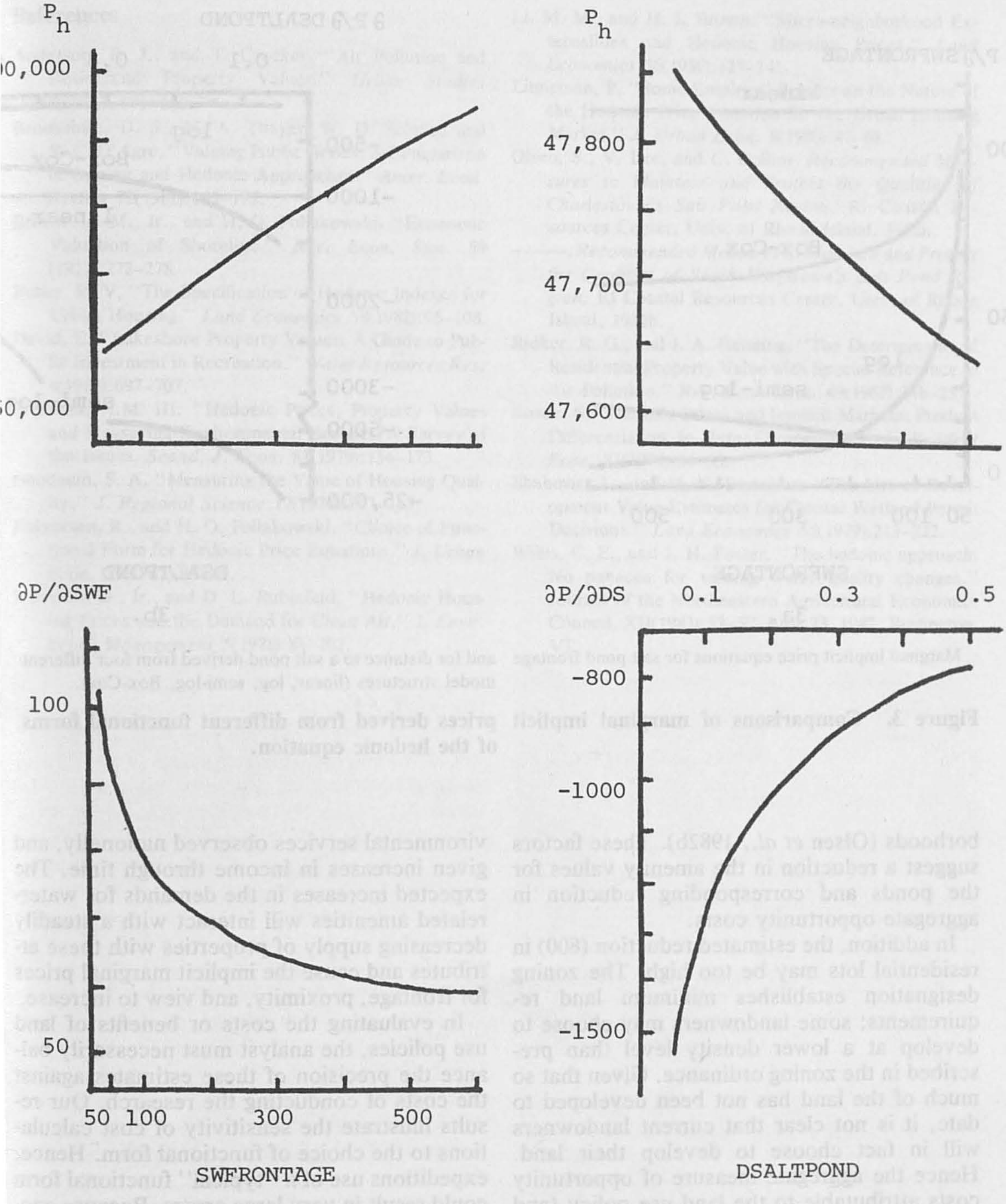
Figure 1. Functional form (with 95% confidence region) selected by the Box-Cox estimation procedure.

timates from the linear, log, and semi-log models rejected above (Figure 3). The implicit prices for the linear model are constant because attribute values enter additively. The shapes of the marginal implicit price equations derived from the log model were similar to those of the Box-Cox model. However, estimates of marginal implicit prices were relatively lower for the log form. In contrast, the equations derived from the semi-log model deviated strongly from the Box-Cox results within the range of values for SWFRONTAGE and DSALTPOND used here. The marginal benefits of frontage increased exponentially and the marginal costs of living outside the salt pond region were almost constant. Estimates of the value of a water view were considerably less for the log ($592) and semi-log ($20) specifications in comparison to the optimal or linear functional forms.

Policy Implications

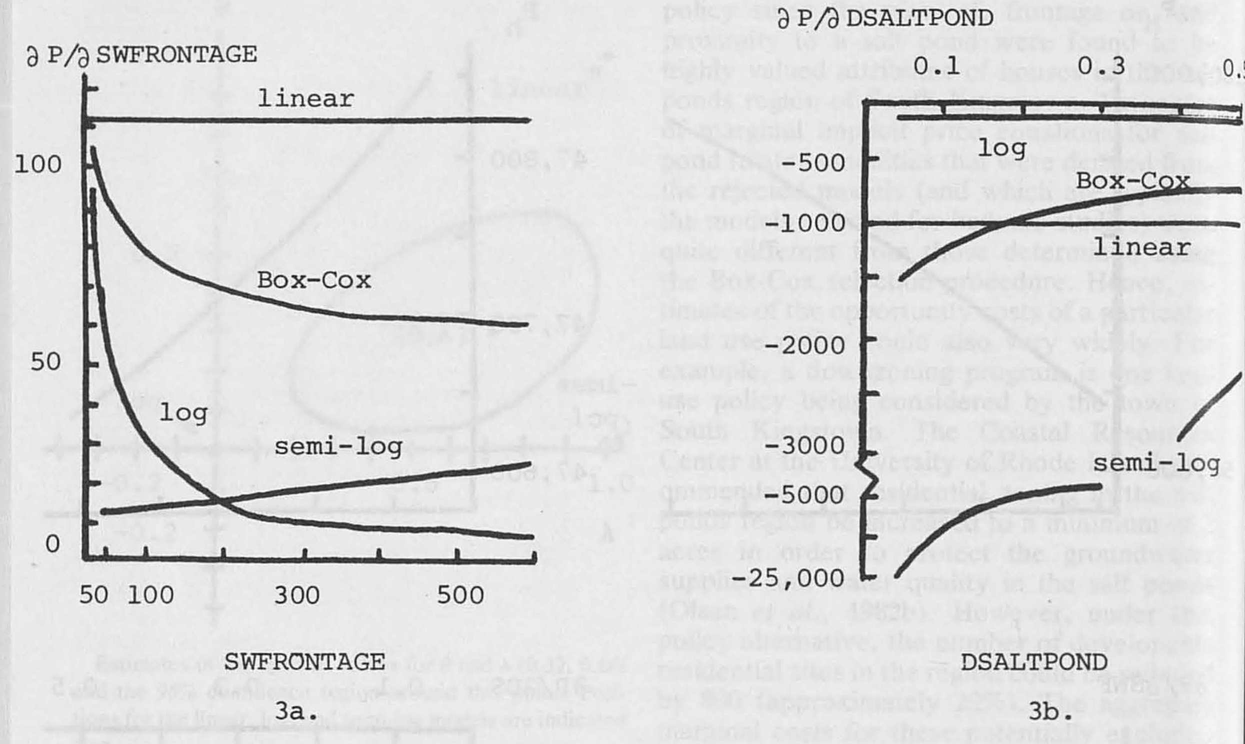
The choice of functional form for a hedonic model has important ramifications for public policy since the view of, frontage on, and proximity to a salt pond were found to be highly valued attributes of houses in the salt ponds region of South Kingstown. Estimates of marginal implicit price equations for salt pond related amenities that were derived from the rejected models (and which are typically the models selected for hedonic studies) were quite different from those determined using the Box-Cox selection procedure. Hence, estimates of the opportunity costs of a particular land use policy could also vary widely. For example, a downzoning program is one land use policy being considered by the town of South Kingstown. The Coastal Resources Center at the University of Rhode Island recommended that residential zoning in the salt ponds region be increased to a minimum of 2 acres in order to protect the groundwater supplies and water quality in the salt ponds (Olsen *et al.*, 1982b). However, under this policy alternative, the number of developable residential sites in the region could be reduced by 800 (approximately 22%). The aggregate marginal costs for these potentially excluded households can be estimated if it is assumed that households must alternatively locate in the northern section of the town. Under these conditions, the opportunity cost (defined as the difference between marginal implicit price of DSALTPOND for houses with average attribute levels in the salt ponds region versus the northern part of the town) is estimated to be $509. Hence, the aggregate marginal opportunity cost is approximately equal to $407,200 for all 800 households. The aggregate marginal opportunity costs estimated from the other models were $4,515,000 for the log model, $0 for the linear model, and −$55,200 for the semi-log model.

In calculating aggregate opportunity costs using the Box-Cox equation, a number of implicit and explicit assumptions are made. First of all, coefficients for individual attributes are derived from a 3-year sample. Hence it is assumed that the coefficients are invariant over an unspecified period of years. During the sample period, water quality has not changed significantly. However, new residential development as well as rapid conversions of summer homes to year-round residences will increase density and decrease water quality (sewage pollution from cesspools). A generally declining trend in water quality has been observed since 1950 for sections of the salt ponds adjacent to densely developed neigh-



Hedonic prices and marginal implicit prices for houses with different levels of salt pond frontage and at different distances from a salt pond, *ceteris paribus*.

Figure 2. Hedonic and marginal implicit prices corresponding to changes in frontage and distance to a salt pond.



Marginal implicit price equations for salt pond frontage and for distance to a salt pond derived from four different model structures (linear, log, semi-log, Box-Cox).

Figure 3. Comparisons of marginal implicit prices derived from different functional forms of the hedonic equation.

borhoods (Olsen *et al.*, 1982b). These factors suggest a reduction in the amenity values for the ponds and corresponding reduction in aggregate opportunity costs.

In addition, the estimated reduction (800) in residential lots may be too high. The zoning designation establishes minimum land requirements; some landowners may choose to develop at a lower density level than prescribed in the zoning ordinance. Given that so much of the land has not been developed to date, it is not clear that current landowners will in fact choose to develop their land. Hence the aggregate measure of opportunity costs attributable to the land use policy (and not to the decisions of current landowners) would be less.

On the other hand, the measure of opportunity costs could be an underestimate as well. It is not possible to predict by how much households' willingness to pay for water-related amenities will change through time. However, it is likely that willingness to pay will increase given changing preferences for consuming environmental services observed nationally, and given increases in income through time. The expected increases in the demands for water-related amenities will interact with a steadily decreasing supply of properties with these attributes and cause the implicit marginal prices for frontage, proximity, and view to increase.

In evaluating the costs or benefits of land use policies, the analyst must necessarily balance the precision of these estimates against the costs of conducting the research. Our results illustrate the sensitivity of cost calculations to the choice of functional form. Hence, expeditions use of a "typical" functional form could result in very large errors. Because economic theory provides so little guidance, the use of a search procedure such as the Box-Cox technique provides at least statistical rationale for selecting the best functional form. While the additional computational costs may be prohibitive for the Halvorsen-Pollakowski technique, the technique employed by Linneman and Goodman should be given consideration by analysts.

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