EVALUATION OF THE ENVIRONMENT: A SURVEY OF REVEALED PREFERENCE TECHNIQUES

by

Ian Bateman

CSERGE Working Paper GEC 93-06

EVALUATION OF THE ENVIRONMENT:

A SURVEY OF REVEALED PREFERENCE TECHNIQUES

by

Ian Bateman

School of Environmental Sciences,
University of East Anglia
and
Associate Fellow,
Centre for Social and Economic
Research on the Global Environment,
University of East Anglia, Norwich
and
University College London

Acknowledgements

The Centre for Social and Economic Research on the Global Environment (CSERGE) is a designated research centre of the UK Economic and Social Research Council (ESRC).

The author is grateful to Ken Willis and Guy Garrod at the University of Newcastle upon Tyne, Ian Langford at the University of East Anglia and Professor Kerry Turner at CSERGE and Professor Robert Sugden at the University of East Anglia for comments regarding this paper. Errors remain the responsibility of the author.

ISSN 0967-8875

Abstract

This paper sets out to examine in detail the theoretical and methodological basis underpinning two revealed preference methods for valuing environmental preferences namely the travel cost method (TCM) and the hedonic pricing method (HPM). A guide to empirical application is provided together with analysis of relevant specific economic theory. Considerable emphasis is given to discussions of methodological problems arising from such application. A general conclusion is that both methods require a number of strong assumptions to hold if they are to produce valid welfare estimates.

Individuals' preference for and evaluations of environmental goods can, in some circumstances, be revealed via their purchases of certain marketed goods associated with the consumption of those environmental goods. Both the travel cost method (TCM) and hedonic pricing method (HPM) discussed in this paper adopt revealed preference approaches to environmental evaluation. The TCM estimates the recreational value of a recreation site by analysing the travel expenditures (petrol, etc.) of visitors to that site, while the HPM often uses variation in house prices to estimate the value of local environmental quality. Both techniques only capture use values and thereby omit any passive-use values associated with the environmental goods under investigation. As such these techniques may underestimate the total economic value of such goods. However use values will often be of prime importance (and acceptability) to decision makers and both of these evaluation techniques have been widely applied.

THE TRAVEL COST METHOD

Introduction

The original idea behind the travel cost method (TCM) can be traced back to a letter from Hotelling (first reported in Prewitt, 1949) to the Director of the US National Park Service in which he suggested that the costs incurred by visitors could be used to develop a measure of the recreation value of the sites visited. However it was Clawson (1959) and Clawson and Knetsch (1966) who first developed empirical models along these lines.

TCM is a survey technique. A questionnaire is prepared and administered to a sample of visitors at a site in order to ascertain their place of residence; necessary demographic and attitudinal information; frequency of visit to this and other sites; and trip information such as purposefulness, length, associated costs, etc. From this data, visit costs can be calculated and related, with other relevant factors, to visit frequency so that a demand relationship may be established. In the simplest case this demand function can then be used to estimate the recreation value of the whole site, while in more advanced studies, attempts can be made to develop demand equations for the differing attributes of recreation sites and values evaluated for these individual attributes.

THEORETICAL ISSUES

The demand function estimated by the TCM is an uncompensated ordinary demand curve incorporating income effects and the welfare measure obtained from it will be that of Marshallian consumer surplus.

The Method

In essence the TCM evaluates the recreational use value for a specific recreation site by relating demand for that site (measured as site visits) to its price (measured as the costs of a visit). A simple TCM model can be defined by a 'trip-generation function' (tgf) such as;

$$V = f(C,X) \qquad \text{EQN T.1}$$

where: V = visits to a site

C = visit costs

X = other socioeconomic variables which significantly explain V.

The literature can be divided into two basic variants of this model according to the particular definition of the dependent variable V. The 'Individual Travel Cost Method' (ITCM) simply defines the dependent variable as the number of site visits made by each visitor over a specific period, say one year. The 'Zonal Travel Cost Method' (ZTCM) on the other hand, partitions the entire area from which visitors originate into a set of visitor zones and then defines the dependent variable as the visitor rate (ie., the number of visits made from a particular zone in a period divided by the population of that zone).

The ZTCM approach redefines the tgf as;

$$V_{hj}/N_h = f\ (C_h,X_h) \qquad \text{EQN T.2}$$

where: V_{hj} = Visits from zone h to site j
N_h = Population of zone h
C_h = Visit costs from zone h to site j
X_h = Socioeconomic explanatory variables in zone h

The visitor rate, V_{hj}/N_h, is often calculated as visits per 1,000 population in zone h.

The underlying theory of the TCM is presented with reference to the zonal variant, and discussion of the differences between this and the individual variant is presented subsequently before consideration of more general issues.

The Zonal Travel Cost Method (ZTCM)

Discussion of the ZTCM is illustrated by reference to a constructed example detailed in Table T.1 which estimates the recreation value of a hypothetical site. The method proceeds as follows:

(i) Data on the number of visits made by households in a period (say annually) and their origin is collected via on-site surveys.

(ii) The area encompassing all visitor origins is subdivided into zones of increasing travel cost (column 1 of Table T.1) and the total population (number of households) in each zone noted (column 2).

(iii) Household visits per zone (column 3) is calculated by allocating sampled household visits to their relevant zone of origin.

(iv) The household average visit rate in each zone (column 4) is calculated by dividing the number of household visits in each zone (column 3) by the zonal population (number of households; column 2). Note that this will often not be a whole number and commonly less than one.

(v) The zonal average cost of a visit (column 5) is calculated with reference to the distance from the trip origin to the site.

(vi) A demand curve is then fitted relating the zonal average price of a trip (travel cost) to the zonal average number of visits per household. This curve estimates demand for the "whole recreation experience" rather than just the time spent on-site. In our hypothetical example this demand is explained purely by visit cost and the curve has the (unlikely) linear form given in EQN T.3.

$$V_{hj}/N_j = 1.3 - 0.3\ C_h \qquad \text{EQN T.3}$$

where: V_{hj}/N_j = visit rate (average number of visits per household) from each zone
C_h = visit costs from each zone

Figure T.1 illustrates this particular whole recreation experience demand curve. The estimation of this curve involves the implicit assumption that households in all distance zones react in a similar manner to visit costs. They would all make the same number of trips if faced with the same costs ie. they are assumed to have identical tastes regarding the site.

(vii) In each zone the household consumer surplus for all visits to the site (column 6) is calculated by integrating the demand curve (EQN T.3) between the price (cost) of visits actually made from each zone and that price at which the visitor rate would fall to zero (ie. the vertical intercept of the demand curve at point P in Figure T.1)[1]. Households in

[1]Several texts make the simplifying assumption that consumer surplus for the marginal user (here the most remote zone) is zero (Sinden and Worrell, 1979; Hufschmidt et al., 1983). This will typically lead to an underestimate of true consumer surplus.

zone 3 for example would have a consumer surplus equal to area ABP for all their trips to the site ie:

$$\text{Consumer surplus for zone } 3 = \int_{C_h=B}^{P} (1.3 - 0.3C_h).dC_h \qquad \text{EQN T.4}$$

(viii) In order that annual total consumer surplus for the whole recreation experience can be estimated in each zone, total household consumer surplus must firstly be divided by the zonal average number of visits made by each household to obtain the zonal average consumer surplus per household visit (column 7). This can then be multiplied by the zonal average number of visits per annum (column 3) to obtain annual zonal consumer surplus (column 8).

(ix) Cumulating annual zonal consumer surplus (column 8) across all zones gives our estimate of total consumer surplus per annum for the whole recreational experience of visiting the site.

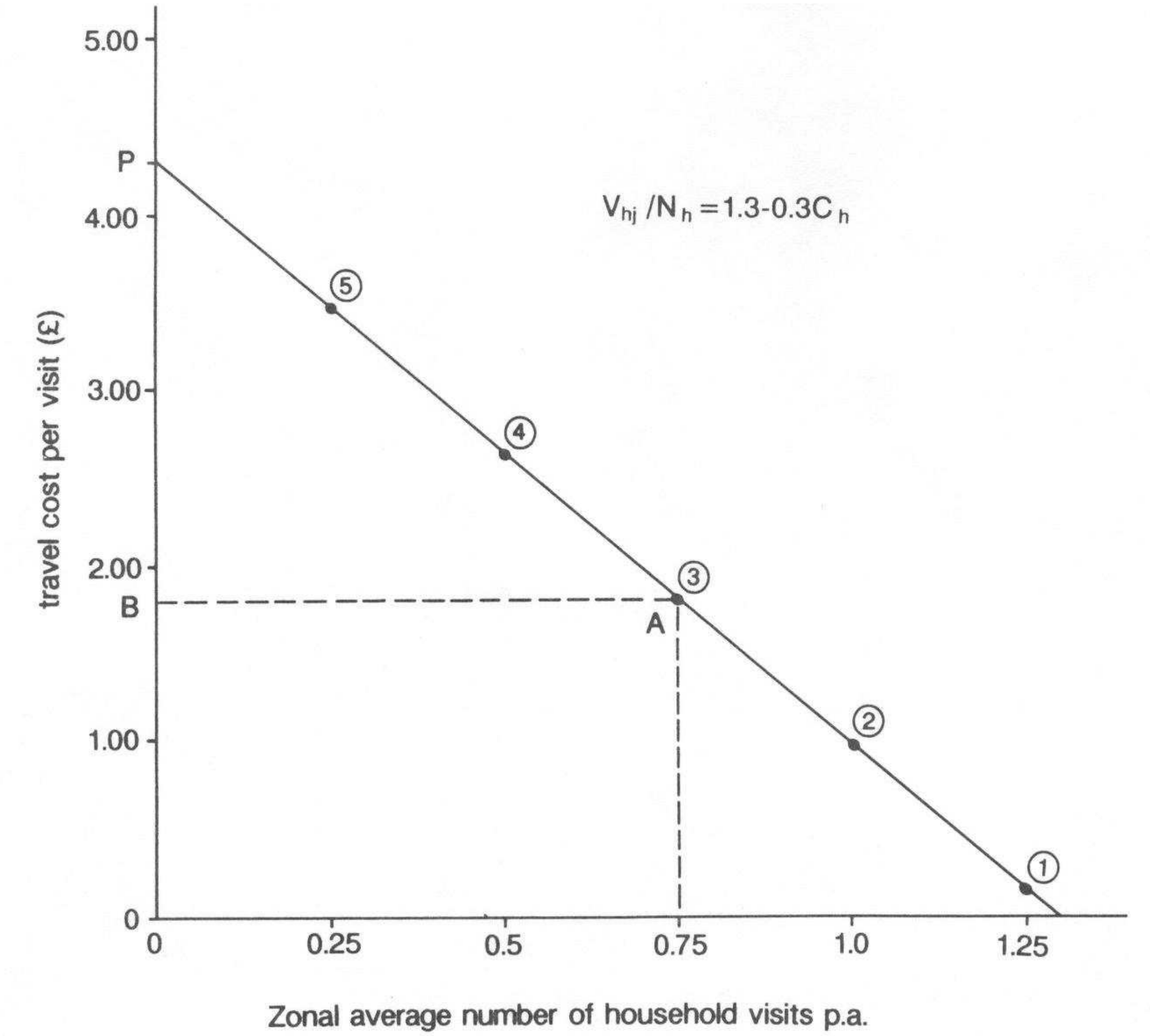
Table T.1: Consumer Surplus Estimates for the Whole Recreation Experience Using the ZTCM

	Zone No.	Zonal population (no. of households)[1] (N_h)	No. of household visits to site p.a.[2] (V_{nj})	Average no. of visits per household p.a.[3] (V_{nj}/N_h)	Average travel cost per household visit[4] (£) (C_h)	Consumer surplus per household all visits p.a. (£)	Consumer surplus per household per visit (£)	Total consumer surplus p.a. (£)
Column No.	1	2	3	4	5	6	7	8
	1	10,000	12,500	1.25	0.16	2.60	2.08	26,040
	2	30,000	30,000	1.00	1.00	1.67	1.67	50,100
	3	10,000	7,500	0.75	1.83	0.94	1.25	9,400
	4	5,000	2,500	0.50	2.66	0.42	0.84	2,100
	5	10,000	2,500	0.25	3.50	0.10	0.40	1,000
Total annual consumer surplus of the whole recreational experience = 88,000								

Notes: All figures rounded to 2 decimal places. Trip generating function $V_{hj}/N_h = 1.3\text{-}0.3C_h$.

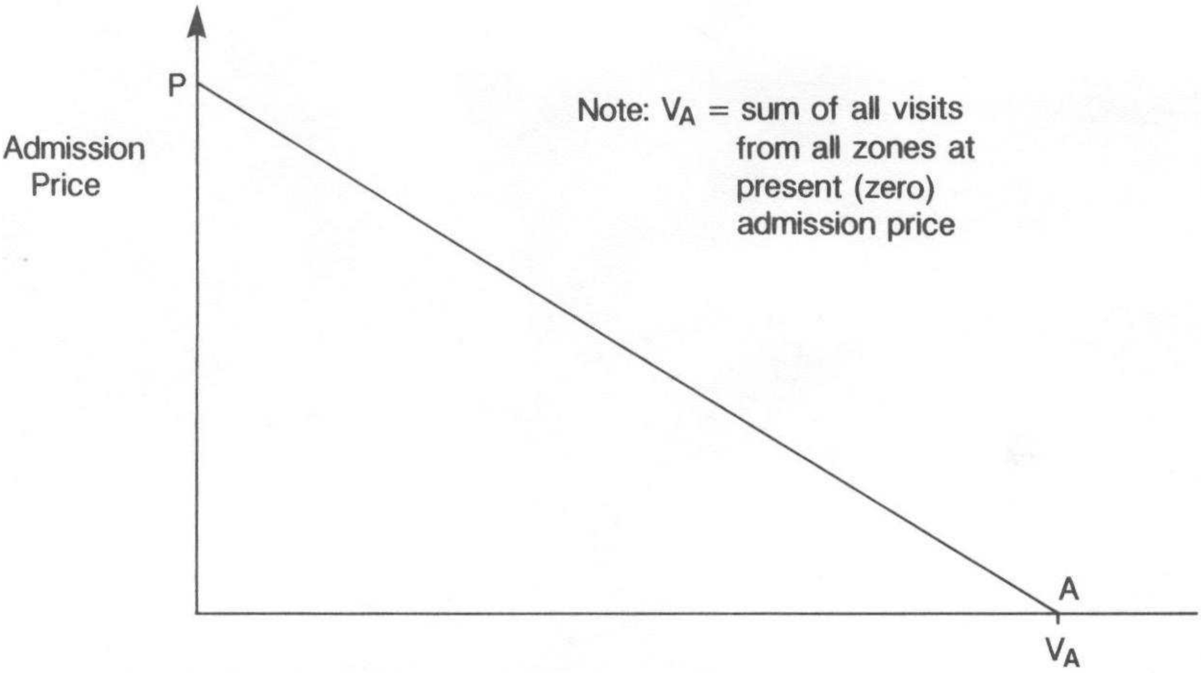
1. from census records.
2. from survey; annual totals derived by extrapolating from sample data according to available information regarding tourism rates.
3. column 4 = column 3/column 2.
4. either calculated with reference to zonal distance or via survey (see subsequent discussion re. travel costs).

Figure T.1: Demand Curve for the Whole Recreation Experience



One immediate problem with the above approach is that it yields value estimates for the whole recreational experience of the entire day trip to a (zero-priced) recreation site rather than an evaluation of the site alone. Freeman (1979) points out that the information gathered in a TCM survey only in fact defines one point on the demand curve for the on-site recreational experience. Many goods incur a travel cost for their consumption, but their price is set by the market. However the market price of recreation is zero therefore the sum of all visits across all zones represents the demand for on-site recreation with a zero admission price. This point is shown as point A in Figure T.2.

Figure T.2: Demand Curve for the On-Site Recreation Experience



In estimating consumer surplus for the on-site recreation experience, most texts (e.g. Sinden and Worrell, 1979; Hufschmidt et al., 1983) follow Clawson and Knetsch (1966) and estimate consumer surplus by first assuming that people would react to increases in admission price in the same way as they would react to increases in their travel costs ie. the demand curve function stays as estimated for the whole experience but each zones travel cost is increased by an incremental admission cost and visits from each zone re-calculated according to the estimated demand curve. Summing visits across all zones at each admission cost maps out the on-site experience demand curve. Integrating under this curve between the initial zero admission price and that admission price at which visits in all zones fall to zero estimates total consumer surplus for the on-site recreational experience. Table T.2 extends our previous hypothetical example to illustrate this approach, ie. by assuming that visitors react to admission fees in the same way as travel costs, we can use EQN T.3 to estimate the number of visitors at various admission fee levels as shown in Table T.2.

We can now plot admission fees against the total number of visitors from all zones at each fee level to obtain a demand curve for the on-site recreational experience as shown in Figure T.3. Consumer surplus estimates are obtained as usual by integrating under this curve between a zero admission price and that price at which the total number of annual household visits falls to zero. Applying this approach to our example gives an estimated annual consumer surplus for the on-site recreation experience of £90,500.

The on-site demand curve estimates the maximum amount which people would be willing to pay for the recreational use value of a site once they have paid the travel cost of getting to the site. The relative magnitudes of the on-site and whole experience consumer surplus sums will depend upon the shapes of the relevant demand curves. The more concave the whole-experience demand curve the larger the relative size of the on-site value. In the above example the whole-experience value is some 2% smaller than the (additional) on-site value, while in both the hypothetical example used by Sinden and Worrell (1979) and the real number experiments of Clawson and Knetsch (1966) this discrepancy was of the order of 5%. However this larger discrepancy is to be expected because both of these studies calculated the whole-experience values by assuming that the consumer surplus of marginal users (which in effect meant the entire most distant zone) was zero. This further reduced total whole-experience consumer surplus compared to on-site values for which such an assumption was not employed (on-site valuation utilised the entire area under the relevant demand curve).

The weak link in the Clawson-Knetsch approach to on-site valuation is the need to assume that individuals will react in the same way to admission fees as they do to travel costs[2]. If individuals have different willingness to pay for an environmental good because of the method of payment which is used then it is likely that the above TCM assumption may well be violated.

In practise many TCM studied have rejected the Clawson-Knetsch approach to on-site valuation, preferring modification of the whole-experience demand curve.

[2]The problems of vehicle bias, so often discussed with regard to the contingent valuation method (Bateman and Turner, 1992), are pertinent here.

Table T.2: Total Annual Visits to a Site at Various Admission Fee Amounts

Trip generating function: $V_{hj}/N_h = 1.3 - 0.3\, C_h$

where: V_{hj}/N_h = visit rate

C_h = total visit cost = travel cost (from Table T.1) + admission fee

		Admission fee = £0.00			Admission fee = £1.00			Admission fee = £2.00		
Zone	Zonal population	Total visit cost (£)	Visit rate	Number of visits	Total visit cost (£)	Visit rate	Number of visits	Total visit cost (£)	Visit rate	Number of visits
1	10,000	0.16	1.25	12,500	1.16	0.95	9,520	2.16	0.65	6,520
2	30,000	1.00	1.00	30,000	2.00	0.70	21,000	3.00	0.40	12,000
3	10,000	1.83	0.75	7,500	2.83	0.45	4,510	3.83	0.15	1,510
4	5,000	2.66	0.50	2,500	3.66	0.20	1,010	4.66	0.00	0
5	10,000	3.50	0.25	2,500	4.50	0.00	0	5.50	0.00	0
Total visits(fee=£0)=55,000					Total visits (fee=£1)=36,040			Total visits(fee=£2)=20,030		

		Admission fee = £3.00			Admission fee = £4.00		
Zone	Zonal population	Total visit cost (£)	Visit rate	Number of visits	Total visit cost (£)	Visit rate	Number of visits
1	10,000	3.16	0.35	3,520	4.16	0.05	520
2	30,000	4.00	0.10	3,000	5.00	0.00	0
3	10,000	4.83	0.00	0	5.83	0.00	0
4	5,000	5.66	0.00	0	6.66	0.00	0
5	10,000	6.50	0.00	0	7.50	0.00	0
Total visits(fee=£3)=6,520					Total visits(fee=£4)=520		

Note: an admission fee of £4.33 or more will result in no visits being made from any zone.

A common approach is to ask visitors to evaluate how much of the utility of the whole recreation experience is due to the on-site experience. Typically visitors are asked to allocate percentage points to the on-site and off-site experience. This information can then be used to either reduce travel costs (ie. evaluate how much of incurred costs can justifiably be said to have been purely related to the on-site experience) or the information can be directly entered into the trip generating function as a separate continuous explanatory variable (for an example see Willis and Garrod, 1991). In either case the whole-experience demand function will be altered. The resultant curve will not be the same as the on-site demand curve as defined by Clawson and Knetsch above. However its validity may well be more defensible in that it does not rely upon the previous assumption of travel cost effects perfectly duplicating admission price effects.

Extending the Model

The simple model discussed above relies upon the assumption that visits are a function of their price, ie. total visit costs. Total visit costs can be defined as the sum of money expenditure on travel (eg. petrol costs, etc), the opportunity cost of travel time and the opportunity cost of on-site time. More exactly we can define[3];

$$C_{hj} = PTC.D_{hj} + PTT_{hj}.TT_{hj} + PST_j.ST_j \qquad \text{EQN T.5}$$

where: C_{hj} = Total visit cost from zone h to site j (visit price)

PTC = Money expenditure on travel (petrol, etc) per mile/km

D_{hj} = Distance from zone h to site j (miles/km)

PTT_{hj} = Opportunity cost per hour of travel time from zone h to site j. Note that this variable is subscripted as (unlike PTC) PTT may vary according to zone of origin of journey and site of destination.

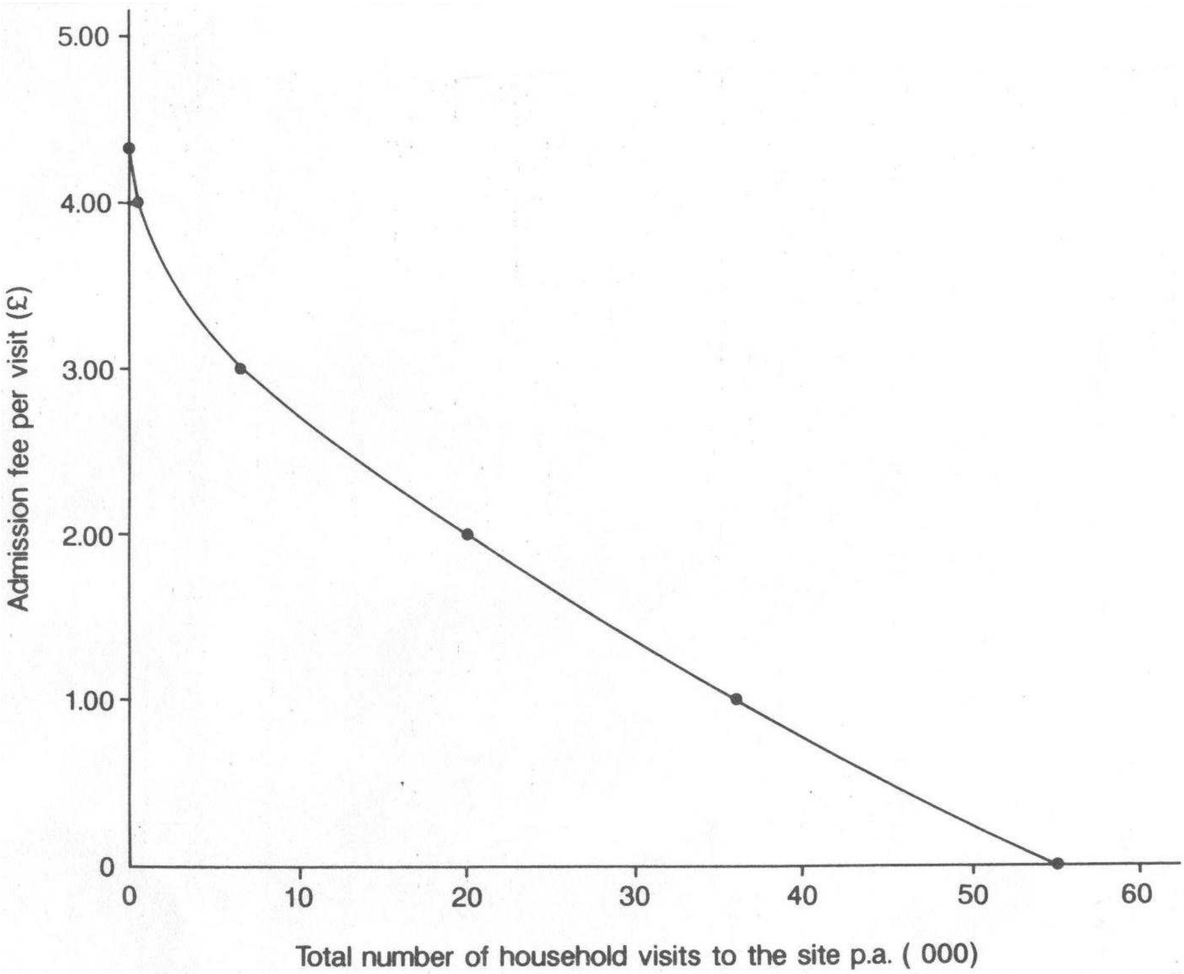
TT_{hj} = Length of travel time from zone h to site j (hours)

PST_j = Opportunity cost per hour of on-site time at site J. This will probably vary by site but not by zone.

ST_j = Length of per visit on-site time at site j. This may or may not vary by zone of origin (here not); see later discussion of the value of time.

[3]Many empirical studies employ a variety of simplifications of EQN T.5 eg. on-site time costs may be ignored. All these variables will be considered subsequently.

Figure T.3: Demand Curve for the On-Site Recreational Experience (from Table T.2)



We now need to consider the other explanatory variables X in EQN T.1. These will include factors such as income levels, spending on other goods, the qualities of this and substitute sites, etc. Consideration of these factors leads us to specify a 'trip-generation function' (tgf) such as;

$$V_{hj}/N_{hp} = f\,(C_{hj},\ P_{Vj},\ Q_j,\ SC_{hn},\ P_{Vn},\ Q_n,\ Y_h,\ P_x) \qquad \text{EQN T.6}$$

where: V_{hj}/N_h = Visitor rate from zone h to site j

C_{hj} = Total visit cost from zone h to site j (see EQN T.5)

P_{vj} = Entrance fee (may be zero) at site j

Q_j = Quality index at site j

SC_{hn} = Vector of total visit costs from zone h to n substitute sites (ie. j is site number n+1)

P_{Vn} = Vector of entrance fees (may be zero) at n substitute sites

Q_n = Vector of quality indices of n substitute sites

P_x = Vector of private goods prices

Now the demand for visits to site j is a function (along with other variables) of the attributes of site j and all substitute sites. Further explanation variables are plausible, for example Bojö (1985) includes a dummy variable for the mode of transport used (car or train) which, in an empirical test, he finds significant.

Once adequate data is collected, the tgf may be estimated. In practice, because of data limitations, a reduced form of EQN T.6 is usually estimated (eg. P_x is usually omitted). Furthermore, as discussed in the previous section, it is usually the modified whole-experience demand curve (equating to the on-site demand curve), rather than the theoretically pure Clawson-Knetsch on-site demand curve, which is calculated (ie. whole-experience costs are allocated between off-site and on-site activities as discussed previously). This demand curve can then be mapped out by examining the partial derivative $\delta V_{hj}/\delta C_{hj}$. Consumer surplus in each zone h is then found as in the previous example while total consumer surplus is found by summing across all zones.

The Individual Travel Cost Method (ITCM)

The fundamental difference between the ZTCM and ITCM is that the latter defines the dependent variable as V_{ij}, the number of visits made per period (annum) by individual i to site j (Brown and Nawas, 1973; Gum and Martin, 1975). We can therefore rewrite the simple tgf of EQN T.1 as its ITCM equivalent;

$$V_{ij} = f\,(C_{ij}, Xi) \qquad \text{EQN T.7}$$

where: V_{ij} = number of visits made per year by individual i to site j

C_{ij} = visit cost faced by individual i to visit site j

X_i = all other factors determining individual i's visits

The demand curve produced by this model relates individual's annual visits to the costs of those visits (ie. there is no requirement to convert from zonal visitor rate to actual visits as in the ZTCM). As discussed previously, the above tgf relates to the whole recreational experience. On-site recreational experience demand curves can again be obtained as outlined by Clawson and Knetsch (1966) although, as before, many practical studies adopt a modified whole-experience approach by including as a separate variable a measure of how much of the visits utility can be attributed to the on-site experience[4].

The move from a zonal to an individual basis allows the specification of a number of individual-specific explanatory variables, for example, we could respecify our ITCM tgf as;

$$V_{ij} \quad = \quad f\,(C_{ij}, E_{ij}, S_i, A_i, Y_i, H_i, N_i, M_i) \qquad \text{EQN T.8}$$

where: V_{ij} = number of visits made per year by individual i to site j

C_{ij} = individual's total visit cost of visiting site j

E_{ij} = individual i's estimate of the proportion of the day's enjoyment which was contributed by the visit to site j

S_i = dummy variable; individual i's assessment of the availability of substitute sites

A_i = age of individual i

Y_i = income of individual i's household

H_i = size of individual i's household

N_i = size of individual i's party

M_i = dummy variable; whether individual i is a member of an outdoor or environmental organisation

The tgf given in EQN T.8 will have a variety of possible exact specifications. The total visit cost variable (C_{ij}) will often be some simplification of EQN T.6. Furthermore the dummy variables M_i and S_i may either be specified as single 0-1 variables or as a series of switches or as continuous variables eg. the number of substitute sites, or distances to those sites. The E_{ij} variable allows for the modification of the whole-experience to the on-site experience and would usually be defined as a continuous variable between 0 and 1[5]. The move from zonal averages would have little meaning in the tgf.

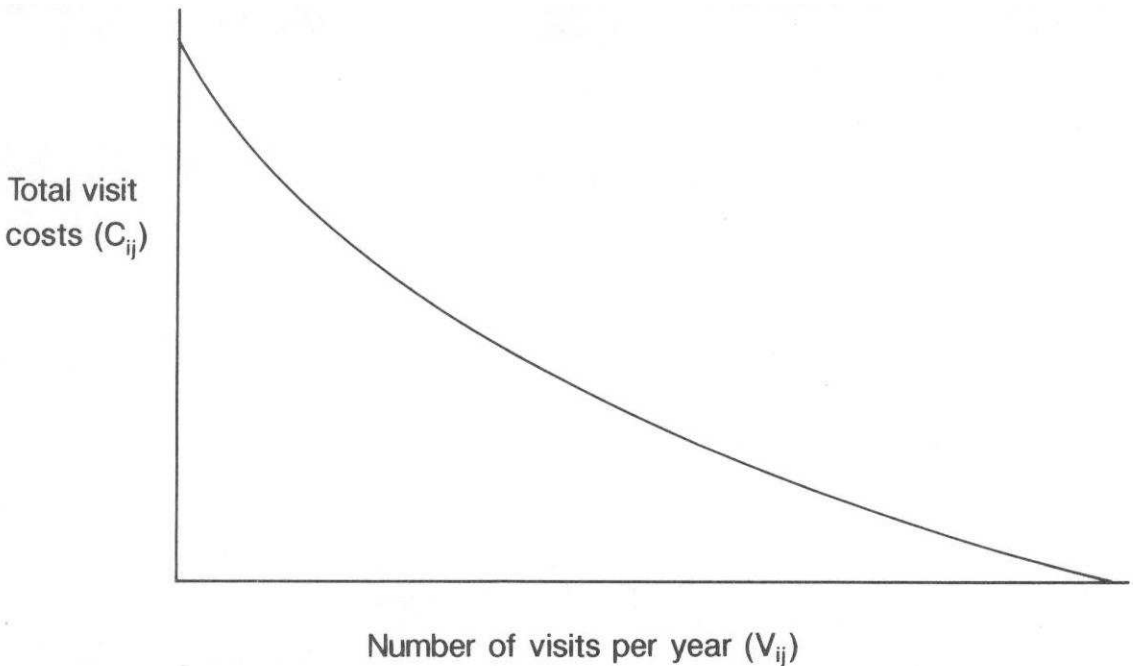
The demand curve for the site will be defined by the $dV_{ij}/\partial C_{ij}$ relationship as illustrated in Figure T.4. Integrating under this curve gives us our ITCM estimate of consumer surplus per

[4]See Willis and Garrod (1991) for an application of this latter approach to both ZTCM and ITCM models.

[5]eg. if individual i states that 60% of the days enjoyment was due to the on-site experience then $E_{ij} = 0.60$.

individual. Our estimate of consumer surplus for the site is then obtained by multiplying by the number of individuals visiting the site annually[6], ie;

Figure T.4: An ITCM Demand Curve for a Recreational Site



$$\text{Total consumer surplus} = N_j . \int f(C_{ij}, X_i).\, dC_{ij} \qquad \text{EQN T.9}$$

where: N_j = number of individual visits to site j per year

(C_{ij}, X_i) = defined as per EQN T.7.

METHODOLOGICAL ISSUES

The Central Assumption

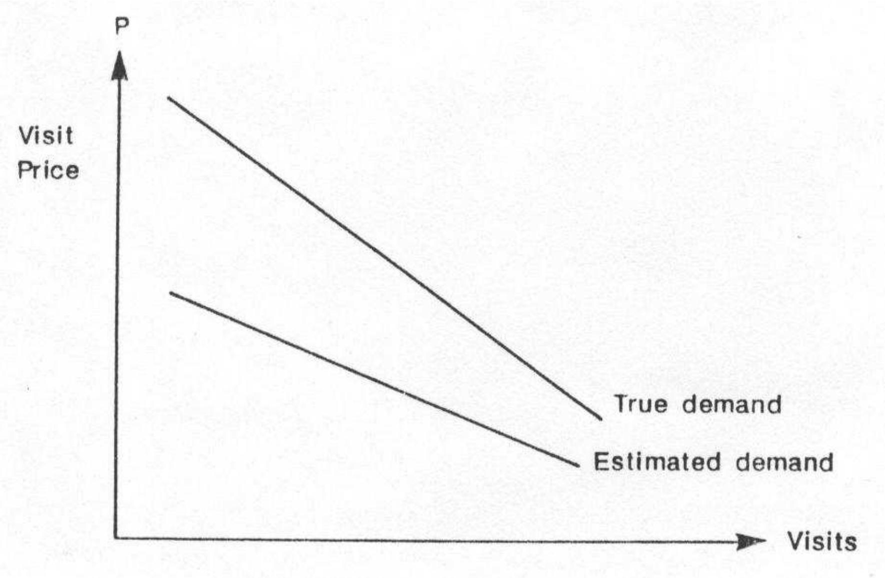
The underlying assumption that visit costs can in some way be taken as an indication of recreational value requires qualification. In a perceptive early study Gibson (1978) discusses cases where this assumption is invalid[7]. Where individuals have changed their place of residency so as to be close to a site (eg. moving into a country area to be near a recreation site) then the price of a trip becomes endogenous and the central assumption violated. In

[6]Care has to be taken in the aggregation procedure as data may well have been gathered in the form of household or party visits whereas total annual visitor data is usually held as numbers of individuals. Household data must be converted to individual visit data to avoid underestimation (or, on occasion, double counting).

[7]This problem is also noted in earlier studies, eg. H.M. Treasury (1972).

such a case the estimated demand curve will lie below the true demand curve and consumer surplus will be underestimated. Figure T.5 illustrates such a case.

Figure T.5: TCM Demand Estimates Where Individuals Move House to be Near a Site



Very few empirical studies have taken account of this potentially highly important criticism. However in a recent study, Parson (1991) argues that the endogeneity may be eliminated using an instrumental variables approach (place of work, job characteristics, etc). A simple variant of this would be to include a survey question regarding the importance of proximity to the recreation site in deciding place of residency. A dummy variable could then be used to split up responses with significance tests determining the importance of this factor. A second challenge to the central TCM assumption arises where the on-site time is not the only or even major objective of the trip. Cheshire and Stabler (1976) define three categories of visitor; the 'pure visitor' who is strongly site orientated; 'transit visitors' who make multi-visit trips; and 'meanderers' who gain utility primarily from the journey itself. While pure visitors pose no theoretical problem, transit visitors pose the problem of how journey costs are to be allocated amongst the sites visited. This problem also applies to meanderers where the on-site time is by definition only a side issue in the trip decision and where travel time in particular may not represent a true opportunity cost, ie. the utility of travel time may range from negative to positive across these visitor categories. These latter issues are discussed subsequently in the context of time costs.

Calculating Visit Costs

Following EQN T.5 we can decompose total visit costs into travel costs and time costs; the latter being subdivided into travel time and on-site time costs. An immediate problem arises when visitors include both day-trippers and holidaymakers making single or multiple site visits. The ascribing to one site of the full travel costs of a multiple site visit will lead to an overestimation of the benefit value of that site. A common approach is to weight costs according to the proportion of the day's enjoyment attributable to the site in question (discussed subsequently). Furthermore Christensen et al. (1983) discuss solutions to the problem of disaggregating holiday from visit costs. However more fundamental is the problems of measuring and evaluating in money terms the travel and time components of visit costs.

i. Travel Costs

Here we are referring to the money expenditure necessary to reach a site ($PTC.D_{hj}$ in EQN T.5). In calculating travel costs, Bojö (1985) simply multiplied household size by the economy class rail fare. However such a simple approach is less applicable to car travel, where three cost calculation options exist;

(1) Petrol costs only (marginal costs)

(2) Full car costs; petrol, insurance, maintenance costs, etc.

(3) Perceived costs as estimated by respondents.

Clearly using option (2) will raise visit costs above that of (1) and ultimately increase consumer surplus estimates. Hanley and Common (1987) apply both options to the same forest recreation data finding that option (2) gave a consumer surplus estimate more than twice as large as option (1).

Willis and Benson (1988) obtained a similar result in a study of visitors to wildlife areas in Yorkshire. Results for one of the sites studies are given in Table T.3 showing that the move from defining travel costs as petrol only to a definition of petrol plus standing charges made no significant difference to the explanatory power of the model (same functional form retained); and only a minor impact upon the cost coefficient (highly significant in both cases) i.e. both assumptions had equal statistical validity. However this translated through into a major increase in consumer surplus per visitor (over 70% bigger for the full cost assumption) and thereby to total site consumer surplus.

Table T.3: Impact upon Estimated Consumer Surplus (CS) of Alternative Travel Cost Specifications

Case study : Wildlife visitors to Skipwith Common, Yorkshire

Method : ZTCM

Functional form : Double log throughout

Travel cost Specification	Travel cost coefficient	Model R^2	CS/visitor £	Visitors p.a.	Total CS estimate (£)
Petrol only	-2.667 (6.73)	0.83	0.59	15,235	9,001
Petrol plus standing charges	-2.6050 (6.49)	0.83	1.02	15,235	15,574

Notes : CS/visitor rounded to nearest penny.
t values given in brackets
Source:abstracted from Willis and Benson (1988).

Price (1983) argues that the correct cost measure is that which visitors perceive as relevant to the visit. It may well be that visitors are poor at perceiving daily insurance and maintenance cost equivalents or that they see these as sunk costs which do not enter the tgf, ie. they only consider the marginal cost of a visit, equating this with marginal utility.

The empirical use of perceived cost statements (option (3) above) was pioneered in the UK by Christensen (1983)[8]. A recent study (Bateman et al., forthcoming) examines the statistical performance of all three options concluding that option (2) performed significantly worse than the others with option (1) marginally outperforming option (3). This result suggests that respondents' actual marginal (petrol) cost provides a superior predictor of visits[9].

ii. Time Costs

As indicated in EQN T.5, time enters the total travel cost function in two ways;

(1) PTT_{hj} = Opportunity cost per hour of travel time from zone h to site j (travel time cost)

(2) PST_j = Opportunity cost per hour of on-site time at site j (on-site time cost).

---

[8]Unfortunately an ambiguity in the questionnaire for this study made it impossible to determine whether responses represented visitors perceptions of marginal (petrol only) or average (petrol plus standing charges) cost.

[9]Examples adopting such an approach includeBöjo (1985) and Seller et al., (1985).

The marginal utility of a visit will be influenced by both travel and on-site time and omission of either can be shown to lead to potential bias and indeterminacy in the welfare estimates. Consider first the utility maximisation problem[10];

Maximise: $U = U(X,V_j,Z_{ij})$ EQN T.10

where: X = consumption of composite good

V_j = number of visits to site j

Z_{ij} = total distance travelled by individual i to site j (miles), this is equal to $V_j.D_{ij}$ where D_{ij} is the round trip distance from individual i's home to site j

Subject to an income constraint:

$$M - PxX - \sum_j PV_j.V_j - \sum_j PTC.Z_{ij} = 0 \qquad \text{EQN T.11}$$

where: M = income

Px = price of composite good

X = quantity of composite good

PV_j = entrance fee at site j

PTC = money expenditure on travel (petrol,etc) per mile

and subject to the time constraint:

$$T - \sum_j ST_j.V_j - \sum_j t_{ij}Z_{ij} = 0 \qquad \text{EQN T.12}$$

where: T = total recreation time (fixed)

ST_j = length of per visit on-site time at site j

t_{ij} = travel time per mile for individual i to site j

To maximise utility the individual equates the marginal utility of visits with their total cost (money cost and time cost). Freeman (1979) considers a simple additive utility function

[10] This analysis follows McConnell (1975), Wilman (1977), Freeman (1979) and Johannson (1987).

(although more complex forms yield consistent results)[11] which we shall use for illustrative purposes, substituting V_jD_{ij} for Z_j in EQN T.10 to give the utility form:

$$U = U_1(X) + U_2(V_j) + U_3(V_jD_{ij}) \qquad \text{EQN T.13}$$

We can now define the marginal utility of a visit as the partial differential of EQN T.13 with respect to V_j, namely:

$$\frac{\delta U_2}{\delta V_j} = \lambda PV_j + \lambda PTC.D_{ij} - D_{ij} \cdot \frac{\delta U_3}{\delta V_j D_{ij}} \qquad \text{EQN T.14}$$

where: λ = marginal utility of income

μ = marginal utility of time

EQN T.14 demonstrates the potential importance of on-site and travel time as determinants of visits. Furthermore it shows that the relevant opportunity costs per hour need not be the same for these two items. However determination of these opportunity costs raises considerable problems.

iii. Empirical estimation of the value of travel and on-site time

Travel time values are particularly difficult to analyse in that, as noted previously, we have no definite a-priori notion about whether travel time utility is positive or negative. If travel time has positive utility (i.e. individuals enjoy the travel as part of their recreational experience, e.g. 'meanderers' as previously defined) then using some general travel time cost figure to price this will overestimate the consumer surplus of a visit. Bojö (1985) does not include a travel time cost (i.e. implicitly he gives such time an opportunity cost of zero) on the grounds that 80% of survey respondents expressed a positive utility for travel time to the site under analysis. This approach assumes that ignoring residual travel time costs only leads to a minor underestimate of the true consumer surplus. If travel time has a negative utility (i.e. individuals actually dislike travelling to recreation sites) then the use of a generalised time cost may now underestimate total travel costs and consequently consumer surplus of a visit. Johansson (1987) points out that, in such cases "the estimated curve will be located inside and be less steep than the 'true' one, except possibly for those living very close to the

[11]The entrance of priced and non-priced recreation goods into the household production function is briefly considered in Appendix A.

recreation site, since the underestimation of costs increases in relation to distance from the visitors zone of origin".

One practical approach to this problem is to apply a utility weighting to a standard travel time cost, the weighting being derived by direct questioning of respondents. By asking respondents to rate their enjoyment of the travel time alone an inverse index can be set up such that a respondent who hates travelling (pure visitor) is given an index value of 1 while a respondent who prefers travelling to visiting (meanderer) is given an index value of O, with continuous gradations between these extremes. The resultant index score can be used to weight any per hour travel time cost. However this still leaves the problem of determining the unit cost of travel time.

One approach to the pricing of travel time is to examine its relationship with individuals' wage rates. The seminal work in this area is that of Cesario (1976) and Cesario and Knetsch (1970; 1976). This approach examined commuters choice of transport to and from work (and relevant costs) to estimate an implicit value of travel time. Cesario concluded "that, on the basis of evidence collected to date, the value of time with respect to nonwork travel is between one quarter and one half of the (individuals) wage rate" (Cesario, 1976), and subsequently used a value of one-third the wage rate to price travel time. An alternative approach is that of Nelson (1977) who calculated a marginal implicit price of proximity to the central business district with housing data for Washington DC, from which he derived a value of time which, when related to wage rates, falls within the Cesario range. However, as he recognised at the time, Cesario's analysis only considers commuter time and there is no necessary reason why the marginal utility obtained should be applicable to recreation travel time[12].

Common (1973) and McConnell and Strand (1981) used an iterative process whereby successive time values are substituted into the tgf the final choice being determined where the explanatory power (R^2) of the model is maximised. Desvouges, Smith and McGivney (1983) applied the value of time results of Cesario (1976), McConnell and Strand (1981) and a full wage rate assumption to the following simple model (EQN T.15) of individual visitation patterns at 23 water recreation sites in the USA.

$$Ln(V_{ij}) = a_o + a_1\,MC_j + a_2\,TC_j + a_3\,Y \qquad \text{EQN T.15}$$

[12]A further practical problem arises when attempting to estimate a model which contain both a wage related time cost variable and an income variable as the two are likely to be highly or perfectly collinear.

where: V_j = visits to site j

MC_j = mileage cost per visit to site j

TC_j = time cost per visit to site j

Y = household income

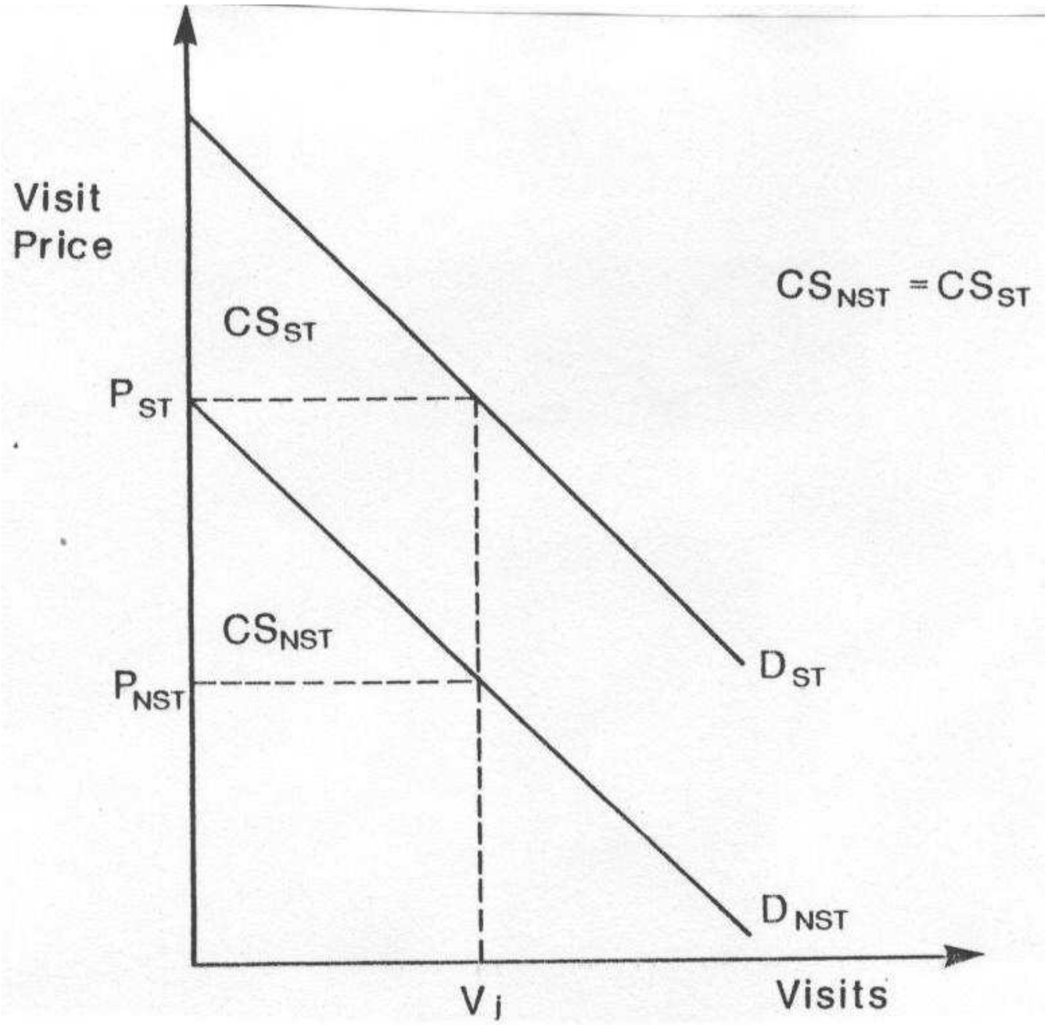
Now if the Cesario (1976) estimation (that the opportunity cost of travel time was approximately one-third wage rate) is correct then we would expect that $a_2/a_1 = 1/3$. Similarly if the full wage was a better approximation of the value of travel time we would expect $a_1 = a_2$.

Testing EQN T.15 at the 10% confidence level, Smith, Desvouges and McGivney (1983) rejected the McConnell and Strand (1981) approach, while both the Cesario (1976) and full wage assumptions performed equally well, both being rejected in roughly 7 of the 23 cases. On the basis of these results Smith and Desvouges (1986) concluded that "for practical purposes, there is no clearcut alternative to our using the full wage rate as a measure of the opportunity cost. Even though it may overstate the opportunity costs ... none of the simple adaptations are superior"[13].

A further approach to the valuations of time, theoretically applicable to both in-travel and on-site time, is that of Bockstael, Strand and Hanemann (1984) who examined labour supply functions mapping the various relationships between earned income and leisure time which occur during the working week, eg. normal work time; overtime working; second jobs; and recreation time. Unfortunately, because of the rigidities of normal working practise, individuals are usually unable to reallocate hours according to their personal preferences and this line of research has not received any significant empirical application.

[13]This upper bound assumption runs contrary to the contingent valuation protocol recently developed by Arrow et al. (1993) who recommend the adoption of lower bound assumptions (ie. here using 1/3 rather than full wage rate as the opportunity cost of travel time) wherever uncertainty is high.

Figure T.6: The Effect Upon Consumer Surplus Estimates of Adding in Constant On-site Time Costs

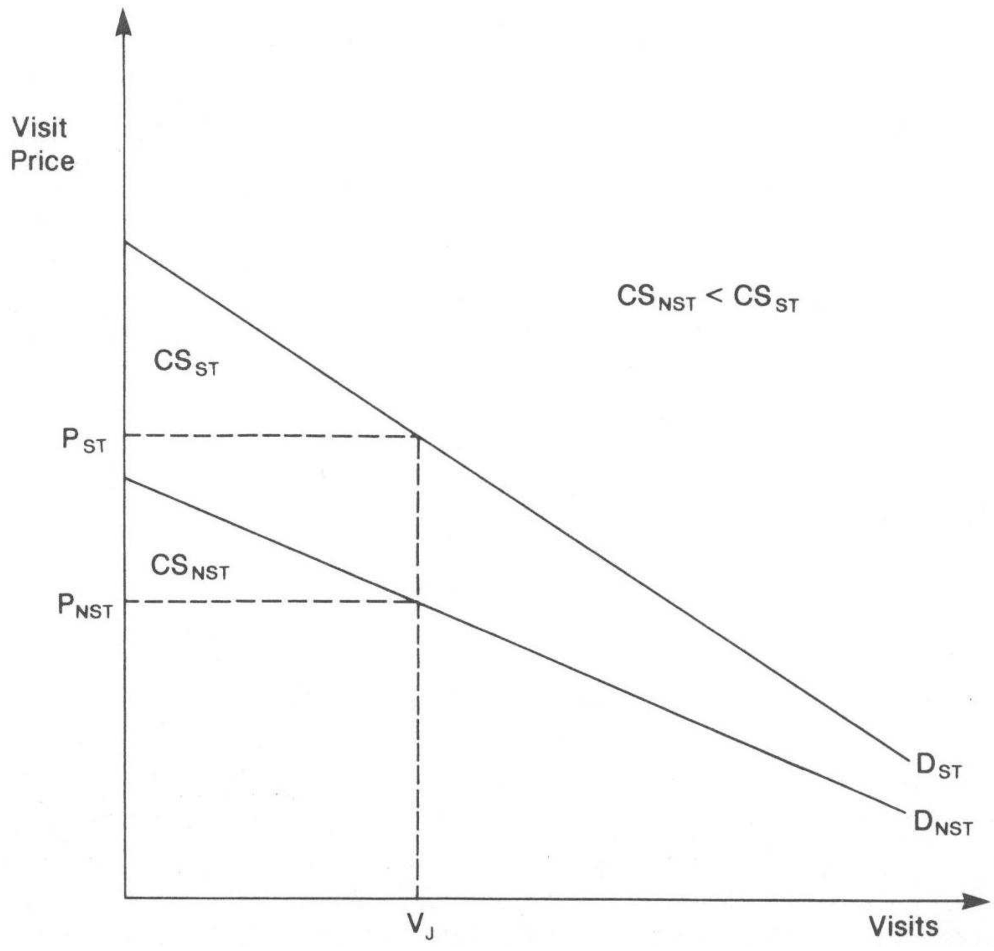


Turning to consider the unit value of on-site time, if the length of time spent on-site were a constant for all visits to a particular site, then such costs could effectively be ignored as they would imply only an increase in absolute visit costs but not in marginal relationships. Figure T.6 shows that, in such a situation, ignoring on-site costs results in the estimation of the lower demand curve D_{NST}, visit price P_{NST} and consumer surplus CS_{NST}. Adding in constant on-site time costs causes a vertical shift of the estimated demand curve to D_{ST} with increased visit price P_{ST} but identical magnitude consumer surplus CS_{ST}, i.e. omission of constant on-site time costs does not produce a biased estimate of consumer surplus.

Bojö (1985) finds no evidence to refute an assumption of constant on-site time costs and therefore omits these from his analysis. However there is no reason why this should necessarily be the case. Say, for example, that on-site time varied inversely with distance from the site, i.e. those living nearer the site spend longer on-site than those coming from far away (low on-site time costs)[14]. Figure T.7 illustrates such a situation. Demand curve D_{NST} is that estimated when all on-site time costs are omitted. Observed visits V_j then relate to a visit price P_{NST} giving consumer surplus CS_{NST}. Including increasing on-site time costs has little impact upon estimates of non-local visit price, however those for visitors living near the site increase considerably so that the new demand curve is D_{ST} with visit price P_{ST} and consumer surplus CS_{ST}. Notice that in this situation $CS_{NST} < CS_{ST}$, i.e. here the omission of on-site time costs leads to an underestimate of true consumer surplus.

We could plausibly reverse such a distance/on-site time cost assumption. If on-site time varied directly with distance from the site then the result of Figure T.7 would be reversed such that $CS_{NST} > CS_{ST}$.

Figure T.7: The Effect Upon Consumer Surplus Estimates of Adding in Increasing On-site Time Costs



[14] A reverse scenario could also be plausibly constructed.

In summary we have noted that the opportunity cost of both travel time and on-site time are important arguments in the tgf and considerable problems can arise if these costs are ignored. We suggest that tests be carried out as per Bojö (1985) to ascertain some estimate of the magnitude of the consumer surplus estimation error likely if time costs are ignored. If this error is not thought to be acceptably minor then time costs must be included. However we recommend that in such situations a sensitivity analysis be carried out using a range of wage-rate based, time value estimates. As a working approximation we suggest that values of 0.25; 0.5; 0.75 and full wage rate be used.

Site Attributes (Environmental Quality and Multicollinearity)

The trip generating function described in EQN T.6 highlights several independent variables as explanatory of visits, one of which is the site environmental quality variable, Q_j. In a simple single stage analysis the entire function is estimated as one with conventional significance and other statistical testing being carried out. While this is a common approach it is, strictly speaking, only universally valid for quantifiably unidimensional sites, that is, sites which possess only a single environmental quality attribute which can be measured in a quantitative manner. The reason for this is that, where sites possess multiple attributes, these attributes should enter the tgf as separate variables. However these attributes may themselves be highly correlated, i.e. a potential multicollinearity or 'suppressor variables' (Conger, 1974) problem exists making single stage OLS estimators invalid.

In reality recreation sites very often provide multi-attribute services. For example Vaughan and Russell (1982) include the explanatory variable Q_{kj}, the level of quality characteristic k at site j where k may be one or more. If k>1 then there may be multiple environmental quality factors significantly influencing visit rate. These factors may well be collinear, for example, wildlife parks which are large may also have many access routes, but both of these factors may be positively related to visits.

To illustrate the suppressor variables problem consider a simplified version of the Smith and Desvousges (1986) lake-recreation study in which it is thought that the true ITCM trip generating function is the estimating equation[15]:

$$V_{ij} = b_o + b_c C_{ij} + b_y Y_{ij} + b_s S_j + b_a A_j + e \qquad \text{EQN T.16}$$

[15]In addition Smith and Desvousges (1986) also consider the site attribute lake size relative to whole site size and two measures of water quality (see full version in Appendix B). However, for simplicity, these are ignored here.

where: V_{ij} = visits by individual i to site j

C_{ij} = individual i's total costs (time and travel) of visiting site j

Y_{ij} = income of individual i visiting site j

S_j = shore length at site j

A_j = access points at site j

e = error term

A suppressor variable problem occurs where at least two of the explanatory variables are highly collinear. Suppose that, as is quite possible, shore length (S_j) and access points (A_j) are strongly positively correlated (say a Pearson correlation factor in excess of 0.5) with insignificant multicollinearity elsewhere in the model. Now suppose that we omit A_j and estimate the model to get an estimator for b_s the coefficient on S_j (which we shall denote $\hat{b}_s^o$ and illustrate as model 1 in Figure T.8). By substituting A_j for S_j and re-estimating the model we can similarly estimate b_a the coefficient on A_j (denoted $\hat{b}_a^o$ and illustrated as model 2 in Figure T.8). While they are admittedly imperfect, these estimators $\hat{b}_s^o$ and $\hat{b}_a^o$ are statistically valid measures of the relationships $\partial V_{ij}/\partial S_j$ and $\partial V_{ij}/\partial A_j$ respectively.

However if we now re-estimate the full model in EQN T.16, i.e. including both S_j and A_j, then, in the presence of the high collinearity between these latter variables, our newly estimated coefficients $\hat{b}_s^1$ and $\hat{b}_a^1$ can be very different from $\hat{b}_s^o$ and $\hat{b}_a^o$.

Model 3 in Figure T.8 illustrates one such potential outcome of such an experiment. Here we have the newly estimated coefficient on S_j (ie. $\hat{b}_s^1$ being roughly similar to that obtained in model 1 (ie. $\hat{b}_s^o$). However model 3 includes the explanatory variable A_j as well as S_j (and C_{ij} and Y_{ij}). The coefficient upon A_j is unstable in that the variation in the dependent which it explains is also explained by S_j and in this example the resulting coefficient upon A_j ($\hat{b}_a^1$) is highly biased, being very different to the estimate of model 2 ($\hat{b}_a^o$).

In reality a number of possible outcomes may arise from a suppressor variable problem. Coefficients may alter radically, even changing signs. Furthermore the significance of parameters becomes disturbed and may even spuriously increase (see Langford, 1992).

Despite the potentially serious nature of the problem of suppressor variables in multi attribute sites, no single definitive solution has yet been found[16]. Clearly a first step is to test for the presence of such a problem by calculation of correlation tables. A further test is to estimate single explanatory variable regression models for significant variables and examine how coefficients and significance levels alter in subsequent multiple regression models. If such a problem is confirmed one proposed course is to replace all site attribute variables with a single index of site attractiveness, thus removing collinearity (Talheim, 1978; Ravenscraft and Dwyer, 1978). However, such an index cannot be adequately set up without full knowledge of the functional relationship between demand and site attributes. As this relationship is dictated by individual preference for different attributes, the creation of a truly representative index is infeasible. Ideally we would wish to respecify the individual's utility function in terms of the attributes of sites. Morey (1981, 1984, 1985) adopts various functional forms for the utility function which include site attributes and levels of use. By assuming budget constrained utility maximisation we can obtain estimating equations from which parameters (including those for site attributes) can be estimated. However, the need to specify the form of the utility function constitutes a weak link in this approach.

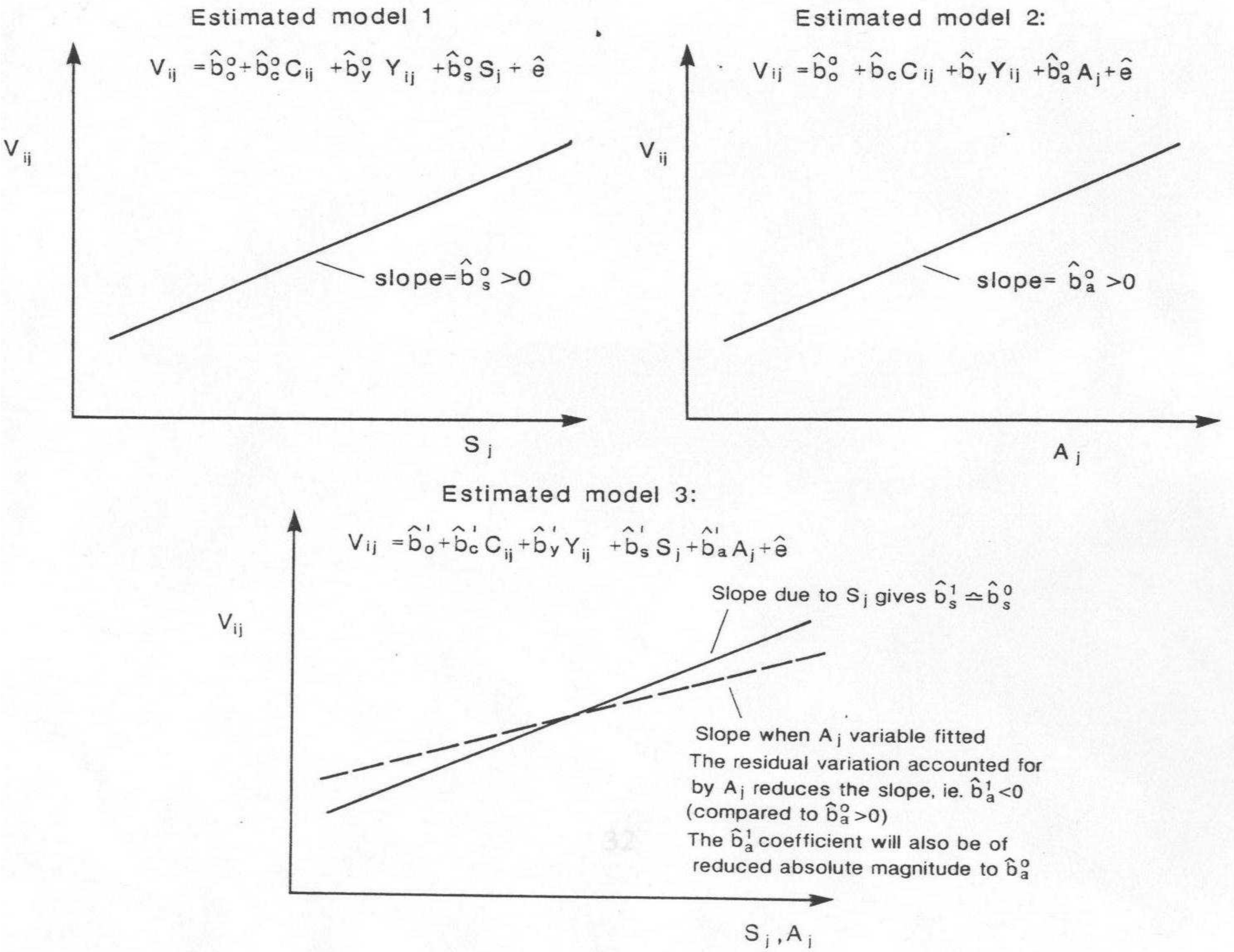
Another approach to the problem of suppressor variables is to use a two stage generalised least squares approach[17] (the generalised travel cost method). Such an approach is adopted in the Smith and Desvousges (1986) lake resources example given before. Here the authors postulate a 'true' trip generating function as per EQN T.16. However, in the absence of information, exact specification of this function with respect to the site characteristics Shore (S_j) and Access (A_j) is infeasible and the likelihood of suppressor variable effects is significant (although no tests are reported). Smith and Desvousges therefore use a two stage approach, the first stage of which consists of omitting all potentially collinear site attribute variables and estimating the simple equation given in EQN T.17[18].

[16]Interestingly Maddala (1988) comments that "some solutions often suggested for the multicollinearity problem can actually lead us on a wrong track. The suggested cures are sometimes worse than the disease" (p.224).

[17]An alternative two stage approach is to employ factor analysis or principal components analysis approaches (Goddard and Kirby, 1976; Johnston, 1978). These approaches rely on the formation of combination variables made up of weighted combinations of the explanatory variables. While this weighting can be adjusted to maximise the statistical significance of the model, the resulting combination variables often defy practical interpretation thereby greatly reducing the usefulness of the model in any predictive economic analysis. Such an approach has been used more in the context of urban planning literature and is not pursued here.

[18]Smith and Desvousges (1986) actually use a semi-log (dependent variable) form of EQN T.17 (see Appendix B) however for simplicity a linear form is reported here. This study used both travel and time costs in its definition of C_{ij} with the full wage rate being taken as the opportunity cost of time.

Figure T.8: The Suppressor Variable Problem



$$V_{ij} = a_o + a_1 C_{ij} + a_2 Y_{ij} + e_j \qquad \text{EQN T.17}$$

with variables defined as per EQN T.16.

Estimation of EQN T.17 gives the estimated parameters a_0, a_1 and a_2 and generally accounts for significant variance in V_{ij}[19]. However, some of the remaining variability can be explained by the relationship between, for example, C_{ij} and S_j. Similarly, statistically (if not theoretically) certain variability can be accounted for in the relationships between C_{ij} and A_j; Y_{ij} and S_j; Y_{ij} and A_j. In other words, supposing that EQN T.17 gave R^2 = 20%, then some of the remaining 80% variation can be explained by the relationship between the explanatory variables in EQN T.17 and the additional explanatory variables specified in the 'true' relationship given in EQN T.16. Therefore the second stage of the technique involves the estimation of generalised demand functions for site attributes by regressing the parameter estimates of intercept, C_{ij} and Y_{ij} (ie. $\hat{a}_o$; $\hat{a}_1$ and $\hat{a}_2$ respectively) on S_j and A_j thus:

$$\hat{a}_o = f\,(S_j, A_j)$$
$$\hat{a}_1 = f\,(S_j, A_j)$$
$$\hat{a}_2 = f\,(S_j, A_j) \qquad \text{EQN T.18}$$

In effect we have now expressed the variation due to site attributes (S_j and A_j) as a function of the variation due to individual characteristics (C_{ij} and Y_i), i.e.

$$V_{ij} = f[C_{ij}, Y_{ij}, \{S_j=f(C_{ij}, Y_{ij})\}, \{A_j=f(C_{ij}, Y_{ij})\}] \qquad \text{EQN T.19}$$

Because of the form of EQN T.19, if we now wish to calculate the relationship (partial derivative) between V_{ij} and a particular site attribute, say S_j, then we will need some information regarding the values of both C_{ij} and Y_{ij}. Smith and Desvousges (1986) address this problem by substituting in EQN T.19 values for mean costs ($C_{ij} = \overline{C}_{ij}$) and income ($Y_{ij} = \overline{Y}_{ij}$) at each site. Thus, for example, the partial derivative $\partial V_{ij}/\partial S_j = f(\overline{C}_{ij}, \overline{Y}_{ij})$ then forms our estimate of the coefficient for the variable S_j.

---

[19] In estimating a semi log (dependent variable) version of EQN T.17 for 22 US lakes Smith and Desvousges report R^2 values between 0.02 and 0.54 with an unweighted mean of 0.22. Results for both OLS and ML estimation techniques are reported (see later discussion).

By adopting such an approach Smith and Desvousges (1986) produce estimates of the impact of individual site attributes upon visits, i.e. they estimate attribute demand functions. This provides an important extra facility to the TCM in that such demand estimates allow the analyst to investigate which attributes contribute most to overall site demand and thus to welfare. In effect such functions allow us to specify which attribute, or combination of attributes, individuals most enjoy at a recreation site and thus facilitate the optimum planning of site development and creation. However it should be noted that, while this approach is valid, statisticians have no single agreed definitive approach to the treatment of suppressed variables[20].

The valuation of attributes rather than sites provides an important focus of analysis which we discuss later with regard to the hedonic travel cost method (HTCM). The specific final form of EQN T.19 as estimated by Smith and Desvousges (1986) is also discussed subsequently in Appendix B.

Weighted Observations (Heteroskedasticity and Sampling Bias)

The observations used for estimating the demand curve in ZTCM analyses represent a series of samples of varying size from zones which themselves will often have varying populations. As such these observations may have varying degrees of precision; they may have non-constant variance (ie. subject to heteroskedasticity). This means that[21]:

1. The least squares estimators are unbiased but inefficient;
2. Estimates of the variances are biased thus invalidating significance tests.

A common approach to heteroskedasticity problems is to transform the data by logs[22], however Snedecor and Cochran (1976) state that a general approach "is to weight each estimate inversely as its variance" i.e. a weighted least squares (WLS) approach in which observations of low precision are given low weight. Such an approach is adopted by Bowes and Loomes (1980) who suggest that observations be weighted directly by zonal population (ie. large populations should produce more precise observations). However Christensen and Price (1982) points out that heteroskedasticity arises not only because of differing zonal populations but also from differing zonal sample sizes which in turn derive from differences in visitation rate across zones (an individual's visitation rate is likely to be higher in zones

[20]Approaches such as cluster analysis and multi level modelling (Jones, 1991) are not discussed here.

[21]Maddala (1988).

[22]Maddala (1988) outlines a variety of possible approaches (p.161 et sec).

nearer to the site). Following this line in a subsequent paper, Price et al., (1986) weight demand curve observations by zone population/visit rate.

Lucas (1963) shows that a weighting approach may also be appropriate where sampling bias arises in the presence of a correlation between length of stay and travel cost eg. individuals who travel further (higher travel costs) stay at sites for shorter periods than those who come from nearby and thus the former group are less likely to be sampled. Lucas argues that, in such cases, weighting individual travel costs by the reciprocal of the length of stay will correct this bias. Price et al. (1986) present various permutations of a forest recreation model, one of which combines both their own heteroskedasticity weighting and Lucas's sampling bias weighting.

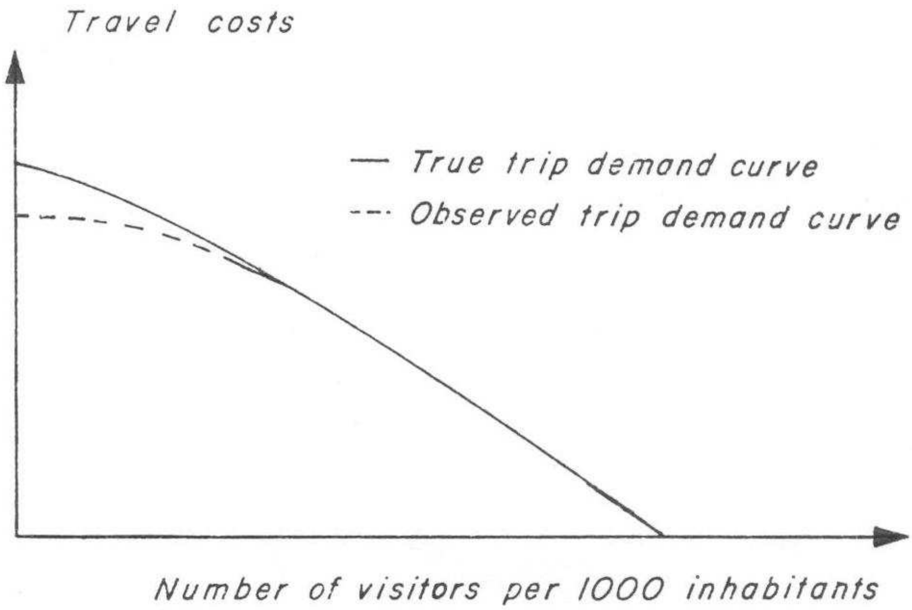
Substitute Sites

EQN T.6 showed that substitute sites should impact upon visit demand in three ways: the visit price of the substitute sites; their entrance fees; and environmental quality at substitute sites. In practice such variables are rarely included in estimated forms (eg. Smith and Desvousges, 1986), the major practical difficulty being the high data costs involved. In effect a TCM survey would have to be performed at all significant substitute sites in order to provide the full data requirement.

The presence of substitute sites deflates recorded demand as shown in Figure T.9. The further away that people live from a site the higher the probability that there are substitute sites closer to them than the site in question ie. the observed trip demand curve is depressed below the true demand curve at higher travel costs.

By concentrating upon site loss (i.e. the sites 'contribution value' to the total recreation value of all sites) rather than conventional TCM site value, Price (1975, 1978) and Connolly and Price (1991) show that, in fact, the presence of substitute sites leads the TCM to either systematically over or underestimate true consumer surplus dependent upon the spatial relationship between sites and population centres. Assuming that population is randomly distributed, Price et al. argue that if recreation sites are clustered then the loss of one site will, on average, make little difference to the general proximity of population to sites ie. the conventional TCM site value will overestimate the value of site loss. Conversely if sites are systematically-spaced (particularly relevant for man-made recreation areas) then the loss of one site will induce a major site-proximity change for the nearby population and the TCM value will underestimate the true value of site loss. Only where sites (as well as population) are randomly distributed will these over and underestimations on average cancel out and the TCM value accurately represent the true value of site loss[23].

Figure T.9: Impact of Substitute Sites



Source: Christensen (1983); Price (1983)

A number of solutions to the substitute sites problem have been put forward. Price (1979a) addresses the problem "by the simple expedient of basing visit rates, not on visits per year per 1000 population, but on visits per year per 1000 population for whom this is the nearest facility of its type". However this is at best a partial lower-boundary approach, ignoring distant visitors who presumably value their visits highly.

Burt and Brewer (1971) use their subjective judgement to identify presumed substitute sites and enter the distances from respondents' homes to these sites as explanatory variables in the tgf. Such an approach is admittedly subjective however a more fundamental criticism is that it implicitly assumes homogeneity of sites, an improbable assumption. Greig (1977) imposes a predetermined, utility-based model linking visits to site characteristics. Such an approach may also be criticised both for lack of adequate prior information regarding the appropriate utility relationship and the need to define site characteristics. A hybrid of the Greig/Burt and Brewer approach could theoretically be constructed if data were available on actual visits to substitute sites. Given such data we could run a Burt and Brewer substitute-distance model and compare predicted visitor rates under the homogeneity

[23]Interestingly in a simulated model test of this hypothesis, Connelly and Price (1991) found that curve fitting errors could more than outweigh the impacts of substitute sites (see discussion of functional form).

assumption with recorded actual visit rates. Differences between actual and predicted figures could then be used to provide information regarding the utility characteristics of the sites.

Connelly and Price (1991) suggest a fundamental change to the Clawson procedure by asking visitors hypothetical questions regarding their expected visit pattern if the site in question was to be closed. These responses could then be fed into the TCM model as proxy variables regarding substitute sites.

An interesting attempt to formulate a substitute availability index is given in Bojö (1985). The following index is constructed;

$$S_j = \sum_{k=1}^{n} \frac{P_j W_k}{P_k} \qquad \text{EQN T.20}$$

where: S_j = Substitute availability from site j
P_j = travel cost to site j
P_k = travel cost to n substitute sites k
W_k = measure of the degree of substitutability between sites j and k.

Bojö measured W_k by questioning respondents as to their preferences for substitute sites. Unfortunately his field experiment found that the majority of respondents all named one and the same site as their preferred substitute and it became impossible to operationalise the index.

The lack of adequate consideration of substitute sites remains a weakness in many TCM models[24].

Congestion

A site becomes congested when the number of visitors at a site rises to the point where the supply of the characteristics of that site becomes restricted (ie. the presence of marginal users diminishes the utility of other users). In extreme cases congestion will invalidate a TCM study as the observed visits correspond not to the standard demand constrained

[24]Appendix C considers the impact of improvements in the environmental quality of a single and substitute sites.

system but to the intersect of an undefined demand curve with an unknown supply curve ie. the system becomes under-identified.

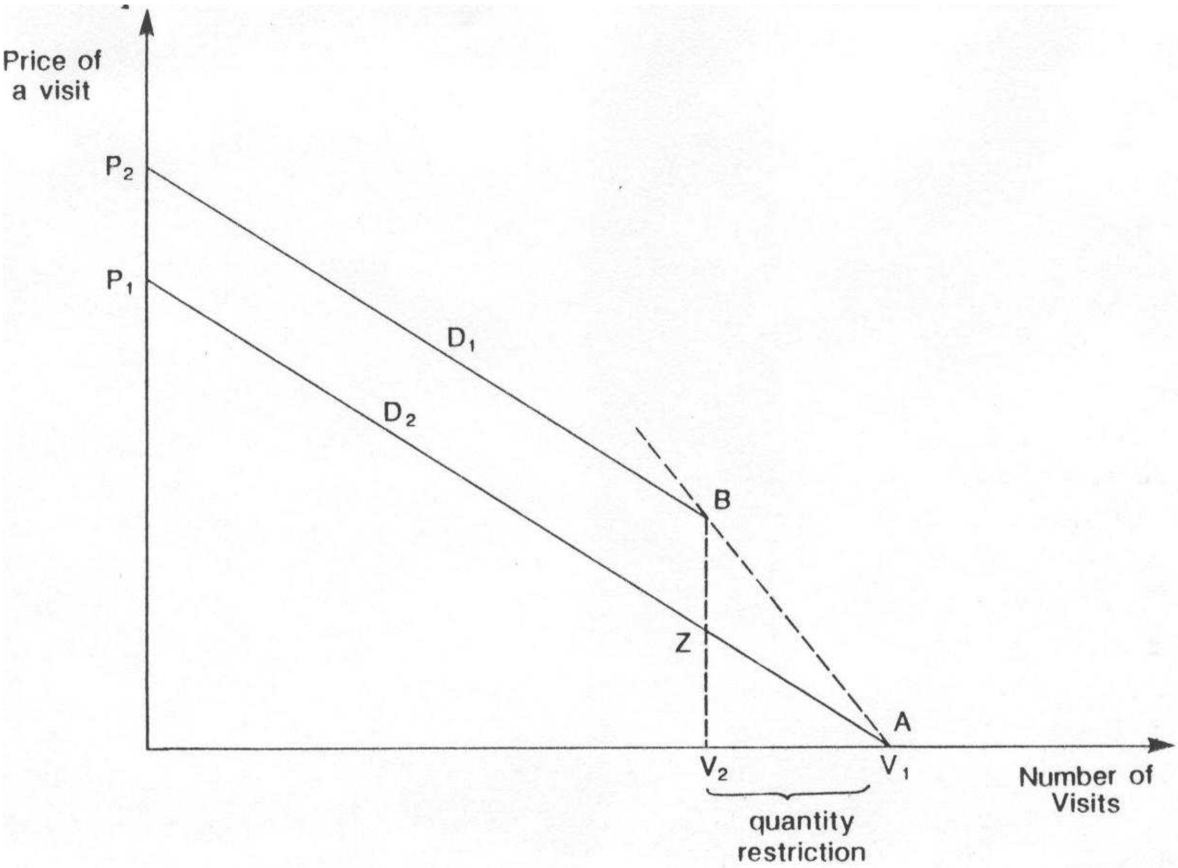
While Vaux and Williams (1977) feel that this problem is not of "overriding importance", in an early experiment Stankey (1972) records that 82% of his sample felt that "solitude - not seeing many other people except those in your own party" was desirable. Johannson (1987) points out that site visitor numbers (X_v) may be a separate argument in the individual's utility function. Furthermore this argument may be complex in that, where X_v is very low (or zero), utility may be impaired as people feel lonely or intimidated at the site (this will obviously not be so for all individuals). As X_v increases to a small number so utility may rise with the possibility of social interaction. However as X_v becomes large utility may again decline as congestion sets in. The visit decision may therefore well be dependent upon individual's expectations of X_v. Such differences between expected and actual X_v might also prove significant in contingent valuation-type studies.

The presence of congestion (or excess demand) means that the observed demand curve is an underestimate of true demand. The classic treatment of this problem is presented by Fisher and Krutilla (1972) as summarised in Figure T.10. Here a zero admission price with no formal visitor restrictions (other than congestion) results in V_1 visits to a site with an observed demand curve (estimated via TCM procedures) D_1. Suppose that the site is recognised as being congested and a quantity restriction was placed upon visitors reducing total visits to V_2. The consequent reduction of congestion would improve the utility of the site for the remaining visitors such that the observed demand curve expands out to D_2. The benefit of restricting visits can be seen to be the area P_1ZBP_2 while the cost of this restriction is ZV_2V_1, the net benefit being the difference between these sums (positive in Figure T.10).

This movement implies that the true demand curve of the non-congested site is given by the curve AB, i.e. TCM models underestimate consumer surplus in the face of congestion.

Christensen (1983) shows that we can repeat the Fisher-Krutilla analysis so as to map out the entire non-congested demand curve. However because of the difficulty of imposing quantitative restrictions upon visitor numbers, it is difficult to envisage how a study might obtain the information necessary to estimate the divergence between observed and non-congested demand. Often the most practical approach is simply to test for the presence of site congestion and qualify TCM results in the light of this test.

Figure T.10: Fisher-Krutilla Analysis of Congested Sites



Smith and Desvousges (1986) attempt to account for potential site congestion by eliciting the opinions of recreation site managers as to the level of site congestion. On the basis of received responses they concluded that congestion was not a significant factor at the sites studied and omitted it from further consideration. However the use of site managers rather than visitors responses is questionable. Freeman (1979) lists several references to the use of non-visitor samples drawn from the regional population of travel cost zones to examine how many present non-users would use the site if environmental quality were to be improved (Burt and Brewer, 1971; Brown and Nawas, 1973; Gum and Martin, 1975) and such an approach could be extended to the analysis of congestion. However, through a series of papers, Price (1979b, 1980, 1981, 1983) concludes that, in cases of severe congestion, expressed rather than revealed preference techniques may be more appropriate.

Functional Form

Analysts are faced with a variety of functional forms under which the tgf can be specified (typically linear, quadratic, semi-log and log-log). None of these has strong theoretical ascendancy over the others. However specification of a linear form exhibits a first derivative which will be a constant and is therefore theoretically problematic. Log forms may be useful for elasticity estimates and have the advantage of avoiding negative values for the dependent variable[25].

An altered functional form (even if it has similar explanatory power) can have a highly significant impact upon the demand curve and resultant consumer surplus estimates. In a ZTCM study of recreational fishing in Grafham Reservoir (UK), Smith and Kavanagh (1969) found that both semi log (dependent variable) and double log functions fitted the data very well (R^2 = 0.91 and 0.97 respectively)[26]. However when the resultant demand curves were examined it was found that, at a zero admission price, while the semi log form predicted 54,000 annual visits the double log form predicted over 1,052,000 annual visits with obvious consequences for consumer surplus estimates. Subsequent re-estimation made little difference to this divergence. Table 4 details a similar result found by Hanley (1989) in his ZTCM study of forest recreation.

Table T.4: Estimated Trip Generating Functions for a Forest Recreation Site

Functional Form	Equation	Consumer Surplus/Capita	R^2
Quadratic	$\frac{V_i}{N_i} = 0.478 - 0.329TC_i + 0.05TC_i^2$ (4.06) (3.47) (3.11)	£ 0.32	.34
Semi-log Independent	$\frac{V_i}{N_i} = 0.1523 - 0.146\ln TC_i$ (3.91) (3.05)	£ 0.56	.24
Semi-log Dependent	$\ln\left[\frac{V_i}{N_i}\right] = -2.6 - 0.6TC_i$ (6.06) (3.41)	£ 1.70	.37
Log-Log	$\ln\left[\frac{V_i}{N_i}\right] = -2.76 - 1.7\ln TC_i$ (8.39) (4.18)	£15.13	.37

Notes: V_i/N_i = visits per capita from zone i (only one site considered)
TC_i = round trip travel costs (petrol plus any entry fee) from zone i
Figures in parentheses are t values
Source: Hanley (1989)

[25] See, for example, Ziemer, Muser and Hill (1980); Vaughan, Russell and Hazilla (1982); Desvousges, Smith and McGivney (1983), Smith and Desvousges (1986); Hanley (1989); and Benson and Willis (1990).

[26] See subsequent comments re. R^2 figures for ZTCM studies.

All the functional forms reported in Table T.4 produce significant and correctly signed travel cost coefficients. In theory the most appropriate functional form may be evaluated by examining relative degrees of explanation. However, R^2 tests are strictly non-comparable where the dependent variable changes (eg. between linear and log forms) so that only semi-log (dependent variable) and log-log can be compared in this manner. In the above study both the quadratic and semi-log independent forms were subject to strong heteroskedasticity[27]. Transforming the dependent variable by natural logs is a common approach to this problem[28] but rules out both of these forms. The semi-log dependent and double log forms produced identical (and comparable) R^2 statistics but very different consumer surplus estimates. Hanley (1989) rejects the double log form on the grounds that the consumer surplus estimates produced were very high compared to those reported in comparable UK studies using the TCM approach. A more valid test is to compare visitor rates predicted by the model with actual observed visitor rates using either a large sample, Wilcoxon signed rank test[29] or a Mann Whitney U test[30] as appropriate[31]. However the double log form may also be criticised on theoretical grounds as its asymptotic properties imply infinite visits at zero costs, an attribute which is particularly unlikely for on-site experience demand curves (see Everett, 1979).

Truncation Bias and Estimation Procedure

TCM surveys can only sample those individuals who actually visit a site, i.e. non-visitors (zero visits often corresponding to higher visit price) are ignored. The truncation of non-visitors may bias our estimate of consumer surplus. This is illustrated in Figure T.11 where our estimated demand curve is D_{EST}. However if the non-visitors (shown as points on the vertical axis) are also considered then the demand curve moves to D_{TRUE}. The size and sign of this change in consumer surplus is indeterminate, but some degree of truncation bias appears likely.

Pearce and Markandya (1989) point out that a further truncation bias will be introduced where least squares estimation techniques are employed. The normal error distribution inherent in this technique allows the estimation of continuous and negative visitor rates

[27]Tested by standard Breusch-Pagan test.

[28]See Maddala (1977) p.265. However Price (1991) shows that such transformation may in turn affect the variability of data such that more reliable observations are given insufficient weight. Price outlines a joint transformation and weighting procedure to address this problem.

[29]Wilcoxon (1945), see Mendenhall et al. (1986), p.806.

[30]Mann and Whitney (1947), see Kazmier and Pohl (1987), p.496.

[31]Box-Cox approaches to fitting functional forms are discussed with reference to the Hedonic Pricing Method.

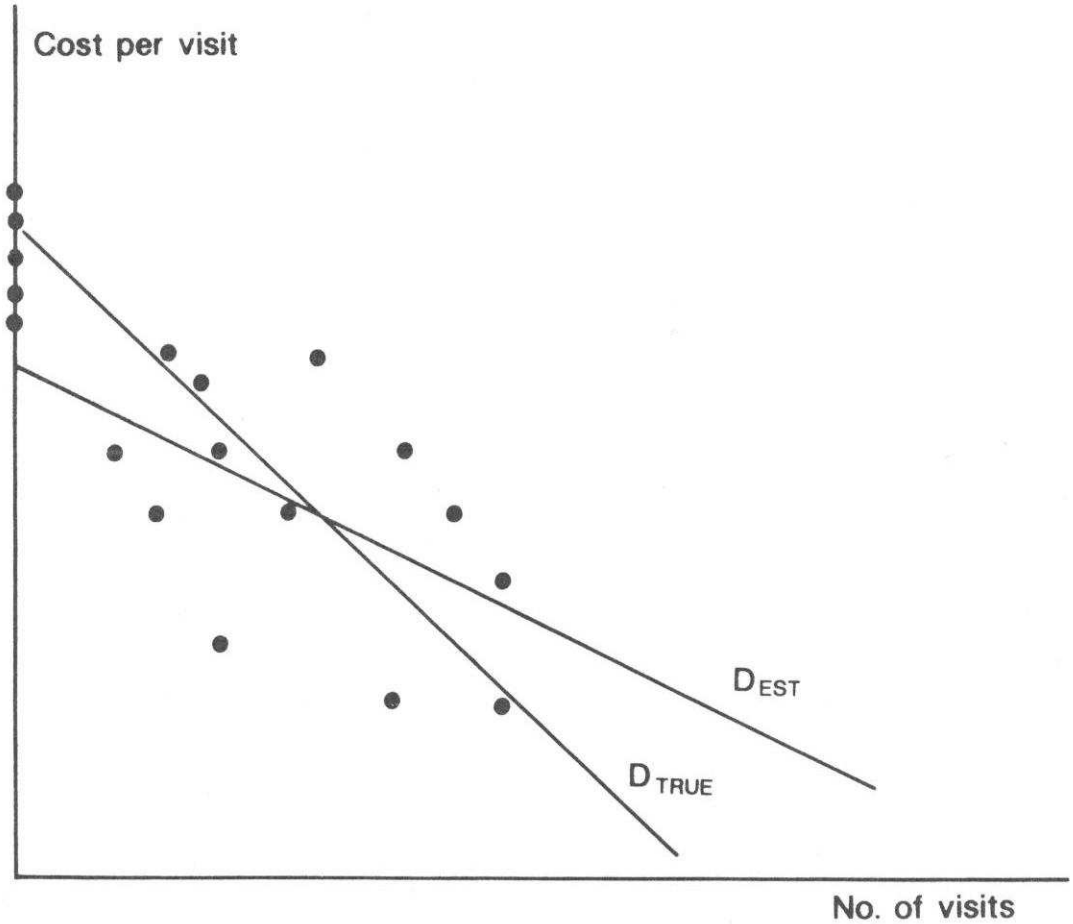
rather than its discrete non-negative reality. This problem will not be solved by simply resorting to log dependent variable functional forms. OLS estimation is, strictly speaking, inappropriate for TCM models and should be replaced by procedures such as maximum likelihood (ML) estimation.

Empirical studies come to differing conclusions regarding the extent of variance between OLS (truncated) and ML (non-truncated) estimates of consumer surplus. In a TCM study of deer hunting quality, Balkan and Kahn (1988) found that OLS and ML estimates differed by relatively small amounts. On the other hand Garrod and Willis (1991) found that, while some forest recreation sites produced relatively similar OLS and ML consumer surplus estimates, other sites produced very different results (one site differing by a factor of nearly 20).

Smith and Desvousges (1986) compared OLS and ML estimated TCM models for 33 water recreation sites. Estimates of mean variance obtained under both approaches were compared, and highly significant differences were taken as indicating high truncation effects. Using this approach 11 of the 33 sites were identified as highly truncated and were omitted from further investigations.

Other work fundamentally questions the appropriateness of switching to ML estimation as a counter to truncation bias. Both Kling (1987, 1988) and Smith (1988) suggest that, while ML techniques are theoretically more appropriate, OLS techniques (once trimmed to remove predicted negative visits) may actually produce more accurate consumer surplus estimates. Future research appears necessary before any firm conclusions can be drawn regarding this problem.

Figure T.11: Truncation of Non-Visitors



Source: Pearce and Markandya (1989)

Zonal v Individual TCMs

Throughout this chapter we have referred to both the zonal and individual variants of the TCM and, as Hanley (1990) points out "there is no consensus in the literature as to which option is preferable on theoretical grounds". However when both approaches are applied to the same data the two methods are capable of producing disturbingly different results. Table T.5 illustrates this point with regard to a joint ZTCM/ITCM study of six UK forest sites. Using the same estimation procedure (OLS) and cost definition (full running costs) throughout, estimates of consumer surplus produced by the ZTCM ranged between almost 40% less to almost five times larger than those produced by the ITCM. As all cost coefficients produced by both methods are statistically significant this points towards some serious methodological problems for one or both of these approaches.

Table T.5: ZTCM/ITCM Consumer Surplus Estimates for Six UK forests

	ZTCM		ITCM		CS:
Forest	Travel Cost Coefficient	CS/visitor(£)	Travel Cost Coefficient	CS/visitor(£)	ZTCM/ITCM
Brecon	-0.384	2.60	-0.358	1.40	1.86
Buchan	-0.444	2.26	-0.996	0.50	4.52
Cheshire	-0.525	1.91	-1.259	0.40	4.78
Lorne	-0.694	1.44	-0.327	1.53	0.94
New Forest	-0.702	1.43	-0.215	2.32	0.62
Ruthin	-0.396	2.52	-0.386	1.29	1.95

Notes: All coefficients produced via OLS techniques and significant at 5% level
Travel cost defined as full running costs
Consumer surplus estimates at 1988 prices
N = 21 for all forests
Sources: Garrod and Willis (1991), Willis and Garrod (1991).

There are a number of methodological problems associated with the use of an average value as a dependent variable. The use of a zonal visitor rate means that it is impossible to specify individual-specific explanatory variables. For example membership of an environmental or outdoor pursuits association may well be a highly significant predictor of recreational visits. However in the ZTCM such individual characteristics information cannot be used, and a constructed zonal average for such a variable is likely to be highly inefficient (Brown and Nawas, 1973). Similarly, intra-zonal variation is to a considerable degree lost in the ZTCM, as inter-zonal average effects dominate in curve-fitting. An extreme case of this may occur where concentric zones are used; outer zones may encompass areas which are geographically very different from each other. For example, suppose that we were to carry out a ZTCM study estimating the recreation value of the Malvern Hills (Worcestershire, England) using 25 mile wide distance bands. Here the distance band between 100 and 125 miles from the Malvern Hills encompasses both the Snowdonia Mountains of North Wales and the flat Fenlands of Eastern England (see Figure T.12). It is likely therefore that anyone with a predisposition for hills (as the visitors to Malvern presumably have) would have far more substitute sites if he lived in Snowdonia than if he lived in the Fens. However ZTCM approaches can at best only construct comparisons of the attributes of the studied site with those of all sites perceived by the analyst as substitutes, irrespective of the distance individuals would have to travel to reach such substitutes. Such variables will always be weak compared to the individual-specific substitute variables which can be employed by the ITCM.

Figure T.12 also highlights a problem with the ZTCM if straight line distances are equated directly with both travel and time costs. Both Snowdonia and the Fens have relatively poor road links with Malvern whereas Leeds (in the same distance zone) has a direct motorway link. Therefore both time and travel costs from Leeds will be considerably less than those for either of the others, a distinction which may be lost in any zonal average[32].

A further problem for the ZTCM, which again does not afflict the ITCM, is that R^2 statistics will always be upwardly biased. This arises as a natural consequence of aggregating individual responses across zones and so reducing the number of curve fitting points to the number of zones. Figure T.13 illustrates this point. Panel A shows the spread of individual observations recorded in a hypothetical TCM survey, each point being represented by a number which in turn is defined by a distance band away from the site. In fitting a demand curve the ITCM would employ all these observations as individual points. In Panel B these individual observations have been converted into zonal averages for use in a ZTCM. The number of observations has thus been reduced to the number of zones (here 6) which will in turn spuriously increase the R^2 of the fitted line.

Consequently the very high R^2 values recorded in many ZTCM studies should be treated with extreme caution. Their only real validity is as indicators of which model has relatively higher explanatory power within any particular functional form, their absolute value should be disregarded (and even not reported as it may well be misleading). This criticism does not apply to the ITCM for which R^2 figures are, in this respect, unbiased.

A final criticism of the ZTCM approach arises from the methods by which zones are defined. Zones are conventionally defined as concentric circules. However this need not necessarily be so[33], for example Böjo (1985) uses county boundaries. The definition of the width and number of zones is typically either arbitrary or influenced by the availability of population data. In effect each possible definition of zones implies a different aggregation of population and in practice almost certainly a different visitor rate. This in turn will imply changes in the estimated demand curve and thereby different consumer surplus estimates. Therefore, in

[32]Here technological innovations may lend a hand. Geographical Information Systems (GIS) are capable of manipulating digital maps of road networks so as to calculate travel distances and times. An early example is given by Green et al (1990) who use the Automobile Association's AUTOROUTE mapping software to calculate travel distances.

[33]Furthermore zones may be cut off at some finite distance although the outer band may be infinite. Englin and Mendelsohn (1991) in their study of rainforest tourism analyse visits from all countries.

practice, it is almost certain that an analyst could respecify zones so as to either inflate or reduce valuation estimates as required. The extent to which such a change is possible is uncertain and the subject of ongoing research[34].

Brown and Nawas (1973) argue that the ZTCM is therefore, at best highly inefficient and therefore prefer the use of the ITCM, a sentiment echoed by Gum and Martin (1975) and Bowes and Loomis (1980). However the ITCM is not without problems.

Dobbs (1991) points out that most such studies to date have incorrectly estimated consumer surplus in that they have ignored the inherently discrete nature of the dependent variable. In such cases the integration of a smooth demand function may lead to significant bias in consumer surplus estimates. However Dobbs develops a programmable approach to the computation of discrete dependent variable benefits which overcomes this problem.

A more fundamental problem for the ITCM occurs where a high proportion of visitors make only one visit per annum or are first time visitors (Freeman, 1979; Bowes and Loomis, 1980). In such cases statistical techniques used in the ITCM will not have a sufficient spread of observations to make the technique operational. Ironically, those sites which have the highest proportions of repeat visitors are also those which are most likely to be attracting a high proportion of locally based visits who walk to the site and incur zero monetary travel costs (eg. Bishop, 1992). Again ITCM (and ZTCM) techniques will break down in such cases.

In conclusion the decision to use either zonal or individual TCM approaches is likely to have a significant impact upon the results obtained. While there appears no theoretical reason for preferring one approach ahead of the other, this discussion highlights a number of methodological problems associated with the application of the ZTCM. However this does not imply a clean bill of health for the ITCM and certainly all the application issues raised throughout this chapter would have to be satisfactorily addressed before we might begin to consider the adequacy of such an approach.

[34]One of the few examinations of the impact of zonal respecification is given by Price et al., (1986) wherein a 10 zone and a 6 zone concentric system are compared, the impact upon consumer surplus being, in this case minimal. In related work, Christensen (1983) examines the impact of changing the zonal population division from visits per 100,000 population to visits per 1000 population. The author is currently examining the problem of zonal respecification.

Figure T.12: Concentric Distance Zones around the Malvern Hills

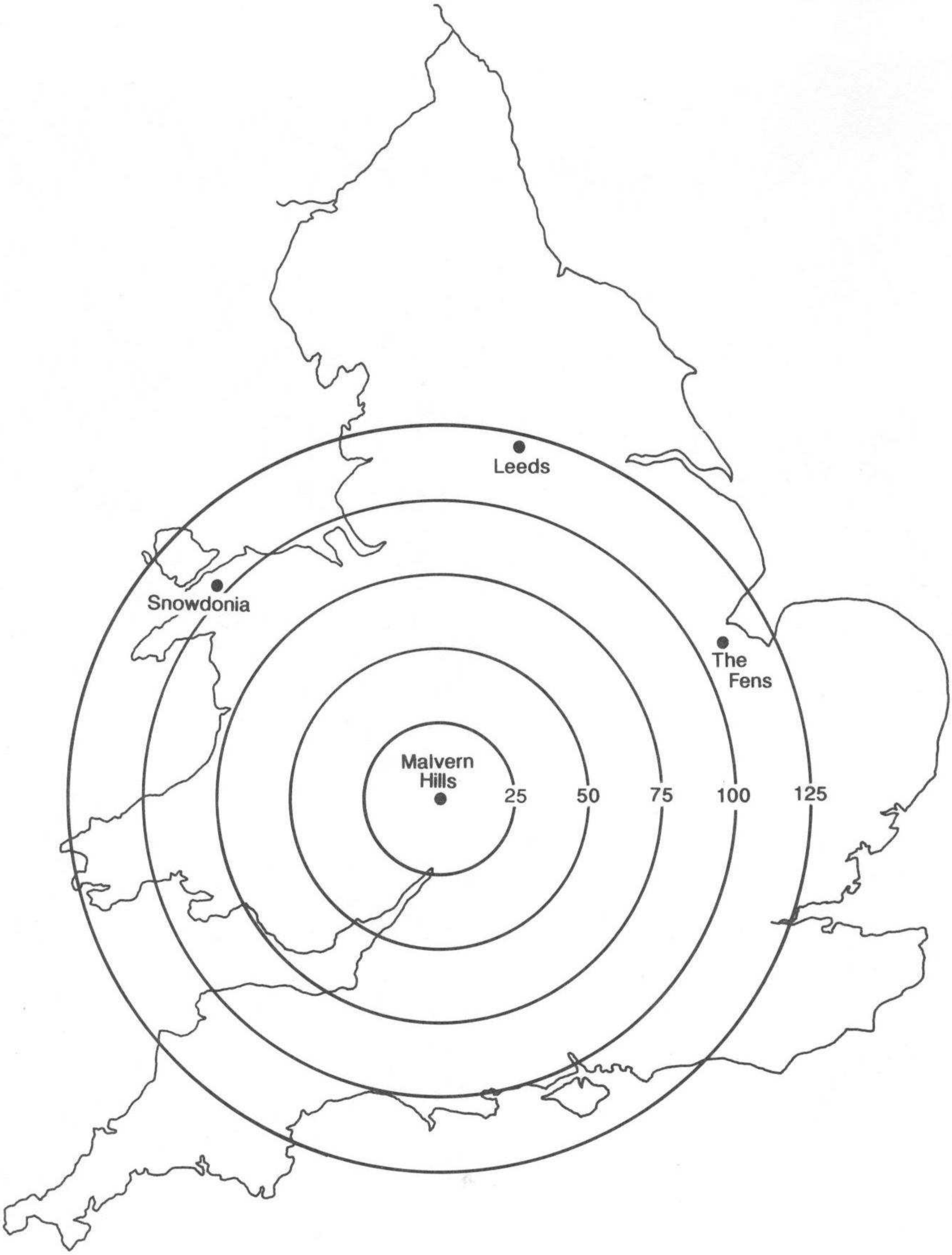
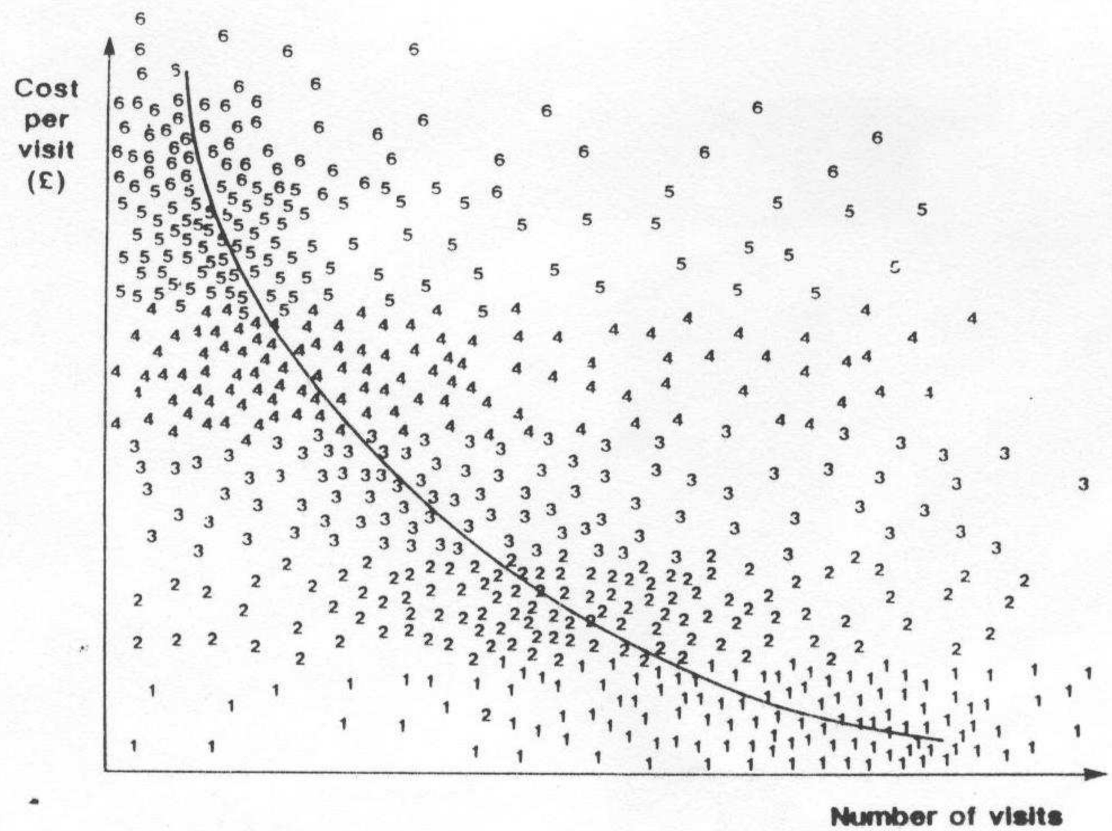
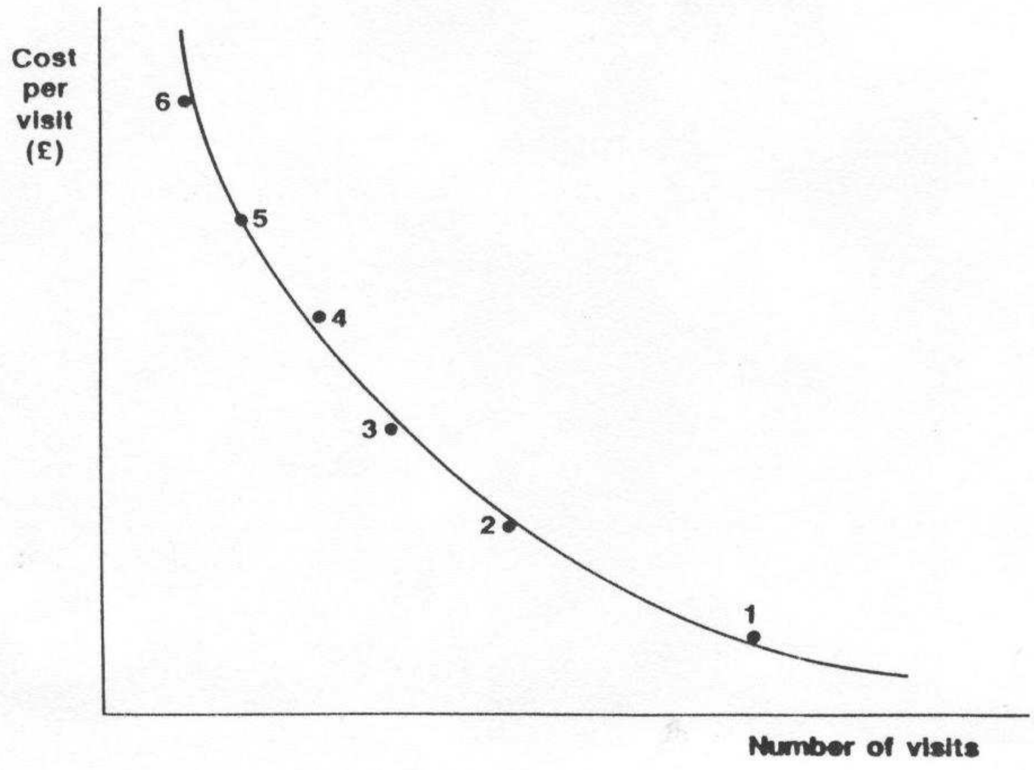


Figure T.13: R^2 Bias in TCM Studies

Panel A: ITCM and R^2



Panel B: ZTCM and R^2



Non-Use Values

TCM measures only the 'use value' of recreation sites. Underestimation of the total value of a site due to the truncation of non-visitors would be made worse if the non-use value of both visitors and non-visitors was significant. TCM is not capable of producing any total economic value estimate in that it cannot estimate non-use items such as existence value. This is because the basis of the technique is the level of use-based costs incurred by visitors in visiting a site. If non-use values are thought to be significant then an appropriate methodology (eg. the contingent valuation method, CVM) must be employed to capture these values.

Comparison of CVM and TCM-derived values may therefore be difficult given the various possible permutation of respondents perception of CVM questions. Three potential scenarios can be envisaged.

(i) Respondents may perceive CVM questions as relating to their total willingness to pay (WTP) for the use value of the good in question[35]. In such a situation CVM and TCM measures are comparable although even here we may expect some divergence given that the CVM produces income-compensated (Hicksian) welfare measures whilst the TCM produces uncompensated (Marshallian) consumer surplus measures[36].

(ii) Respondents may perceive CVM questions as relating to their total WTP for both the use and non-use value of the good under investigation. In such a situation, once we have made any adjustment with regard to the compensated/uncompensated measures problem of scenario (i), (which will still apply), then we would expect a residual difference between CVM and TCM measures such that CVM > TCM measure[37].

(iii) Respondents may perceive CVM questions, not as relating to their total valuation of the site, but rather as relating to the surplus over that already paid (as travel costs,

---

[35]Several permutations of scenario (i) and (ii) are possible given the four feasible variants of CVM question: WTP or willingness to accept (WTA) compensation for a welfare gain or welfare loss. See discussion in Bateman and Turner (1992) where the additional complications surrounding assymetry of gains and losses is also discussed.

[36]Bateman and Turner (1992) note that, whereas standard economic theory would lead us to expect that the divergence between compensated and uncompensated welfare measures will be small, recent theoretical advances have shown that this may not be the case for public goods such as those provided by the environment, ie. the divergence between CVM and TCM measures under scenario (i) may not be insignificant.

[37]Note that the adjustment arising from scenario (i), which still applies, may feasibly outweigh that arising from scenario (ii).

etc) to use the site. Here the CVM measure relates not to the total value of the site but to the consumer surplus over the price paid.

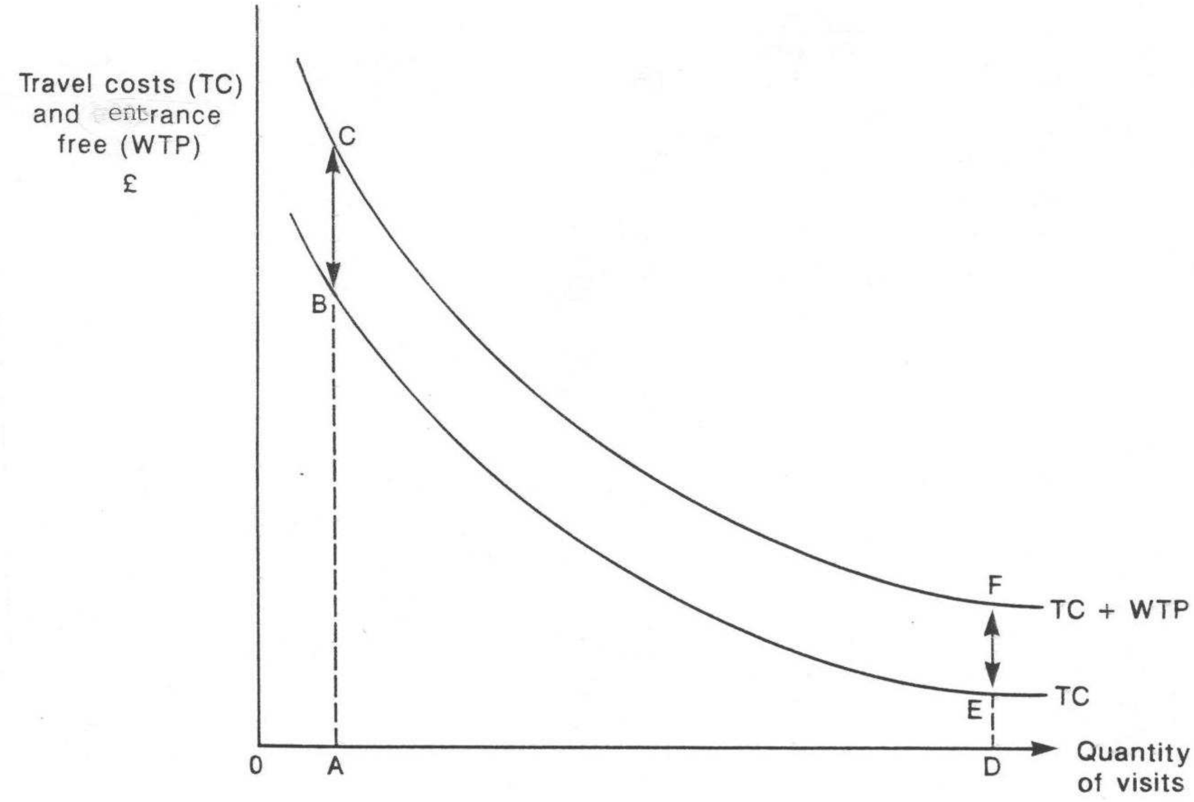
A recent joint TCM/CVM experiment regarding woodland recreation (Bateman et al., forthcoming) suggests that, where CVM questions regarding WTP are presented via an entrance fee payment vehicle, scenario (iii) most accurately describes the relationship between respondents expressed and revealed preferences. Here stated WTP was almost always below already expended travel costs[38]. The absolute level of WTP appeared to be directly related to travel cost i.e. inversely related to the distance between the site and the respondents home and, similarly, the frequency of visits. One interpretation of these results is illustrated by Figure T.14. Here respondents have stated WTP as proportional to their actual travel costs. Those who live far from the site make few trips (OA) as they face high travel costs (AB). These in turn result in relatively high sums being stated in response to the CVM entrance fee question (BC). Conversely those who live close to the site and face low travel costs (DE) consequently make many visits to the site (OD). Setting entrance fee responses in proportion to these travel costs they state a relatively low WTP (EF).

However this is not the only feasible explanation of these comparative results. Another, not exclusive, interpretation is that respondents feel that they have a fixed overall budget for the site and accordingly divide this by the number of visits they make per annum. Such a rationale would produce the same result that frequent (nearby) visitors have a lower WTP (and travel cost) than those who make few visits (generally living further away).

Given that 'convergent validity' tests (Mitchell and Carson, 1989) are commonplace, we feel that insufficient work has been done to date regarding the nature of the perceptions underlying visitors responses and flag this as an area for future research.

[38]This funding accords with the national survey undertaken by Benson and Willis (1990).

Figure T.14: Comparison of TCM and CVM Values



Variants of the TCM

Apart from those already discussed, a number of variants on the TCM have been developed. Pearse (1968) in a study of big-game hunting in Canada develops a variant of the ZTCM, stratifying his sample by income rather than distance zones. The individual with the highest visit costs is assumed to be the marginal user with no net benefits. All other users are assumed to have net benefits equal to the difference between their visit costs and those of the marginal user. Summing these net benefits across all visitors therefore gives us our consumer surplus estimate.

Burt and Brewer (1971) and Cicchette et al. (1976) develop an 'Extended TCM' approach to the valuation of a proposed new site. The first stage involves the estimation of a system of demand equations for existing sites. The existing site which is believed to be the closest substitute for the proposed new site is then isolated. Visitor patterns at this site are held constant while its travel costs are replaced with those which are expected to apply at the proposed new site. The entire system is then re-estimated. The introduction of the new site will cause a fall in net travel costs and this will provide our consumer surplus estimate of the benefit of introducing the new site. This approach of course assumes that the demand function for the new site can be adequately described by that of its closest substitute[39].

Brown and Mendelsohn (1984) develop a 'Hedonic TCM' approach in which the property prices of the hedonic price method are replaced with travel costs as below;

$$TC = f(Z_k, Y, X) \qquad \text{EQN T.21}$$

where: TC = total travel cost (travel expenditure and time costs)

Z_k = site attributes (k=1 to n)

Y = income

X = composite good

The HTCM uses travel costs to estimate values for separate site attributes rather than whole site values. A two stage process is employed (as discussed previously with regard to the work of Smith and Desvousges, 1986). In stage one the independent variables of EQN T.21 (including characteristic levels for each of the k site attributes) are regressed, in separate estimations, against travel costs (ie. distance from zone i to site j) and time costs[40].

Thus, for simplicity setting n=3 and ignoring non-Z explanatory variables, we have;

$$A: \quad PTC.d_{ij} = a_0 + a_1 Z_1 + a_2 Z_2 + a_3 Z_3$$
$$B: \quad PTT_{ij}.TT_{ij} = b_0 + b_1 Z_1 + b_2 Z_2 + b_3 Z_3 \qquad \text{EQN T.22}$$

where: PTC = money expenditure on travel (petrol etc) per mile

d_{ij} = distance from zone i to site j (miles)

PTT_{ij} = opportunity cost per hour of travel time from zone i to site j

TT_{ij} = length of travel time from zone i to site j (hours)

To calculate the implicit prices of each Z_i attribute we now insert cost per mile and time costs. Hanley (1990) illustrates this using values of £0.20 per mile and £1.50 per hour respectively. Using these figures and the amalgamated variables A and B in EQN T.22, the implicit price[41] of characteristic Z_i will be:

[39] See Hof and King (1982) for further discussion of this assumption.

[40] Brown and Mendelsohn (1984) only consider travel time ie. they assume that on-site time is a constant, a separate regression (on site time cost) equation would be required if this were not the case.

[41] The implicit price tells us the value of a marginal improvement in attribute i.

$$\frac{\delta P}{\delta Z_i} = 0.2 \frac{\delta A}{\delta Z_i} + 1.5 \frac{\delta B}{\delta Z_i} \qquad \text{EQN T.23}$$

Stage two involves the estimation of demand curves for each attribute Z_i by regressing implicit price on the observed level of Z_i and other explanatory variables[42]. Summing over all observations gives an aggregate demand function for each attribute from which consumer surplus estimates may be obtained. While the HTCM has had considerable recent application[43] its extreme data requirements have cast doubt upon its practical decisionmaking applicability. In particular it is questionable as to whether the relevant site characteristics may be identified a priori and accurately measured.

CONCLUSIONS

The TCM is a potentially useful evaluation tool producing uncompensated consumer surplus estimates of use value. It is best applied to the evaluation of well defined recreation sites or to the evaluation of a well-perceived, separable, environmental attribute within such a site.

This survey has highlighted several potential problems which may arise during the practical application of the TCM. These include;

- i. The decision whether to use zonal and individual approaches and variation in results between these methods.
- ii. Calculation of the cost elements and in particular determination of the opportunity cost of on-site and travel time.
- iii. Multicollinearity between explanatory variables especially site environmental characteristic levels.
- iv. Problems of heteroskedasticity.
- v. Treatment of substitute sites.
- vi. Accounting for potential congestion effects.

[42] These include income, other socio-economic variables and the predicted number of trips from each zone, the latter being derived from a standard TCM tgf.

[43] Further examples of the HTCM approach include Loomis et al. (1986); Bell and Leeworthy (1990); Bowes and Krutilla (1989); Englin and Mendelsohn (1991); and Hanley and Ruffell (1992). The latter three studies all describe applications to forestry.

vii. Choice of the appropriate functional form and its impact upon consumer surplus estimates.

viii. Truncation bias and the choice of appropriate estimation technique.

The validity of TCM welfare measures will be dependent upon the extent to which these problems can be minimised.

THE HEDONIC PRICE METHOD

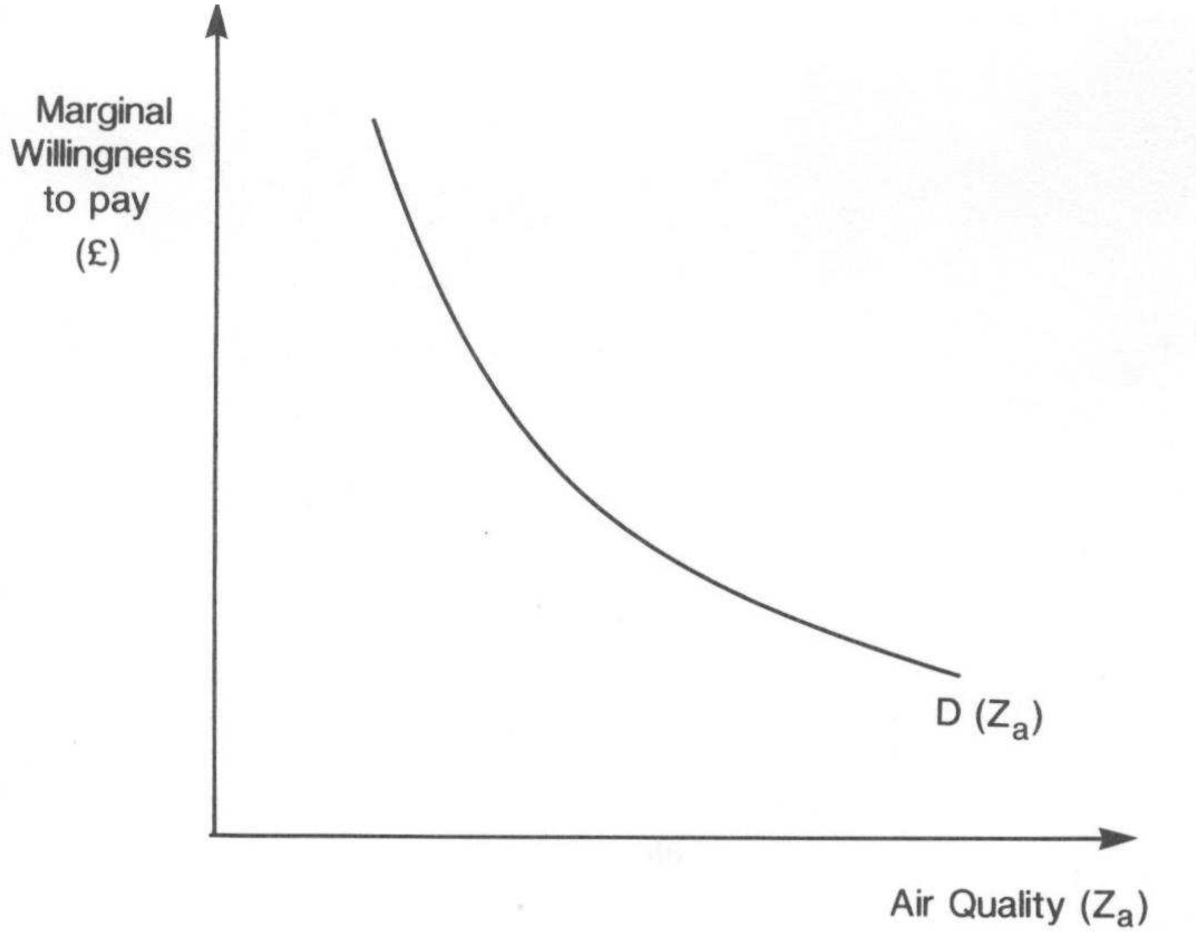
INTRODUCTION

The hedonic price method (HPM) attempts to impute a price for an environmental good by examining the effect which its presence has on a relevant market priced good. The notion of land characteristics being reflected in land values can be traced back at least to Ricardo. However, it was Ridker (1967) who conducted the first recognisable HPM study, noting that "If the land market were to work perfectly, the price of a plot of land would equal the sum of the present discounted stream of benefits and costs derivable from it" (i.e. environmental values are reflected in associated market prices) and, equally importantly, that "Since air pollution is specific to locations and the supply of locations is fixed, there is less likelihood that the negative effects of pollution can be significantly shifted onto other markets" (i.e. single markets can be identified as capturing these environmental values). While Rosen (1974) shows that the HPM can be applied to any market which can be fully estimated, the vast majority of HPM studies have looked at the property market as a reflection of surrounding environmental characteristics such as air quality, water quality, noise etc. By controlling for the structural (eg. size etc), locational (eg. access to workplace etc) and other characteristics of a house, we can isolate the effect which environmental characteristics have upon house price and thereby ascertain the implicit price of a specific public good such as air quality.

The objective of HPM studies is to define the (inverse) demand function relating the quantity of the environmental good to individuals marginal willingness to pay for that good. Figure H.1 illustrates a typical demand curve for air quality.

Once the (inverse) demand function has been isolated then we can evaluate a welfare change as the area under the demand curve between the initial and final environmental quality level. As this demand curve is obtained from property market price data it includes income effects and therefore its integration produces uncompensated consumer surplus estimates of welfare change.

Figure H.1: Demand Curve for Air Quality



THEORETICAL ISSUES

The Method

This discussion will centre around a hypothetical property value application of the HPM to the evaluation of air quality benefits[44].

The HPM is dependent on a number of assumptions for its operation. For the moment we will define these as follows[45];

1. Willingness to pay is an appropriate measure of benefits.

2. Individuals can perceive environmental quality changes; these changes affect the future net benefit stream of a property and therefore people are willing to pay for environmental quality changes.

---

[44] Air quality has been the main focus for empirical HPM studies, see studies and reviews by: Anderson and Crocker (1971); Waddell (1974); Pearce (1978); Pearce and Edwards (1979); Freeman (1979a,b); Brookshire et al. (1982); Pearce and Markandya (1989); Pennington et al. (1990); Turner and Bateman (1990).

[45] See also Mäler (1977) and Hufschmidt et al. (1983).

3. The entire study area can be treated as one competitive market with freedom of access across the market and perfect information regarding house prices and environmental characteristics.

4. That this housing market is in equilibrium ie. individuals continually re-evaluate their location such that their purchased house constitutes their utility maximising choice of property given their income constraint.

We shall discuss the validity of the less fundamental of these assumptions subsequently but for the moment we assume that they hold.

We first define our property value or hedonic price function describing for any housing unit i, its house price (P_i) as the function;

$$P_i = f\,(S_{1i} \ldots S_{ki},\ N_{1i} \ldots N_{mi},\ Z_{i1} \ldots Z_{ni}) \qquad \text{EQN H.1}$$

where: S = Structural characteristics (1... k) at house i e.g. house size, number of rooms, type of construction, etc.

N = Neighbourhood characteristics (1... m) at house i e.g. accessibility to work, quality of schools, local crime rates, etc.

Z = Environmental characteristics (1... n) at house i e.g. air quality, etc.

For simplicity we will assume that only one environmental variable is significant, namely air quality (Z_{ai}).

The functional form of EQN H.1 will be determined by the underlying utility function. For illustrative purposes let us suppose that this is linear so that EQN H.1 can be re-specified as;

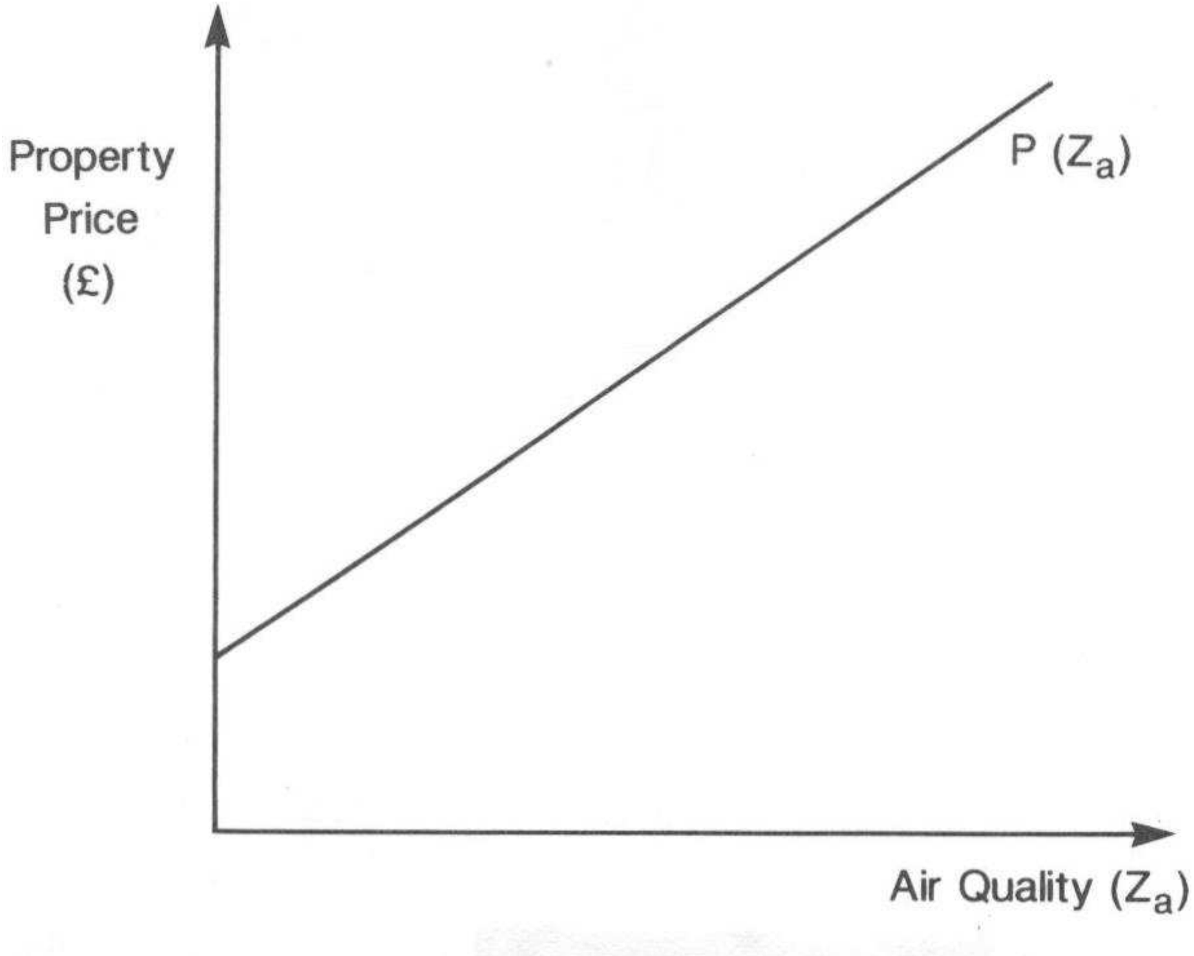
$$P_i = \alpha_o + \alpha_1 S_{1i} + \alpha_{2i} S_{2i} + \ldots. + \alpha_k S_{ki} + \beta_1 N_{1i} + \beta_2 N_{2i} + \ldots + \beta_m N_{mi} + \gamma_a Z_{ai} \qquad \text{EQN H.2}$$

Estimating EQN H.2 we would expect that □$_a$ >0 ie. house price increases with air quality improvement. This gives the total house price relationship (or rent function) for air quality as illustrated in Figure H.2.

By differentiating EQN H.2 with respect to Z_a we can obtain the implicit marginal purchase price for air quality.

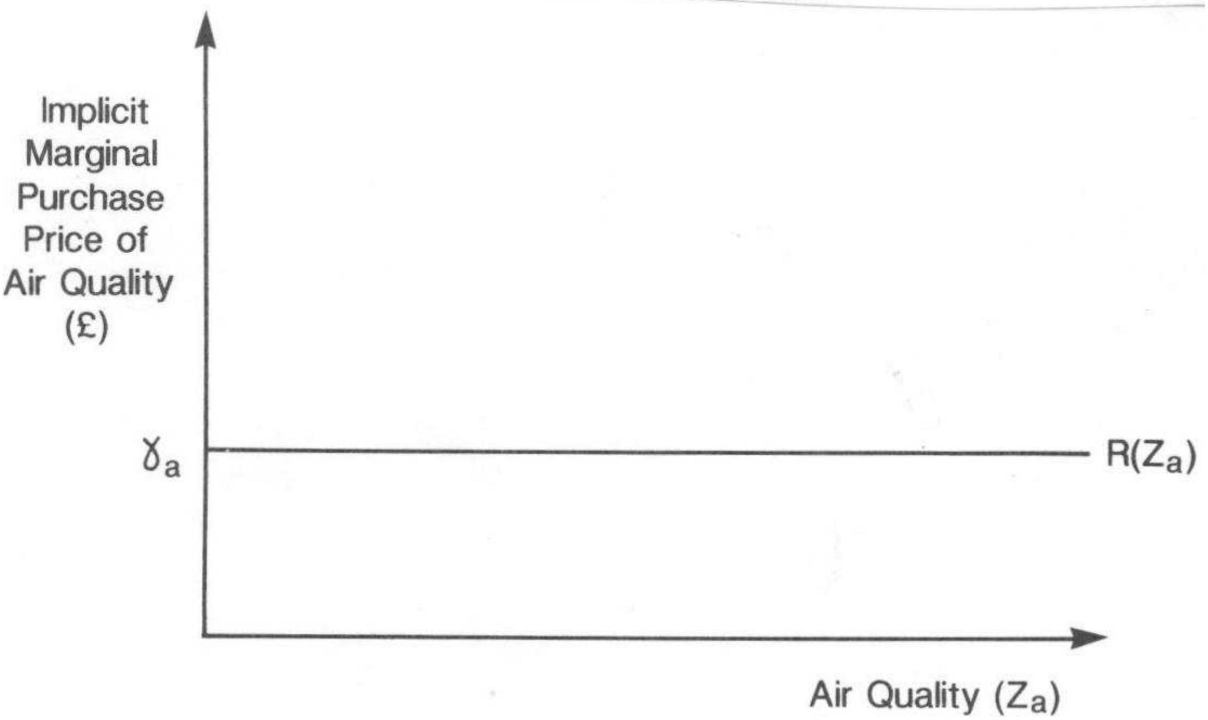
Implicit marginal price of air quality = $\frac{\delta P}{\delta Z_a} = \gamma_a$ EQN H.3

Figure H.2: Rent Function for Air Quality (Linear Hedonic Price Function)



This shows the purchase price of each successive unit of air quality. Because of the linear form of EQN H.2 this is a constant as shown by the line $R(Z_a)$ in Figure H.3.

Figure H.3: **Implicit Marginal Purchase Price of Air Quality (Linear Hedonic Price Function)**

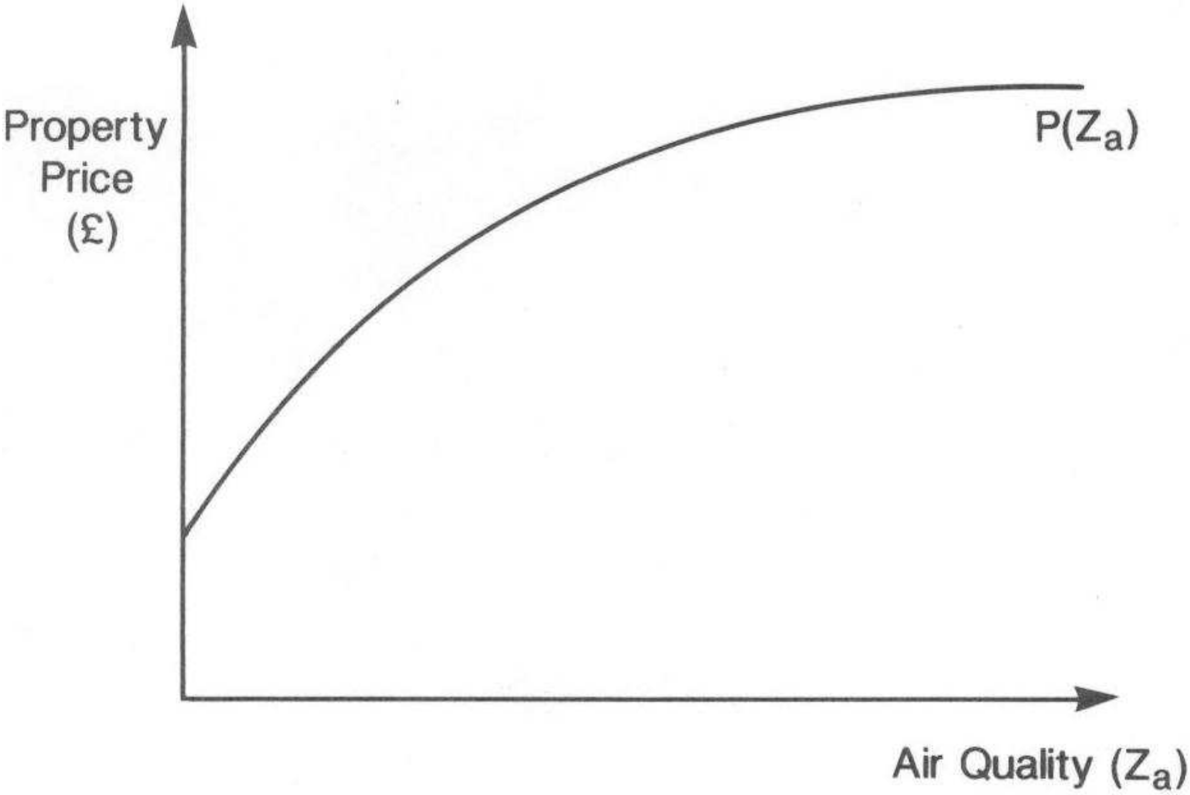


The constant marginal purchase price implied by the linear hedonic price function of EQN H.2 is unlikely to occur in reality. Air quality is likely to be a normal good and exhibit diminishing marginal utility. The hedonic price function is therefore likely to be non-linear. If we have a multiplicative underlying utility function then a double log hedonic price function such as EQN H.4 may be appropriate (the number of non-environmental explanatory variables being reduced for simplicity):

$$\ln P_i = \alpha_i \ln S_{1i} + ... + \beta_i, \ln N_{1i} + ... + \gamma_a \ln Z_{ai} \qquad \text{EQN H.4}$$

This yields the rent function illustrated in Figure H.4.

Figure H.4: Rent Function for Air Quality (Double Log Hedonic Price Function)



Differentiating EQN H.4 with respect to Z_a gives the implicit marginal purchase price of air quality;

$$\frac{\delta P}{\delta Z} = \gamma_a \frac{P}{Z_a} \qquad \text{EQN H.5}$$

Now notice that the implicit marginal purchase price of Z_a varies according to the ambient level of Z_a prior to the marginal change. This function is mapped out by the curve $R(Z_a)$ in Figure H.5[46].

---

[46] Ignoring non-environmental explanatory variables we have the hedonic price function.

$\ln P = \gamma_a \ln Z_a$

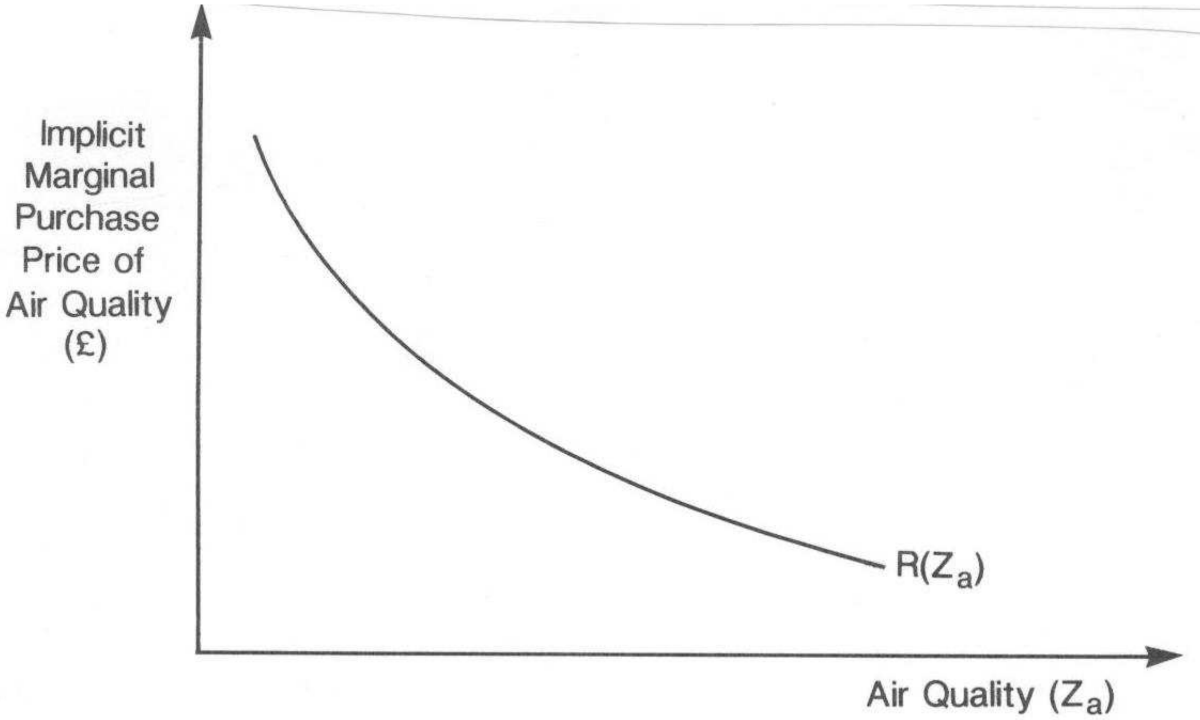
using the integral log rule: $\int \frac{\delta P}{P} = \gamma_a \int \frac{\delta Z_a}{Z_a}$

we can rewrite the function as:

$$\therefore \frac{\delta P}{P} = \gamma_a \frac{\delta Z_a}{Z_a}$$

$$\frac{\delta P}{\delta Z_a} = \gamma_a \frac{P}{Z_a}$$ ie. the implicit marginal purchase price air quality (Z_a)

Figure H.5: Implicit Marginal Purchase Price of Air Quality (Double Log Hedonic Price Function)



The implicit marginal purchase price function describes the price paid for marginal increments of air quality (Z_a). However, it does not necessarily follow that it is the household demand curve for Z_a (see Figure H.1) in the sense that it is unlikely to correspond to households marginal willingness to pay for Z_a. To demonstrate this first consider household (inverse) demand for Z_a which will itself be a function of the level of Z_a, income and other preference variables and can be determined by the regression of EQN H.6[47].

$$W_{Zai} = f\,(Z_{ai}, Y_i, X_i) \qquad \text{EQN H.6}$$

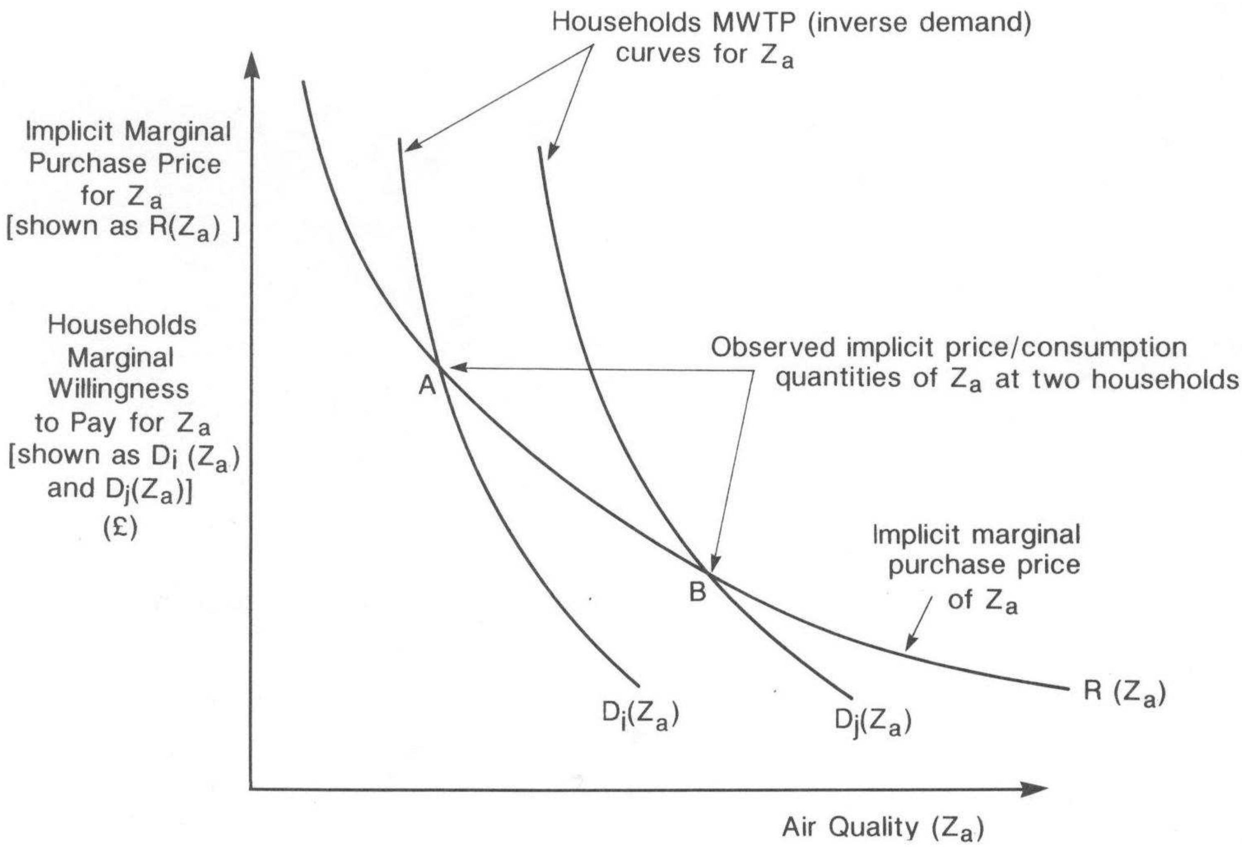
where:	W_{Zai}	=	household i's marginal willingness to pay for Z_a
	Z_{ai}	=	air quality at household i
	Y_i	=	income of household i
	X_i	=	other explanatory variables

The potential non-correspondence between this marginal willingness to pay (MWTP) function and the implicit marginal purchase price function (EQNH.3 or EQNH.5 depending upon

[47]Necessary assumptions being that households only buy one housing bundle and that household utility functions are weakly separable.

functional form) can be demonstrated intuitively by considering an individual household's decision about whether or not to buy an additional unit of Z_a. At some low level of Z_a a particular household may be more than willing to pay the marginal purchase price of an additional unit of Z_a (MWTP > implicit marginal purchase price). However at high levels of Z_a that same household may not be willing to purchase an additional unit (MWTP < marginal implicit purchase price). Logically there will be some intermediate level of Z_a where the household is only just willing to pay for the incremental Z_a unit (MWTP = marginal implicit price). Figure H.6 illustrates this relationship between household MWTP and implicit marginal purchase price for two households (i and j).

Figure H.6: Relationship Between Implicit Marginal Purchase Price of Air Quality and Household Marginal Willingness to Pay (Inverse Demand Curve) for Air Quality for Two Households



We can now show that, assuming all variables are continuous, then at its utility maximising equilibrium, household MWTP for Z_a will be equal to this marginal implicit price. If we define utility (U) as a function of the consumption of the characteristics of housing (S, N and Z as per

EQN H.1) and of all other goods (X). Then the conventional utility maximisation problem will be to:

Maximise U = U (X, S, N, Z)

subject to $Y = P_x.X + P$

where: Y = income

P = price of property

P_x= vector of prices of all other marketed goods

Then, considering the first order utility maximisation conditions, we can see that MWTP for the characteristic Z_a will be:

$$W_{Zai} = \frac{\delta U}{\delta Z_a} \qquad \text{EQN H.7}$$

This is the demand function for Z_a. At equilibrium, this will equal the marginal implicit price of Z_a ie;

$$\text{At equilibrium} \qquad \underset{\substack{\text{MWTP} \\ \text{for } Z_a}}{\frac{\delta U}{\delta Z_a}} = \underset{\substack{\text{implicit marginal} \\ \text{price of } Z_a}}{\frac{\delta P}{\delta Z_a}} \qquad \text{EQN H.8}$$

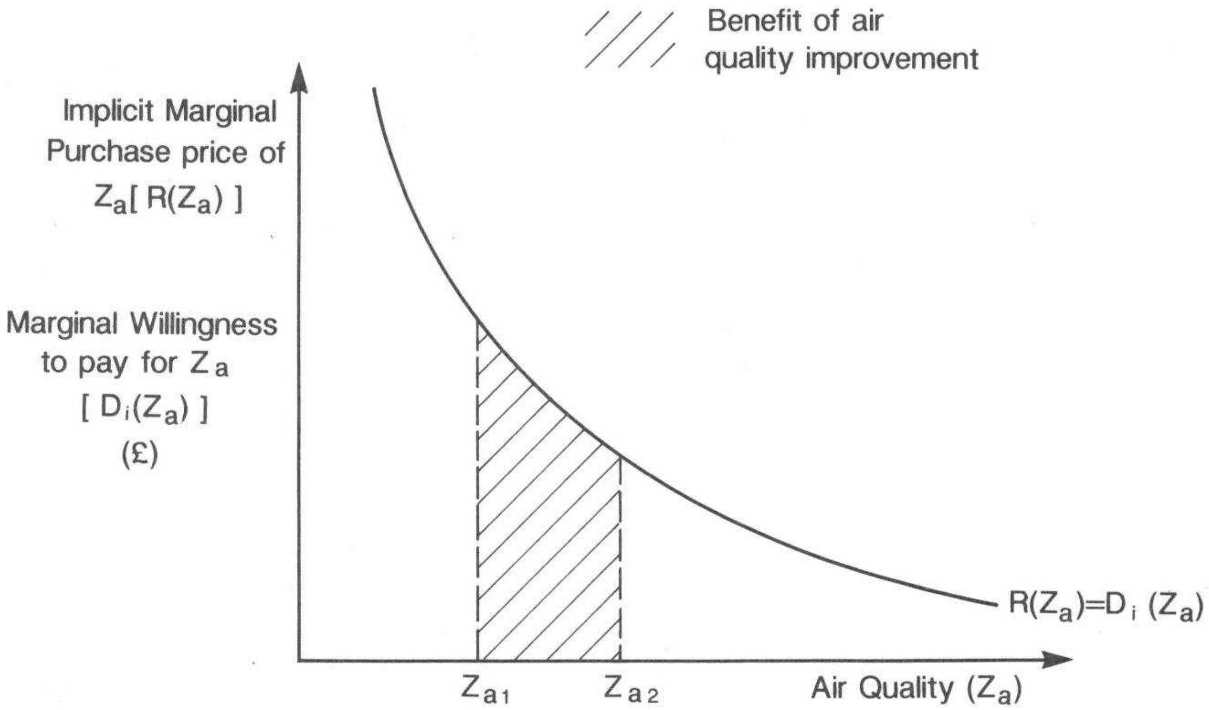
Each household therefore chooses a position where its own MWTP for Z_a is equal to the marginal implicit price of Z_a.

Therefore we can see that empirical observations of implicit marginal purchase price and corresponding level of air quality (as mapped out by $R(Z_a)$) only tell us about single points on each household's inverse demand curve for air quality. Thus the implicit marginal purchase price curve can normally only be used to approximate the benefit of marginal changes in air quality. In the case of such small changes the implicit marginal purchase price curve is an acceptable approximation of the household's inverse demand curve. However as soon as we consider non-marginal changes these curves begin to diverge markedly and the implicit marginal purchase price curve will give a biased estimate of the benefits of air quality change.

Freeman (1979c) shows that there is one case in which the implicit marginal purchase price curve correctly estimates the benefits of non-marginal air quality changes. This occurs when all households have identical utility functions and incomes[48]. In such a case all household inverse demand curves will lie on top of each other along the marginal implicit price curve which can then be integrated to determine consumer surplus welfare measures. Figure H.7 illustrates such a case for an air quality improvement from Z_{a1} to Z_{a2} with resultant benefits shown as the shaded area.

Such an assumption is obviously weak[49] therefore we are left with two broad courses of action; either we can make certain assumptions about the shape of household inverse demand curves; or we can attempt to directly estimate the shape of these curves. Freeman (1979c) and Hufschmidt et al. (1983) consider both options.

Figure H.7: Estimating the Benefits of Air Quality Improvement Assuming Identical Household Utility Functions and Incomes

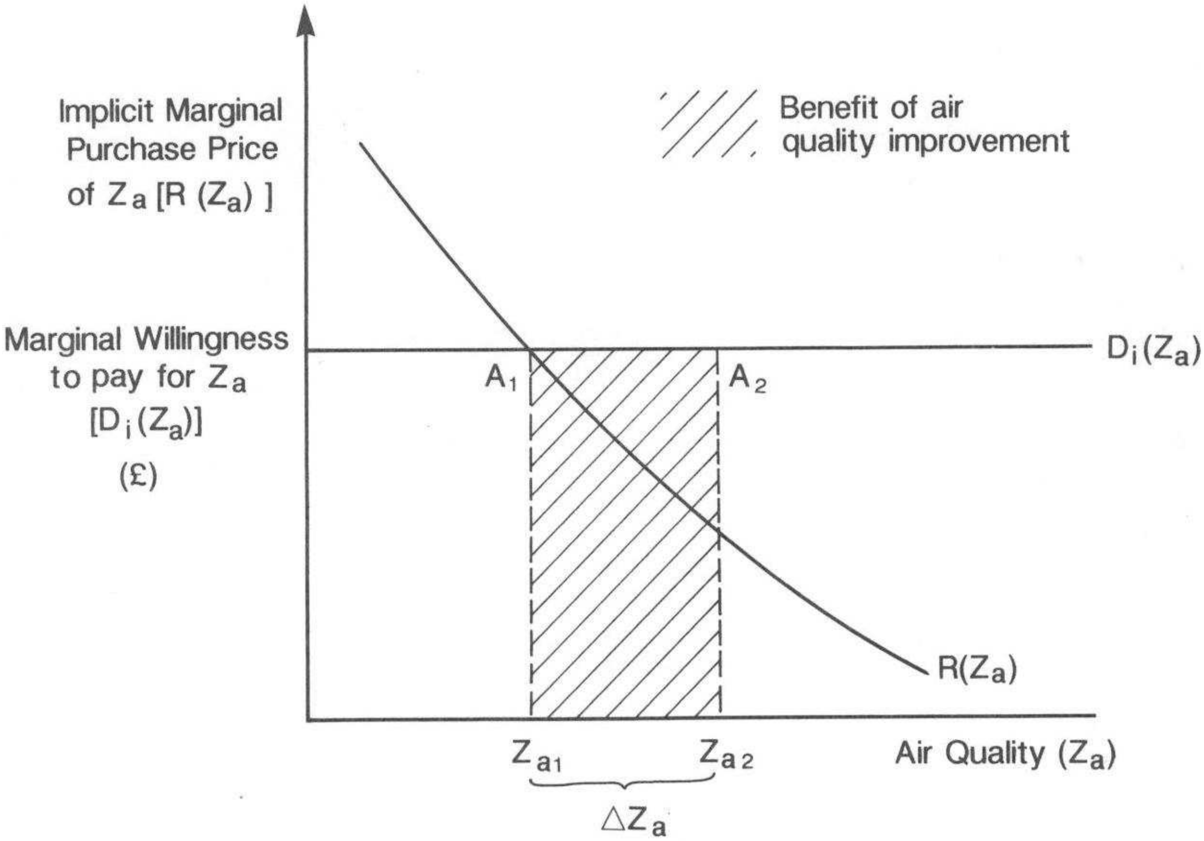


[48]Strictly speaking this correspondence would also occur if the (hedonic) implicit price function were linear as this would imply a constant marginal implicit price, i.e. there would be no price/quantity relationship. However empirical studies have found non-linear functional forms to be consistent with data (Freeman, 1979c).

[49]Although this is unlikely to be the case, some studies have adopted an assumption of identical household inverse demand curves (ie. identical utility curves) so as to use the marginal implicit price function as a demand curve for the purposes of welfare measure estimation (e.g. Brown and Pollakowski, 1977).

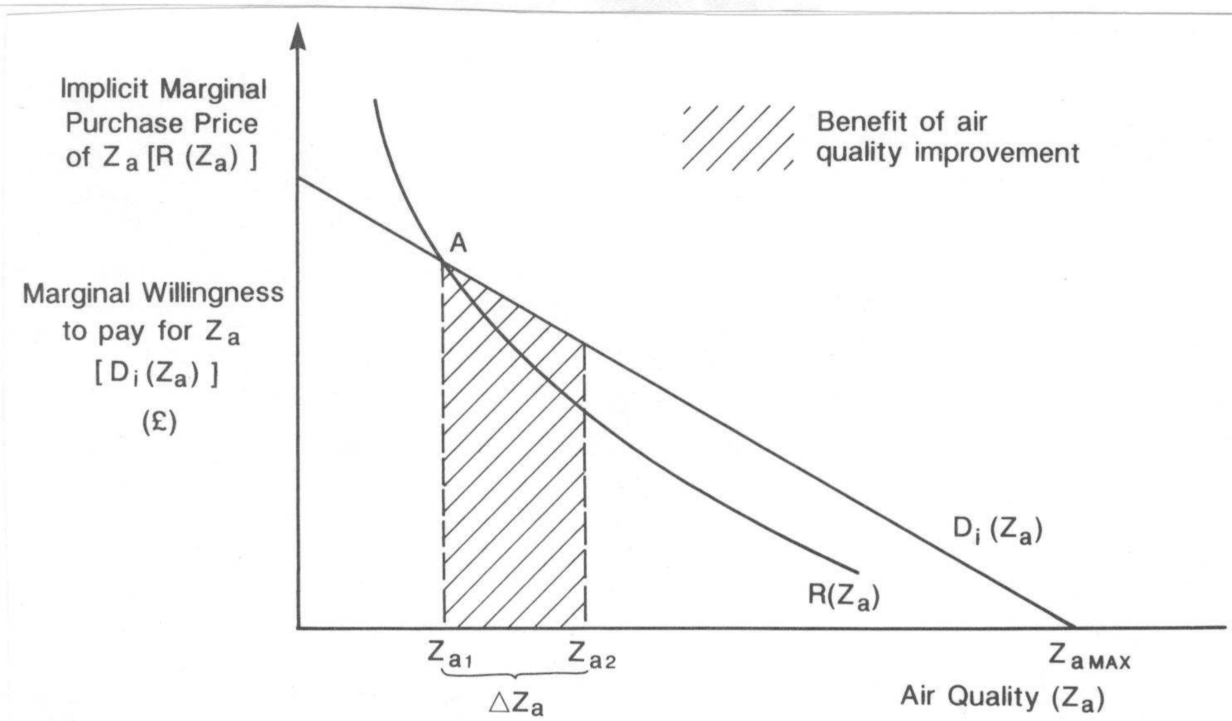
One assumption considered by Freeman is that households might have a constant marginal benefit for air quality improvements i.e. they have a horizontal inverse demand curve, $D_i(Z_a)$, as in Figure H.8. If this is so and the magnitude of the air quality change (Z_a) also being known, then the benefits of that change are calculable as the rectangle Z_{a1} A_1 A_2 Z_{a2}.

Figure H.8: Estimating the Benefits of Air Quality Improvement Assuming Constant Marginal Household Benefits for Air Quality



A second assumption considered by Freeman (1979c) is that household marginal willingness to pay might decline linearly from its observed level (point A in Figure H.9) to reach zero where air quality reaches a maximum (ie. zero pollution level) at Z_{aMAX}. Given such an assumption the slope of $D_i(Z_a)$ can be estimated and, knowing Z_a, we can calculate the benefit of air quality improvement.

Figure H.9: Estimating the Benefits of Air Quality Improvement Assuming Linearly Declining Household Benefits for Air Quality



Despite Freeman's (1979c) assertions that all of the assumptions underlying Figures H.7; H.8 and H.9 are "plausible", in reality all three are highly improbable. Given that (as Figure H.6 shows) a utility maximising explanation of household behaviour requires that household inverse demand curves be steeper than the implicit marginal purchase price curve, the three assumptions discussed above are all liable to result in overestimation of the benefits of air quality improvement (or underestimation of the costs of air quality loss). Furthermore both of the assumptions of Figures H.8 and H.9 would fail to result in equilibrium solutions as increases in air quality above the initial ambient level (Z_{a1}) result in a widening excess of household marginal willingness to pay over implicit marginal purchase price.

One alternative assumption which we suggest is to reverse the previous approach and assume that household marginal willingness to pay for the first unit of air quality is equal to the implicit marginal purchase price of that unit[50]. Assuming also that we have linear inverse demand curves we can evaluate the slope of these curves via observations of point A and thereby estimate the benefits of air quality improvement. The assumption of linearity is likely to lead to

[50]In reality this is also weak as the implicit marginal purchase price of the first unit of air quality is a completely abstract concept and is arguably, equal to infinity.

underestimation of benefits but the approach would have the advantage of producing defensible lower boundary benefit estimates. Figure H.10 illustrates such an approach.

All these assumptions regarding the shape of the inverse demand curve are highly questionable. Therefore many commentators have focussed upon direct estimation of this curve, estimating its slope via regression techniques and using this information in conjunction with observed household consumption levels.

Household demand for air quality will be a function of socioeconomic factors, income and other relevant explanatory variables. However as Freeman (1979c) notes, an important issue here is the speed with which the supply side of the property market can adjust to demand for housing characteristics such as air quality. Three permutations are possible. The first of these is that supply may adjust immediately to demand (ie. a demand constrained system with perfectly elastic supply at a given price). Since we can observe the level of Z_a at any given household and we can use our implicit price function to find the marginal willingness to pay for Z_a ($\partial P/\partial Z_a$ denoted W_{Za} below) at that level of provision, then a regression of observed quantities of Z_a against W_{Za} and other independent variables, such as income and other socioeconomic characteristics, should identify the demand function for Z_a thus;

$$S(Z_a) \square D(Z_a) \Rightarrow Z_{ai}$$

where: $S(Z_a)$ = supply of house air quality characteristics
$D(Z_a)$ = demand for house air quality characteristics

i.e. perfectly elastic supply producing a demand constrained system. Therefore, under such an assumption, we can use the implicit marginal purchase price curve to estimate household marginal willingness to pay for air quality (WZ_{ai}). Thus we can directly estimate the inverse demand curve:

$$Z_{ai} = f(WZ_{ai}, Y_i, X_i) \qquad \text{EQN H.9}$$

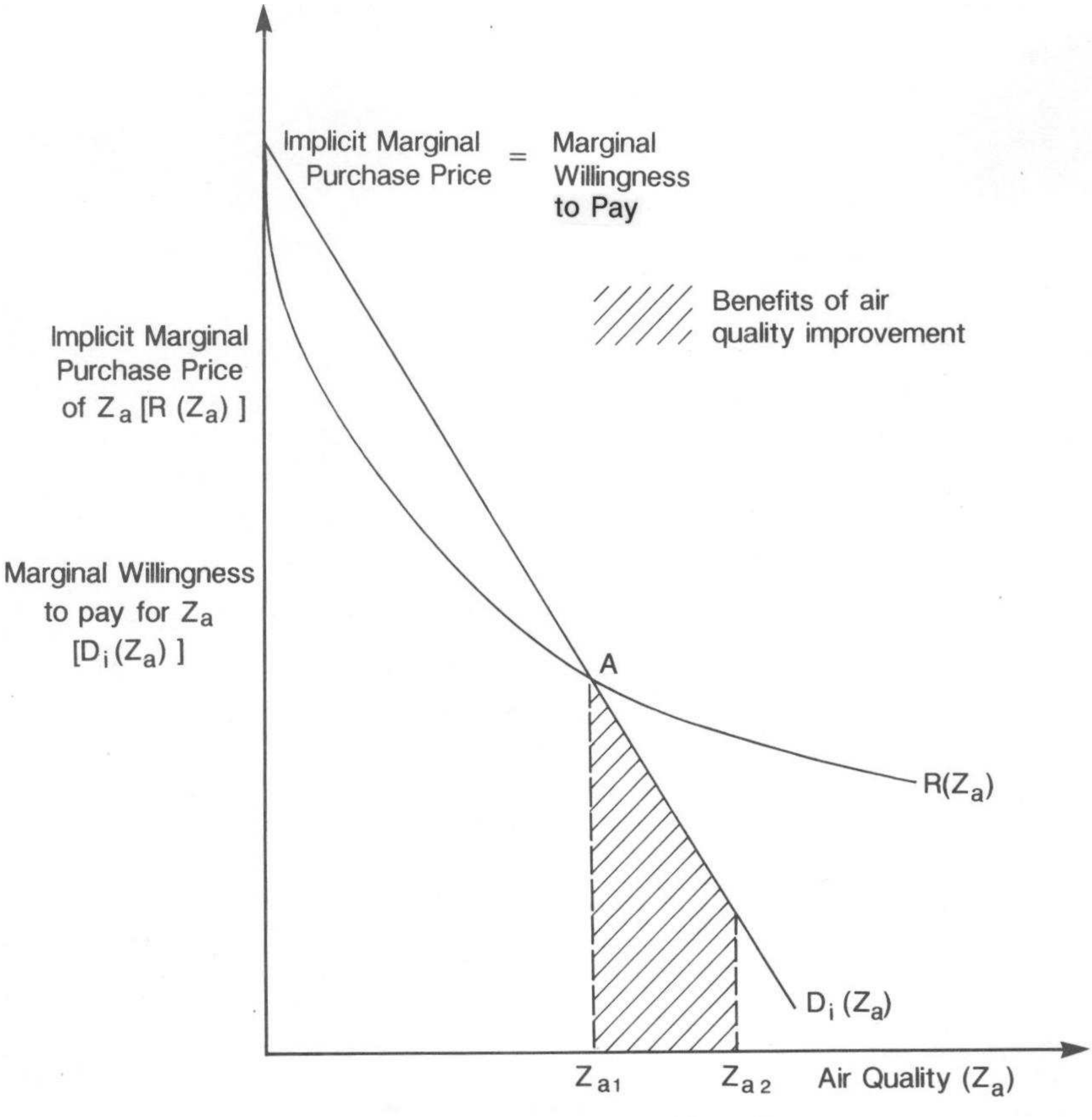
for example the linear form:

$$Z_{ai} = A_o + A_1 W_{Zai} + A_2 Y_i + A_3 X_i + e \qquad \text{EQN H.10}$$

where: Z_{ai} = air quality at household i
Y_i = income at household i

X_i	=	other explanatory variables e.g. socioeconomic factors at household i
e	=	error term

Figure H.10: Estimating the Benefits of Air Quality Improvement Assuming Initial Marginal Willingness to Pay Equals Implicit Marginal Purchase Price.



Rearranging the estimated form of EQN H.10 gives us the slope of the household inverse demand curve [-(1/$\hat{A}_1$)]. Integrating under this curve between the limits of a given air quality increase (decrease) will give our estimate of household benefits (costs) while summing this across all households gives our estimate of total benefits (costs).

An assumption of perfectly elastic supply is however difficult to justify in anything but the long term[51]. House building often exhibits short (and perhaps medium) term lagged response and therefore does not appear to be a vast surplus of housing. An alternative scenario therefore is to postulate a completely supply constrained system with a supply of Z_a fixed irrespective of individual household's demand. In this context, household's bid for fixed amounts of housing with desired environmental characteristics.

In such a case we have;

$$D(Z_a) \square S(Z_a) \Rightarrow Z_{ai} \qquad \text{EQN H.11}$$

i.e. perfectly inelastic supply dictating a supply constrained system. We can now regress observed household marginal willingness to pay for Z_{ai} upon observed quantities of Z_{ai}, household income and other explanatory variables thus;

$$W_{Zai} = f(Z_{ai}, Y_i, X_i) \qquad \text{EQN H.12}$$

for example the linear form;

$$W_{Za1} = B_o + B_1 Z_{ai} + B_2 Y_i + B_3 X_i + e \qquad \text{EQN H.13}$$

Now the slope of the household inverse demand curve is directly given by the estimated coefficient $\hat{B}_1$. Compared to the elastic supply assumption, the assumption of a fixed supply of environmental characteristics may be more defensible. Freeman (1979c) feels that the speed at which market supply can adjust to demand will be sufficiently slow to allow an assumption of fixed supply to hold and asserts that "in general it seems reasonable to treat air quality as exogenous, that is, independent of its implicit price, and to assume that ordinary least squares estimation of (the individual household's MWTP function) identifies the inverse demand curve for (air quality)".

[51] Follain and Jimeniz (1985) and Garrod and Willis (1992) however justify such a decision on the grounds that in studies which deal with microlevel data "an individual household's demand would not normally affect the price function which clears the market" (ibid).

Harrison and Rubinfeld (1978a/b)[52] adopt such a position in their HPM study of air pollution in Boston. The authors' estimated household demand curves with two structural, eight neighbourhood, two access and one environmental (air quality) variables, the latter being the concentration of nitrogen oxide at households measured in parts per hundred million. In estimating the hedonic price function, the air quality variable was shown to be highly significant. The implicit marginal purchase prices could then be estimated as discussed previously giving observations on household marginal willingness to pay for air quality (denoted W_{za} in EQN H.14 below) and the level of household air pollution (denoted by the variable NO_X below). Assuming a supply constrained system, the household inverse demand curve was estimated by regressing W_{za} upon NO_X, household income (INC) and other explanatory variables as per EQN H.12. Harrison and Rubinfeld fitted a variety of functional forms to their data, the double log form being reported as EQN H.14 (all significant variables given).

$$\ln W_{za} = 1.08 + 0.87 \ln NOX + 1.00 \ln INC \qquad \text{EQN H.14}$$

Notice that because the air quality variable NOX measures increasing air pollution (decreasing air quality) it is assigned a positive coefficient ie. marginal willingness to pay for a unit increase in air quality increases as levels of air pollution rise. Therefore we do have the expected negative relationship between increased air quality (decreased NOX) and marginal willingness to pay for that air quality. Notice also that EQN H.14 indicates, as expected, a positive relationship between income and marginal willingness to pay. Figure H.11 illustrates the derived inverse demand curves for three income groups; $Y_1 < Y_2 < Y_3$. In practise Harrison and Rubinfeld (1978b) used average income and NOX figures to calculate the average household benefits arising from cuts in emissions.

While the fixed supply assumption may be empirically attractive, in reality both the quantity supplied of the air quality characteristic Z_a and the quantity demanded may be a function of its implicit price. In such a case the market is simultaneously determined and equations for both the demand and supply sides need to be specified. The demand side can be expressed as;

$$D_i\ (Z_a) = f\ (W_{Zai}, Y_i, X_i) \qquad \text{EQN H.15}$$

and the supply side as;

[52] See also the excellent discussion in Hufschmidt et al. (1983).

$$S_i (Z_a) = f (W_{Zai}, Y_i, X_i) \qquad \text{EQN H.16}$$

Clearly as it stands we would have problems estimating such a system as we cannot identify whether shifts in marginal willingness to pay are the result of demand or supply side pressures. Nelson (1978a) attempts to address such a situation by separately specifying the supply side as;

$$OP = f (Z_a, d, K) \qquad \text{EQN H.17}$$

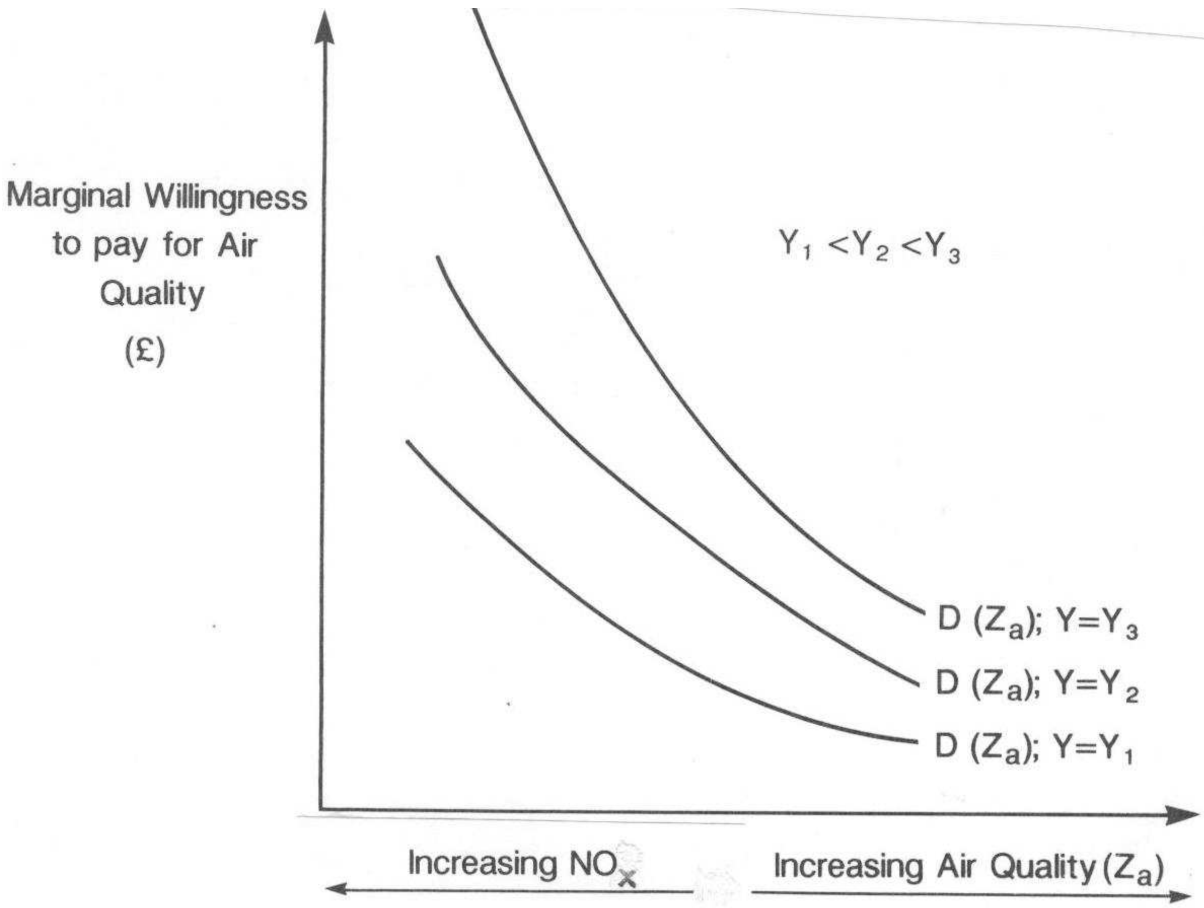
where: OP = offer price (from house vendors)

Z_a = level of air quality

d = distance from central business district

K = other relevant variables

Figure H.11: Inverse Demand Curves for Air Quality for Three Income Groups



Nelson argues that the two-stage least squares estimation of this system identifies both the demand and supply functions for air quality. The validity of such approaches should be judged by the statistical validity of the estimated functions.

Assuming for the moment that the individual household's inverse demand curve has been estimated then the household's welfare gain or loss engendered by some change in the provision of an environmental good, can be estimated by integrating under this curve between the initial and subsequent provision levels. Total benefit is then estimated by summing individual household benefits thus;

$$B = \sum_{i=i}^{n} \int_{Z_{ai1}}^{Z_{ai2}} D_i(Z_a).dZ_a \qquad \text{EQN H.18}$$

where: B = uncompensated consumer surplus change aggregated over all households

I = households (1 to n)

Z_{ai1} = initial level of air quality

Z_{ai2} = final level of air quality

D_i (Z_a) = household's inverse demand for Z_a function (marginal willingness to pay for Z_a)

As stated, this procedure produces measures of uncompensated consumer surplus. We can test the specific validity of such a measure as an estimator of true (compensated) welfare change using the Willig (1973, 1976) formulae. Freeman (1979c) uses such a procedure to test figures from Harrison and Rubinfield's (1978a/b) HPM study of nitrogen oxide and particulates in Boston. However while Freeman uses the results obtained using Harrison and Rubinfeld's linear form we can repeat this test using their preferred single log (dependent) functional form. Using mean values for all explanatory variables this function estimates a mean capitalised consumer surplus value for air quality of $1,613 which (following Freeman's approach) we can annualise to about $160 p.a. using an assumed 10% discount rate. Reported values for average income and income elasticity were $11,500 pa and 1.0 respectively. Willig shows that for consumer surplus to be a valid estimator of compensated welfare change two conditions must be satisfied. Following Varian's (1984) simplification, the first condition is that:

$$\frac{CS}{Y} \cdot \frac{\varepsilon^Y}{2} \leq 0.5 \qquad \text{EQN H.19}$$

where: CS = annual consumer surplus estimate

Y = income

ε^Y = income elasticity

here we have

$$\frac{160}{11{,}500} \cdot \frac{1.0}{2} = 0.007$$

therefore the first condition is well satisfied. Willig's second condition is that:

$$\frac{CS}{Y} \leq 0.9 \qquad \text{EQN H.20}$$

here we have

$$\frac{161}{11{,}500} = 0.014$$

therefore the second condition is again well satisfied. We can conclude that, in this study at least, consumer surplus estimated by the HPM can be taken as a valid approximation of the compensated welfare measure.

We conclude, therefore, that the HPM does have a consistent theoretical basis which allows for the valid estimation of consumer surplus measures of welfare change. We now turn to consider methodological aspects and applications issues specific to the method.

METHODOLOGICAL ISSUES

Assumptions

The HPM relies upon a number of restrictive assumptions, the most fundamental of which are the assumptions of perfect information and perception regarding the environmental characteristics which define a particular housing bundle. In the case of air quality change this assumes that individuals can perceive such change as a continuous variable. However, it is quite feasible that individuals will have perception thresholds for pollutants such that concentrations below this threshold are not perceived. This leads to the possibility of a non-continuous implicit marginal purchase price function and associated estimation and interpretation problems. A similar problem arises where pollution related diseases are subject to long time delays or only arise due to a critical accumulation of pollutants. The degree to which individuals perceive environmental quality (or its absence) is therefore a crucial determinant of the validity of any particular HPM study.

A further aspect of this problem is whether individuals' perceptions and consequent property purchase decisions are based upon actual or historic levels of pollution and environmental quality. If expectations are not the same as actuality (as measured by present pollution readings) then there are clearly problems in relating this to values as derived from purchases. Similarly Mäler (1977) points out that expectations regarding future environmental quality may bias present purchases away from that level dictated by present characteristic levels.

Concern can also be raised regarding the extent to which an assumption of utility maximisation can be maintained within the rigidity of the property market (see subsequent discussion). Mäler (1977) also criticises the HPM for making the implicit assumption that households continually re-evaluate their choice of location.

Furthermore there is considerable doubt that such an assumption can hold in the context of spatially-large study areas (see Garrod and Willis; 1992). If people cluster for social or transportation reasons (for example if intra-urban transport is poor) then HPM results will be biased.

These criticisms regarding the dubious nature of the assumptions underpinning the HPM (compounded by the severe difficulties surrounding the construction of satisfactory assumptions regarding the form of the inverse demand curve discussed previously) constitute the most fundamental problem facing the practical application of the HPM.

Statistical Problems

i. Functional Form

As with CVM and TCM studies, HPM researchers face a fundamental problem in that theory provides us with no particular expectation regarding the nature of the functional form for the implicit marginal purchase price and inverse demand function (other than they are unlikely to be linear). The most commonly adopted forms are the double and semi-log[53].

Apart from the linear form, most functional forms generally produce the expected result that the implicit marginal purchase price of air quality is dependent upon its absolute level. However, the nature of that dependency (diminishing or increasing) varies according to the specific functional form. We have previously examined a double log form, and we can contrast this with the exponential form discussed by Hanley (1991). Here the environmental characteristic is measured as the air pollution level variable POL rather than air quality. A simple geometric form[54] (ignoring all other explanatory variables) is;

$$P_i = aPOL^b \qquad \text{EQN H.21}$$

where: P_i = property price

Setting b < 0, we obtain the hedonic and implicit marginal purchase price functions shown in Figure H.12. Notice that, as we are dealing with increasing levels of air pollution (decreasing levels of air quality) along the horizontal axis, we now have a downward sloping hedonic price function (upper graph) in contrast to the upward sloping curve used in our previous discussions (re. increasing air quality). However such a function provides the implicit marginal purchase price curve shown in the lower graph which now diminishes with absolute pollution level (i.e. the hedonic price function has a positive second derivative) indicating, as we would expect, that initial doses of pollution impose a greater marginal cost than do subsequent units of pollution. This seems plausible, however, in this example the choice of functional form has been imposed, i.e. it is not data-determined. Anderson and Bishop (1986) discuss the adoption of a Box-Cox transformation procedure in which relationships are not imposed from the outset but instead functional form is derived using tests of best statistical fit (the linear, semi-log and double-log forms all being special cases of the Box-Cox linear model). Such an approach could adopt a function form such as:

$$\frac{P_i^c - 1}{c} = a + bPOL \qquad \text{EQN H.22}$$

where: c = an unknown parameter

[53]Freeman (1979c) presents and discusses empirical results for some 15 case studies (Table 2, pp.156-160).

[54]The double log equivalent is log P_i = a + b log POL.

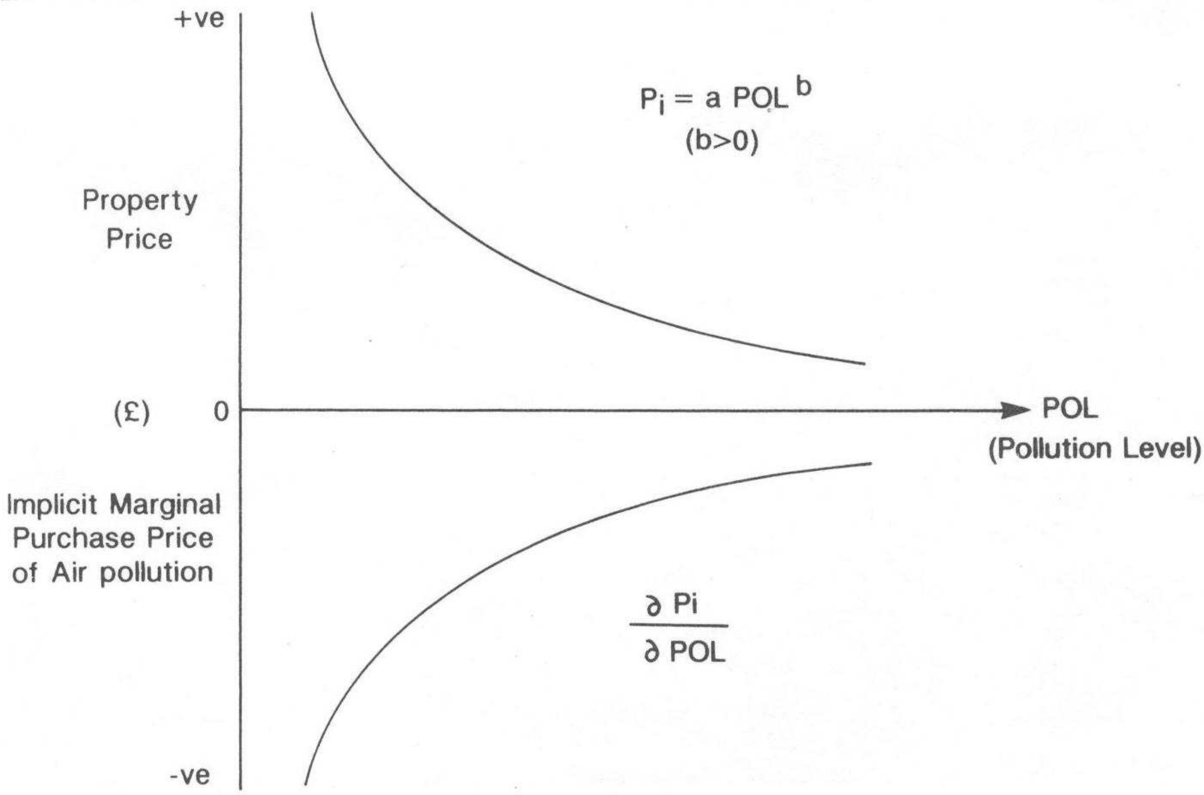
Such a functional form gives the following second derivative[55].

$$(1\text{-}c)b^2\ P_i^{1-2c} \qquad \text{EQN H.23}$$

this will be signed as:

- Positive for c < 1 (i.e. diminishing implicit marginal purchase price of pollution)
- Zero for c = 1 (i.e. constant implicit marginal purchase price of pollution)
- Negative for c > 1 (i.e. increasing implicit marginal purchase price of pollution)

Figure H.12: Hedonic Implicit Marginal Purchase Price of Air Pollution Assuming an Exponential Functional Form



ii. Measurement and Multicollinearity

Pollution measurements may well be subject to temporal variation, however, there is no clear rationale for aggregation. In particular, as previously noted, individuals may be more perceptive of peak intensities rather than averages. Even if averages are appropriate the periodicity is again uncertain (e.g. monthly? annual? etc).

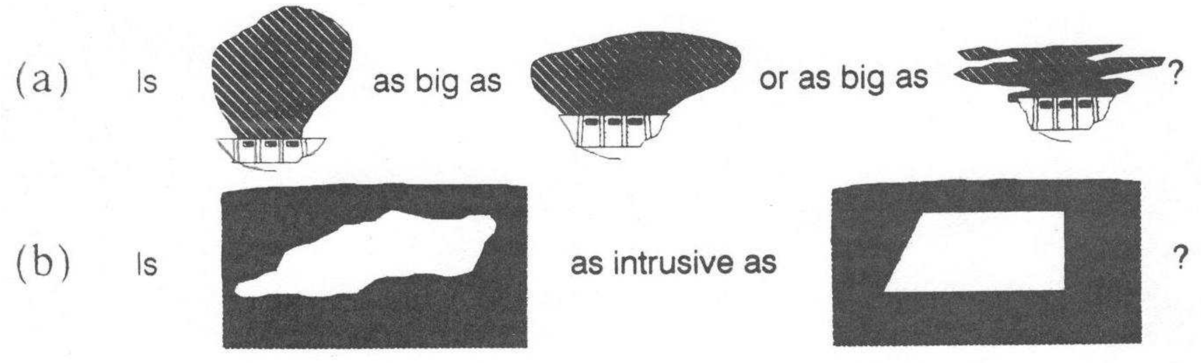
[55]Note that the inclusion of P_i in the second derivative of the Box-Cox form implies that the implicit price of pollution is

Price (1991) comments upon HPM measurement problems in the context of landscape evaluation noting that "a view is not measured only by the surface area covered, and may as easily be related to the edge perimeter with other components of the view, as to the solid angle subtended at the viewpoint". Panel (a) of Figure H.13 illustrates this point.

Multicollinearity is a similarly endemic problem for HPM studies. Explanatory variables are very likely to be collinear, e.g. sulphates and particulates; noise and dust. Ignoring such problems by using one pollution variable will lead to biased OLS estimators (usually upwardly biased as the chosen single pollutant picks up variation due to other pollutants) unless it is made clear that the chosen environmental characteristic is a flag variable for all those it is collinear with (see Turner and Bateman, 1990).

Again Price (1991) highlights the relevance of such concerns in HPM landscape evaluation exercises noting that multicollinearity invalidates the assumption that different attributes affect utility separably; "given that landscape quality is strongly determined by composition of features, this assumption is unsound". Panel (b) of Figure H.13 illustrates this point.

Figure H.13: Landscape Evaluation Problems for the HPM



Source: Price (1991)

iii. Other Variables

Given that estimation of a valid hedonic price function involves the inclusion of a variety of variables alongside environmental characteristics, omission of any of the structural, locational or neighbourhood variables will lead to biased estimators (Turner and Bateman, 1990). Freeman (1979c) makes an interesting argument for the potential inclusion of income as a neighbourhood explanatory variable. Generally a hedonic price function would not include

---

also dependent upon the level of the other non-environmental characteristics in the housing bundle.

income, it being a characteristic of households rather than houses. However, it can be argued that the general income level of households in the area may be perceived as a socioeconomic characteristic of a particular house so that, for example, some median income figure might defensibly be included.

However researchers should also be wary of 'kitchen-sink' type approaches in which a plethora of spurious explanatory variables is included in order simply to boost overall explanatory power statistics. All explanatory variables should have a valid theoretical basis for their inclusion.

A major problem for HPM researchers has been the gathering and measurement of the large volume of explanatory variable data necessary to operationalise models, e.g. measuring access distances to a variety of amenities (workplace, leisure centres etc.). A new tool which holds great promise for such applications is the Geographical Information System (GIS) which is capable of manipulating a number of digitised maps simultaneously and can, for example, computerise the measurement of access distances so as to facilitate a considerable improvement in the collection and analysis of data. A second application of GIS would be the simulation of 3-D maps (viewsheds) around a house to allow the use of actual views to amenity/disamenity sites rather than just using straight line distances which may be less relevant. There is good reason to suppose that such an approach would provide a very considerable enhancement of HPM studies. In a HPM study of amenity values, McLeod (1984) used a visual inspection of the view from each sample property related to whether or not that property had a river view. The resultant variable was found to be highly significant. However, we are currently not aware of any studies which have yet taken advantage of the specific advantages afforded by GIS[56].

The Property Market

i. Data

Property value data may be obtained directly from sales (eg. Garrod and Willis, 1992) or estimated using professional or homeowners estimates (eg. Button and Pearce, 1989). Clearly there are potential errors and/or biases inherent in the latter options and sales price is always to be preferred. However, the availability of such data may be restricted. Thus in England and Wales sales price tends to be known only by the vendor, purchaser and mortgage lender[57]. Data in Scotland is far more accessible via the sales register while in the USA availability varies by State but can be very good (see Brookshire et al; 1982). Australian data is typically excellent

[56]Current work between the author and others at CSERGE, UEA is examining the application of GIS to HPM studies.

[57]As Garrod and Willis (1992) show, UK mortgage companies can prove good sources of house price data.

with database records of house valuations for most urban properties (see McLeod, 1984). The cost of obtaining data is likely to rise inversely with its availability and this may be an important factor limiting the applicability of HPM studies.

ii. Price Distortions

As already indicated, property prices are just as likely to reflect supply conditions as demand. This is particularly true of the UK where large scale state intervention, both directly through provision of public housing[58] and indirectly via tax concessions to homeowners, has considerably distorted the market. Therefore, the analyst must consider both sides of the market and the adjustments necessary to avoid the biasing of benefit values.

Another consideration in the treatment of property price data is the possibility of averting behaviour (defensive expenditure). For example, a houseowner may mitigate against local pollution levels by say, fitting double glazing to reduce noise, or installing air purifiers to combat air pollution. Such behaviour may enhance the value of the house above that defined by local environmental characteristics. Therefore, where such factors are significant, the hedonic price function should be fitted with a specific variable to account for this, however such a variable may be difficult to operationalise.

iii. Market Rigidities

The HPM assumes that the property market is both fluid and in equilibrium, ie. that individuals are free to move to utility maximising positions subject only to their income constraints and that the housing market clears in each period. Violation of these assumptions means that individuals will no longer be able to equate their MWTP curves with the implicit marginal purchase price function and, in some circumstances, this will cause the HPM to be invalid.

Further complication arises where the property market studied is shown not to be a single whole but a segmented collection of regional markets (Hyman, 1981). This will occur where there are certain barriers to mobility between regions (for example due to ethnic discrimination) and at the same time demand and/or supply conditions vary between these regions[59].

iv. Is the Property Market Sufficient?

[58]The recent widespread sale of UK public sector housing to private individuals at below-market prices is also relevant here.

[59]Straszheim (1974) showed this to be significant in San Francisco whereas Nelson (1978b) could not show segmentation to be a significant factor in Washington DC.

The HPM only examines households' willingness to pay for environmental quality at the home. It therefore ignores both the value of improvements which occur away from the home but which directly affect the household (i.e. HPM does not capture the totality of use values) and those which do not directly affect the household but are still valued (i.e. HPM does not capture non-use values). For example, air quality both at the home and at the workplace may affect the decision to locate. Therefore both property prices and wage differentials may need examination. However, we do run a risk of double counting if we add all benefit estimates obtained from various individually valid sources. For example, if, for a reduction in air pollution, we added soiling benefits to property value benefits and wage differentials, then we are likely to double count and overestimate the value of environmental improvements (see Cummings et al., 1986; Freeman, 1979c).

CONCLUSIONS

The HPM is founded upon a coherent theoretical base. As such it is theoretically capable of producing valid uncompensated consumer surplus estimates.

However the method can be strongly criticised according to the number and strength of assumptions which need to be made in order that valid results be obtained. Pearce (1978) feels that these stringent requirements invalidates the practical use of HPM, while Price (1991) feels that any results obtained are at very best highly site specific and non-transportable. These difficulties are compounded by the need to consider both the supply and demand side of the property market dictating that the use of HPM is likely to remain restricted to a few expert-users.

Optimal applications for the HPM are defined by the requirements of the method itself. The environmental characteristic under evaluation must be well perceived by households and the impacts of that characteristic must be well contained within the market being studied. Typical applications include the evaluation of visible air pollution or well-perceived noise in areas where the property market is fluid and can reasonably be said to be in equilibrium. In such conditions the HPM may provide defensible evaluations of those environmental characteristics.

References

The Travel Cost Method

Arrow, K., Solow, R., Portney, P.R., Leamer, E.E., Radner, R. and Schuman, H. (1993) "Report of the NOAA Panel on Contingent Valuation", Resources for the Future, Washington, D.C.

Balkan, E. and Kahn, J.R. (1988) "The Value of Changes in Deer Hunting Quality: A Travel-Cost Approach", *Applied Economics*, vol.20: 533-539.

Bateman, I.J. and Turner, R.K. (1992) "Valuation of the Environment: The Contingent Valuation Method" *CSERGE GEC Working Paper 92-18*, Centre for Social and Economic Research on the Global Environment, University of East Anglia and University College London.

Bateman, I.J., Diamand, E. and Wall, J. (forthcoming) "Recent Experiments in Monetary Evaluation of the Environment", Environmental Appraisal Group, University of East Anglia.

Bell, F. and Leeworthy, V. (1990) "Recreational demand by tourists for saltwater beach days", *Journal of Environmental Economics and Management*, vol.18: 189-205.

Benson, J.F. and Willis, K.G. (1990) "The Aggregate Value of Non-Priced Recreation Benefits of the Forestry Commission Estate". Report to the Forestry Commission, Dept. of Town and Country Planning, University of Newcastle, Newcastle.

Bishop, K. (1992) "Assessing the Benefits of Community Forests: An Evaluation of the Recreational Use Benefits of Two Urban Fringe Woodlands", *Journal of Environmental Planning and Management*, vol.35, no.1: 63-76.

Bockstael, N.E., Strand, I.E. Jr. and Hanemann, W.M. (1984) "Time and Income Constraints in Recreation Demand Analysis", Dept. of Agricultural and Resource Economics, University of Maryland, College Park, Maryland.

Bojö, J. (1985) "A Cost-Benefit Analysis of Forestry in Mountainous Areas: The Case of Valadalen". Stockholm School of Economics, Sweden.

Bowes, M.D. and Loomis, J.B. (1980) "A note on the use of travel cost models with unequal zonal populations", *Land Economics*, vol.56: 465-70.

Bowes, M.D. and Loomis, J.B. (1982) "A note on the use of travel cost models with unequal zonal populations: Reply", *Land Economics*, vol.58: 408-410.

Bowes, M. and Krutilla, J. (1989) *Multiple-use Management: The Economics of Public Forestlands. Resources for the Future*, Washington D.C.

Brown, G. and Mendelsohn, R. (1984) "The Hedonic Travel Cost Model", *Review of Economics and Statistics*, vol.66: 427-433.

Brown, W.G. and Nawas, F. (1973) "Impact of Aggregation on the Estimation of Outdoor Recreation Demand Functions", *American Journal of Agricultural Economics*, vol.55, no.2: 246-249.

Burt, O.R. and Brewer, D. (1971) "Estimation of Net Social Benefits from Outdoor Recreation", *Econometrica*, vol.39, no.5: 813-827.

Cesario, F.J. (1976) "Value of Time in Recreation Benefit Studies", *Land Economics*, vol.55: 32-41.

Cesario, F.J. and Knetsch, J.L. (1970) "Time bias in recreation benefit estimates", *Water Resources Research*, vol.6, no.3: 700-704.

Cesario, F.J. and Knetsch, J.L. (1976) "A Recreation Site Demand and Benefit Estimation Model", *Regional Studies*, vol.10: 97-104.

Cheshire, P.C. and Stabler, M.J. (1976) "Joint consumption benefits in recreational site 'surplus'; An empirical estimate", *Regional Studies*, vol.10: 343-351.

Christensen, J.B. (1983) "An Economic Approach to Assessing the Value of Recreation with Special Reference to Forest Areas", Ph.D Thesis, University College of North Wales, Bangor.

Christensen, J.B. and Price, C. (1982) "A Note on the Use of Travel Cost Methods with Unequal Zonal Populations: Comment", *Land Economics*, vol.58(3): 395-399.

Christensen, J.B., Humphreys, S.K. and Price, C. (1983) "A Revised Clawson Method: One Part Solution to Multidimensional Disaggregation Problems in Recreation Evaluation". *Journal of Environmental Management*, vol.20: 333-346.

Cicchetti, C.J., Fisher, A.C. and Smith V.K. (1976) "An Econometric Evaluation of a Generalized Consumer Surplus Measure: The Mineral King Controversy", *Econometrica*, vol.44, no.6: 1259-1276.

Clawson, M. (1959) "Methods of Measuring the Demand for and Value of Outdoor Recreation", *Reprint*, no.10, Resources for the Future, Washington D.C.

Clawson, M. and Knetsch, J.L. (1966) "Economics of Outdoor Recreation". Resources for the Future, John Hopkins Press, Baltimore.

Common, M. (1973) "A Note on the Use of the Clawson Method", *Regional Studies*, vol.7: 401-406.

Conger, A.J. (1974) "A Revised Definition for Suppressor Variables: A Guide to their Identification and Interpretation", *Educational and Psychological Measurement*, vol.34: 35-46.

Connelly, D.S. and Price, C. (1991) "The Clawson Method and Site Substitution: Hypothesis and Model", manuscript, University College of North Wales, Bangor.

Desvouges, W.H., Smith, V.K. and McGivney, M.P. (1983) "A comparison of alternative approaches for estimating recreation and related benefits of water quality improvements".

EPA-230-05-83-001 (Washington, D.C., Office of Policy Analysis, U.S. Environmental Protection Agency).

Dobbs, I.M. (1991) "The Individual Travel Cost Method: Estimation and Benefit Assessment with a Discrete and Possibly Grouped Dependent Variable", *Countryside Change Unit Working Paper 17*, University of Newcastle upon Tyne.

Englin, J. and Mendelsohn, R. (1991) "A hedonic travel cost analysis for valuation of multiple components of site quality: the recreation value of forest management", *Journal of Environmental Economics and Management*, vol.21: 275-290.

Everett, R.D. (1979) "The Monetary Value of the Recreational Benefits of Wildlife", *Journal of Environmental Management*, vol.8: 203-213.

Fisher, A.C. and Krutilla, J.V. (1972) "Determination of Optimal Capacity of Resource-Based Recreation Facilities", in Krutilla, J.V. (ed) *Natural Environments: Studies in Theoretical and Applied Analysis. Resources for the Future*, John Hopkins University Press, Baltimore, pp.352.

Freeman, A.M.III (1979) "The Benefits of Environmental Improvement: Theory and Practice", *Resources for the Future*. John Hopkins University Press, Baltimore and London.

Garrod, G. and Willis, K.G. (1991) "Some Empirical Estimates of Forest Amenity Value", *Working Paper 13*, Countryside Change Unit, University of Newcastle upon Tyne.

Gibson, J.G. (1978) "Recreation Land Use", in Pearce, D.W. (ed). *The Valuation of Social Cost*, Allen and Unwin, London.

Goddard, J. and Kirby, A. (1976) "An Introduction to Factor Analysis", *CATMOG 7*, Geo Books, Norwich.

Green, C.H., Tunstall, S.M., N'Jai, A. and Rogers, A. (1990) "Economic Evaluation of Environmental Goods", *Project Appraisal*, vol.5, no.2: 70-82.

Greig, P.J. (1977) "Forecasting the Demand Response to Changes in Recreational Site Characteristics", in; Elsner, G.H. (ed) *State of the Art Methods for Research, Planning and Determining the Benefits of Outdoor Recreation*, USDA Forest Service, Washington, D.C., 11-22.

Gum, R.L. and Martin, W.E. (1975) "Problems and Solutions in Estimating the Demand for and Value of Rural Outdoor Recreation", *American Journal of Agricultural Economics*, vol.57: 558-566.

Hanley, N.D. (1989) "Valuing Rural Recreation Benefits: An Empirical Comparison of Two Approaches", *Journal of Agricultural Economics*, vol.40: 361-74.

Hanley, N.D. (1990) "Valuation of Environmental Effects: Final Report - Stage One". Industry Department of Scotland and the Scottish Development Agency, Edinburgh.

Hanley, N.D. and Common, M.S. (1987) "Evaluating the Recreation Wildlife and Landscape Benefits of Forestry: Preliminary Results from a Scottish Study", *Papers in Economics Finance and Investment*, no.141. University of Stirling, Scotland.

Hanley, N.D. and Ruffell, R. (1992) "The Valuation of Forest Characteristics", Institute for Economic Research, Working Paper 849, Queens University, Kingston, Ontario.

H.M. Treasury (1972) "Forestry in Great Britain: An Interdepartmental Cost/Benefit Study", HMSO, London.

Hof, J.G. and King, D.A. (1982) "On the Necessity of Simultaneous Demand Estimation", *Land Economics*, Vol.58: 547-552.

Hufschmidt, M.M., James, D.E., Meister, A.D., Bower, B.T. and Dixon, J.A. (1983) "Environment, Natural Systems and Development: An Economic Valuation Guide". John Hopkins University Press, Baltimore and London.

Johansson, P.-O. (1987) "The Economic Theory and Measurement of Environmental Benefits". Cambridge University Press, Cambridge.

Johnston, R.J. (1978) "Multivariate Statistical Analysis in Geography". Longman, London.

Jones, K. (1991) 'Multi-level models for geographical research' *CATMOG 54*, Institute of British Geographers, Norwich.

Kazmier, L.J. and Pohl, N.F. (1987) "Basic Statistics for Business and Economics", McGraw-Hill, Singapore.

Kling, C.L. (1987) "A Simulation Approach to Comparing Multiple Site Recreation Demand Models Using Chesapeake Bay Survey Data", *Marine Resource Economics*, vol.4: 95-109.

Kling, C.L. (1988) "Comparing Welfare Estimates of Environmental Quality Changes from Recreation Demand Models", *Journal of Environmental Economics and Management*, vol.15: 331-340.

Knetsch, J.L. (1977) "Displaced Facilities and Benefit Calculations", *Land Economics*, vol.53, no.1: 123-129.

Krupnick, A. (1991) "Progress on the valuation studies: US Synthesis", paper given at the joint US EPA/EC Joule Project conference "The External Costs of Fuel Cycles", held in Oxford, 23-25 October, 1991.

Langford, I. (1992) "Childhood Leukaemia and Infections", PhD thesis, School of Environmental Sciences, University of East Anglia.

Loomis, J., Sorg, C., and Donnelly, D. (1986) "Economic losses to recreational fisheries, due to small-head power development", *Journal of Environmental Management*, vol.22: 85-94.

Lucas, R.C. (1963) "Bias in Estimating Recreationists Length of Stay from Sampling Interviews", *Journal of Forestry*, vol.61: 912-914.

Maddala, G.S. (1988) "Introduction to Econometrics", Macmillan, New York.

Maddala, G.S. (1977) "Econometrics", McGraw-Hill, New York.

Mann, H.B. and Whitney, R. (1947) "On a Test of Whether One or Two Random Samples is Stochastically Larger than the Other" *Annals of Mathematical Statistics*, 18: 50-60.

McConnell, K. (1975) "Some Problems in Estimating the Demand for Outdoor Recreation", *American Journal of Agricultural Economics*, vol.57, no.2: 330-334.

McConnell, K.E. and Strand, I. (1981) "Measuring the Cost of Time in Recreation Demand Analysis: An Application to Sport Fishing", *American Journal of Agricultural Economics*, vol.63, no.1: 153-56.

Mendenhall, W., Reinmuth, J.E., Beaver, R. and Dunhan, D. (1986) "Statistics for Management and Economics", 5th ed., Duxbury Press, Boston.

Mitchell, R. and Carson, R. (1989) "Using Surveys to Value Public Goods: The Contingent Valuation Method", Resources for the Future, Washington DC.

Morey, E.R. (1981) "The Demand for Site-Specific Recreational Activities: A Characteristics Approach", *Journal of Environmental Economics and Management*, vol.8, no.4: 345-71.

Morey, E.R. (1984) "Confuser Surplus", *American Economic Review*, vol.74, no.1: 163-73.

Morey, E.R. (1985) "Characteristics, Consumer Surplus and New Activities: A Proposed Ski Area", *Journal of Public Economics*, vol.26: 221-36.

Nelson, J.P. (1977) "Accessibility and the Value of Time in Commuting", *Southern Economic Journal*, vol.43, no.3: 1321-1329.

Parson, G.R. (1991) "A Note on Choice of Residential Location in Travel Cost Demand Models", *Land Economics*, vol.67: 360-364.

Pearce, D.W. and Markandya, A. (1989) "The Benefits of Environmental Policy", Organisation of Economic Cooperation and Development, Paris.

Pearse, P.H. (1968) "A New Approach to the Evaluation of Non-Priced Recreation Resources", *Land Economics*, vol.44, no.1: 87-99.

Prewitt, R.A. (1949) "The Economics of Public Recreation - An Economic Survey of the Monetary Evaluation of Recreation in the National Parks", National Park Service, Washington DC.

Price, C. (1975) "Right Use of Land in National Parks", unpublished PhD thesis, Department of Forestry, University of Oxford.

Price, C. (1978) *Landscape Economics*. MacMillan Press, London, 168pp.

Price, C. (1979) "Interpreting the Clawson Demand Curve: Some Philosophical Problems In Evaluating Additional Facilities", *Proceedings for IUFRO Meeting: Economics of Recreation*, (March 11-15, 1979), Washington D.C.

Price, C. (1979b) "Public Preference and the Management of Recreational Congestion", *Regional Studies*, vol.13: 125-139.

Price, C. (1980) "Public Preference and the Management of Recreational Congestion: A Modification", *Regional Studies*, vol.14: 427-428.

Price, C. (1981) "Are Extra Recreation Facilities Unproductive?", *Journal of Environmental Management*, vol.12: 1-5.

Price, C. (1983) "Evaluation of Congestion and Other Social Costs: Implications for Systems of Recreation Parks", *Sistemi Urbani*, vol.1: 119-139.

Price, C., Christensen, J.B. and Humphreys, S.K. (1986) "Elasticities of Demand for Recreation Site and Recreation Experience", *Environment and Planning A*, vol.18: 1259-1263.

Price, C. (1991) "Landscape Valuation and Public Decision Making", manuscript, School of Agricultural and Forest Sciences, University College of North Wales, Bangor.

Ravenscraft, D.J. and Dwyer, J.F. (1978) "Reflecting Site Attractiveness in Travel Cost-Based Models for Recreation Benefit Estimation", *Forestry Research Report 78-6*, Dept. of Forestry, University of Illinois at Urbana-Champaign, Urbana, Illinois.

Sellar, C., Stoll, J.R. and Chavas, J.-P. (1985) "Validation of Empirical Measures of Welfare Change: A Comparison of Non-market Techniques", *Land Economics*, vol.61, no.2: 156-175.

Sinden, J.A. and Worrell, A.C. (1979) "Unpriced Values: Decisions without Market Prices". John Wiley, New York.

Smith, R.J. and Kavanagh, N.J. (1969) "The Measurement of Benefits of Trout Fishing: Preliminary Results of a Study at Grafham Water, Great Ouse Water Authority, Huntingdonshire", *Journal of Leisure Research*, vol.1: 316-32.

Smith, V.K. (1988) "Selection and Recreation Demand", *American Journal of Agricultural Economics*, vol.70: 29-36.

Smith, V.K. and Desvouges, W.H. (1986) *Measuring Water Quality Benefits*. Kluwer and Nijhoff, Boston.

Snedecor, G.W. and Cochran, W.G. (1967) "Statistical Methods", 6th ed., The Iowa State University Press, Ames, Iowa.

Stankey, G. (1972) "A Strategy for the Definition and Management of Wilderness Quality" in Krutilla, J.V. (ed), *Natural Environments: Studies in Theoretical and Applied Analysis, Resources for the Future*, John Hopkins University Press, Baltimore.

Talheim, D.R. (1978) "A General Theory of Supply and Demand for Outdooor Recreation in Recreation System", manuscript, Department of Agricultural Economics, Michigan State University.

Tobias, D. and Mendelsohn, R. (1991) "Valuing Ecotourism in a Tropical Rain-Forest Reserve", *Ambio*, vol.20, no.2: 92-93.

Vaughan, W.J., Russell, C.S. and Hazilla, M. (1982) "A Note on the Use of Travel Cost Models with Unequal Zonal Populations: Comment", *Land Economics*, vol.58, no.3: 400-407.

Vaughan, W.J. and Russell, C.S. (1982) *Freshwater Recreational Fishing: The National Benefits of Water Pollution Control*, Resources for the Future, Washington D.C.

Vaux, H.J. and Williams, N.A. (1977) "The Costs of Congestion and Wilderness Recreation", *Environmental Management*, vol.1: 495-503.

Wilcoxon, F. (1945) "Individual Comparisons by Ranking Methods". *Biometrics*, 1: 80-83.

Willis, K.G. and Benson, J.F. (1988) "A Comparison of User Benefits and Costs of Nature Conservation at Three Nature Reserves", *Regional Studies*, vol.22: 417-428.

Willis, K.G. and Garrod, G. (1991) "An Individual Travel-Cost Method of Evaluating Forest Recreation". *Journal of Agricultural Economics*, volume 42, no.1: 33-42.

Wilman, E.A. (1977) "A Note on the Value of Time in Recreation", mimeo referred to in Freeman (1979).

Ziemer, R., Musser, W.N. and Hill, R.C. (1980) "Recreational Demand Equations: Functional Form and Consumer Surplus", *American Journal of Agricultural Economics*, vol.62: 136-41.

The Hedonic Price Method

Anderson, G. and Bishop, R. (1986) "The Valuation Problem" in Bromley, D. (ed). *Natural Resource Economics*, Kluwer-Nijhoff, Boston.

Anderson, R.J. and Crocker, T.D. (1971) "Air Pollution and Residential Property Values". *Urban Studies*, 8: 171-80.

Brookshire, D., Thayer, M., Schulz, W. and d'Arge, R. (1982) "Valuing Public Goods: A Comparison of Survey and Hedonic Approaches". *American Economic Review*, vol.72, no.1: 165-171.

Brown, G.M. and Pollakowski, H.O. (1977) "Economic Valuation of Shoreline". *Review of Economics and Statistics*, vol.59: 272-278.

Button, K. and Pearce, D.W. (1989) "Infrastructure Restoration as a Tool for Stimulating Urban Renewal". *Urban Studies*, vol.26: 559-571.

Cummings, R.G., Cox, L.A. and Freeman, A.M.III (1986) "General Methods for Benefit Assessment" in Bentkover, J.D., Corello, V.T. and Mumpower, J. (eds). *Benefit Assessment: The State of the Art*, Reidel Publishing, Kluwer.

Follain, J.R. and Jimenez, E. (1985) "Estimating the Demand for Housing Characteristics". *Regional Science and Urban Economics*, vol.15: 77-107.

Freeman, A.M. III (1979a) "The Hedonic Price Approach to Measuring Demand for Neighborhood Characteristics". *The Economics of Neighborhood* (ed. D. Segal). Academic Press, New York.

Freeman, A.M. III (1979b) "Hedonic Prices, Property Values and Measuring Environmental Benefits: A Survey of the Issues". *Scandinavian Journal of Economics* 81(2): 154-73.

Freeman, A.M. III (1979c) "The Benefits of Environmental Improvement: Theory and Practice". John Hopkins University Press, Baltimore.

Garrod, G. and Willis, K.G. (1992) "The Environmental Economic Impact of Woodland: A Two Stage Hedonic Price Model of the Amenity Value of Forestry in Britain". *Applied Economics*, vol.24: 715-728.

Hanley, N.D. (1991) "Valuation of Environmental Effects". ESU Research Paper No. 22. Industry Department for Scotland/Scottish Development Agency.

Harrison, D.Jr. and Rubinfeld, D.L. (1978a) "Hedonic Housing Prices and the Demand for Clean Air". *Journal of Environmental Economics and Management* 5: 81-102.

Harrison, D.Jr. and Rubinfeld, D.L. (1978b) "The Distribution of Benefits from Improvements in Urban Air Quality". *Journal of Environmental Economics and Management* 5: 313-32.

Hufschmidt, M.M., James, D.E., Meister, A.D., Bower, B.T. and Dixon, J.A. (1983) "Environment, Natural Systems and Development: an Economic Valuation Guide". John Hopkins University Press, Baltimore.

Hyman, E.L. (1981) "The Valuation of Extramarket Benefits and Costs in Environmental Impact Assessment". *Environmental Impact Assessment Review* 2(3): 227-64.

Mäler, K.G. (1977) "A Note on the Use of Property Values in Estimating Marginal Willingness to Pay for Environmental Quality". *Journal of Environmental Economics and Management* 4: 355-69.

McLeod, P.B. (1984) "The Demand for Local Amenity: An Hedonic Price Analysis", *Environment and Planning A*, Vol.16: 389-400.

Nelson, J.P. (1978a) "Residential Choice, Hedonic Prices and the Demand for Urban Air Quality". *Journal of Urban Economics*, Vol.5: 357-369.

Nelson, J.P. (1978b) "Economic Analysis of Transportation Noise Abatement". Ballinger, Cambridge, Mass.

Pearce, D.W. (ed) (1978) "The Valuation of Social Cost". Allen and Unwin, London.

Pearce, D.W. and Edwards, R. (1979) "The Monetary Evaluation of Noise Nuisance: Implications for Noise Abatement Policy". (ed. T. O'Riordan and R.C. d'Arge). *Progress in Resource Management and Environmental Planning*, vol.1. Wiley, New York. Pearce, D.W. and Markandya, A. (1989) "The Benefits of Environmental Policy", OECD, Paris.

Pennington, G., Topham, N. and Ward, R. (1990) "Aircraft Noise and Residential Property Values Adjacent to Manchester International Airport". *Journal of Transport Economics and Policy*, vol.24: 49-59.

Price, C. (1991) "Landscape Valuation and Decision Making". School of Agricultural and Forest Sciences, Bangor University.

Ridker, R.G. (1967) "Economic Costs of Air Pollution: Studies and Measurement". Praeger, New York.

Rosen, S. (1974) "Hedonic Prices and Implicit Markets: Product Differentiation in Perfect Competition". *Journal of Political Economy* 82(1): 34-55.

Straszheim, M. (1974) "Hedonic Estimation of Housing Market Prices: A Further Comment". *Review of Economics and Statistics*, vol.56, no.3: 404-406.

Turner, R.K. and Bateman, I.J. (1990) "A Critical Review of Monetary Assessment Methods and Techniques". Environmental Appraisal Group, University of East Anglia.

Varian, H.R. (1984) *Microeconomic Analysis*, Norton, New York.

Waddell, T.E. (1974) "The Economic Damage of Air Pollution". Report No. EPA-600/5-74-012. U.S. Environmental Protection Agency, Washington, D.C.

Willig, R.D. (1973) "Consumers Surplus: A Rigorous Cookbook". Technical Report No. 98. Institute for Mathematical Studies in the Social Sciences, Stanford.

Willig, R.D. (1976) "Consumers Surplus Without Apology". *American Economic Review*, 66: 589-597.

Appendix A: Household Production Functions

A fundamental assumption implicit in all monetary evaluation methods is that recreation goods enter the household production function in the same manner as do non-recreation market priced goods so that, at utility maximisation, the marginal utility product of each item in the utility function relative to its price (or implicit price) is equal. So, if we have a recreation services production function;

$$K_r = f(V_j, X_r)$$

where: V_j = Visits to site j

X_r = all other recreation explanatory variables (entrance fees, time, costs, etc)

and we have a non-recreation services production function;

$$K_{nr} = f(X_{nr})$$

where: X_{nr} = all non-recreation explanatory variables (market prices, etc)

then the utility function is;

$$U = U(K_r, K_{nr})$$

and at utility maximisation we have:

$$\left[\frac{MU_{kr}\dfrac{\delta K_r}{\delta V_j}}{IP_j}\right] = \left[\frac{MU_{kr}\dfrac{\delta K_r}{\delta X_r}}{P_r}\right] = \left[\frac{MU_{knr}\dfrac{\delta K_{nr}}{\delta X_{nr}}}{P_{nr}}\right]$$

where: IP_j = Total implicit price of visiting site j

P_r = Price of other recreation explanatory variables

P_{nr} = Price of non-recreation explanatory variables.

For further details see Smith and Desvousges (1986).

Building from this, for a travel cost study, the consumer surplus value of a site can be estimated as the integral of the demand curve relating visits to travel costs with respect to these costs.

Appendix B: Applying the Two Stage TCM Approach: Smith and Desvousges (1986)

The discussion of suppressor variables given in this chapter concentrates upon the two stage approach adopted by Smith and Desvousges (1986).

The reported 'true' relationship given as EQN T.16 refers to two site characteristic variables; Shore (S_j) and Access (A_j). In fact Smith and Desvousges specify a further three site characteristic variables (omitted from chapter discussion for simplicity), such that the generalised demand function actually estimated was;

ln visits =

[-0.044 + 0.001 Shore - 0.039 Access + 1.461 Pool + 0.020 DO - 6.47x10^{-5} VDO]
(-0.024) (-0.782) (-1.071) (1.030) (2.076) (-2.077)

+[-0.022 TC - 0.11x10^{-4} Shore x TC + 0.27x10^{-2} Access x TC - 0.089 Pool x TC
(-0.431) (-0.382) (1.301) (-1.522)

- 0.10x10^{-3} DO x TC + 1.48x10^{-7} VDO x TC] + [0.17x10^{-4} Inc - 0.60x10^{-7} Shore x
(-0.286) (0.127) (0.657) (-1.449)

Inc + 0.14x10^{-6} Access x Inc + 0.86x10^{-4} Pool x Inc -0.24x10^{-6} DO x Inc
(0.074) (2.731) (-0.766)

+ 5.28x10^{-10} VDO x Inc]
(0.573)

where:

TC	=	travel cost (vehicle + time costs)
Inc	=	income
Shore	=	total shore miles at site during peak visitation period
Access	=	number of multipurpose and developed access area at site
Pool	=	size of water pool surface relative to total site area
DO	=	dissolved oxygen (percent saturation)
VDO	=	variance in DO over the six observations during the recreational season of the survey

Source: Krupnick, A. (1991)

1st square bracket = main effect (also TC & Income)

2nd/3rd square brackets = 'two factor interactions' combined effects.

Mean travel cost and income figures at each lake were used to calculate values for the coefficients given above.

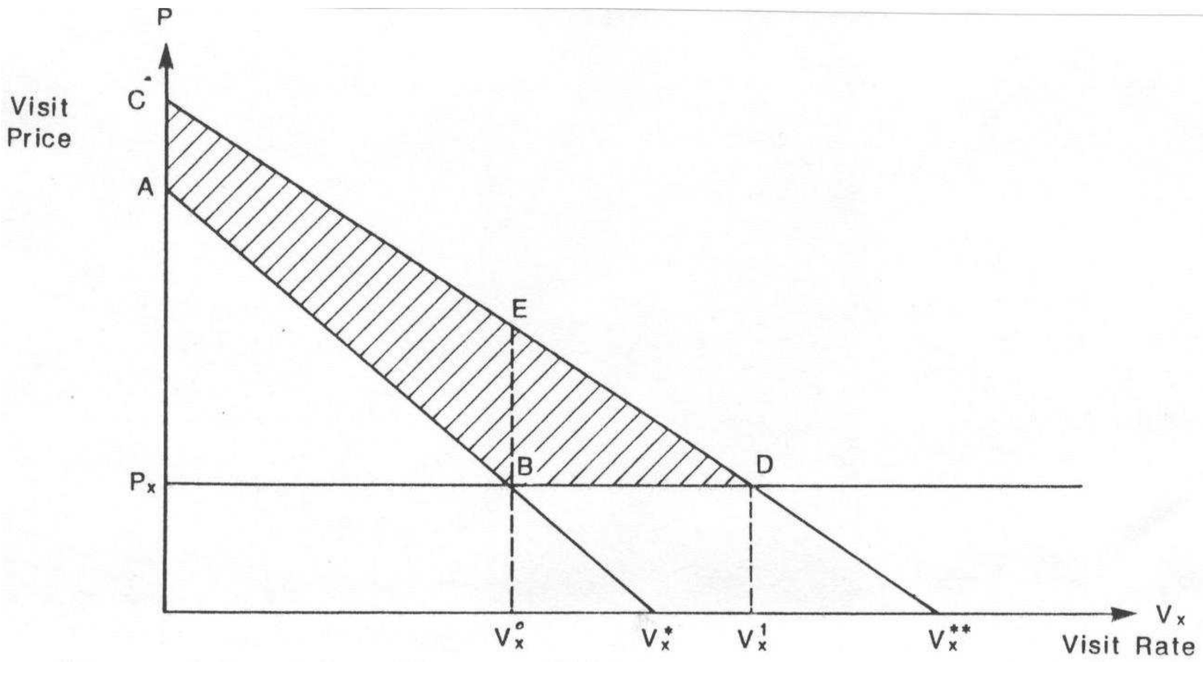
Appendix C: TCM and the Value of Improving Sites

This appendix considers the value of improving the environmental quality of a recreation site j. In effect, if we could specify the relevant utility function, then we could use an expenditure function approach arguing that the benefit (B) to each individual (n) of improving environmental quality (Q) at site j (Q_j increases from Q^o_j to Q^1_j) is;

$$B = -\int_{Q_j = Q_j^0}^{Q_j^1} \frac{\delta E_n}{\delta Q_j} . dQ_j \qquad \text{EQN AC.1}$$

where E_n is the individuals expenditure function, and the negative sign is necessary to correctly sign B as the improvement to Q_j will lower necessary expenditure upon recreation (eg., individuals may now not need to visit several recreation sites but can instead get the same utility from fewer improved sites). We can validly use EQN T.6 (see travel cost section of this paper) in place of EQN AC.1 if the quality improvement only occurs at site j. In such a case the quality improvement from Q^o_j to Q^1_j will lead to an expansion of the demand function. In Figure AC.1 this is illustrated as a shift from the original demand curve AV_x^* to the new demand curve CV_x^{**}. For simplicity visit rate and price information for a single zone is shown.

Figure AC.1: The Value of Improving Environmental Quality at a Specific Site.



Source: Adapted from Freeman (1979c)

Assuming zero entrance fee with a constant visit price P_x, initial visit rate from zone X to site j is V^o_x. Improving environmental quality from Q^o_j to Q^1_j increases zone visitor rate to V^1_x. The new demand curve CV_x^{**} can then be mapped out as before. The resultant increase in consumer surplus is shown as the shaded area ABDC which may be decomposed into an increased willingness to pay for existing trips (ABEC) and that associated with the increased visitor rate (BDE)[60].

If the environmental quality improvement is general across all sites, including those not used by our sample of visitors, then we can still apply the same approach to evaluation providing that we accept a weak complementary assumption that individuals only gain utility from those sites which they personally visit, i.e. option and existence values are insignificant. If this is not so then the consumer surplus measure derived from EQN T.6 will underestimate the true value of this improvement as expressed in EQN AC.1. Assuming that this is not the case (ie. option and existence values are significant) then for a quality improvement at two (or more) sites j and m we should[61]:

i) Evaluate and integrate the demand curve for site j holding environmental quality at site m at its original level;
ii) Then evaluate and integrate the demand curve for site m given the improved quality level of site j.

This partial derivative approach will produce the same net welfare measure regardless of the order in which sites are considered. Freeman (1979c) illustrates this procedure with reference to Figure AC.2.

In the absence of any environmental improvement suppose that the demand curve for site j is Dj_om_o (thin line BE) and that for site m is Dm_oj_o (thin line SV) and that visit prices are Pj and Pm respectively. To evaluate the net welfare change of an improvement at both sites we need to break this down into a two stage process. Suppose that we firstly consider the environmental improvement at site j, holding the quality of site m constant at it's initial level. The improvement at site j causes demand for the site to expand to Dj_1m_o (broken line DG) bringing an increase in welfare BEGD. Some of this demand will be substituting away from site m so that demand for the latter will contract to Dm_oj_1 (broken line RU). However Knetsch (1977) shows that, as there

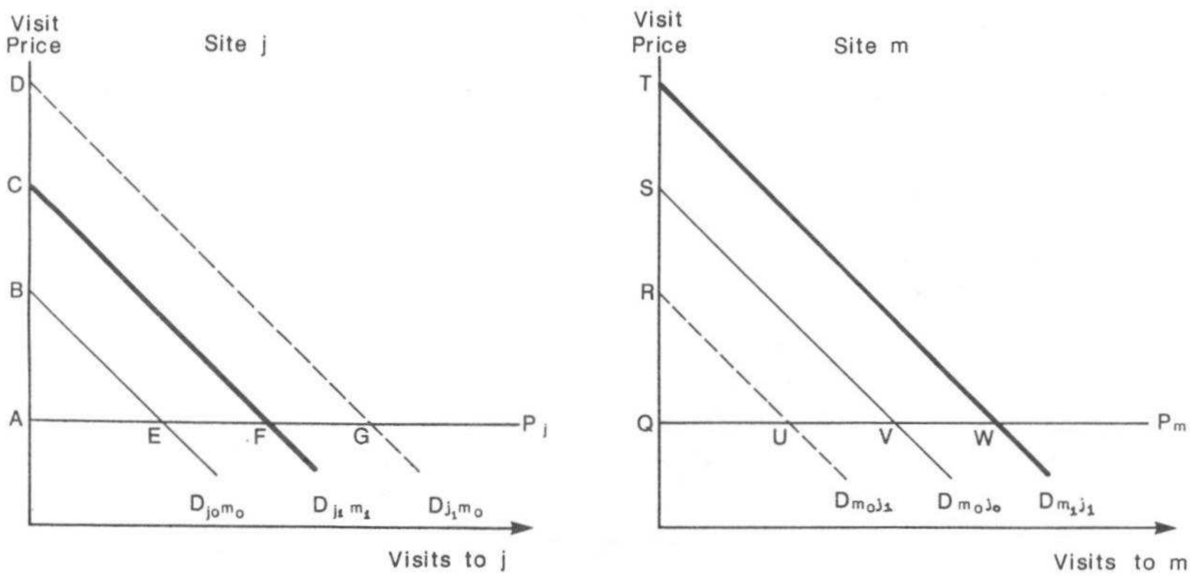
[60]See also the discussion of 'Extended ' TCM approaches to the evaluation of proposed new recreation sites by the examination of close substitutes (Burt and Brewer, 1971; Cicchetti et al., 1976).

[61]See Freeman (1979c) for further details.

has been no quality change at site m, this fall in demand does not imply a loss of welfare. More precisely we can note that the integral of EQN AC.1 will be zero for site m as dQ_m is zero. Therefore the net welfare change of considering the increase in environmental quality at site j, ceteris paribus, is just BEGD.

We now consider our second stage, the improvement in quality at site m holding quality at site j constant at its new improved level. Increasing quality at site m expands its demand out to Dm_1j_1 (thick line TW) bringing a welfare gain over Dm_oj_1, of RUWT. This improvement in site m will in turn cause re-substitution from site j where demand contracts from Dj_1m_o to Dj_1m_1 (thick line CF). However, following Knetsch (1977) we can again show that the re-substitution process at site j does not involve a welfare loss at site j; again the integral of EQN AC.1 is zero as dQ_j is zero. Therefore the net welfare change of considering an increase in environmental quality at site m, ceteris paribus, is RUWT.

Figure AC.2:   Evaluating an Increase in Environmental Quality Occurring at Two Sites



Source: Freeman (1979c)

Considering the entire two-stage process we can now see that the total welfare gain of increasing quality at both site j and m is BEGD + RUWT. Note that this is larger than the measure we would have obtained by simply observing the areas between the initial and final demand curves at both sites (BEFC + SVWT respectively). Therefore if we are to correctly estimate the welfare change of increases in environmental quality at multiple sites we need to consider the substitution effects which exist between these sites (see discussions regarding empirical approaches to the incorporation of substitute sites).