

## **Valuing Goods' Characteristics: an Application of the Hedonic Price Method to Environmental Attributes**

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This study examines the effect of selected countryside characteristics on house prices in a rural area of the United Kingdom centred around the Forest of Dean in Gloucestershire. Data are gathered from a variety of sources and the hedonic price method is then used to derive a model of property prices from which the marginal costs of particular characteristics can be estimated. Some countryside characteristics, for example woodland, are observed to have a positive influence on house prices while others, like open water, are found to have no observable effect. The proximity of less desirable characteristics, such as marshland, are shown to have the effect of reducing house prices.

*Keywords:* hedonic price method, forestry, countryside characteristics, property values, environmental valuation.

### **1. Introduction**

Countryside and environmental characteristics such as a pleasant landscape, hedgerows, woodland, wildlife, flora, peace and quiet, etc., are normally treated as a benefit and their loss as a form of pollution or an undesirable consequence of the production activity of some industry. Such countryside attributes, however, are not a private property right: industries and firms do not have to pay for the privilege of eroding/destroying these goods. The reasons for the lack of property rights are partly historical, but mainly due to the difficulty of defining and measuring the quantity and quality of such goods. What is a clean river, and how can a pleasant landscape be defined? The difficulty of getting affected parties to arrive at a mutual contract in a free market, except in unusual circumstances (Crocker, 1971), to maximize benefits to all (Coase, 1960), usually suggests the necessity of state intervention (Willis, 1980).

This raises the question as to whether such countryside attributes are "public goods". Even in small areas, households have the option of "buying" or consuming these commodities (as a joint product with a house or a job) at a price, and individuals can buy a lot or a little, since many are provided as a continuum with varying quantities in different spatial areas. Clearly, countryside goods are not a pure public good as far as the consumer is concerned. Consequently, countryside attributes can be viewed as

quantities which are scarce and for which people are prepared to pay. However, the market for these attributes is implicit. If a household wished to enjoy a view over a pleasant landscape, it would buy such a house, rather than another house on flat land surrounded at high density by hundreds of others, such as a house in the middle of Lower Earley! (see H.R.H. Prince of Wales, 1989). The premium on a house with a view would measure, *ceteris paribus*, the expenditure thought to be worthwhile to enjoy such a countryside commodity.

Only by measuring and valuing such countryside goods and comparing them in a commensurate way with the financial costs, returns and profits of agriculture, forestry and other productive activities in the countryside, can a satisfactory allocation of resources be made and appropriate government regulatory policies be formulated.

A number of methods are available to value countryside characteristics, namely contingent valuation techniques (CVT), hedonic price methods (HPM) and travel cost methods (TCM). In the context of the countryside change research programme at Newcastle University, CVTs have been reviewed (Garrod and Willis, 1990) and the technique is being applied in the Yorkshire Dales National Park (Willis and Garrod, 1991*b*). The TCM has been applied to non-priced open access recreation in forests (Willis and Garrod, 1991*a*) and to recreation on inland waterways (Willis and Garrod, 1990), as well as being used in the Yorkshire Dales National Park study to value landscapes and provide a check on CVT estimates. The purpose of this study is to explore the merits of HPM as a means of valuing countryside characteristics.

Since it is the value of marginal change that is important, the analysis is directed towards assessing the monetary impact of marginal change in countryside characteristics. While the countryside has changed dramatically in many instances since 1945 (Bowers and Cheshire, 1983), the amount of change between one year and the next is imperceptible. Consequently, it is not practical to relate change over time to house prices. Moreover, people's preferences can change over time, which would bias any regression coefficient (Kennedy, 1979) and, hence, the marginal valuation of an attribute. People tend to disproportionately stick with the status quo (Samuelson and Zeckhauser, 1988) at any point in time, so that valuation in time  $t$  can or would be very different from that in  $t \pm n$ . However, the marginal valuation of countryside characteristics can be assessed in today's prices/preferences by investigating changes in these environmental characteristics and house prices over space. This is the approach adopted, using the Forest of Dean and neighbouring rural areas as a case study.

## 2. Hedonic price models

Hedonic price models derive from consumer theory (Lancaster, 1966) in which utility is related to the attributes of a good. Because each house represents a unique combination of characteristics, the price a potential buyer is willing to pay (WTP) depends upon:

- 1 Physical characteristics: number of rooms, bathrooms, central heating, age and condition of structure, etc.
- 2 Accessibility characteristics: access to major centres of employment, shops, etc.
- 3 Public sector characteristics: accessibility to schools, post office, etc., local tax rates, etc.
- 4 Neighbourhood and environmental characteristics: aspect, view, tree cover, road traffic, water frontage, etc.
- 5 Alternative use characteristics: land with planning permission for a higher value use, etc.

Although the theory of goods' characteristics or attributes has no logical flaws, its application is less than satisfactory, often involving deviations from model assumptions, and measurement and sampling errors in the data. The chief criticisms of the HPM centre on these assumptions and include:

- 1 the conditions under which observed implicit prices can be assumed to reflect a household's marginal WTP for a particular level of environmental amenity; and
- 2 the assumptions required to aggregate individual household's marginal WTP estimates to a market demand function (Harris, 1981).

The equality of the marginal WTP and the implicit price of that characteristic requires equilibrium in the housing market (Harris, 1981). Whether a competitive equilibrium exists is an empirical question. Given constraints on information, institutions and mobility of individuals, equilibrium cannot be realistically assumed at a point in time; but constraints may introduce random rather than systematic errors into WTP estimates (Freeman, 1979*b*). Only systematic biases in estimates of WTP will produce erroneous hedonic price results.

HPMs will only reflect households' marginal WTP for a particular attribute if the measured level of the attribute corresponds to that perceived by the consuming household (Harris, 1981). This is more likely to affect the valuation of some attributes than others. In the case of chemical hazards, such as air pollution, radiation and water pollution, individuals are not likely to have full information on the physical levels of non-observable pollutants and their impacts on health. In such cases marginal WTP may under- or over-estimate (if biased perception exists) the true damage. However, for many countryside attributes, such as pleasant views, this is unlikely to be the case, as the perceived attribute and its consequences are likely to be immediately apparent to the household.

HPM relies on the interpretation of a regression coefficient to represent WTP for any particular characteristic. This assumes the individual values the environmental characteristic independently of all other commodities he consumes (Price, 1990). This separability assumption, for example that the value of a block of forest is independent of topography, or that the amenity value of the size of a forest is independent of its shape, is clearly difficult to standardize for in practice (Pearce *et al.*, 1981). This renders the problem empirically difficult but not theoretically impossible.

Concern about HPMs has centred on their ability to estimate the value of particular attributes rather than their ability to predict the overall price of the good. Follain and Malpezzi (1979) have shown that a simple specification of five to 10 structure variables (number of rooms, baths, etc.) produces about as good a fit as 40 variables. In other words, prediction of the dependent variable is not sensitive to the number of variables, given a reasonable reduced set and fit and an instrumental perspective on logic (Boland, 1979). This conclusion has also been demonstrated in a number of studies of British housing in which HPM estimates have been compared with the valuation of dwellings derived from other sources: estate agents estimates (Dodgson and Topham, 1990) and sale prices (Willis and Nicholson, 1991). However, when the focus is on individual implicit prices, specification is more critical (Butler, 1982; Ozanne and Malpezzi, 1985). The reasons for this include the assumptions in the theory, omitted variable bias, separability and the functional form of the model.

How accurately HPMs measure aggregate utility loss from a reduction in the quantity of a countryside characteristic (CC) depends upon the demand and supply curves. The effect on house prices of a reduction in the quantity of a CC will depend

upon the flow of new houses. If new houses can be built which have the CC at a cost equal to the market price of CC houses prior to the environmental reduction, then the price of non-CC houses will fall, since the supply of non-CC houses has now increased. But, if say, due to planning restrictions, only houses without the CC can be built, at a cost equal to the market price before the environmental reduction, then CC houses will rise in price, since the supply curve of such houses will have shifted upwards to the left. Either way the change in price will be the same.

Assume, following Mishan (1975), that only non-CC houses will be built; that all households have either identical tastes and different incomes, or identical incomes and different tastes; and that migration is costless. Before the loss of the CC, the stock of houses (Figure 1) is valued at  $OV PQ$ , with a market price  $p_0$ , equal to marginal cost, the value placed on the CC houses by the household with the lowest income or least preference. Let the difference  $VP - V_1R$  be the subjective value of the CC. If  $Q_1Q$  houses are affected by the loss of CC, then the loss of value (or utility) is  $ABPR$ . In equilibrium, the value of a house with and without the CC is  $\Delta V$ ; which equals  $\Delta p$ , the difference in the price. Houses without the CC now sell for  $p_1$ , the value at the margin. Hence, a CC house sells for  $p_1 + \Delta p = p_2$ .

$Q_1Q$  households are willing to pay less than  $\Delta p$  for the CC, and thus occupy non-CC houses. For  $OQ_1$  households  $WTP > \Delta p$  or the market premium for a CC house, hence they occupy CC houses (recall migration is costless).

The HPM estimate of the social cost from the CC loss is  $\Delta p \times Q_1Q$ , whereas the actual cost is  $ABPR$ . Thus, HPM overstates the loss of value. Conversely, HPM would

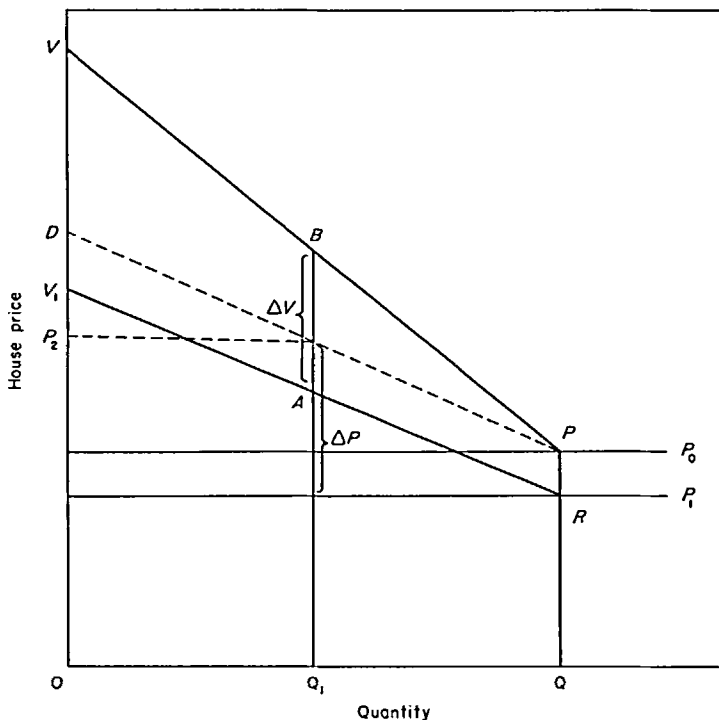


Figure 1. Hedonic housing demand model of the value of an environmental attribute.

underestimate the social cost from the loss of CC houses ( $Q_1QPR$ ) compared to the actual cost ( $ABPR$ ), in predicting the consequence of a CC lost from position  $Q$ . Only where every household has the same valuation of the CC, i.e. DP is horizontal, will the HPM estimate equal the true social cost. However, the problem of mis-estimation can be solved if the demand curve for the CC can be estimated, and some recent studies have attempted to measure demand with a two-stage hedonic approach to valuing environmental amenities (Clark and Kahn, 1989).

The HPM also assumes that submarkets do not exist within the area: separate housing markets where the structure of demand and supply varies, imply separate demand functions for each market. This is a further empirical complication rather than a criticism of the HPM in principle (Harris, 1981).

The inclusion of migration costs complicates the analysis (Mishan, 1975). Essentially, migration costs drive a wedge between the net maximum (value minus legal search and other migration costs) a household can afford to pay, and the net minimum (value plus migration costs) a household would have to receive to induce the sale of the CC house. The impact of migration costs also depends upon whether least sensitive or more sensitive households are affected by the CC loss.

### 3. The study region

This study encompasses some 4800 km<sup>2</sup> of central England and the Welsh borders, taking in most of Gloucestershire, part of Hereford and Worcester and smaller areas of Gwent, Wiltshire, Oxfordshire and Avon. This area was chosen because its diversity of landscape gives ample opportunity for exploring the effects which a variety of landscape characteristics have on house prices. Throughout the analysis, attention is focused only on the less urban areas in the study region, with any large towns, cities and their environs being omitted. This leaves a broad tract of mainly agricultural land, dotted with villages and small towns and endowed with a wide selection of woodland, rivers, valleys and uplands. It is this land, and the houses built on it, which form the basis for the study.

Forestry is well represented in the study region, particularly by the Forest of Dean, an area of mixed woodland which occupies a large part of west Gloucestershire to the north of the River Severn. As well as extensive woodland, the forest also has a long industrial history and plays host to many villages and small towns such as Lydney, Coleford and Mitcheldean. In addition, there are a number of smaller forests and plantations scattered through the area, plus numerous small coppices and woods.

To the west of the forest lie the towns of Chepstow and Monmouth serving a wide variety of small settlements scattered along the Welsh border, while lying to the east is the fertile Severn Vale. This wide floodplain supports a relatively large population with a healthy rural economy based on large mixed farming interests, while urban populations are concentrated in the commercial centres of Gloucester and Cheltenham. To the south are the Stroud Valleys, a thriving nest of communities, both small and large, inhabiting the hilly areas on the edge of the Cotswolds. Around 100 000 people live and work in these valleys engaging in anything from light engineering to sheep farming. Further south lie the mainly rural southern reaches of Gloucestershire and the northern edge of Avon.

To the north of the Severn Vale, the study region takes in a large part of south and central Herefordshire, including the agricultural areas around Leominster, Ledbury, Ross and Hereford, plus the western edge of the Malvern Hills. A wider area of uplands

are, however, supplied by the Cotswolds. These occupy most of east Gloucestershire and part of Oxfordshire and are justly famous for their high blue hills and picturesque villages which feature in many a picture postcard and tourist guide. Here, the economy is more agriculturally based, though increasingly large revenues are generated by the leisure and tourism industries. Finally, the study region moves south-east and takes in the western edge of Oxfordshire and the northern fringes of Wiltshire with the areas around Cricklade, Farringdon and Carterton.

In addition to hill, forest and valley, the region's principle rivers including the Severn, Wye, Arrow, Dore and Windrush, provide many miles of attractive scenery, and along with a selection of lakes, water parks and reservoirs, give the area a wide variety of waterside landscape. Several pleasant riverside villages are included in the study, including Oldbury on Severn, Frampton and Peterchurch.

#### 4. The data

When investigating the effects of external factors on house price for a particular area, it is necessary that the data set used covers the whole area and contains sufficient variables to explain those differences in price attributable to the variation in the physical characteristics of the houses involved. In the absence of any detailed public records, acceptable sources of such data include the archives of any large building society with branches distributed throughout the area of interest. When these institutions grant a mortgage a large amount of data is recorded referring to the property involved. These data for individual transactions includes details of the selling price, number of rooms and various structural characteristics of the house, such as garaging, central heating, floorspace and several other variables which may be reflected in observed differences in house prices.

Data were obtained from one of these organizations, which in addition to being one of the largest building societies in Great Britain has the added benefit of a large and well-established database. One aspect of their records is a set of mortgage data kept on magnetic tape. This data set contains a detailed record of every mortgage approved by the company in a given 12-month period and includes a 1 km grid square reference for the properties involved. For example, their 1987 file gives details of over 300 000 houses, flats and bungalows located by grid square throughout the country.

The composition of these files makes them an appropriate source of data for the investigation of the potential effects of countryside characteristics on house price. Individual records are not only located by grid square but by district and postcode, which allows the approximate identification of those houses in rural areas. In this way, a data set consisting almost exclusively of houses in rural areas can be derived.

Using these properties, a database of house sales for the study region, covering the 5-year period from 1985 to 1989, was extracted. Allowing for missing data, this provided a set of nearly 2000 observations of houses from rural areas in 13 different local authority districts on over 100 variables. However, many of the variables included by the building society for its own accounting purposes were not relevant to the hedonic house price study. Other variables which would have been relevant and important factors in determining house price were omitted at source. These include details of construction date, site area, gardens and the provision of public utilities such as telephone and mains gas. The lack of these variables may have adverse effects and could result in a lower degree of explanation being provided by the model.

As well as data on the structural characteristics of a property, it was also necessary to

know something about its neighbourhood, including the presence of any important landscape features, the socio-economic composition of the population and labour market characteristics of the locality. Three sources of data provided information on these matters: Ordnance Survey (OS) maps; 1981 Census small area statistics and data from the Department of Employment's National Online Manpower Information System (NOMIS).

Ordnance Survey 1:50 000 maps were used to derive nearly 50 variables relating to the grid squares in which the individual houses from the database were located. These variables measured a range of attributes for each kilometre square including:

1. approximate cover of land by forestry, buildings, open water and parkland;
2. approximate distance from nearest urban centre, post office and schools;
3. the presence of post office, pub, river, canal, overhead cable, etc.;
4. the presence in surrounding 9 km<sup>2</sup> area of important industrial and leisure facilities;
5. average height above sea level, predominant aspect, gradient;
6. potential view (i.e. whether a square overlooked a wooded or urban area);
7. whether it contained a named settlement;
8. the approximate lengths of major roads and rail track.

Though accuracy was always desirable, deriving these variables required a certain amount of approximation and a set of working conventions for consistency. Preparation including updating the OS maps to ensure that the approximate location of all local schools (as shown on LEA registers) was noted, and checking the location and existence of sub-post offices. Even with the aid of accurate measuring grids and an opisometer, areas and distances could only be approximate due to the possibility of changes in the locality since it was last surveyed. However, as the house price data were taken from a 5-year period and the map data from a one point source, some inaccuracy is inevitable. To keep these errors to a minimum, certain conventions were used for consistency. These particularly concern data on gradient, aspect and height above sea level. Clearly, such variables are likely to vary over a square, and, as there is no indication as to where in a particular square the house in the sample is located, it was considered expedient to take average values for gradient and height and to simply indicate whether aspect was predominantly southerly or westerly.

Other variables which may have a significant effect on house prices and housing markets are those which reflect the condition of the area in which a property is located. Various local socio-economic characteristics are used as proxies for these external factors. The 1981 census small area statistics provide somewhat dated information at a local level on variables such as population density, proportion of population over 60 years of age and the number of households with two or more cars (a proxy for local affluence). NOMIS on the other hand can provide regularly updated statistics on the labour market, including monthly or quarterly information on unemployment, details of existing vacancies and 3-yearly breakdowns of the number of people employed in a range of industrial categories. Much of this data can only be suitably accessed at a local authority district level and may prove to be too general to be significant in the model.

## 5. The model

The general model for rural property value can be expressed as:

$$P_i = f(AC_i, B_i, CC_i, LAD_i, Q_i, S_i, SE_i, Y_i) \quad (1)$$

where:  $P_i$  = the market price of the  $i$ th property;  $AC_i$  = a vector of variables indicating the proximity of public amenities to the  $i$ th property;  $B_i$  = a vector of external variables which may effect the value of the  $i$ th property;  $CC_i$  = a vector of the countryside characteristics in the neighbourhood of the  $i$ th property;  $LAD_i$  = the local authority district containing the  $i$ th property;  $Q_i$  = the quarter of the year in which the  $i$ th property was purchased;  $S_i$  = a vector of the structural characteristics of the  $i$ th property;  $SE_i$  = a vector of variables describing the socio-economic characteristics of the district containing the  $i$ th property;  $Y_i$  = the year in which the  $i$ th property was sold.

Appendix 1 documents these variables more fully. Following the nomenclature of Graves *et al.* (1988), these variables can be divided into three categories: focus; free; and doubtful variables. Focus variables are those of particular interest from a policy point of view, and in this case consist of the countryside characteristics contained in vector  $CC_i$ . Free variables, on the other hand, are those variables, such as structural characteristics and time of sale, which are known to affect property value but which are of no special interest. There remain the doubtful variables, those which may or may not affect the dependent variable. These include local socio-economic characteristics, neighbourhood characteristics, the proximity of public amenities and the Local Planning Authority area. It may be noted that in this study only a few neighbourhood characteristics (e.g. unemployment, population over 60) are considered, due to difficulties with data collection. The omission of such variables should not, however, be considered too important. Several studies, including Butler (1982) and Follain *et al.* (1979), find evidence that the errors induced into individual coefficient estimates by the omission of neighbourhood variables are sufficiently small that such variables may be safely ignored.

In this study, the focus variables include the presence of upland, woodland, parkland, orchards, rural settlements, open water, rivers and natural wetlands. The larger sets of free and doubtful variables were selected on the basis of their inclusion in previous studies (e.g. Ohsfeldt, 1988; Nicholson and Willis, 1991) and of their availability.

The implicit price of an individual characteristic can be found by differentiating the price function [equation (1)] with respect to that characteristic, so if the price function is linear, then the implicit price of a characteristic will be constant. However, as Rosen (1974) points out, there is no reason to expect the price function to be linear. In fact, non-linearity is to be expected, because consumers cannot treat individual housing attributes as discrete items from which they can pick and mix until the desired combination of characteristics is found. On the contrary, for most properties such attributes are fixed and homebuyers must attempt to select from the properties available, one which optimizes the number and mix of desired characteristics.

If equation (1) is indeed non-linear, then the implicit price of any characteristic depends on the level at which that characteristic is present and possibly on the level of other characteristics. For a given characteristic, each consumer will, assuming utility maximizing behaviour, seek to equate the marginal cost of that characteristic with his or her marginal WTP. Clearly then, assuming that the housing market is in equilibrium, the calculation of the marginal cost of a given characteristic will provide an estimate of the consumer's marginal WTP for that characteristic.

Of course, as was stated earlier, the assumptions underlying this procedure are open to criticism. Added to this are the problems of multicollinearity in the data. This is a common problem in hedonic price functions and one which is often conveniently



ignored. However, as Ozanne and Malpezzi (1985) note, multicollinearity makes it difficult to produce reliable coefficient estimates for the parameters in models such as the one shown in equation (1). Overall, though, the predictive properties of a model should not be impaired by this condition, so at the very least the method should give some insight into the influence which landscape attributes have on housing markets.

Another important consideration is the functional form of the hedonic price function. Rosen (1974), Freeman (1979b) and others have stressed that economic theory fails to indicate any particular form as being appropriate. However, empirical studies such as Cropper *et al.* (1988) give some information upon which to base a choice. For cases such as this, where some important explanatory variables are known to be missing, Cropper *et al.* state that simpler functional forms such as the linear, semi-log, double-log and Box–Cox linear perform best, with quadratic forms faring relatively badly. This poor performance is attributed the fact that for quadratic forms each marginal price is dependent on more coefficients than in other cases. Thus, omitted variable bias affects more coefficients in the quadratic case than in others, implying that this form should be rejected when mis-specification is a known factor.

Now, ignoring the quadratic forms and concentrating on the simpler ones, it is necessary to define some criteria for the choice of the hedonic price function. Simple  $r^2$  measurements give some basis for decision-making, but in cases where this coefficient is of similar magnitude for two or more candidate forms, a more pragmatic approach may be adopted. Because the aim of this study is to attempt to estimate homebuyers' marginal WTP for countryside characteristics, it makes sense when comparing functional forms which otherwise perform similarly, to prefer the function which gives the greatest number of significant coefficients for focus variables (in this case CCs). Finally, because goodness of fit does not necessarily imply more accurate estimates of the marginal cost of characteristics, the chosen functional form must provide estimates which are reasonable and consistent with those gained from other studies.

Under these conditions, it is immediately clear that the main non-linear forms are a significant improvement over the linear one (see Table 1). However, while there is little to choose between the semi- and double-log forms, the former performs best under the second criterion, with seven CCs having significant coefficients compared with six for the double-log form. Consequently, the semi-log form is preferred. The results for the linear, double-log and semi-log forms are summarized in the first three columns of Table 1. The Table shows that the size,  $N$ , of the data set varies between the price functions; this is a result of the difference in the number of missing observations associated with the variable set for each respective model.

While this procedure may lack analytical depth, such a pragmatic, data-led approach seems reasonable in light of the lack of research into the relative impact of functional form on hedonic prices. The semi-log form has been widely used in hedonic price studies (e.g. Mieszkowski and Saper, 1978; Schafer, 1979; Cobb, 1984; Brookshire *et al.*, 1985; Graves *et al.*, 1988; Palmquist and Danielson, 1989) and while more complex functional forms may be adopted in order to maximize some criterion, such as the absolute value of the log-likelihood (e.g. Berndt *et al.*, 1977), there is little evidence to suggest that such analyses provide benefit estimates which are, in any practical sense, better than those provided by more conventional specifications.

Despite this, it was felt that further investigation of the functional form was necessary before any conclusions could be made. Following the ideas outlined by Halvorsen and Pollakowski (1981) and Graves *et al.* (1988) the quadratic Box–Cox functional form was introduced. Over the years, Box–Cox transformations have been

TABLE 1. Summary of hedonic price regressions†

	Form of hedonic price function			
	Linear	Semi-log	Double-log	Box-Cox ( $\theta = -0.1$ )
$r^2$	0.6672	0.7682	0.7771	0.7678
$r^2$ (adj.)	0.6605	0.7630	0.7770	0.7625
F-value	98.88	147.02	154.17	147.52
Focus variables‡	3	7	6	7
Total variables‡	35	40	39	40
N	1762	1826	1766	1826

† OLS regression based on N observations.

‡ All variables have coefficients significant at the 10% significance level.

used by several authors in studies similar to this (e.g. Goodman, 1988; Blomquist *et al.*, 1988; Dinan and Miranowski, 1989). However, this approach has met with serious criticism, notably from Cassel and Mendelsohn (1985), who point out its drawbacks in relation to prediction, estimation, negative inputs and general operationalization. The quadratic Box-Cox model is;

$$P^{\theta} = a_0 + \sum a_i X_i^{\pi} + 0.5 \sum_i \sum_j b_{ij} X_i^{\pi} X_j^{\pi} \quad (2)$$

where;

$$P^{\theta} = \begin{cases} (P^{\theta} - 1)/\theta & \text{for } \theta < 0 \text{ and } \theta > 0 \\ \ln P & \text{for } \theta = 0 \end{cases}$$

$$X_i^{\pi} = \begin{cases} (X_i^{\pi} - 1)/\pi & \text{for } \pi < 0 \text{ and } \pi > 0 \\ \ln X_i & \text{for } \pi = 0 \end{cases}$$

where  $X_i$  is the value for the  $i$ th characteristic of the house;  $a_i$  and  $b_{ij}$  are the first- and second-order coefficients, respectively, and  $\pi$  and  $\theta$  are the Box-Cox transformation parameters (see Box and Cox, 1964).

This model is sufficiently general to include most of the more conventional functional forms as special cases:

- e.g. linear:  $\pi = \theta = 1$  and  $b_{ij} = 0$  for all  $i, j$   
 semi-log:  $\pi = 1, \theta = 0$  and  $b_{ij} = 0$  for all  $i, j$   
 double-log:  $\pi = \theta = 0$  and  $b_{ij} = 0$  for all  $i, j$   
 quadratic:  $\pi = \theta = 1$   
 translog:  $\pi = \theta = 0$

Previous studies of a similar nature (e.g. Willis and Nicholson, 1991) have shown that the use of the second-order terms introduced additional multicollinearity problems, which reduced the significance of first-order terms without making any significant improvement to the fit. In addition, Cassel and Mendelsohn (1985) point out that the large number of coefficients estimated with the quadratic Box–Cox functional form reduces the accuracy of the estimation of single coefficients, which could in turn lead to poorer estimations of marginal cost. This, coupled with the aforementioned advice of Cropper *et al.* (1988), led to all second-order terms being excluded, thus eliminating from the analysis those forms which are most susceptible to mis-specification bias. This led to a concentration on the linear Box–Cox transformation which is the approach strongly favoured by Cropper *et al.*

The transformation utilized is similar to that used by Goodman (1988) and is of the form:

$$P^{\theta} = a_0 + \sum a_i C_{ij} \quad (3)$$

where:

$$P^{(\theta)} = \begin{cases} (P_i^{\theta} - 1)/\theta & \text{for } \theta < 0 \text{ and } \theta > 0 \\ \ln P_i & \text{for } \theta = 0 \end{cases}$$

and  $C_{ij}$  is the  $j$ th characteristics of the  $i$ th property.

A line search using the linear Box–Cox transformations was undertaken for values of  $\theta$  between  $-1.0$  and  $1.0$  at intervals of  $0.1$ . The value of  $\theta$  giving the highest  $r^2$  value ( $0.7682$ ) was  $\theta = 0$ , which corresponds to the semi-log distribution. A similar result was obtained by Bender *et al.* (1980), when their use of a Box–Cox linear transformation implied that the semi-log form was the appropriate one to use. The results for the Box–Cox transformation giving the next highest value of  $r^2$  (with  $\theta = -0.1$ ) are shown in column 4 of Table 1.

In view of the above, the semi-log form of the hedonic house price function is preferred and will subsequently be used to derive the empirical estimates reported in the next section.

## 6. Empirical results

Estimates of equation (1) employing the semi-log formulation are shown in Table 2; all coefficients are significant at the 10% significance level. As well as agreeing with Rosen's (1974) prediction of non-linearity, the semi-log form implies a monotonically increasing price function for those characteristics which affect house price positively.

The regression estimates shown in Table 2 fit the data reasonably well, with over 76% of variation in the dependent variable being explained. This level of explanation is consistent with that gained by several recent hedonic price studies (e.g. Brookshire *et al.*, 1985; Graves *et al.*, 1988) and better than others (e.g. Jud and Watts, 1981; Goodman and Kawai, 1984; Blomquist *et al.*, 1988). It can be postulated that most of the variation left unexplained may be accounted for by data unavailable at source, such as lot size and construction date, while much of the rest may be due to the use of proxy variables and to random errors.

TABLE 2. Hedonic price function: semi-log form

	Coefficient	t-ratio
Focus variables		
FOR20	0.07104	2.53
RIVER	0.04897	2.74
SETT	0.08341	5.34
WET	-0.18005	-1.75
WVIEW	-0.07346	-3.10
UVIEW	-0.05795	-3.55
GRAD	-0.00302	-2.50
Free variables		
ROOMS	0.06932	11.08
BATHS	0.14664	6.21
DET	0.20635	5.20
DETBUN	0.20392	4.58
SEMI	-0.11551	-3.03
TERR	-0.20068	-5.30
TENURE	0.31328	8.06
DOUB	0.24517	8.03
SING	0.06875	4.32
FULLCH	0.06517	3.61
PARTCH	0.06381	2.52
FLOOR	0.00028	6.09
YEAR86	0.03554	1.76
YEAR87	0.20846	9.34
YEAR88	0.49631	18.33
YEAR89	0.60704	16.34
TQTR	0.08321	5.14
LQTR	0.11819	7.35
BMKT1	-0.44311	-6.07
BMKT2	-0.90490	-25.05
BMKT5	-0.35198	-4.26
BMKT8	-0.30502	-9.99
BMKT11	-0.59928	-6.67
BMKT12	-0.15869	-5.22
BMKTRM	-0.15180	-3.76
Doubtful variables		
DIST1	-0.24948	-5.75
DIST4	0.16357	5.60
DIST6	-0.06180	-2.02
DIST13	-0.07487	-2.68
RETD	-0.04181	-8.72
ROAD	0.02785	3.66
RAIL	-0.05426	-2.77
UNEM	-0.00623	-2.20

In the model, the majority of significant focus variables have coefficients with appropriate sign and magnitude, for instance the variable RIVER, indicating the proximity of a river or canal, has a strong, positive influence on house value. The only unexpected result is the negative effect attributed to the possession of a woodland view. However, this relationship was found for all of the functional forms investigated in the last section, so it must be concluded that while a significant tract of woodland within

1 km has a positive benefit to property values (cf. FOR20 variable), its presence as a significant element of a view has the opposite effect.

The continuous focus variable WOODS (per cent woodland cover) did not enter the model, suggesting that rural homebuyers may be indifferent to the absolute level of local woodland cover. In response to this, a succession of partitions was introduced into the data to investigate whether house values were affected by adjacent woodland only when that woodland exceeded a critical density. This was done by categorizing squares into groups with over  $X\%$  woodland cover, where  $X$  is a multiple of 10, and then deriving a series of dichotomous (0–1) variables indicating whether the level of cover exceeded a given  $X$  value. Each of these variables was used individually in the model and it was found that the one indicating a partition at the 20% level gave the most significant coefficient value. This result was utilized and the resulting variable FOR20 indicates whether a property was located in a square with over 20% woodland cover. It is possible that higher levels of woodland cover could have a negative effect, rather than the positive effect found for FOR20. However, in this study, less than 2% of houses were located in squares with more than 60% woodland cover, too small a proportion to give significant results when FOR20 was replaced by two new variables FOR2060 (squares with between 20% and 60% cover) and FOR60 (squares with over 60% cover).

Now, because the coefficients of a semi-log equation represent the average percentage change in value for a unit change in a characteristic (marginal cost), these results suggest that the presence of a canal or river would raise the value of the average house by 4.9% while the proximity of at least 20% woodland cover would raise it by 7.10%.

Location in or near a rural settlement, such as a village or country town, also has a positive effect, probably due to the “best of both worlds” scenario offered by the combination of proximity to both the countryside and to local services (e.g. shop, doctor, post office, pub, etc.). On the other hand, having a view over an urban area, or being within 1 km of an area of wetland, serve to lower property values. These relationships are expected, as is the negative effect on house price of building on a steep gradient. Countryside characteristics which did not enter the model include height above sea level, predominant aspect and the proportions of parkland, orchard and open water in the kilometre square. These may either be relatively unimportant to rural property values or some may be victims of measurement error caused by out of date OS map surveys.

Nearly all of the free variable coefficients have the expected sign and magnitude with  $t$ -values indicating a significant contribution to the explanation of variation in property values. The overall estimates for the marginal cost of physical characteristics are generally consistent with those in other published studies. At the mean, an additional room increases property value by about 7%, with an extra bathroom collecting twice that premium. A single garage adds a 6.9% differential, three times less than a double garage (the coefficient of which may be picking up the effect of the important missing variable lot size), while central heating, both full and part, adds about 6.5% to value. Importantly, these premiums correspond quite closely with Cobb's (1984) estimates based on rural households in the United States. Cobb found that in rural areas an extra room commanded a 7.9% premium, while a house with more than one bathroom had a 14.8% differential over a single-bathroom house. Similarly, a garage (single or double) added a 16.8% premium while central heating contributed 8.7%.

Several doubtful variables enter the model, including four local authority variables and measures of local unemployment, population over 60 years of age and incidence of major roads.

When regressions are performed on time series data such as this, there is a possibility that the errors may not be independent. Frequently, errors are autocorrelated which may be symptomatic of a systematic lack of fit. However, use of the Durbin–Watson  $d$ -statistic as a test for autocorrelation, reveals no evidence to suggest that autocorrelation is different from zero in the semi-log model.

## 7. Conclusion

No comprehensive hedonic price indices of countryside characteristics have been produced, so to some extent this study breaks new ground. However, this study is constrained by empirical data. The environmental data is neighbourhood-specific rather than house-specific, relating to the 1 km<sup>2</sup> in which the house is located. It would be clearly desirable in future studies to have environmental and locality data measured with respect to the specific house; although, with the Data Protection Act, it is difficult to see how this could be achieved with the house price database adopted here. The effect of such a procedure on coefficients and characteristics values is uncertain: for some attributes estimated values may be little different from those estimated here. While some aspects of landscape have been quantified in this study, it is apparent that these variables do not reflect all aspects of the landscape in terms of its composition, contrasting forms, cultural qualities, natural diversity, colour, texture, atmosphere and mood, so pictorially portrayed by Crowe and Mitchell (1988). Much more research is required to measure these attributes as well as assessing the question of their separability or additivity in a utility function.

In the analysis, most of the continuous environmental (focus) variables did not prove to be statistically significant, leaving discrete environmental variables to explain house price variation. Because of this it was not possible to estimate the demand for particular countryside characteristics. Estimates of the demand function could resolve the theoretical problem posed by Mishan (1975) and Harris (1981), of valuing a major change in environmental quality. However, these theoretical objections may not be relevant to this study, since environmental changes here are marginal and measured over a short time period with adjustment in the housing market. This situation is quite different to that of dramatic sudden change, such as the imposition of a new airport with its attendant noise in the countryside as envisaged by Mishan (1975).

Hedonic values of countryside recreational characteristics include both the consumer surplus from the recreational use of the environmental attributes, and the direct utility amenity from living near the attribute. The travel cost method (TCM) only measures the former. Indeed, McConnell (1990) has shown that the total value of an environmental change is not the sum of HPM estimates plus TCM estimates, since this would involve some double counting. Thus, McConnell has argued that the HPM is more general. This may be so in theory. However, the results of this HPM indicate that the value of some environmental attributes are not statistically significant. Examples include wetlands, which may be unattractive as a housing position, being subject to flooding, drainage and access difficulties; but such an environment is extremely important as a wildlife habitat, given their increasing rarity because of agriculture, forestry and other developments. For countryside characteristics such as this, a TCM appears a more suitable method for evaluating recreational use, and a contingent valuation technique (CVT) to measure option and existence values.

Analysis of data on rural house prices throughout Great Britain has revealed that willingness-to-pay (WTP) for dwellings does vary, *ceteris paribus*, by composite land-

scape types within housing market areas (Garrod and Willis, 1991). The present HPM has attempted to extend that research by quantifying some specific countryside characteristics, to determine their individual impacts on house prices from people's WTP to live near or consume them. Results suggest that the two most important landscape attributes are proximity of woodland and water, which raise house prices by 7% and 5%, respectively.

Rational theory upon which this type of modelling is based, suggests that landscapes could be designed and enhanced with woodland planting and water provision. It is notable that water has played a large part in the making of landscape and architecture, from garden rills, cascades and lakes, to the outline of whole cities. Buildings in villages and towns take advantage of rivers and other water features to enhance their functional design and capture the spirit and genius of the place. Jellicoe and Jellicoe (1971) provide many examples around the world from Britain to Japan. However, a considerable amount of research is still required to specify what changes in combination, scale and composition of characteristics would most alter the value of an existing landscape.

An alternative mathematical model would be to view the essence of the earth's beauty as stemming from disorder (Gleick and Porter, 1990): the grasses and wild flowers strewn in the meadow, blotching of lichen on a tree, the irregular shape of rock formations, the layout of settlements evolved over the centuries without conscious rhyme or reason, the scatter of isolated farm buildings and houses over the landscape, etc. Such landscape beauty is more intricate, subtle, natural and pleasing than the landscape created by the architect. Scientists are now discovering such vivid images and senses of beauty, but their mathematical characterization and social interpretation has yet to be fully understood.

The importance of diversity and disorder was revealed in a psychological study of preferences for forests by Lee (1990). Respondents were asked how they thought forests should appear in the landscape in terms of 12 attributes using five point scales. Respondents considered overall, that forests should look natural, be colourful and beautiful, blend into the landscape and have a lot of variety. Variation in support for these attributes was small and non-significant. In a factor analysis on the 12 attributes, the dominant factor, characterized by attributes associated with diversity, accounted for 23.8% of the variance. Factor 2 labelled "wilderness" including negatively related items such as orderly rows of trees, etc., accounted for a further 14.1% of variance.

Interestingly, when landscape architects were asked to evaluate 10 attributes [scale, shape, broadleaved-conifer, overall diversity, species diversity, age diversity, colour diversity, spacing-density, human intrusion; genius loci (spirit of place or its sense of character)] on a scale from 1 to 5, correlation or correspondence between respondents was only moderate. Correlation coefficients between architects varied from +0.85 for the broadleaved-conifer attribute, to -0.273 for the impressions of colour diversity (Lee, 1990).

This result suggests that expert or professional judgement cannot be a substitute for data-based aids and mathematical modelling. Expert opinion does not form a consistent decision-making or diagnostic process. So there is a strong case for pressing ahead with further research on the quantitative appraisal of landscapes and countryside attributes.

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## Appendix 1: variables for initial inclusion in the model

### 1.1. FOCUS VARIABLES

FOR20=0–1 variable, over 20% woodland in kilometre square; RIVER=0–1 variable, river or canal in kilometre square; SETT=0–1 variable named settlement in kilometre square; WOODS=per cent land covered by woodland in kilometre square; WATER=per cent land covered by open water in kilometre square; ORCH=per cent land covered by orchards in kilometre square; PARK=per cent land covered by parkland or ornamental gardens in kilometre square; WET=0–1 variable, wetlands in kilometre square; WVIEW=0–1 variable, whether kilometre square commands a woodland view; UVIEW=0–1 variable, whether kilometre square commands an urban view; GRAD=predominant gradient slope in kilometre square; HEIGHT=average height above sea-level of kilometre square; WASPECT=0–1 variable, predominant westerly aspect in kilometre square; SASPECT=0–1 variable, predominantly southerly aspect in kilometre square; CABLE=0–1 variable, overground cable in kilometre square.

### 1.2. FREE VARIABLES

ROOMS=number of bedrooms and reception rooms; BATHS=number of bathrooms; DET=0–1 variable, detached house (greater than one storey); DETBUN=0–1 variable, detached bungalow; SEMI=0–1 variable, semi-detached house; TERR=0–1 variable, terraced house; FLAT=0–1 variable, flat; TENURE=0–1 variable, freehold;

DOUB=0-1 variable, double garage; SING=0-1 variable, single garage; SPAC=0-1 variable, own parking space; FULLCH=0-1 variable, full central heating; PARTCH=0-1 variable, part central heating; FLOOR=total floor area (square metres); YEAR86=property purchased in 1986; YEAR87=property purchased in 1987; YEAR88=property purchased in 1988; YEAR89=property purchased in 1989; SQTR=property purchased in second quarter of year; TQTR=property purchased in third quarter of year; LQTR=property purchased in fourth quarter of year; BMKT1=0-1 variable, property has sitting tenant; BMKT2=0-1 variable, property is council owned; BMKT5=0-1 variable, property is being built by mortgage applicant; BMKT8=0-1 variable, property requires improvements; BMKT11=0-1 variable, property under community leasehold; BMKT12=0-1 variable, property value underestimated; BMKTRM=0-1 variable, property sold below market value for other reasons.

### 1.3. DOUBTFUL VARIABLES

DIST1=property in Northavon LAD; DIST2=property in North Wiltshire LAD; DIST3=property in Thamesdown LAD; DIST4=property in Cotswold LAD; DIST5=property in Stroud LAD; DIST6=property in Dean LAD; DIST7=property in Tewkesbury LAD; DIST8=property in Leominster LAD; DIST9=property in South Herefordshire LAD; DIST10=property in Malvern LAD; DIST11=property in West Oxfordshire LAD; DIST12=property in Vale of the White Horse LAD; DIST13=property in Monmouth LAD; POPLN=population density of LAD; RETD=population over 60 years of age in LAD (%); PROF=population in professional or managerial positions in LAD (%); CARS=households with two or more cars in LAD (%); ROAD=kilometres of major road (B-roads and above) in kilometre square; RAIL=kilometres of rail track in kilometre square; UNEM=yearly proportion of workforce unemployed in LAD (%); AGRIC=yearly proportion of workforce in agriculture in LAD (%); SKILL=yearly proportion of workforce in skilled labour in LAD (%); KMSEC=kilometres from nearest secondary school; KMPRI=kilometres from nearest secondary school; KMPOST=kilometres from nearest post office; KMURB=kilometres from nearest town; POST=0-1 variable, post office in kilometre square; PUB=0-1 variable, pub in kilometre square; INDUST=0-1 variable, major industrial facility in surrounding 3 square kilometres; GOLF=0-1 variable, golf course in surrounding 3 square kilometres; CPNT=0-1 variable, whether kilometre square contains National Trust or Country Park Land.