WESTERN REGIONAL RESEARCH PUBLICATION W-133

BENEFITS & COSTS IN NATURAL RESOURCES PLANNING

INTERIM REPORT

COMPILED BY

John B. Loomis
University of California, Davis
Davis, CA 95616

Under the procedure of cooperative publication, this regional report becomes, in effect, an identical publication of each of the participating experiment stations and agencies and is mailed under the indicia of each.

1 August 1988

VALUING RECREATIONAL SERVICES WITH QUALITY ADJUSTED PRICES

JOHN P. HOEHN
MICHIGAN STATE UNIVERSITY

AND

GIDEON FISHELSON
TEL AVIV UNIVERSITY

INTRODUCTION

The prospect of valuing environmental services through the demand for market goods is well established. Mäler identifies "weak complementarity" [(1974), p. 183] as the basic sufficient condition. Weak complementarity implies that (1) the environmental service of interest is enjoyed jointly with a market good and (2) the individual is indifferent to changes in the environmental service when the quantity demanded of the market good is zero. Independently, Bradford and Hildebrandt (1977) develop the weak complementarity concept for the case of multiple market goods.

A drawback of the weak complementarity approach is that it often requires a substantial data base. For example, given J prices and K environmental services, the weak complementarity approach requires variation across at least J + K parameters in order to estimate an appropriate demand function.[1] These data requirements make application difficult. Appropriate serial data appear to be virtually nonexistent; there are no widely recognized studies that have been able to use serial price and environmental variation to estimate the weak complementarity relation. Travel cost applications using spatial price and environmental variation are somewhat more common. Smith, Desvousges, and Fisher (1986) and Vaughn and Russell (1982) exemplify the use of the travel cost technique for valuing environmental quality.

In this paper, we suggest a new method for estimating the weak complementarity relationship. Using an argument first introduced by Fisher and Shell (1971), we reduce the dimensionality of the estimation problem by introducing the idea of quality adjusted prices. With quality adjusted prices, variation in environmental quality alone is sufficient for demand estimation.

The quality adjusted price method is applied to the valuation of site-specific viewing services at a major urban observation point, the Hancock Tower Observatory (HT) in Chicago, IL. The HT case is interesting for three reasons. First, admission prices are typically changed only once a year and visitation records are kept for only a few years at a time. Ordinary demand estimation procedures are therefore not feasible. Second, the ability to see the Chicago landscape varies with day to day changes in visual air quality. This variation in viewing services makes it possible to define a quality adjusted price with sufficent variation to estimate demand. Third, against a background of continuing regulatory interest in visual air quality [Bachman (1985)], the HT case provides an opportunity to estimate the value of visual air quality through the use of realized, rather than contingent, behavior.

The HT case demonstrates the feasibility of the quality adjusted price method. Price elasticities estimated on quality adjusted prices range from -1.055 to -1.090. Statistical tests find no significant difference between these estimates and the HT price elasticity of -1.146 estimated by a previous study using an ordinary demand approach and a different serial data set.

The quality adjusted price method indicates that a ten percent increase in visual air quality results in an site-specific increase of $56,000 to $69,000 per year in aggregate surplus. Elasticity estimates from the ordinary demand approach indicate an aggregate surplus of $71,000 for the same increase in quality.

WEAK COMPLEMENTARITY AND THE QUALITY ADJUSTED PRICE METHOD

The weak complementarity approach (WCA) values a change in environmental quality through the demand for a market good. An algebraic statement of the WCA clarifies both its conceptual and empirical requirements.

We begin with an individual that derives utility, u, from both market goods, $x \in R^J$, and environmental services, $s \in R^K$. The service indexes, s, are defined in an entirely general fashion and may include attributes of both market and nonmarket services. Given market prices, **p**, we can define an expenditure function, e(**p**,u;s) that is concave and increasing in **p**, and convex and decreasing in s.[2] At an initial set of prices, utility, and environmental services, the expenditure function is equal to an individual's initial income, m. The vector of income compensated or Hicksian demands is derived by differentiating e(•) with respect to **p**, $D_p e(\mathbf{p},u;s) = \mathbf{x}(\mathbf{p},u;s)$.[3]

Suppose that the ith market good, x_i, is weakly complementary to the ith quality index, s_i. Let $\mathbf{p}_{-i}$ and s_{-i} denote, respectively, the price and environmental service vectors with their ith elements, p_i and s_i, deleted. Let p_i^* be a price such that $x_i(p_i^*,\mathbf{p}_{-i},u;s) = 0$ for all s_i. The WCA requires that $e(p_i^*,\mathbf{p}_{-i},u;s_i,s_{-i})$ is a constant for all s_i [Small and Rosen (1981)].

If the requirements of the WCA are met, the Hicksian welfare measure for a change from an initial s_i^0 to a subsequent s_i^1 is

$$(1) \qquad hm(s_i^0, s_i^1) = \int_{p_i^0}^{p_i^*} [x_i(p_i,\mathbf{p}_{-i},u;s_i^1,s_{-i}) - x_i(p_i,\mathbf{p}_{-i},u;s_i^0,s_{-i})]dp_i$$

where p_i^0 is the initial price [Small and Rosen (1981)]. Equation (1) computes hm as the difference between the area under the demand for x_i evaluated at s_i^1 and the area under the demand for x_i evaluated at s_i^0. The quantity hm is a Hicksian compensating measure if u is the initial level of utility.

Because the Hicksian demands are not directly observable, an approximation of hm begins with an estimate of the Marshallian demand, $x_i(\mathbf{p},m;s)$.[4] A general estimate of $x_i(\mathbf{p},m;s)$ requires variation across x_i, **p**, m, and s -- across J + K + 2 dimensions. However, these data requirements can be reduced. For instance, if we assume that changes in p_i, m, and s_i are uncorrelated with changes in $\mathbf{p}_{-i}$ and s_{-i}, unbiased least squares estimates of the coefficients of p_i, m, and s_i in $x_i(\mathbf{p},m;\mathbf{s})$ can sometimes be obtained with variation in only three dimensions -- those involving p_i, s_i, and m. Data requirements can be reduced to variation in p_i and s_i alone if we assume that p_i and s_i are uncorrelated with changes in m. Unfortunately, there are many cases where even these last, rather limited data requirements may not be met. For instance, in the case of HT, p_i is virtually constant over long periods of time.

The quality adjusted price method (QAPM) is useful where existing variation in p_i or s_i is insufficient to estimate $x_i(\mathbf{p},m;\mathbf{s})$. The basic approach is to substitute a quality adjlisted price $\tilde{p}_i$ for p_i where $\tilde{p}_i$ is a function of both p_i and s_i.

The idea of a quality adjusted price is a general concept [Fisher and Shell (1971); Deaton and Muellbauer (1980)]. For instance, given a fixed s_i^0, it is always possible to find a price index $\hat{p}_i$ such that

(2) $$e(p_i,\mathbf{p}_{-i},u;s_i,\mathbf{s}_{-i}) = \hat{e}(\hat{p}_i,\mathbf{p},u;s_i^0,\mathbf{s}_{-i})$$

for any s_i [Deaton and Muellbauer (1980)]. In its most general form, $\hat{p}_i$ is a function of $\mathbf{p}$, $\mathbf{s}$, and u. Thus, in this general form, $\hat{p}_i$ does not help with the dimensionality problem.

Fisher and Shell show that the general form of $\hat{p}_i$ can be simplified if one assumes that $D_{s_i}\hat{p}_i$ is independent of the of $\mathbf{p}_{-i}$, $\mathbf{s}_{-i}$, and u. In this case, the quality adjusted price can be written as a simple function of p_i and s_i alone; specifically, $\tilde{p}_i = p_i/s_i$. Using $\tilde{p}_i$, the expenditure function is

(3) $$e(p_i,\mathbf{p}_{-i},u;s_i,\mathbf{s}_{-i}) = \tilde{e}(\tilde{p}_i,\mathbf{p}_{-i},u;\mathbf{s}_{-i})$$

and the ith compensated demand is

(4) $$x_i = x_i(p_i,\mathbf{p}_{-i},u;s_i,\mathbf{s}_{-i}) = g_i(\tilde{p}_i,\mathbf{p}_{-i},u;\mathbf{s}_{-i})/s_i$$

where $g_i = D_{\tilde{p}_i}\tilde{e}(\cdot)$ is the demand for total services, x_i times s_i, available through the purchase of x_i. In order to specify the demand for x_i, one focuses on specifying appropriate s_i and g_i.

Given an estimate of $g(\cdot)$, one can approximate equation using the Marshallian demand, $x_i(\cdot) = g(\cdot)/s_i$, in place of the Hicksian compensated demand, $x_i(\mathbf{p},u;s)$. This approximation is very close to the underlying hm if the income elasticity of demand or the budget share of $x_i(\cdot)$ is small [Willig (1976)].

Overall, the QAPM reduces two barriers to the estimation of x_i and hm. First, it reduces the overall dimensionality of the estimation problem by the number of environmental services that can be respecified in terms of quality adjusted prices. Second, where price variation is absent, the QAPM can be used to introduce quality adjusted price variation that may be sufficient for the estimation of a demand function.

THE DEMAND FOR VIEWING SERVICES AT HANCOCK TOWER

Hancock Tower (HT) provides an average of 350,000 visitors a year with an opportunity to view the Chicago landscape. Because the quality of the HT view varies with visual air quality, daily visitation at HT is positively correlated with changes in visual range -- the maximum distance at which objects can be seen against the horizon [Horvath (1981)]. The objective of our empirical research was to value changes in visual range at HT through the demand for HT admissions. Since HT admission prices were virtually constant during the year and a half for which we had data, aggregate demand was specified using the QAPM.

The HT demand relation may be viewed as a function of admission price, p_h, the prices of substitutes and complements, $\mathbf{p}_0$, and an index of view quality, s_h.[5] Climactic and weather variables, z, such as rain and snow may also affect HT demand due to their impact on the nonmonetary costs of a trip to downtown Chicago. Times series variables, $\mathbf{t}$, such as the season of the year and day of the week effects, may shift the demand function due to long term leisure plans and conventional labor contracts [Hoehn (1986)]. In log-linear form, the demand relation is

(5) $$x = A(p_h/s_h)^{-a}(p_{oi})^b \exp(\mathbf{z}\mathbf{c} + \mathbf{t}\mathbf{d} + e)/s_h$$

where A is a constant, e is a lognormally distributed error term, and each element of $\mathbf{p}_o$ would be entered in the same fashion as the price p_{oi}.[6] Because p_h is a constant, (5) reduces to

(6) $$x = B(s_h)^{a-1}(p_{oi})^b \exp(\mathbf{z}\mathbf{c} + \mathbf{t}\mathbf{d} + e)$$

where $B = A(p_h)^{-a}$ is a constant. Equation (6) contains no explicit HT admission price information -- yet it does contain information on the price elasticity of demand. Specifically, the exponent on the viewing services index, s_h, is the absolute value of the price elasticity, a, minus one.

Two different indexes of viewing quality, s_h, were used in empirically implementing equation (6). First, s_h was assumed to be equal to visual range, v. This first index was intended to account for the depth of the HT view. The second index was intended to account for depth, the breadth of a view, and the fact that similar objects at different distances from an observer may yield different viewing services. The second index measures overall viewing services,

(7) $$vs = \int_0^v 2\pi r \exp(-\tau r)dr = 2\pi[1 - (1 + \tau v)\exp(-\tau v)]/(\tau^2).$$

In (7), the term $2\pi r$ represents the potential to view objects in a circle of radius r about the tower. This circular effect takes into account the breadth of the HT view. The view along each circle is discounted at a rate τ using the term $\exp(-\tau r)$. To account for depth, the potential view at radius r is summed from 0 to the maximum distance at which objects can be seen, v.

Assuming that income effects are negligible for HT visitation, surplus estimates can be computed directly from an estimate of (6). Following equation (1), hm for a change from s_h^0 to s_h^1 is

$$hm(s_h^0, s_h^1) = [p_h^0/(a-1)][(x^1/x^0) - 1]x^0 \tag{8}$$

where p_h^0 is the price of admission to HT, x^1 is HT visitation at s_h^1, and x^0 is HT visitation at s_h^0. For the log-linear form, the calculation of surplus reduces to a simple formula: the average surplus obtained per visit -- p_h^0 divided by (a-1) -- times the percentage change in visitation brought about by the change in viewing quality times the initial level of visitation, x^0. Importantly, even if p_h is constant, (a-1), x^0, and x^1 can be obtained from an estimate of equation (8).

THE VALUE OF AN IMPROVEMENT IN VISUAL RANGE AT HANCOCK TOWER

The HT demand relation given in (6) was estimated using ordinary least squares and daily visitation data beginning on January 1, 1979 and ending on June 30, 1980. Ordinary least squares was appropriate since the supply of admissions could be viewed as perfectly elastic within the range of visitation. The estimated equations explained approximately 60 percent of the variation in visitation and coefficient estimates were consistent with intuition. Iterated least squares was used to select values of τ in the viewing services index. Values of τ between 0.10 and 0.12 maximized the explained variation in daily visitation and were selected as the best estimates of τ [Granger and Newbold (1976)].

Table 1 presents the estimates of (a-1) and the HT valuation results.[7] Results are given for both the QAPM analysis carried out in this paper and, in the fourth column, for a previous analysis [Hoehn (1986)] that used an ordinary demand approach and a different serial data set. We first review the QAPM results and then use the previous analysis as a point of comparison.

TABLE 1
HT Surplus Estimates Obtained from the Quality Adjusted Price Method and an Ordinary Demand Analysis[a]

Estimate	Quality Adjusted Price Method			Ordinary Demand Analysis[b]
	Visual Range	Visibility Services, τ = to 0.10	Visibility Services, τ = to 0.12	
1. Estimate of (a-1)	0.0904	0.0550	0.0565	0.1460[c]
2. Standard error	0.0189	0.0113	0.0117	0.415
3. t-statistic for the difference from the QAPM visual range estimate	-	1.50	1.47	0.41
4. t-statistic for the difference from the ordinary demand analysis estimate	0.41	0.67	0.66	-
5. Surplus per additional visit ($)[d]	18.5	30.4	29.6	15.0[e]
6. Change HT daily visitation for a for a 10% change in V	8.3	6.2	5.7	13.0
7. Total surplus induced by a 10% change in V ($ per day)	154	188	169	195[e]

a. Dollar values given at the 1980 price level.
b. Estimates are computed fron the results given in Hoehn (1986).
c. The estimate of (a-1) and its standard error are computed from results given in Hoehn (1986). Since the Hoehn regression estimated a demand equation that was exponential in admission price, an estimate of "a" was computed by taking the product of the Hoehn coefficient estimate, 0.533, and the average price of admission, 2.15, for the time period analyzed. The standard error estimate was computed by multiplying the standard error of the Hoehn coefficient by the average price of admission.
d. These estimates are corrected for the fact that the price elasticity is a random variable. The correction followed Mood, Graybill, and Boes [(1974), p. 180].
e. Computed using ordinary demand estimates and equation (8).

The first two rows of Table 1 report the QAPM estimates of (a-1) and the corresponding standard errors. Each coefficient estimate is significantly different from zero. The estimate of (a-1) for the visual range and extinction coefficient indexes is about 60 percent larger than the estimates obtained with the visibility services index. Since this variation has an impact on value estimates, the statistical significance of the difference between these estimates is of interest. As shown in the third row, these differences are statistically insignificant.

The fifth and sixth rows of Table 1 report value estimates and visitation changes for a ten percent change in visual range. The visual range index gives an average surplus of $18.5 per visit and a change in visitation of 8.3 persons per day. Taking the product of these terms as in equation (8), the total surplus estimate is $154 for a ten percent change in visual range.

For the viewing services index, the average surplus obtained from HT visitation is $30.4 per visit for τ equal to 0.10 and $29.4 per visit for τ equal to 0.12. Through equations (7) and (6), a ten percent change in visual range induces a change in visibility services and a concomitant change in visitation ranging from 6.2 persons for τ equal to 0.10 and 5.7 persons for τ equal to 0.12. The total surplus estimate for the visibility services equations ranges from $169 for τ equal to 0.10 to $188 for τ equal to 0.12.

The QAPM total surplus estimates range from $154 to $188 for a ten percent change in visual range. However, the visibility service indexes did provide a marginally better fit to the data. Thus, one would suspect that the true surplus measure lies in the upper portion of the estimated range.

Additional perspective on the QAPM estimates comes from comparing them with results of an ordinary demand analysis. Hoehn (1986) used admission price variation during the Spring of 1981 to estimate an ordinary demand function that was exponential in admission price. Column 4 of the first row of Table 1 gives the estimate of (a-1) computed from the demand parameters reported by Hoehn. The fourth row of Table 1 shows that the differences between the QAPM estimates and the ordinary demand estimate are not statistically significant. Thus, in terms of parameter estimation, the QAPM appears to perform at least as well as an ordinary demand analysis.

Surplus estimates computed using the QAPM compare very favorably with those obtained using the ordinary demand estimates. The fourth column of the fifth and seventh rows in Table 1 give surplus estimates that were computed using equation (8) and the demand parameters estimated by Hoehn. The ordinary demand estimate of average surplus of $15.0 is slightly less than the smallest QAPM estimate of $18.5. In terms of total surplus, however, the ordinary demand estimate of $195 is slightly larger than the largest QAPM estimate of $188. Given the order of magnitude criterion that is often used to compare the surplus estimates of different estimation methods [Cummings, et al., (1986)], the difference between the QAPM and ordinary demand estimates is negligible.

CONCLUSIONS

This paper presents a new method for estimating the weak complementarity relationship between market goods and environmental services. Derived from the work of Fisher and Shell, this quality adjusted price method (QAPM) permits the estimation of demand relations even where "nominal" price variation is nonexistent. The basic idea is to reduce both the price and environmental service dimensions into a single quality adjusted price index. Variation in either prices or environmental services alone is enough to introduce variation into this price index.

In the application to data from Hancock Tower, the QAPM performed at least as well as a previously reported ordinary demand analysis. Statistical tests showed no significant difference between the QAPM estimates and the ordinary demand estimates. The QAPM estimates indicate that a ten percent increase in visual range results in an annual increase of surplus at Hancock Tower ranging from $56,000 to $69,000. This range of surpluses compares favorably with the surplus estimate of $71,000 obtained using an ordinary demand analysis.

The QAPM provides an additional approach to estimating the value of environmental services. The QAPM relies on realized rather than intended behavior and may therefore provide past-choice corroboration for the values obtained from methods such as contingent valuation. As shown by the HT case, the QAPM yields demand estimates that are entirely comparable to those obtained with an ordinary demand approach.

REFERENCES

Bachman, John, ed. 1985. Developing Long-Term Strategies for Regional Haze: Findings and Recommendations of the Visibillty Task Force, USEPA, Research Triangle Park, NC.

Bergland, Olvar, and Alan Randall. 1985. "Exact Welfare Analysis with Quantity Rationing," ASSA meetings, New York, December 28-30, 1985.

Bradford, David F. and G. Hildebrandt. 1977. "Observable Public Good Preferences," Journal of Public Economics, 8:111-131.

Cummings, Ronald G., David S. Brookshire and William D. Schulze, eds. 1986. Valuing Environmental Goods, Rowman and Allanheld, Totowa, NJ.

Deaton, Angus and John Muellbauer. 1980. Economics and Consumer Behavior, Cambridge, New York.

Diamond, P.A. and D. McFadden. 1974. "Some Uses of the Expenditure Function in Public Finance," Journal of Public Finance, 3:3-22.

Fisher, F.M. and K. Shell. 1971. "Taste and Quality Change in the Pure Theory of the True Cost of Living Index," in Z. Griliches, ed., Price Indexes and Quality Change: Studies in New Methods of Measurement, Harvard, Cambridge, MA.

Granger, C. and P. Newbold. 1976. "R^2 and the Transformation of Regression Variables," Journal of Econometrics, 4:205-210.

Hoehn, John P. 1986. "Contingent Valuation and the Prospect of a Satisfactory Benefit Cost Indicator," paper presented at the First National Symposium on Social Science in Resource Management, Oregon State University, May 12-16, 1986.

Horvath, H. 1981. "Atmospheric Visibility," Atmospheric Environment, 15:1785-1795.

Mäler, Karl-Göran. 1974. Environmental Economics: A Theoretical Inquiry, Johns Hopkins, Baltimore.

Mood, Alexander M., Franklin A. Graybill, and Duane C. Boes. 1974. Introduction to the Theory of Statistics, McGraw-Hill, New York.

Small, Kenneth, and Harvey S. Rosen. 1981. "Applied Welfare Economics with Discrete Choice Models," Econometrica, 49:105-130.

Smith, V. Kerry, William H. Desvouges and Ann Fisher. 1986. "A Comparison of Direct and Indirect Methods for Estimating Environmental Benefits," American Journal of Agriculltural Economics, 68:280-290.

Vaughan, William J. and Clifford S. Russell. 1982. "Valuing a Fishing Day: An Application of a Systematic Varying Parameter Model," Land Economics, 58(4):450-463.

Willig, Robert D. 1976. "Consumers' Surplus Without Apology," American Economic Review, 66:589-597.

FOOTNOTES

1. Procedures for identifying demand may require additional data beyond that required for estimating the relation between quantities demanded, prices, and environmental services.
2. For a discussion of the derivation of the expenditure function, see Diamond and McFadden (1974) and Small and Rosen (1981).
3. The notation $D_y f(\mathbf{y})$ indicates the derivative of the function $f(\mathbf{y})$ with respect to $\mathbf{y}$.
4. A variety of procedures could be used to approximate equation (1). For instance, an approximation based on the results of Willig (1976) would involve three steps: (1) estimate the Marshallian demand, $x_i(\mathbf{p},m;s)$; (2) compute the Marshallian surpluses conditioned on s_i^0 and s_i^1, and (3) use the Willig procedures to transform the Marshallian measures to Hicksian measures. Bergland (1985) suggests an alternative exact procedure.
5. Income would ordinarily enter the demand specification. However, data on income is not available for HT visitors and aggregate income is relatively constant over the year and a half for which we have data. We therefore exclude income from the analysis and assume that income effects are negligible.
6. The model was actually developed and estimated with three functional forms: a log-linear form, a linear model, and an semi-log form. Using the R^2 criterion of Granger and Newbold (1976), the log-linear model provided the best fit. To meet the page requirements of a selected paper, we discuss only the best-fitting, log-linear form.
7. The estimated demand equations are available upon request.