# Encyclopaedia of Environmental Pollution

Vol. 1

# ENCYCLOPAEDIA OF ENVIRONMENTAL POLLUTION

## ENVIRONMENTAL NOISE POLLUTION

VOLUME - 1

S.K. SHUKLA
P.R. SRIVASTAVA

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# *Preface*

The recognition of Noise as an environmental problem, with an impact on both the community and occupational environment, is rapidly growing, there appears to be several indicators of an expanding interest record proportions at all governmental levels. The desire to restrict occupational noise exposure has resulted in the promulgation of central and state laws.

Community noise is also receiving increasing attention. Public recognition of noise and the need for its control is increasing. Although other environmental have been previously in the forefront, noise is gradually commanding greater and greater attention by the public large. The public appears today to be equally concerned about the acoustical quality of the environment as with air water quality. Environmentalists public interest organizations, and citizen group are expressing an increasing interest in the subject. Public information programmes now include noise with its other environmental counterparts. "Monetary ,evaluation of Environmental Noise Pollution", offers the reader practical solutions applicable to real-world needs, and allows the individual to participate in learning about solutions to Noise Pollution problems.

EDITORS

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# *The Monetary Evaluation of Noise Nuisance*

It is interesting to reflect on the way in which the cost-benefit paradigm has been adopted and modified in terms of actual policy in the Western world. While the principle that 'the polluter should pay' is of some antiquity in the economics literature (see, for example, Pigou, 1932), it was during the 1960s in the United States that the idea of actually constructing and implementing pollution taxes was advanced to the level of active policy consideration (see, for example, Kneese and Bower, 1968). In the early 1970s it was taken up by the newly formed Environment Directorate of the Organisation for Economic Cooperation and Development (OECD) and there eventually emerged the "Polluter Pays Principle (Organisation for Economic Cooperation and Development, 1975). This principle was in turn adopted by the European Economic Community as a 'Directive,' which effectively gives it legal status within the membership of the Community, whereas the OECD recommendation remains exhortatory only.

As it happened, the polluter pays principle that was finally formulated was a far cry from the 'ideal' tax outlined earlier. It speaks of internalizing the "cost of whatever pollution prevention and control measures are determined by the public authorities" (Organisation for Economic Cooperation and Development, 1975, p. 6). Hence the principle is consistent with setting standards, on almost any basis, and then implementing some mechanism for making the polluter bear these costs. Note that the benefit function is assumed as a 'given' in the establishment of standards, since it is not empirically calculated and assessed against abatement costs. The essential reason for this 'watering down' of the principle was the recognition that, while abatement costs could be estimated with some reasonable degree of accuracy, the state of the art in measuring the benefits of abatement was such that benefit functions could not be identified. Numerous reviews were undertaken to ensure that this was the case.

Interestingly, the state of the art has changed somewhat dramatically within the past few years and this has led to the reemergence of a school of thought which seeks to identify pollution optima in terms of both monetary abatement cost and benefit functions. To date, the work has centred mainly on the theoretical and practical problems of identifying the benefit function, but in at least one case (Council on Wage and Price Stability, 1977) a call has been made for pollution charges to be based on estimates of pollution damage.

Just how significant is this swing of the pendulum and what does it mean, if anything, for the polluter pays principle? The aim of this chapter is to survey, concisely, the 'new' literature on benefit estimation in the context of one pollutant —noise. Noise has been selected because it is readily perceived and is not therefore, unlike some pollutants, imperceptible to the point where individuals' behaviour is unaffected by changes in the level of pollution. Moreover, while noise is undoubtedly the cause of hearing impairment, it has no long-run cumulative effects in the environment which make cost-benefit evaluations so difficult (see Pearce, 1976; Nobbs and Pearce, 1976).

The argument presented here is that the developments of the last few years do *not* constitute a legitimate reason for changing the nature of policy prescriptions in the field of pollution. Neither the theoretical nor the practical work on placing money measures on noise nuisance appear to succeed in estimating benefit functions. If they fail for noise, we argue by implication that they must also fail for other pollutants where similar techniques have been used. The theoretical foundations of the recent work are challenged in greater detail in a separate paper (Harris, 1978). This chapter looks a little more closely at the empirical aspects of benefit functions. The work that is criticized is that based on house price depreciation—*i.e.* the idea that pollution values are capitalized in house prices. At the end of the paper we look at some recent survey work which has perhaps the promise of providing more likely results.

## Property Price Approaches

Whereas the original work using property prices simply referred to the technique as the 'house price depreciation' approach, it has now become fashionable to refer to this approach as the 'hedonic price' technique. The idea is that a house may be thought of as comprising a bundle of attributes—a number of rooms, proximity to shopping areas, size of garden, schools, etc. The local level of pollution is simply one more attribute. The house price is then some combination of the implicit, or 'hedonic,' prices of the constituent attributes. Noise is a negative attribute and should therefore have a negative price. Conversely, one can think of peace and quiet as a positive attribute with a positive price. The household is assumed to have a utility function of the form:

$$U = U(X, c_1 \ldots c_n) \qquad \ldots(1)$$

where $X$ is the bundle of *non-housing* goods consumed (*e.g.* newspapers, music lessons) and $c_i$ is the level of any house-related attribute $i$. The budget constraint is given as

$$Y = P_x X + \sum_{i=1}^{n} P_i c_i \qquad \ldots(2)$$

where $P_x$ is the price of non-housing goods, $P_i$ is the implicit price of the *i*th attribute, and $Y$ is income.

Maximizing $U$ with respect to the budget constraint yields a function relating the house-related attributes and other commodities to expenditure levels. This function has the form:

$$g(c_1 \ldots c_n, X, Y)=0 \qquad \ldots(3)$$

If the utility function (1) is separable between house-related attributes and $X$ (*i.e.* the utility derived from the house-related attributes is not dependent on the consumption of other goods—a most restrictive assumption); then equation (3) can be expressed solely in terms of the house-related attributes $c_1 \ldots c_n$ and housing expenditure $H$ in the form:

$$f(c_1 \ldots c_w H)=0 \qquad \ldots(4)$$

where $H=Y-P_xX$. The implicit function (4) can be written in explicit form as

$$H=h(c_1 \ldots c_n) \qquad \ldots(5)$$

which tells us that housing expenditure $H$ is a function of the attributes of the house. $H$ is expressed in rental terms. To convert to present-value terms we have:

$$V = \frac{H}{r} = \frac{1}{r}\, h(c_1 \ldots c_n) \qquad \ldots(6)$$

or $$V=V(c_1 \ldots c_n) \qquad \ldots(7)$$

Expression (7) tells us that the capitalized value of the property (the house price) is dependent upon the levels of the attributes of the house. Since noise is one such attribute, it follows that the house price is partly determined by the level of noise.

Now, the *marginal valuation* of any house-related attribute $i$ is given by

$$\frac{\partial V}{\partial c_i}$$

That is, $\partial V/\partial c_i$ measures the marginal willingness to pay for an extra unit of house-related attribute $i$. This is the bedonic price of that attribute. Hence, to find the 'cost of noise' equation (7) is estimated and the differential with respect to the noise attribute is taken to obtain the marginal willingness to pay for noise reduction.

Equation (7) is presented in general terms. Its specific form is dependent upon the form of the underlying utility function (1). Thus, if the utility function is *linear*, the form of equation (7), the equation to be estimated, will be

$$V=a_1c_1+a_2c_2+\dots+a_nc_n \qquad \dots(8)$$

where the $a$'s are constants and, since $\partial V/\partial c_i=a_i$, these constants are themselves the hedonic prices. Effectively, then, equation (8) can be set up as a regression equation and the coefficients will give the hedonic prices. In this way, we supposedly obtain a 'value' for noise reduction.

The regression equation (8) will look quite different if a different form of utility function (1) is used. For example, a multiplicative utility function yields a log-linear regression equation:

$$\log V=a_1 \log c_1+a_2 \log c_2\dots+a_n \log c_n \qquad \dots(9)$$

Note that in this form the coefficients are no longer the hedonic prices. Instead,

$$\frac{\partial V}{\partial c_i}=\frac{\partial \log V}{\partial \log c_i}\cdot\frac{V}{c_i}=a_i\frac{V}{c_i} \qquad \dots(10)$$

in this case the hedonic price depends on both the property value $V$ and the level of the attribute $c_i$.

## *Critique of Hedonic Price Theory*

To place any reliance on the hedonic technique outlined above it is essential to identify a generalized approach for deriving the hedonic prices applicable to individuals in the defined area affected by noise. Unfortunately, the conditions necessary to achieve this generality are restrictive to the point where they make the theory tenuous in the extreme.

First, individuals must be utility maximizers (they must seek to maximize $U$ in expression 1). While this is a standard assumption in economics, it is not demonstrable. Second, and more important, the housing market must contain no imperfections such that individuals are constrained by anything other than their budget (2). Of all markets, however, the housing market is the one in which such an assumption is least likely to be met (Maclennan, 1977; Harris, 1978; Pearce, 1978).

The actual measurement of hedonic indices can also be troublesome. Not only must all the attributes of the houses in qnestion be identifiable and quantifiable, but we must be able to determine which of these attributes are important when it comes to housing choice. It is unclear in practice whether the 'attribute set' is in fact similar for each individual (Maclennan, 1977). One might also add that, in the case of noise, it remains unclear what a 'best' measure is, especially given the subjective preference assessments underlying any noise measure based on annoyance or perceived noise (Hart, 1973).

However, these are essentially minor criticisms compared to the restrictions which must be placed on the utility functions of individuals before estimating equations of the form of (8) or (9) can be used meaningfully. First, *all* individuals must have *identical* utility functions. If this is not so, functions (6) and (7) will vary from one individual to the next. What matters here is how equation (6) or (7) is used. As we saw, they gave rise to estimatable forms like equations (8) and (9). But if these forms are not identical for each individual, the observations used to estimate the equations will in fact be *single observations on many different functions.* Yet what is required is the reverse of this—many observations on a single function. Because of this failing, what the regression equations (8) and (9) will estimate are coefficients which will in fact be a weighted average of differing individual marginal valuations of noise at the particular level of noise being experienced by each individual, *and at no other level.* This contrasts with what is required, namely single marginal valuations for *all levels* of the given attribute, in this case noise. The problem does not change if the observations for estimating an equation such as (8) are derived from time series (they generally come from cross-sectional studies).

Second, not only must the utility functions be identical for all individuals, but those functions must also take on a specific form. They must have the property of being *homogeneous.* In other words, when taking a utility function of the form $u=u(c_1...c_n)$, the independent variables, $c_1...c_n$ can be multiplied by some factor, say $b$, so that the value of the function changes by $b^k$. That is, $u(bc_1...bc_n)=b^k u(c_1..c_n)$. The power $k$ is the degree of the function: in this case the utility function is homogeneous of degree $k$. Non-homogeneity leads to the result that marginal valuations (the hedomic prices) depend on the individual's *level of utility.* Hence, if the sample of households studied contains individuals with different utility levels no unique estimatable price can be obtained. The gives rise to the oddity that, since the aim of policy to alter utility levels, the existence of non-homogeneous utility functions means that the policy itself will alter the price used to determine policy! These issues are dealt with more fully in Harris (1978). In passing we might also note that homogeneity necessarily produces an income elasticity of demand for pollution abatement of unity. It is unclear, therefore, if findings such as those of Nelson (1978) to the effect that environmental benefits are associated with unitary income elasticities are more than an inevitable outcome of the form of model chosen.

So far, then, it has been argued that hedonic prices are meaningful *only* if utility functions are the same for all affected individuals and *only* if the form of the utility function is homogeneous. Of course, the latter problem can be overcome if we confine analysis to a set of individuals whose utility *levels* are all the same. Simply expressing the requirement in these terms serves to underline the extreme unlikelihood that prices obtained from hedonic models mean anything at all.

To add to the restrictiveness, however, we must recall that we only obtained the estimating equations for hedonic prices by assuming separable utility functions. That is, the price of $X$, non-housing attributes, was not dependent in any way on the price of house-related attributes. However, to make matters worse, it is also essential for the separability to apply to the attributes themselves. This means that the price of any one attribute must not be dependent on *any* other factor affecting house price. A simple example may suffice to indicate why this form of separability is unlikely. Imaginge someone who listens only to Gregorian chants because he dislikes noisy music. This individual's marginal valuation of noise is likely to be greater than that of his neighbour who listens only to 'big bands,' even if all their other tastes are identical. More generally, the utility obtained from *combinations* of attributes (and non-housing commodities) is unlikely to be the same as the sum of utilities from individual attributes.

In order to overcome this problem one would have to identify a set of households *identical in all respects* other than the level of noise to which they are exposed. That is, they must consume exactly the same amount of everything except peace and quiet. The fact that varying levels of noise may well affect expendi tures on other items (double-glazing, sleeping pills, etc.) makes the chances of such an experiment remote.

On the demand side, then, we have shown that hedonic prices are 'meaningful' if and only if utility functions are everywhere the same (for the affected population) and are homogeneous and separable between all house-related attributes and between such attributes and non-household goods. On the supply side, we have effectively assumed that house-related attributes are exogenously determined. To put it another way, hedonic prices are determined only by demand for the particular attribute. If endogenous supply of attributes is permitted the estimating procedures will fall prey to the usual problems of econometric identification and simultaneity. Further, all that has been said about utility functions has to be applied to the supply of house-related attributes, with cost being substituted for utility. Are such attributes endogenously determined? The very existence of a second-hand market in housing would suggest that they are. To put it another way, only if such attributes can be assumed to be completely price inelastic can we concentrate on a demand-determined hedonic price model (and its associated problems). But if such attributes are price elastic, then the supply side must be explicitly considered and the same restrictions as applied to demand must be applied to supply.

At the theoretical level, the hedonic price technique suffers so many restrictions of a sufficiently severe nature that the only proper conclusion is that it tells us nothing. As the next section shows, it can and does come up with some absolute magnitudes, but what those magnitudes mean is another issue. The argument here is that they mean nothing. They cannot even be construed as guiding us towards maximum ar minimum values. It is not in the least evident that further research will improve this assessment of the 'state of play.' The recent literature has undoubtedly clarified the nature of models based on house price depreciation and for that we should be grateful. Unfortunately, that clarification leads to only one conclusion, namely the general irrelevance of house price approaches for pollution control policy.

### *Hedonic Price Studies: Empirical Results*

Studies of house price depreciation have been carried out for noise surrounding airports and for traffic noise. Table 1.1 attempts to bring together the results obtained for aircrafs noise. The studies are primarily American, but we have included the results obtained by the Research Team of the Commission on the Third London Airport (Commission on the Third London Airport, 1970, 1971; Walters, 1975) for comparison. The CTLA study does not strictly belong in a comparison of hedonic models because no regression equation approach was used. (One was attempted but produced no significant results.) Instead, the CTLA study relied upon estate agents' assessments of what they thought depreciation would be for houses in differing noisy zones. Insofar as those assessments relate to noise alone, as they were supposed to, then they can be thought of as being analogous to the coefficients obtained in a property price model of the hedonic kind.

Table 1.1 has attempted to 'normalize' the various results in terms of a percentage depreciation for a standard house

TABLE 1.1

**Noise Depreciation Index:[a] Aircraft Noise**

| *Author (date of study)* | *Nelson (NEF)*[b] | *Walters (NNI)*[c] | *Nelson (NNI)*[d] | *Walters (NNI + adjusted price)*[e] | *Airport* |
|---|---|---|---|---|---|
| McClure (1969) | — | 0.7 | — | 0.78 | Los Angeles |
| Colman (1972) | — | 0.7 | — | 0.78 | Engelwood California |
| Paik (1970) (1972) | 1.6-2.0[g] | 0.7 | 0.7-0.9 | 0.78 | Kennedy |
| Emerson[g] (1969) | 0.4 | 0.55 | 0.18 | 0.62 | Minneapolis |
| Dygert and Sanders (1972) | — | 0.4-0.8 | — | 0.45-0.90 | San Francisco |
| Dygert (1973) | 0.5 | — | 0.20 | — | San Francisco |
| Price (1974) | 0.4 | — | 0.18 | — | Boston Logan |
| Nelson (1975, 1976) | 1.0 | — | 0.44 | — | Washington |

| | | | | | |
|---|---|---|---|---|---|
| Mieskowski and Saper[j] (1978, (a)) | (CNR) 0.3-0.5 | — | (NNI) 0.2-0.34 | (NNI adj) 0.18-0.31 | Toronto |
| (1978, (b)) | 0.8-1.0 | — | 0.54-0.67 | 0.49-0.60 | |
| CTLA (1970) | — | 1.0 | — | 1.12 | Heathrow |
| | — | 1.3 | — | 1.46 | Gatwick |

*Notes*

[a] NDI=% change in house price with respect to a unit increase in noise.

[b] Nelson's original results per unit NEF (noise exposure forecast) with house price of $28,000.

[c] Walters' original results per unit NNI (noise and number index) with house price of **$25,000**.

[d] Nelson's results converted to NNI using INEF=2.5 NNI. Simple transformations of this kind are legitimate within fairly narrow noise ranges.

[e] Walter's original results converted to a $28,000 'standard' house. In Emerson's study depreciation is an increasing function of house price so that the result here may understate the 'true' value. However, Walters (1975) doubts the validity of the assumed increasing function in Emerson's study.

[f] A dash means that the study in question was not considered by the relevant author,

[g] The figure of 1.6 obtained from Paik's study but Nelson reports an adjusted figure of 2.0. In fact the Paik study has a range of 1.85-2.46 for 20-40 NEF.

[h] It is not clear why Walters and Nelson report such different results for Emerson's study.

[i] The Dygert, and Dygert and Sanders studies report the same results.

[j] The Mieskowski and Saper study was not considered by either Nelson or Walters. Noise units used were CNR and the conversion used for Table 1.1 is 1 CNR—1.5 NNI. Study:

(a) relates to Etobicoke for CNR=95-105, house price of $35,000, and an apartment price of $25,000. Study

(b) relates to Mississuaga for the same noise and price level.

Houses and apartment are in the approximate ratio of 60:40 so we have used a weighted average of $31,000 as the price to be converted to $28,000 to secure comparison with other studies: *i.e.* a conversion factor of 0.9.

of $28,000 in 1970. There are formidable difficulties on doing this since noise measures differ between studies and in some cases functions have been used which imply valuations which are increasing functions of house price—*i.e.* the percentage depreciation varies with the level of house price. But as far as possible the results have been standardized. The advantages of so doing are to remove exogenous house value differences and any other sources of variation. The table is also built round earlier syntheses by Walters (1975) and by Nelson (1978). Some of the studies are common to both these surveys, but they otherwise differ in their coverage. Some studies not included in either the Walters or Nelson surveys are also included here.

How are the results of Table 1.1 to be interpreted? Walters (1975, p. 105) concludes from his survey that "the most striking feature of ... adjusted NDI's (noise depreciation indices) is the similarity of results." Nelson (1978, p. 362) however, is less dogmatic: "... for 1970" he notes, "the empirical studies suggest a noise depreciation index of at least 0.5 per cent, and no greater than 1.0 per cent. This is as strong a statement as can be made on the basis of presently available empirical evidence." It is fair to point out that Nelson believes that these results *do* have policy relevance.

The comparable statistics in Table 1.1 are shown in the penultimate columns inside 'boxes.' The major point to note is that a one-unit change in NNI leads in all US cases to a *less* than 1 per cent, change in house price. This much supports Nelson's view. Arguably, a 1 per cent change in house price per unit NNI change in the United States is therefore an upper limit of the damage cost estimate. (Note, however, that the CTLA study results are well above unity). Certainly, the 1 per cent, figure has been seized upon in other practical studies of noise charges (see Council on Wage and Price Stability, 1977). However, the *range* of estimates in Table 1.1 is wide (it varies from 0.18 to 1.46) and is certainly too wide to support Walters' view concerning the similarity to results. Walters' range for the US studies is 0.4 to 0.8, although he takes the range 0.4 to 0.7 to be representative. In fact, how-